Comparative study of nutrients and heavy metals in Rwandan macrophytes: *Cyperus papyrus* and *Leersia hexandra*

C Kayirangwa[1*], T Muhizi[1], M.J.P Mpatswenumugabo[2]

**Corresponding Author*: kayirangwaclaudette@gmail.com

Abstract

Macrophytes have been recommended to be naturally most efficient in water purification by fixing heavy metals and nutrients. This study aimed at comparing both nutrient and heavy metal contents in two Rwandan wetland plants, *Cyperus papyrus* and *Leersia hexandra.* Different plant parts and water samples were collected from Nyabugogo, Nyabarongo, Akanyaru and Akagera wetlands in Rwanda. Atomic Absorption Spectroscopy, Ultraviolet-Visible spectrophotometer and Flame Photometer were used to analyze the presence of heavy metals and nutrients. Results from the study revealed that Nitrogen was the most abundant nutrient in water with mean concentration of 9.160mg/mL, while Phosphorus was the least concentrated (0.160mg/mL) from all the sampling sites. However, the highest concentration of plant nutrients in leaves was Potassium (26.67mg/g). On the other side, the highest concentration of heavy metals in water was 40.2 mg/L for Fe in Nyabugogo site while its lowest concentration was found in Akanyaru with 10.05 mg/L. The highest concentration heavy metal in plant was Fe (2.699mg/g) while the least concentrated was Pb (0.060mg/g). This study showed that *Leersia hexandra* contains a high quantity of all heavy metals analyzed, therefore, a further investigation on *Leersia hexandra* should be conducted prior to being used as key material in phytoremediation.

Keywords: Wetlands, Nutrients, Heavy metals, *Cyperus papyrus*, *Leersia hexandra*

[1]Department of Chemistry, College of Science and Technology, University of Rwanda, P.O.Box: 3900 Kigali-Rwanda

[2]Department of Veterinary Medicine, College of Agriculture, Animal Sciences and Veterinary Medicine, University of Rwanda, PO Box 210, Musanze-Rwanda

Introduction

In Rwanda, wetlands are considered as the main water resources. However, they are seriously affected by both seasons and human activities including agriculture and different pollutants. In wet season, the water table is near or above the lowest ground surface while in dry season wetlands can be dry (McCauley et al., 2015). The most recent inventory of wetlands conducted by Rwanda Environmental Management Authority (REMA) in 2008 showed that Rwanda has 860 marshlands and 101 lakes covering a total surface of 278,536 ha corresponding to 10.6 per cent of the country surface area, and 149,487 ha, respectively (Nyandwi et al., 2016). This inventory also found 861 rivers totaling to 6,462 km in length. Moreover, the same report indicated that 41 per cent of the inventoried wetlands are covered by natural vegetation, 53 per cent (about 148 344 ha) are under cropping and about 6 per cent are fallow fields. The same report indicated that *Cyperus papyrus* and *Leersia hexandra* were among the main macrophytes found in Rwandan wetland (REMA, 2009).

Beside this, wetlands are ecosystems providing numerous functions to the environment as well as to humans, since they play a key role in economic activity linked to transportation, food production, water risk management, pollution control, fishing and hunting, leisure and the provision of ecological infrastructure (Turner et al., 2000).They intervene in maintenance of water quality, reduction of erosion, protection of rivers from floods, provision of a natural system to process airborne pollutants, provision of a buffer zone between urban residential and industrial segments to ameliorate climate and physical impacts including noise, control insect population, provide habitats for fish and other organisms and produce food, fiber and fodder to name a few(Mitsch & Gosselink, 2000).

Cyperus papyrus is a perennial plant native to central Africa and the Nile Valley introduced to other warm parts of the world, often as an ornamental species. It has been used as food for humans and livestock, as a source of herbal medicines and perhaps most importantly as the source material for the making of paper (papyrus), cordage, ropes, boats, matting, mattresses, cushions, roofing and flooring(Kyambadde et al., 2004).In Rwanda, especially in Nyabugogo wetland, the monitoring of heavy metals pollution using *Cyperus papyrus* has shown that different parties of this plant (roots, stem and umbel) have the capacity of fixing these chemicals from wetland(Sekomo et al., 2011). This capability was reported by other researchers (Ali et al., 2016; Bizuru et al., 2015; Rohan et al., 2014;Shah et al., 2013; X. Zhang et al., 2009; X.-H. Zhang et al., 2007; Aksoy et al., 2005; Zhu et al., 1999). Furthermore, *Leersia hexandra,* has shown the capability of absorbing pollutants from wetlands (Mganga et al., 2011).

Water from Nyabugogo and Nyabarongo wetlands is reported to be highly polluted by different chemicals and microbes. This high pollution is directly linked to the high population density in Kigali city and to many industrial activities in that area. Many effluents from domestic and different institutions are discharged in these wetlands without a proper treatment. All these activities have been reported to be the major cause of high load of nutrients and heavy metals contamination including lead and cadmium, known as toxic metals (Nhapi et al., 2012). The real challenge of the country is the no existence of common sanitation system to treat effluents from different urban areas (Okurut et al., 2015). Furthermore, intense farming around rivers allows pesticides to reach water and later consumed by users and leading to different diseases (Niyonsenga et al., 2019).

The reported capability of macrophytes to fix and remove chemicals from wetlands can however be used to fight against this pollution incidence. In Rwanda, this possibility is however hindered by few data reported on these wetland plants. This study is one of the solutions to this remarked research gap. It aims at comparing heavy metals and nutrients contents in these two plants and to deduce their possible efficacy in cleaning up water by fixing these chemicals. For this, a comparative study on these two plants, in four locations; Nyabugogo, Nyabarongo, Akanyaru and Akagera wetlands; was conducted to verify their capability to accumulate heavy metals and nutrients.

Materials and methods

Sample collection and Processing

Both macrophytes and water samples have been concurrently taken from Nyabugogo, Nyabarongo, Akanyaru and Akagera wetlands according to six different stations considered. Prior to water sample collection, polyethylene bottles were rinsed with nitric acid and again three times with water to be sampled. Some physical chemical parameters of water including temperature, pH, dissolved oxygen (DO), salinity, total dissolved solids (TDS) and electrical conductivity have been directly measured on the sampling sites using a HQD 40d multimeter equipped with three electrodes for pH, conductivity and dissolved oxygen measurement. Approximately, 500 mL of water were collected and brought to the laboratory of chemistry at the University of Rwanda for further analysis.

Ten plants from each Macrophytes (*Cyperus papyrus* and *Leersia hexandra*) were randomly collected from a superficial area of 10 m^2 and mixed prior to drying and milling. Roots, stems and umbel were considered as main parts of *Cyperus papyrus* while rhizomes and leaves were taken from *Leersia hexandra*. These parts were dried at 105^0C in oven for 24 hours after 10 days of drying at room temperature, followed by grinding into fine powders.

Determination of water quality

Nutrients

Water samples were digested for Total Phosphorus (TP), Total Nitrogen (TN) and Potassium (K) analysis. 25mL of sample and 25mL of digestion reagent were mixed in glass Duran bottles and then digested at a constant temperature of 120˚C for 2 hours. Different reagents and stock solutions have been prepared prior to specific analysis and according to previously described methods(Estefan et al., 2013).

Heavy metals

Water samples were digested by mixing 95mL of water with 5 ml of HNO_3 (65%) and heated until 10mL of the initial solution was obtained, this concentrate was then diluted with distilled water to 100mL flask and left for a 22h settling. Standards of heavy metal solutions were prepared according to the specifications of the Atomic Absorption Spectrophotometer as described by Perkin-Elmer,1996(Elmer, 1996). The concentrations of Pb, Cd, Cu, Zn and Fe were measured by Flame Atomic Absorption Spectrometer

(VARIAN AA240) as previously described(Kansiime et al., 2007).

Analysis of the plant materials

Nutrients

The digestion solution was first prepared and followed by plant digestion. The solution was prepared according to the standard operating protocols. Briefly, 250 mL of concentrated Sulfuric acid (H_2SO_4) was heated on a hot plate until fumes appeared (±300°C), then 0.88 g of Selenium (Se) was added while mixing. Thereafter, 100mL of H_2SO_4-Se mixture was taken, in which 7.2 g of salicylic was dissolved and kept at room temperature. After complete dissolution, this solution has been used within 48 hours. Then after, 0.3 g of the dried plant material was transferred to the destruction tube made in borosilicate**.** To the weighed plant samples a volume of 2.5 mL of digestion mixture (H_2SO_4-Se) was added and swirled carefully until all the plant material was moistened. The mixture was left to stand for 2 hours then placed in oven at 100^0C for 2 hours to allow the reduction of nitro-salicylic acid compounds and cooling, then three aliquots of 1 mL H_2O_2 were successively added. Thereafter, tubes containing the mixture were placed again in the preheated block and heated at 300^0C for three hours. The obtained concentrate digests were diluted with 15mL of distilled water and boiled with 5 pumice grains. After cooling, the solution was brought to 50 mL by adding distilled water and let particles to settle for 24 hours before analysis.

Standards solutions for calibrating the UV spectrophotometer were prepared prior to analysis. Sample solutions were also diluted for accurate measurements. The absorbance of the obtained solutions has been measured on UV/Vis Spectrophotometer (CECIL 2041) on 690 nm, 766.5 nm and 880 nm for Total Nitrogen (TN), Potassium and Total Phosphorus (TP), respectively.

Heavy metals

From each plant part (roots, stems, umbel, leaves or rhizomes), 1.250 g of dried powder were transferred to the destruction tubes before adding 25mL of Nitric acid (65%). The tubes containing the mixture of dried samples and nitric acid were heated in successive steps by changing temperature from 100°C to 200°C with corresponding times; 1 hour and 15 min at 100°C and 125°C respectively. Heating was again increased to 150°C, 175°C and 200°C for 15 minutes each. At 200°C, heating was maintained until the mixture is concentrated to the volume between 5 and 6mL. After cooling, 1 ml of H_2O_2 (30 %) was added to each tube and the new mixture was destructed for 10 minutes. The step was repeated 2 additional times on the same tube and mixture. To the new mixture, volume of 25mL of distilled water was added, mixed and heated till boiling. The solution was cooled and transferred to a 250mL volumetric flask and filled up with distilled water to the mark. Standard solutions were prepared by suitable dilution of the stock standard solutions as previously described(Elmer, 1996). Heavy metals were analyzed by Atomic Absorption Spectrometer at wavelength of 217.0, 324.8, 228.8, 213.9, and 248.3 nm for Pb, Cu, Cd, Zn and Fe, respectively.

Data management and statistical analysis

Data from laboratory analysis were encoded into excel spreadsheet for descriptive analysis. Variations in nutrients and heavy metals concentrations were statistically analyzed using one-way Analysis of Variance (ANOVA) tests. Significance levels were established at 95% confidence interval with critical p values of 0.05.

Results

Quality of the water from the selected wetlands

Water of the wetlands from which plant materials were taken was analyzed to establish the possible relationship between its chemical composition and the composition of the plants. Physical chemicals parameters (Table 1) of the waters were determined to assess its quality as not only an indication of the value of biota and macrophytes, but also to have primary information on the availability of some organisms in sampling sites.

Table 1. *Values of physico-chemical parameters of the water from different wetlands*

Sampling sites	Parameters					
	T (^oC)	pH	DO (mg/l)	TDS (mg/l)	Salinity (‰)	Electrical Conductivity (µS/cm)
NBG	26.30	7.13	5.32	116.80	0.13	282.00
NBR1	26.00	6.96	5.00	125.30	0.06	141.30
NBR2	25.50	6.87	6.50	119.20	0.03	121.40
AKN1	24.90	6.98	6.90	88.90	0.02	101.30
AKN2	25.00	6.77	6.30	95.10	0.06	133.10
AKG	24.70	7.26	5.37	95.70	0.06	134.30

NBG: Nyabugogo, NBR1: Nyabarongo 1, NBR2: Nyabarongo 2, AKN1: Akanyaru 1, AKN2: Akanyaru 2, AKG: Akagera

Beside these physical chemical parameters, temperature of the waters sampled from six sites were ranged between 24.7°C and 26.3°C. The highest values of this parameter were found from Nyabugogo and Nyabarongo wetlands.

Nutrient concentrations

High load of nutrients caused by anthropogenic nutrient inputs to aquatic ecosystems deteriorate the quality of water by the process of eutrophication. Because they are considered as major nutrients for plant, Total Nitrogen (TN), Total Phosphorous (TP) and Potassium (K) were selected to be analyzed in this study. The obtained results showed that Nitrogen was the most concentrated in all water samples with the values ranging between 9.493 and 9.124 mg/mL (Table 2).

Table 2. ***Concentration of major nutrients in water***

Sampling sites	Nutrients (mg/ml) TN	TP	K
NBG	9.400	0.036	5.000
NBR1	9.493	0.397	3.000
NBR2	9.124	0.298	3.000
AKN1	8.891	0.052	2.000
AKN2	8.827	0.069	3.000
AKG	9.227	0.106	4.000

NBG: Nyabugogo, NBR1: Nyabarongo 1, NBR2: Nyabarongo 2, AKN1: Akanyaru 1, AKN2: Akanyaru 2, AKG: Akagera

The analysis of nutrients in plant samples showed that the mean concentration of Potassium (K) in all plant material samples is greater than ones of Total Phosphorus (TP) and Total Nitrogen (TN) for all sites investigated and LH was found to be the most concentrated in all assessed nutrients (Table 3).

Table 3: Mean concentration of major nutrients in plants

Plant per Location	Nutrients (mg/g)		
	TP	**TN**	**K**
NBG CP	0.68	2.04	20
NBG LH	1.36	4.23	23.34
NBR1 CP	0.42	1.83	13.33
NBR1 LH	1.11	3.46	23.34
NBR2 CP	0.36	1.38	12.91
NBR2 LH	0.94	2.54	17.64
AKN1 CP	0.07	3	9.83
AKN1 LH	0.14	1.68	15.62
AKN2 CP	0.49	2.34	13.33
AKN2 LH	1.76	2.18	20
AKG CP	0.03	1.83	8.89
AK LH	3.68	2.66	20

NBG: Nyabugogo, NBR1: Nyabarongo 1, NBR2: Nyabarongo 2, AKN1: Akanyaru 1, AKN2: Akanyaru 2, AKG: Akagera, CP: Cyperus papyrus, LH: Leersia hexandra

Heavy metals concentrations

Heavy metals are classified under environmental pollutant category considering their toxic effects on plants, animals and human being. This study focused on the comparison of some heavy metals fixation by *Cyperus papyrus* and *Leersia hexandra* wetland plants; and their content in water of wetlands where plants are sampled from. Five heavy metals such as Pb, Cd, Cu, Zn and Fe were investigated and their concentrations in water samples are grouped in Table 4.

Table 4. *Content of heavy metal in water samples (mg/l)*

	Heavy metals (mg/l)				
	Pb	Cu	Zn	Fe	Cd
NBG	0.16	1.74	0.739	40.21	0.009
NBR1	0.04	1.69	1.0868	21.93	0.005
NBR2	0.009	0.98	0.613	13.2	0.001
AKN1	0.001	0.11	0.315	10.05	ND
AKN2	0.09	1.17	0.9262	20.9	0.004
AKG	0.09	1.44	1.048	31.8	0.007

ND: Not detected

The results showed that Pb, Cd, Cu, Zn and Fe were present in all analyzed water samples with the lowest concentrations obtained for Pb and Cd. For the plant samples, results indicated that different parts of plants contained all heavy metals, except Cd, which was not detected in water samples (Table 5).

Table 5. *Mean concentration of heavy metals in plant per location*

Plant per location	Heavy metals (mg/g)				
	Cd	Pb	Cu	Zn	Fe
NBG CP	ND	0.05	0.14	0.12	2.34
NBG LH	ND	0.07	0.16	0.175	3.29
NBR1 CP	ND	0.07	0.13	0.14	2.99
NBR1 LH	ND	0.08	0.16	0.18	4.59
NBR2 CP	ND	0.02	0.09	0.07	2.12
NBR2 LH	ND	0.05	0.13	0.12	3.70
AKN1 CP	ND	0.004	0.05	0.02	0.73
AKN1 LH	ND	0.02	0.07	0.09	2.71
AKN2 CP	ND	0.09	0.10	0.16	1.65
AKN2 LH	ND	0.09	0.13	0.18	6.19
AKG CP	ND	0.09	0.12	0.19	0.43
AKG LH	ND	0.10	0.12	0.16	4.61

NBG: Nyabugogo, NBR1: Nyabarongo 1, NBR2: Nyabarongo 2, AKN1: Akanyaru 1, AKN2: Akanyaru 2, AKG: Akagera, CP:Cyperus papyrus, LH: Leersia hexandra, ND: Not Detectable

The analysis of these results in plants showed in addition that the variation of their mean content is correlated to the variation of their content in water samples (Figure 1).

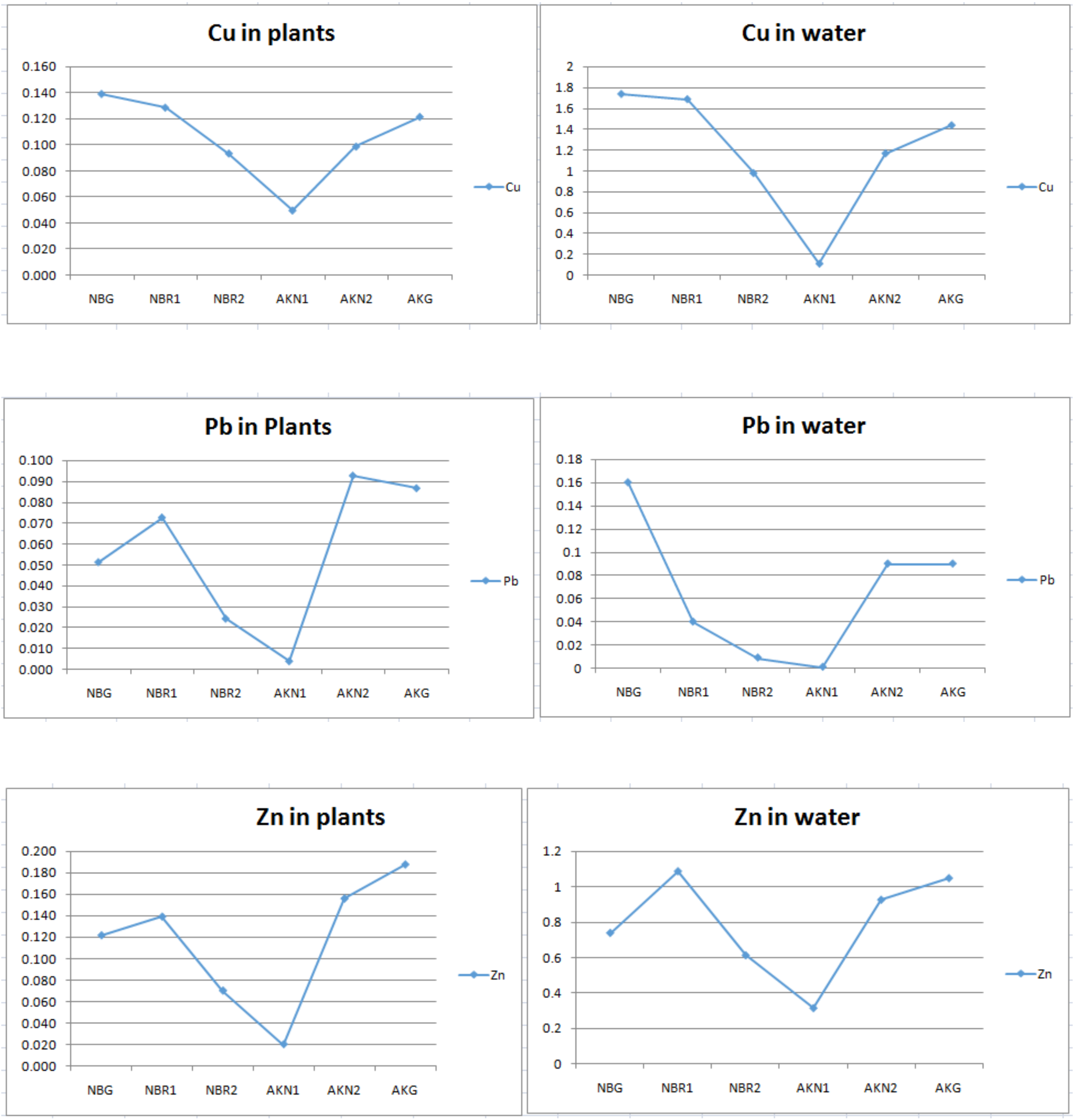

Figure 1. Variation of heavy metals in plant samples and their variation in water sample

Discussion

Water quality

Water is very important for the life of all organisms. However, when not protected it can be source of many intoxications leaving to fatal diseases. Due to anthropogenic activity, water is seriously menaced and their surrounding wetlands too. Many macrophytes which are able to fight against water pollution are progressively disappearing leaving the easy way of the pollutants to reach both surface and ground waters. This study investigated the relationship which may be between some macrophytes chemical contents and those of the wetlands in which they were grown prior to establish its possible efficacy in retaining chemicals and thus to valorize and protect them. The establishment of water quality surrounding the studied plants was a way for estimating this relationship.

The analyzed physical chemical parameters of the waters indicated that some of them were within the normal range, such temperature, between 24.7°C and 26.3°C(Ayers &Westcot, 1985), pH varied between 6.77 and 7.26(Singh et al., 2005), salinity which indicates total concentration of all dissolved salts in the water which was always less than 0.5(Ali et al., 2016). However other parameters were in high values indicating the rate of pollution of the analyzed waters. Dissolved oxygen (DO) is a parameter indicating quantity of oxygen gas that is dissolved in the water making available aquatic life. In this study, the values of DO were found high in Akanyaru 1, Nyabarongo2 and Akanyaru 2 sites compared to that of Nyabarongo2, Nyabugogo and Akagera. These results indicate that water from Nyabugogo and Nyabarongo wetlands may contain more discharged organic matter than Akanyaru and Akagera. The electrical conductivity (ED) or conductance is a physical parameter which indicates the status of major ions in water. It gives idea on total electrolytes and ionized species in the water. The obtained results showed that ED varied between 101.3 µS/cm in Akanyaru and 282 µS/cm in Nyabugogo while the total dissolved solids (TDS) were between 88.9 mg/L in Akanyaru and 125.3mg/L in Nyabarongo. TDS is a parameter indicating all dissolved solids including dissociated electrolytes making salinity and other compounds including organic matters. According to Pal et al.,(Pal et al., 2015), water is considered in the freshwater category if its TDS value is less than 1,000mg/L and as saline if its TDS ranges between 10,000mg/L and 30,000mg/L. In this study, the values of Total Dissolved Solids and Electrical Conductivity were higher in Nyabugogo and Nyabarongo waters compared to ones of Akanyaru and Akagera wetlands. These findings indicated that the two first wetlands were more polluted by solid wastes than the two others. In addition, the site AKN1 which is located far from Nyabarongo river was found to be the least polluted by solid matters. The salinity and TDS showed difference in their values based on the fact that TDS and Salinity are approximately equal in cleaner water while in polluted waters or wastewaters they are not the same(Fondriest, 2014). All the determined physico-chemical parameters indicated that waters from Nyabugogo and Nyabarongo contained external elements that may decrease its quality in comparison with those sampled from Akanyaru and Akagera wetlands. These differences could be explained by the fact that River Nyabugogo which is receiving a lot of solid wastes from Kigali city is very close with Nyabarongo and therefore sharing these pollutants.

Nutrient concentrations

The higher concentration of nitrogen in water samples is an indication that Nyabugogo, Nyabarongo and Akagera rivers contain high quantity of organic matter from both solid and liquid wastes discharged into the wetlands. In addition, this nitrogen could come from the degradation of aquatic animals and vegetable wastes. By comparing quantity of nutrients obtained from plants and those obtained from water, this study showed the same variation and that plant materials were highly concentrated in nutrients than in water. This has allowed suspecting that plants have capability to fix nutrients from water. In fact, the more the water is rich in nutrients the more plants are the same, indicating a positive influencing character.

Leersia hexandra is among the most abundant plant species inside Rwanda marshlands. This study showed that it has very high capacity of Phosphorous, Nitrogen and Potassium fixation thus it should be used as main source of nutrients for green agriculture. The same capability has been shown for *Cyperus latifolius*, another abundant wetland plant in Rwanda(Bizuru et al., 2015).

The analysis showed that variation of nutrient concentrations in different parts of *Cyperus papyrus* and *Leersia hexandra* is statistically significant for TP, TN and highly significant for K with p-value < 0.005. High accumulation of nutrients in wetland plants, especially those collected in non-higher contaminated area, like AKN1, can be explained as a result of hillside fertilizers run off that increases their availability downward in several valleys of Rwanda (Nabahungu, 2012).It was also noted that where nutrient contents are high in waters, plants from the same site had higher value as well. Current results corroborate with those reported by McLaughlin and his colleagues who found that where the nutrients availability increases, the accumulation of nutrients tends to increase(McCauley et al., 2015).

Heavy metals concentrations

Heavy metals concentrations in water samples

In the present study, concentrations of Pb, Cd and Fe from some sampling sites were above permissible limits in water samples compared to drinking water guidelines(Nazir et al., 2015). Since rural communities use these wetlands waters for daily activities, it is worth noting that they are at risk of Lead and Cadmium toxicity. Iron toxicity is known as the main cause of nutrient disorder in plant cultivated in wetlands(Sahrawat, 2005). Those results of heavy metals concentration allow to predict high concentration of heavy metals in plants sampled in the wetlands through the process of accumulation (X. Zhang et al., 2009).

Heavy metals concentrations in plants samples

Plant samples showed the bioaccumulation of all studied heavy metals in different parts of plants except Cd that has not been detected in plant samples. The reason of this may be a very low concentration of this metal in plant samples which is under detected limits by the AAS(Nazir et al., 2015), since plants were not able to fix it in detectable levels.

In all plant samples concentration of copper was recorded above the permissible limits compared to the acceptable levels by WHO(Hasan et al., 2012). The maximum concentration of 0.16mg/g was found in roots of CP from NBG wetland, in rhizomes and leaves of LH from NBG and in rhizomes of LH from NBR1. Even that copper is among essential micronutrients for plant metabolism, it becomes toxic when its quantity is in excess concentration in the plant(Aksoy et al., 2005) Concentration of zinc in plant samples were found above the permissible limit except in roots, stems and umbel of CP from AKN1. WHO's recommended limit of zinc in plants is 0.050 mg/g (Shah et al., 2013).

High concentrations of heavy metals recorded in Nyabugogo, Nyabarongo1, Akanyaru 2 and Akagera could be due to the addition of domestic wastes, industrial effluents and other anthropogenic activities(I. Nhapi et al., 2011)and also to the mining activities situated along Nyabarongo river. Furthermore, this pollution could be attributed to the land use practices in surrounding catchments(Nabahungu, 2012; I. Nhapi et al., 2012). This deterioration of the water quality in turn makes it unsuitable for aquatic life. Current results showed how important native wetland plants have the capacity to absorb and accumulate heavy metals in their tissues, therefore, becoming important for phytoremediation of water. Specifically, for this study, for all sites investigated, the content in heavy metals detected in *Leersia hexandra* is higher than one in *Cyperus papyrus*).

The variation of the content of heavy metals in plant samples per location correlated to their variation in water samples per location, confirm that heavy metals accumulation in plants is related to water quality of their sampling sites.

Due to its high capability of absorbing some heavy metals, *Leersia hexandra* is even considered as an hyperaccumulator of heavy metals, with the ability to take up large amounts of chromium, copper, and nickel from water and soil (You et al., 2014). It should be used as a potential agent of phytoremediation in order to clean up soils and water contaminated by heavy metals (X.-H. Zhang et al., 2007) from industrial wastewater such as electroplating factories (You et al., 2014).

Conclusion

The main objective of this study was to compare both nutrients and heavy metals content in two Rwandan wetland plants (*Cyperus papyrus* and *Leersia hexandra*) in order to contribute in research of solutions to environmental pollution of Rwanda, especially wetlands by using phytoremediation technique. To achieve this objective, both contents in nutrients (TP, TN, K) and some heavy metals (Cd, Cu, Pb, Zn, Fe) of two wetland plants *Cyperus papyrus* and *Leersia hexandra* have been evaluated and compared in order to recommend the best plant to be used in phytoremediation. Samples of water and plant materials were concurrently taken from six critical sites considered in Nyabugogo-Nyabarongo-Akagera-Akanyaru wetlands.

After laboratory analysis, results from this study revealed that water and plants materials contain chemicals varying in the same ways. This observation leads to the confirmed impact of the quality of water on chemical constituents of the plants. Nutrients and heavy metals are accumulated differently in parts of the plants sampled and their concentrations were recorded to be higher than WHO's permissible limits. Furthermore, comparing different sites investigated, Nyabugogo site taken in Nyabugogo wetland was the more polluted site while Akanyaru1 site taken in Akanyaru wetland very far from Nyabarongo river, which is considered as the pillar of pollutants; was the less polluted. Moreover, by comparing the concentration of analyzed elements in two plants, *Leersia hexandra* showed higher accumulation than *Cyperus papyrus.*

Our findings indicate that the wetland plant *Leersia hexandra* is more recommended to be used in phytoremediation than *Cyperus papyrus* and the intensive farming practice in wetlands should be correlated with their good management by protecting the wetland plants, in order to fight the pollution of wetlands, thus maintain the quality of their water . Further studies are recommended to assess the content in chemicals for other wetland plants in order to promote the phytoremediation technique in environmental protection specially wetlands known as main resources of water in Rwanda.

Conflict of Interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

References

Aksoy, A., Demirezen, D., & Duman, F. (2005). Bioaccumulation, detection and analyses of heavy metal pollution in Sultan Marsh and its environment. *Water, Air, and Soil Pollution*, *164*(1–4), 241–255.

Ali, M. M., Ali, M. L., Islam, M. S., & Rahman, M. Z. (2016). Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. *Environmental Nanotechnology, Monitoring & Management*, *5*, 27–35.

Ayers, R. S., & Westcot, D. W. (1985). *Water quality for agriculture* (Vol. 29). Food and Agriculture Organization of the United Nations Rome.

Bizuru, E., Hirwa, M. G., Nkundimana, M. E., Muhizi, T., Uyizeye, M., Umurerwa, M. A., & Kananura, M. L. B. (2015). *Assessment of the Capability of Wetlands Plants Organs to Fix Nutrients and Heavy Metals in Ndobogo Wetland, Southern Province of Rwanda.Journal of Chemical, Biological and Physical Sciences. Vol.6 154-165.6*, 154–165.

Elmer, P. (1996). Analytical methods for atomic absorption spectroscopy. *USA: The Perkin-Elmer Corporation*.

Estefan, G., Sommer, R., & Ryan, J. (2013). Methods of soil, plant, and water analysis. *A Manual for the West Asia and North Africa Region*, *3*.

Fondriest Environmental, Inc (2014). “Conductivity, Salinity and Total Dissolved Solids.” Fundamentals of Environmental Measurements. Accessible on: ttps://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/ >.

Hasan, Z., Anwar, Z., Khattak, K. U., Islam, M., Khan, R. U., & Khattak, J. Z. K. (2012). Civic pollution and its effect on water quality of river Toi at district Kohat, NWFP. *Research Journal of Environmental and Earth Sciences*, *4*(3), 334–339.

Kansiime, F., Saunders, M. J., & Loiselle, S. A. (2007). Functioning and dynamics of wetland vegetation of Lake Victoria: An overview. *Wetlands Ecology and Management*, *15*(6), 443–451.

Kyambadde, J., Kansiime, F., Gumaelius, L., & Dalhammar, G. (2004). A comparative study of Cyperus papyrus and Miscanthidium violaceum-based constructed wetlands for wastewater treatment in a tropical climate. *Water Research*, *38*(2), 475–485.

McCauley, L. A., Anteau, M. J., van der Burg, M. P., & Wiltermuth, M. T. (2015). *Land use and wetland drainage affect water levels and dynamics of remaining wetlands. Ecosphere 6 (6): 92*.

Mganga, N., Manoko, M. L. K., & Rulangaranga, Z. K. (2011). Classification of plants according to their heavy metal content around North Mara gold mine, Tanzania: Implication for phytoremediation. *Tanzania Journal of Science*, *37*(1).

Mitsch, W. J., & Gosselink, J. G. (2000). The value of wetlands: Importance of scale and landscape setting. *Ecological Economics*, *35*(1), 25–33. https://doi.org/10.1016/S0921-8009(00)00165-8

Nabahungu, N.L. (2012) Problems and Opportunities of Wetland Management in Rwanda. Wageningen Universiteit (Wageningen University), Wageningen

Nazir, R., Khan, M., Masab, M., Rehman, H. U., Rauf, N. U., Shahab, S., Ameer, N., Sajed, M., Ullah, M., & Rafeeq, M. (2015). Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. *Journal of Pharmaceutical Sciences and Research*, *7*(3), 89.

Nhapi, I., Garba Wali, U., Usanzineza, D., J Kashaigili, J., Banadda, N., & Kimwaga, R. (2012). Distribution of heavy metals in Lake Muhazi, Rwanda. *The Open Environmental Engineering Journal*, *5*(1).

Nhapi, I., Wali, U. G., Uwonkunda, B. K., Nsengimana, H., Banadda, N., & Kimwaga, R. (2011). Assessment of water pollution levels in the Nyabugogo Catchment, Rwanda. *The Open Environmental Engineering Journal*, *4*(1).

Niyonsenga, J. D., Birame, C. S., & Maniragaba, A. (2019). Rainy seasonal analysis of Physico-chemical parameters of Mukungwa River at NGARU point. *International Journal of Environmental & Agriculture Research*, *5*(8), 21.

Nyandwi, E., Veldkamp, T., & Amer, S. (2016). Regional climate sensitivity of wetland environments in Rwanda: The need for a location-specific approach. *Regional Environmental Change*, *16*(6), 1635–1647.

Okurut, K., Kulabako, R. N., Abbott, P., Adogo, J. M., Chenoweth, J., Pedley, S., Tsinda, A., & Charles, K. (2015). Access to improved sanitation facilities in low-income informal settlements of East African cities. *Journal of Water, Sanitation and Hygiene for Development*, *5*(1), 89–99.

Pal, M., Samal, N. R., Roy, P. K., & Roy, M. B. (2015). Electrical Conductivity of Lake Water as Environmental Monitoring–A Case Study of Rudrasagar Lake. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *9*, 66–71.

REMA, A. (2009). Our Environment for Economic Development: *Rwanda Environmental Management Authority*.

Rohan, Y., Imran, K., & Umar, P. J. (2014). Heavy metal analysis in water, fish and vegetative samples of Lakha-Banjara lake, Sagar, Madhya Pradesh, India. *Journal of Environmental Research And Development*, *8*(3), 425.

Sahrawat, K. L. (2005). Iron toxicity in wetland rice and the role of other nutrients. *Journal of Plant Nutrition*, *27*(8), 1471–1504.

Sekomo, C. B., Nkuranga, E., Rousseau, D. P., & Lens, P. N. (2011). Fate of heavy metals in an urban natural wetland: The Nyabugogo Swamp (Rwanda). *Water, Air, & Soil Pollution*, *214*(1–4), 321–333.

Shah, A., Niaz, A., Ullah, N., Rehman, A., Akhlaq, M., Zakir, M., & Suleman Khan, M. (2013). Comparative study of heavy metals in soil and selected medicinal plants. *Journal of Chemistry*, *2013*.

Singh, K. P., Mohan, D., Singh, V. K., & Malik, A. (2005). Studies on distribution and fractionation of heavy metals in Gomti river sediments—A tributary of the Ganges, India. *Journal of Hydrology*, *312*(1–4), 14–27.

Turner, R. K., Van Den Bergh, J., Soderqvist, T., Barendregt, A., Van der Straaten, J., Maltby, E., & van Ireland, E. C. (2000). The values of wetlands: Landscape and institutional perspectives. *Ecological Economics*, *35*(3), 7–23.

You, S.-H., Zhang, X.-H., Liu, J., Zhu, Y.-N., & Gu, C. (2014). Feasibility of constructed wetland planted with Leersia hexandra Swartz for removing Cr, Cu and Ni from electroplating wastewater. *Environmental Technology*, *35*(2), 187–194.

Zhang, X., Liu, J., Wang, D., Zhu, Y., Hu, C., & Sun, J. (2009). Bioaccumulation and chemical form of chromium in Leersia hexandra Swartz. *Bulletin of Environmental Contamination and Toxicology*, *82*(3), 358.

Zhang, X.-H., Liu, J., Huang, H.-T., Chen, J., Zhu, Y.-N., & Wang, D.-Q. (2007). Chromium accumulation by the hyperaccumulator plant Leersia hexandra Swartz. *Chemosphere*, *67*(6), 1138–1143.

Zhu, Y. L., Zayed, A. M., Qian, J.-H., Souza, M. de, & Terry, N. (1999). Phytoaccumulation of Trace Elements by Wetland Plants: II. Water Hyacinth. *Journal of Environmental Quality*, *28*(1), 339–344.