Scholars Academic Journal of Biosciences (SAJB) **ISSN 2321-6883 (Online)**
Sch. Acad. J. Biosci., 2016; 4(11):975-985 **ISSN 2347-9515 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com DOI : 10.36347/sajb.2016.v04i11.003
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Original Research Article

Assessment of Water Quality and Aquatic Macroinvertebrate of Nyabarongo River, Lake Kivu Catchment, D.R.Congo

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Abstract: The water quality of Nyabarongo River was assessed between January and December 2013 using selected physicochemical factors, bacteriological factors in combination with macroinvertebrate composition and diversity indices using standards techniques of water analysis and biological methods. Three sampling sites were chosen Kabirikarhaba, Cabwine-Mwami, and Ceshero. Suspended sediment concentration was high at the site of Cabwine-Mwami (1.08 ± 0.62 mg/L) in the habited area and less at the site of Kabirikarhaba (0.67 ± 0.23 mg/L) in the forest area. But it was low moderate at the site of Ceshero (0.68 ± 0.54 mg/L). Most nutrient concentrations were highest at the agricultural sites. Fecal bacteria were recorded in sampling water such as *Escherichia coli* and Klesbiella. Invertebrate taxa richness, biotic index, and the number of unique invertebrate species indicated moderate stress at the agricultural site and severe stress at the habituated area of site Cabwine-Mwami. At the agricultural site, declines in taxa richness within intolerant groups were partially offset by increases within tolerant groups. Analysis of seasonal patterns suggested detritus was the most important food source for invertebrates in the forested stream. Dominant macroinvertebrate groups shifted from Ephemeroptera at the forested site, to Chironomidae at the agricultural site, and Oligochaeta at the habited area. Physico-chemical parameters measured at the three sites did not seem sufficient to account for all of the observed differences in the invertebrate communities, suggesting some unmeasured toxicity.
Keywords: Physico-chemical, macro-invertebrate, Nyabarongo River, indexes

INTRODUCTION

Freshwater is perhaps most vulnerable habitat and most likely to be changed by the anthropogenic activities. It is clear that the mismanagement of land constitutes a pressure to physico-chemical and biological quality of water in the river. Several studies have shown that land use has a strong influence on river chemistry and its biotic components [1]. Certain nutrients are known to load from agricultural and urban lands into rivers by runoff [2-5]. The runoff influence distribution and therefore abundance of macroinvertebrates in the catchment and it is depending also on their tolerance or habitat requirements [6].

Human activity represents a major threat of land use and therefore a key impact to the biotic integrity of streams in Lake Kivu basin [7]. With 70% of the regional land allocated to agriculture, it is important to determine to what extent this land use affects water chemistry and biotic community in order to take steps toward more sustainable development. Little research on the relationships between land use and the chemical and biotic integrity of running waters in the region of Lake Kivu watershed have been conducted [7- 10]. The results of these studies show that land use affect quality of water especially dissolved oxygen, nutrients, biological oxygen demand and chemical oxygen demand. But also, reduce macroinvertebrate tolerant taxa. Macroinvertebrate diversities are strongly influenced by physical differences among habitats, water quality and human induced [6, 11]. Characterizing these relationships between environmental factors and invertebrate communities is essential to understanding how aquatic communities in a particular geographic area are responding to change in land use.

Biological monitoring often appears to be more appropriate in the assessment of pollution of aquatic ecosystems than traditional chemical evaluation of water quality. As aquatic organisms may integrate effects of perturbations, numerous methods have been proposed to assess both water and biological quality. In particular, methods based on benthic macroinvertebrate communities have been frequently used [9, 10]. Benthic macroinvertebrates have been one of the most widely used groups of organisms for evaluating the quality of flowing waters. These organisms are easier to sample, are not as restricted in distribution and are easier to identify and to quantify than others are biodiversity in running waters [12-14].

This study evaluates the impact of land use in the Nyabarogo micro-catchment on the physicochemical water quality and macroinvertebrate using indexes. We applying three different indices because previous research has used them successfully: biological index (biotic index) and chemical index (IOP and LISEC index). These indexes were selected because the Iberian Limnological Association (AIL) has recognized it as effective biological and chemical indicators for assessing water quality.

MATERIAL AND METHODS

Sampling sites:

Nyabarongo River is one of the tributaries of the Lake Kivu [15, 16]. It is located between two territories, Kabare and Kalehe in Eastern part of Democratic Republic of Congo. The river takes source in Kahuzi Biega National Park (PNKB) at 2000 m of altitude and passes through cultivated and deforested area of Lwamisakule, Changulube, Lugohwa, Ntagalylwa, Karunvangoma, Cabwine-Mwami, Ceshero and flows in Lake Kivu in the bay of Kasheke-Irambo at 1465 m of altitude (Figure 1).

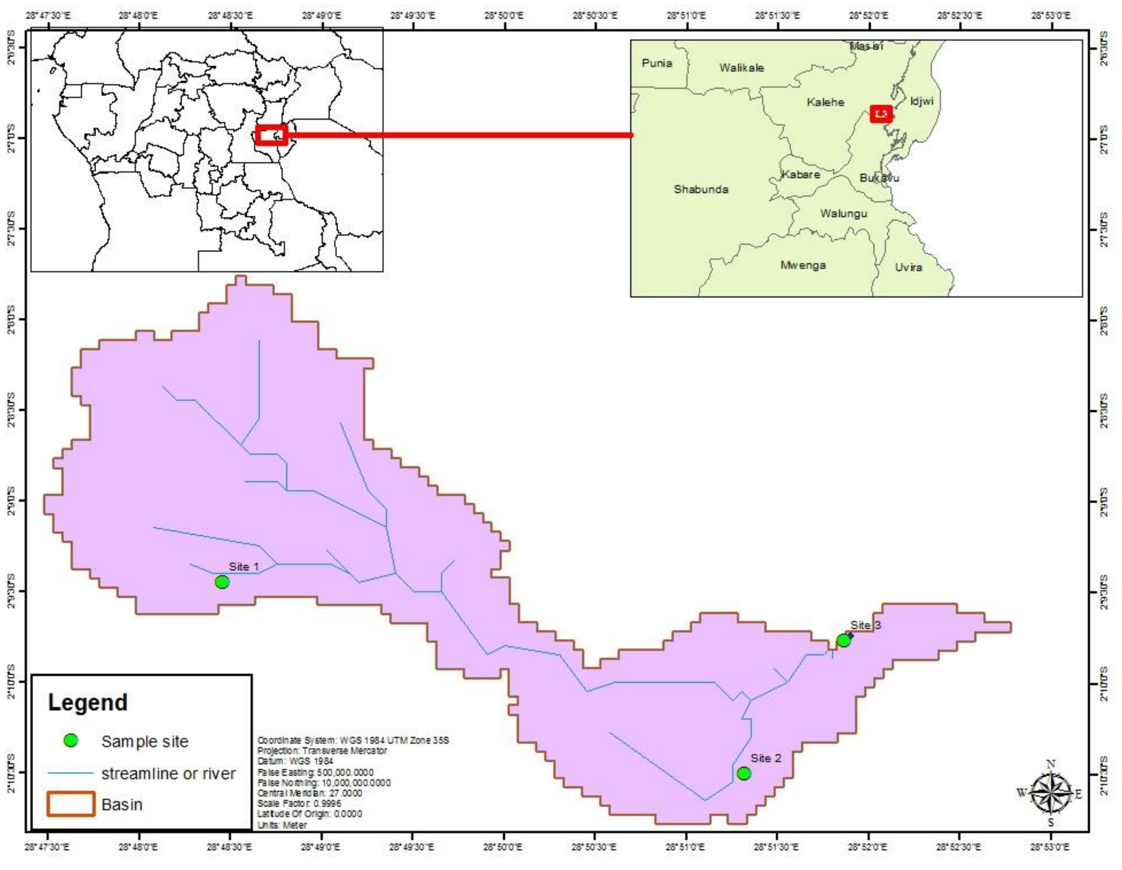

Fig 1: River Nyabarongo watershed and sampling points

The river is 11.9 Km long with a width of 4.15 m maximum at Cabwine –Mwami and a deep of 2 m at Ceshero. Along the river bank Nyabarongo River is used by population for many anthropogenic activities such as drinking, washing, animal drinking and irrigation of sugar cane plantation.

The Nyabarongo micro-catchment is located in tropical humid climate region with two seasons; the dry season with 3 months (June, July and August) and the wet season with 9 months (September to Mai). The mean temperature varied between 19° and 20°C and with high precipitation of about 1500 mm/year [7, 17]. The vegetation is made by cultivated savanna where

Albizia grandibracteata forest trees were replaced [18]. A long the river bank the vegetation is constituted by hydrophilic community composed by *Pennisetum purpureum, Brillantaisia patula, Ensete ventricosum, Commelina diffusa, Miletia dura, Cyperus latifolia, Digitaria vestuda, Fragmites mauritianus,…* and cultivated plants (*Musa sp, Manihota utilisima, Phaseolus vulgaris, Zea mays, Ipomoea batatas* and *Xanthosoma sagitifolia)*.

Three sites were considered for sampling in the main river following the land use characteristics and accessibility during the year.

Site 1 (Kabirikarhaba) at 02°09’26.6’’S; 028°42’27.0’’E and at 1754 m above mean sea level (AMSL), at the exit of the Kahuzi Biega National Park where the source of the river is located. At this site, the water is undisturbed by anthropogenic activities of population and was taken as control site. The mean temperature at this site is 16.3°C with a pH of 8.05 and a mean deep of 16.4 cm. The river bank is covered by macrophytes such as *Pennisetum purpureum, Commelina diffusa*, *Pteridophyta sp* and *Ensete ventricosum*. The substratum consists of stones and mud. Since trees are just a few meters away from the stream on Kabirikarhaba site, most of the leaves were found flowing and settling on the riverbed.

Site 2 (Cabwine-Mwami) is at 1491 m AMSL (02°10’29.7’’S and 028°51’18.8’’E), approximately 5 km downstream of the spring and within an agricultural sector where maize and green beans are grown. The substratum is made by dead vegetation coming from farms. The water is used for bathing and washing and drinking of animals. At the river bank, animal and human excrements are frequently found. The mean temperature at the site is 18.4°C, pH of 7.98 and the mean deep 19.62 cm. Poor vegetation is found at the river bank constituted mainly by *Solanum mauritianum* and *Solanum gigantea* and banana trees.

Site 3 (Ceshero) is the outlet of the river to the Lake Kivu at 500 m of the Lake (02°09’45.6’’S and 028°51’51,4’’E) at 1471 m. The site is located in the irrigated wetland and received all the discharge from other sites but also the wastewater and the waste from domestic activities of the population living between the two sites. The river bank is invaded by *Fragmites mauritianus, Digitaria vestuda, Pennisetum purpureum* and *Cyperus latifolia*, hydrophile plants. Sediment from upstream flooded the wetland and the Lake. Mean water temperature at the site is 20°C, pH about 7.28 and the mean deep 127.62 cm. During the flood period the deep reach 2 m and brings waste along its way.

All the three sampling sites (Kabirikarhaba, Cabwine-Mwami and Ceshero) are characterized by the same substrate but each has been subject to different perturbations from human activities.

METHODS

Macroinvertebrate communities along the stream were sampled monthly from January to December 2011 at each of the three sites, using hand-net samplers (475 µm mesh of 30cm wide, 20 cm high and 50 cm long). The samples were taken from an area of nearly 100 m^2 in order to include all possible microhabitats at each station in 10 minutes per person [19- 21]. In some areas with the presence of large stones, these were first picked out and washed into the hand-net; to remove pupae and other attached macroinvertebrates. All the animals collected were immediately fixed in formaldehyde (4%) at the field and then transported at the laboratory. The macroinvertebrates were sorted, identified to the lowest possible taxon (species, genus or families) and counted under a binocular using the determination keys of Needhan and Needhan [22] and Micha and Noiset [23].

At the same time of sampling macro-invertebrates, water samples were taken monthly and analyzed for the following parameters: NH_4 (µg/L), NO_3 (µg/L), PO_4 (µg/L), TN (µg/L), TP (µg/L), Biological Oxygen Demand (BOD_5 mgL^{-1}) and Dissolved Oxygen(mgL^{-1}). All analyses were done in accordance with national standards. Water temperature and pH were measured at the field by portable equipments. Water quality assessment by physico-chemical parameters was done according to APHA, [24] and Golterman *et al.;* [25].

Bacteriological methods

The spread plate method [24] was employed for the enumeration and isolation of bacteria in water samples. For each water sample 0.1 ml aliquots was inoculated into nutrient agar, thiosulphate citrate bile salt sucrose agar, *Salmonella-Shigella* agar, mannitol salt agar, eosine methylene blue plates for enumeration and isolation of different bacteria. All the plates were incubated aerobically at 37°C for 24 to 48 hours. The colonies were counted and recorded as colony forming units per ml (cfu/ml). Subsequently the isolates were characterized and identified based on cultural and cell morphology, Gram reaction, motility and biochemical tests such as catalase, coagulase, oxidase, urease, indole, citrate, methyl red and sugar fermentation [26].

Benthic macro-invertebrate indices

This study is restricted to indices focused on the determination of water quality. The following nine indices were tested: Average Score Per Taxon (ASPT) [13], Biological Monitoring Working Party (BMWP) [13], Family Biotic Index [27] and number of Ephemeroptera, Plecoptera and Trichoptera (EPT%) taxa.

Three diversity indices, obtained by using the formula of Margalef Diversity Indices (MDI), Simpson Diversity Indices (SDI) and of Shannon and Weaver Diversity Indices (SWDI) as detailed in Ludwig and Reynolds [28] were evaluated. Correlation analysis was based on Pearson's correlation.

Table 1: Water quality classification

Water quality	IPO	LISEC	ASPT	BMWP	BI	ETP
Excellent	5.0-4.6	4-<6	>5.4	>100	0.0-3.75	>10
Very good	4.5-4.0	6-<10	4.8-5.4	71-100	3.76-4.25	6-10
Good	3.9-3.0	10-<14	4.3-4.8	41-70	4.26-5.00	2-5
Moderate	2.9-2.0	14-<18	3.6-4.3	11-40	5.01-5.75	
Poor	1.9-1.0	18-20	3.0-3.6	0-10	5.76-6.50	0-1

LISEC [29], IPO [30], ASTP [31], BMWP [14] and ETP [32]

RESULTS AND DISCUSSION

Human activities affect the chemical properties, richness and abundance of macroinvertebrate communities living on the riverbed. Fluctuations in physicochemical characteristics at the three sampling sites on the river Nyabarongo is given in Table 2.

Table 2: Physico-chemical and bacteriological factors of water at the three sites

	Kabirikarhaba	Cabwine-Mwami	Ceshero
Dissolved Oxygen (mgO_2/L)	11.27 ± 2.53	8.54 ± 3.26	5.57 ± 3.39
Oxygen saturation (%)	118.57 ± 36.82	82 ± 43.45	52.43 ± 37.72
BOD_5 (mgO_2/L)	5.55 ± 3.3	4.05 ± 3.69	3.40 ± 2.77
Total Phosphorus (µg/L)	8.47 ± 6.37	12.10 ± 7.09	21.08 ± 12.73
Nitrate (µg/L)	2.33 ± 2.07	4.64 ± 3.07	7.49 ± 5.07
Ammonium (µg/L)	1.82 ± 1.13	1.58 ± 1.17	2.77 ± 1.67
Temperature (°C)	16.29 ± 0.76	18.43 ± 0.79	20 ± 0.82
Suspended Sediment (mg/L)	0.67 ± 0.23	1.08 ± 0.62	0.68 ± 0.54
Bacteriological factors *Escherichia coli* (cfu/L)	1500	37000	30000
Hafnia (cfu/L)	0	2000	5000
Klesbiella (cfu/L)	1000	3500	5000
Providencia (cfu/L)	0	2000	0
Edwadsiella (cfu/L)	0	0	3000
Salmonella and Shigella (cfu/L)	0	0	0
Vibrio cholerae (cfu/L)	0	0	0

Dissolved Oxygen is high at the Kabirikarhaba (11.27 mg/L) the upstream but decreased gradually to other sites namely, Cabwine-Mwami and Ceshero were the concentration is 5.57 mg/L. For a river to sustain aquatic life, the minimum dissolved oxygen value should be 6 mg O_2/L. The two sampling sites (Kabirikarhaba and Cabwine-Mwami) have DO level above maximum and Ceshero have DO below the required. This indicates that the river at the sites was not capable of supplying oxygen to sustain macroinvertebrate life. The high level of DO is probably due to the rapid turnover of the river which allows water to aerate and produces DO [33]. This is also observed when considered Oxygen saturation. The site of Kabirikarhaba is very saturated in Oxygen (118.57%). The average value of BOD_5 (mg/L) in different sites of the Nyabarongo river was 5.55 mg/L at Kabirikarhaba but also decreased in other sites. For nutrient TP (Total Phosphorus), Nitrate and Ammonium, the concentration is increasing downstream. The site of Cabwine-Mwami showed a concentration of TP less than the other sites but at Ceshero site the concentration increased considerably. Mean Temperature also follows the same trend. It increased downstream. Faulkener *et al.*, [34] suggest that a BOD_5 of less than 3.2 mg/L is very good for the river ecosystems. Cabwine-Mwami and Ceshero sites have the most turbid water when compared to the Kabirikarhaba site upstream. This may be due to high human activities (market, waste garbage, animal watering and washing) which caused water to become cloudy. These parameters in general indicate that organic pollution is currently of little impact at Kabirikarhaba. Furthermore, as some of these parameters are known as measure of ecological wellbeing [34], healthy macroinvertebrate communities are expected to coincide with theses low values.

Five type of bacterial (*Escherichia coli, Edwadsiella*, *Klesbiella*, *Hafnia* and *Providencia*) were found in the water during the sampling period. Faecal coliforms represented 93–99% of coliform bacteria in faeces from humans and animals [35]. The most common is *the Escherichia coli* in all sampling sites of Nyabarongo River. The count number of *Escherichia coli* varied from 0 – 20000 cfu/mL. The high counts of faecal coliforms *Escherichia coli* can be attributed to the indiscriminate defecation along the river banks by both humans and other animals grazing along the river banks and in the river [36]. Nyabarongo River is one of the Tributaries Rivers of Lake Kivu were people used river water to wash animals and can be a source of contamination of water with faecal coliforms. One site was infected by *Edwadsiella*, two sites with *Klesbiella*, *Hafnia* and *Providencia* and three sites with *Escherichia coli*. *Vibrio cholera, salmonella* and *shigella* was not identified in sampling sites. The counts of faecal coliforms in almost all occasions of sampling indicate significant and increasing risk of infectious disease transmission. As faecal coliform levels increase beyond 20 cfc/100 ml, the amount of water ingested required causing infections decreases [35]. The high coliforms recorded (faecal and total coliforms) was also observed in other rivers such as Oti River in Ghana [37].

Chemical pollution index IPO and LISEC calculated in the three sites during the study period (January to December 2011) are presented in Table 3.

Table 3: Chemical pollution index (IPO and LISEC) of the three sites of the Nyabarongo river

	Kabirikarhaba		**Cabwine-Mwami**		**Ceshero**	
Month	**IPO**	**LISEC**	**IPO**	**LISEC**	**IPO**	**LISEC**
January	3	7	2.55	9	3	11
February	4.25	7	4	10	3.25	12
March	4.25	6	4	9	3.5	9
April	4.25	8	4.5	9	3.75	10
May	3.75	9	4	7	3.25	8
June	4	10	4	11	5	17
July	3	8	4	7	3	8
August	3	9	2.75	10	2.75	10
September	2.5	9	3	8	3	9
October	2.25	10	2.25	11	2.5	10
November	2.25	9	2.25	9	2.25	9
December	2.5	11	2.25	11	2.5	9
Mean	**3.25**	**8.58**	**3.30**	**9.25**	**3.15**	**10.17**

Biological results

During this study, in total 1467 individuals were collected. Of the sampling points, Kabirikarhaba was the one where the most individuals were collected (868), and the Cabwine-Mwami was the one where the fewest individuals were collected (256). The individuals collected from the sampling points belong to the class of Gastropoda, Oligochaeta, Hirudinea, Crustacea and Insecta. Fourty five taxa were identified: 5 of Gastropoda (species level), 1 of Oligochaeta (specie level), 2 of Hirudinea (specie level), 1 of Nematoda (specie level), 2 of Crustacea (2 species level) and 32 of Insecta (2 families, 11 genus and 19 species level). This result is clearly presented in Table 4.

Table 4: Liste of macroinvertebrate in Nyabarongo river

Taxa	Kabirikarhaba	Cabwine-Mwami	Ceshero
E. Arthropods			
Class of insecta			
Order of Dictyoptera			
Family Panesthiidae			
Cryptocercus punctulatus	34	0	0
Order of Plecoptera			
Family des Chloroperlidae			
Unknowned specie 1	2	0	0
Family of Perlidae			
Perlinella drymo	18	2	20
Family of Isogeninae			
Isogenus modesta	16	0	0
Family of Nemourinae			
Nemoura venosa	57	0	0

Order of Trichoptera			
Family of Lepidostomatidae			
Lepidostoma sp	108	2	2
Family of Hydropsychidae			
Hydropsyche simulans	145	27	5
Family of Rhyacophilidae			
Glossosoma americanum	3	0	0
Order of Ephemeroptera			
Family of Baetidae			
Baetis sp	16	9	0
Cloeon sp	8	12	0
Acanthrella sp	0	4	0
Caenis sp	8	7	6
Family of Heptagenidae			
Rhithrogena sp	0	1	1
Order of Heteroptera ou Hemiptera			
Family of Belostomatidae			
Belostoma fluminea	2	0	0
Family of Pleidae			
Plea striola	54	0	0
Family of Mesoveliidae			
Mesovelia mulsanti	1	1	1
Unknowed specie 2	2	0	0
Family of Veliidae			
Velia cuneus	3	1	0
Family of Nepidae			
Nepa cinerea	12	8	4
Family of Naucoridae			
Pelocoris femoratus	0	0	17
Family of Gerridae			
Gerris lacustris	5	1	0
Family of Hydrometridae			
Hydrometra martini	1	0	0
Order of Odonates			
Family of Libellulidae			
Tachopteryx thoreyi	105	6	11
Family of Coenagrionidae			
Pseudogrion sp	0	16	114
Family of Gomphidae			
Progomphus obscuris	20	1	0
Order of Diptera			
Family of Chironominae			
Chironomus tentans	0	4	1
Family of Simuliidae			
Simulium venustum	81	26	5
Family of Psychodidae			
Psychoda sp	49	6	9
Family of Anthomyiidae			
Limnophora sp	0	1	0
Family of Syrphidae			
Tubifera sp	0	1	0
Order of Coleoptera			
Family of Elmidae			
Stenelmis lateralis	16	0	0
Family of Gyrinidae			
Gyrinus notatore	17	3	5
Class of Arachnida			
Order of Areneida (Hydracarina)			
Family of Araneae			
Argyroneta aquatica	25	1	2
Argyroneta sp	15	0	0

Class of Crustaceae			
Order of Decapoda			
Family of Potamonidae			
Potamon sp	32	0	0
Order of Isopoda			
Family of Asselidae			
Assellus aquaticus	4	0	0
E. Annelida			
Class of Oligocheta			
Order of Lumbriculida			
Family of Lumbriculidae			
Lumbriculus inconstans	4	11	13
Class ofs Hirudineae			
Order of Arhynchobdellideae			
Family of Glossiphoniidae			
Glossiphonia complanata	7	33	14
Haemopis grandis	0	82	0
E. Nemathelmintha			
Class of Nematoda			
Order of Gordiideae			
Family of Gordiidae			
Gordius robustus	3	0	1
E. Mollusks			
Class of Gasteropoda			
Order of Basomatophora			
Family of Planorbidae			
Biomphalaria pfeifferi	0	0	75
Biomphalaria smithi	0	0	23
Bulinus truncatus	0	0	1
Family of Lymnaeidae			
Lymnaea columella	1	0	1
Lymnaea natalensis	0	0	10
Total of taxa	**874**	**266**	**342**

Taxa richness varied from site to another. The highest number of taxa was obtained at Kabirikarhaba (33) followed by Cabwine-Mwami (25) and the lowest at Ceshero (23). Some taxa are found only at Kabirikarhaba site such as the families of *Panesthiidae, Chloroperlidae, Isogeninae, Nemourinae, Rhyacophilidae, Belostomatidae, Pleidae, Hydrometridae, Elmidae, Potamonidae and Asselidae*. . *Planorbidae, Nauciridae and Lymnaeidae* families were found only at Ceshero site. Anthomyiidae and Syrphidae families were found at the site of Cabwine-Mwami only. The frequency and abundance of species collected at each site are presented in the table 5.

Table 5: Frequency and abundance of macroinvertebrate encountered at Kabirikarhaba, Cabwine-Mwami and Ceshero (January 2011 to December 2011).

	Kabirikarhaba		Cabwine-Mwami		Ceshero	
TAXA (Ordre)	**Abundance**	**Frequency**	**Abundance**	**Frequency**	**Abundance**	**Frequency**
Dictyoptera	34	3.89%	0	0.00%	0	0.00%
Plecoptera	93	10.64%	2	0.78%	20	5.87%
Tricoptera	256	29.29%	29	11.33%	7	2.05%
Ephemeroptera	32	3.66%	33	12.89%	7	2.05%
Hemiptera	80	9.15%	11	4.30%	22	6.45%
Odonata	125	14.30%	23	8.98%	125	36.66%
Diptera	130	14.87%	38	14.84%	15	4.40%
Coleoptera	33	3.78%	3	1.17%	5	1.47%
Araneida	40	4.58%	1	0.39%	2	0.59%
Decapoda	32	3.66%	0	0.00%	0	0.00%
Isopoda	4	0.46%	0	0.00%	0	0.00%
Lumbriculidaea	4	0.46%	11	4.30%	13	3.81%
Arhynchobellidaea	7	0.80%	105	41.02%	14	4.11%
Gordideae	3	0.34%	0	0.00%	1	0.29%
Basomatophora	1	0.11%	0	0.00%	110	32.26%

Abundance of families in the Nyabarongo River varied from site to site. At Kabirikarhaba site, 4 major families are abundant, mainly Tricoptera, Diptera, Odonata and Plecoptera. In Cabwine-Mwami site, the Arhychobellideae, Diptera, Epheroptera and Tricoptera families are dominant. At Ceshero site, the Odonata, Basomatophore, Hemiptera and Plecoptera families are abundant. Distribution of benthic macroinvertebrates community is influenced by environmental conditions such as nutrient and organic matter availability, as well as dissolved oxygen concentration as observed by Beghelli *et al.;* [38].

Monthly variation of individuals collected at the 3 sites of the River Nyabarongo showed a pattern with the seasonality (Figure 2). It was observed a decreased of individuals collected during the small dry season of February and the long dry season of June-August. The individuals collected increased during the rainy season.

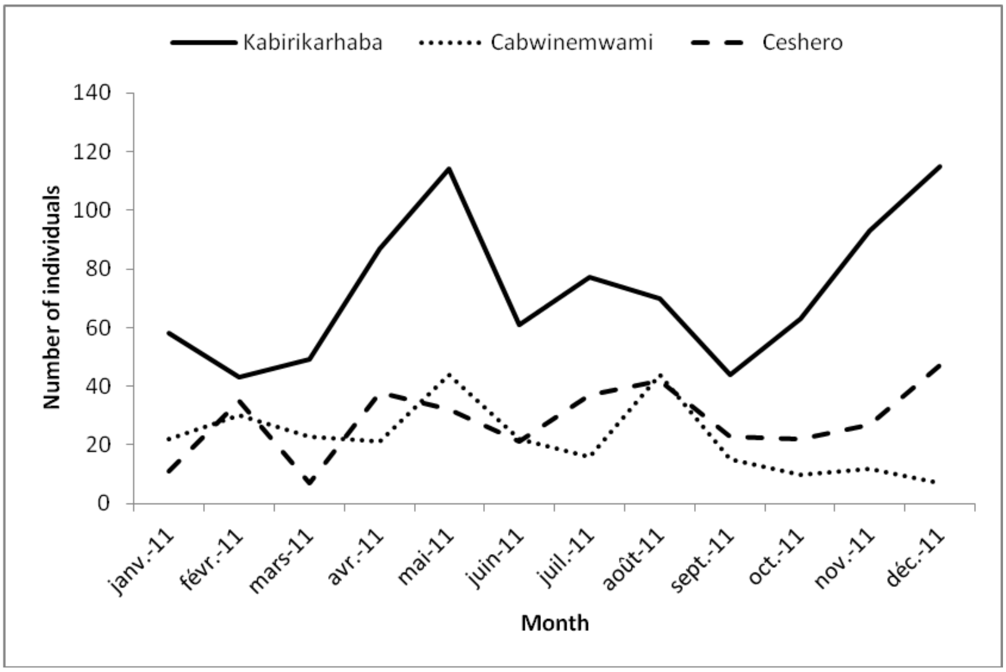

Fig 2: Monthly variation of individuals collected in Kabirikarhaba, Cabwine-Mwami and Ceshero sites (January 2011 to December 2011)

The benthic macroinvertebrate indices calculated at the three sites during the period of one year are presented in table 6.

Table 6: Benthic macroinvertebrate indices at the three sites in Kabirikarhaba, Cabwine-Mwami and Ceshero

	Kabirikarhaba				Cabwine-Mwami				Ceshero			
Month	ASPT	BMWP	BI	ETP	ASPT	BMWP	BI	ETP	ASPT	BMWP	BI	ETP
January	6.0	60	2.24	7	4.0	12	6.64	1	5.20	26	5.73	1
February	7.2	36	3.19	2	5.0	30	6.70	1	5.80	29	4.46	2
March	6.0	60	3.49	4	5.5	33	6.52	2	6.00	18	5.43	1
April	6.3	50	4.44	5	7.0	21	8.10	1	5.50	44	4.32	2
May	5.9	59	4.15	6	6.0	36	6.95	2	3.60	18	5.88	1
June	6.9	62	3.07	7	6.3	19	7.58	1	6.00	18	6.09	1
July	6.5	72	3.66	7	4.3	17	6.63	1	4.56	41	5.86	1
August	5.9	65	2.61	5	7.4	37	6.34	2	6.83	41	7.12	3
September	5.9	41	4.29	4	5.6	28	5.27	2	6.75	27	6.74	1
October	5.7	34	2.16	3	5.6	28	6.70	2	6.00	6	9.00	0
November	6.3	44	4.06	4	6.3	25	6.75	2	4.50	9	8.89	0
December	6.7	40	3.60	3	6.0	30	4.43	2	8.00	24	8.83	1
Mean	**6.3**	**51.9**	**3.4**	**4.8**	**5.7**	**26.3**	**6.6**	**1.6**	**5.7**	**25.1**	**6.5**	**1.2**

The different benthic macroinvertebrate indices varied monthly from one site to another in the river Nyabarongo. The mean ASTP, BMWP and EPT are higher at Kabirikarhaba. Overall BMWP of 51.9 is reasonable compared to the high guidance threshold of 100 [14], while ASTP of 6.3 and BI of 3.4 are classified excellent [39]. But the EPT score of 4.8 at the Kabirikarhaba site is low compared to recommended value [13]. Notably, more than half of all the families and all the EPT families are presented at the Kabirikarhaba site that is why the BMWP, ASTP and BI scores are substantially higher at this location compared to other sites. Macroinvertebrates are adequate bioindicators of water quality due to their sensibility to environmental changes mentioned before. Statistical analyses showed that the variation in the 3 sites between benthic macroinvertebrate indices is significant with respect to BMWP index, BI index and EPT index where the ANOVA test showed a p value very significant ($P > 0.005$). There are some correlations between chemical and benthic macroinvertebrate indices in the different sites. The major correlation was obtained between LISEC and benthic macroinvertebrate indices (BMWP, BI and ETP). Some correlations are highlighted by the large negative p value. Annual benthic macroinvertebrate indices such as BMWP ($F = 19.33$, $p > 0.0005$), BI ($F = 44.63$, $p > 0.0005$) and ETP ($F = 21.03$, $p > 0.005$) were statistically different. No significant difference was observed in ASTP indices during the sampling period.

Mason [14] and Chapman [39] classify water quality as good where BMWP and ASTP exceed 100 and 4.3 respectively. Consequently, the BMWP score of 51.9 and ASTP 6.2 at the upstream and 25.1 and 5.7 respectively downstream of the river Nyabarongo suggested a moderate level at the upstream to poor level of organic pollution at the downstream. EPT richness, four sensitive taxa are present which Suren and McMurtrie [40] suggest representing a reasonable quality of water. Plecoptera have a high requirement for oxygen and are considered very sensitive to organic pollution [14]. In comparison, *Ephemeroptera* are sensitive, but have a higher tolerance than Plecoptera. This suggests the low pollution level to moderate as other indices have shown.

The results of diversity indices presented in Table 5 showed variation during the year. The Margaref Diversity indices varied inversely proportional to the Shannon and Weaver Diversity Indices. This pattern for these two diversity indices is also seen in the Simpson Diversity index but at a lowest level. The Shannon score is greater than one and it suggests being excellent in the Kabirikarhaba site during the all year, however, it fluctuated between 0 and 1.9 respectively in the sites of Ceshero and Cabwine –Mwami which characterized the two sites being moderately or poorly polluted [39].

Table 7: Monthly variation of Diversity indices: Margaref Diversity indices (MDI), Simpson Diversity indices (SDI) and Shannon and Weaver Diversity Indices (SWDI)

	Kabirikarhaba			Cabwine-Mwami			Ceshero		
Month	MDI	SDI	SWDI	MDI	SDI	SWDI	MDI	SDI	SWDI
January	4.68	0.91	2.66	0.97	0.72	1.33	1.67	0.69	1.37
February	1.86	0.81	1.85	2.06	0.79	1.81	1.69	0.72	1.53
March	3.85	0.90	2.53	1.60	0.74	1.55	1.54	0.73	1.35
April	2.69	0.67	1.67	1.64	0.76	1.59	2.47	0.78	1.81
May	3.59	0.85	2.32	2.38	0.83	1.98	2.02	0.84	1.94
June	3.16	0.87	2.28	1.21	0.58	1.08	1.91	0.80	1.78
July	4.60	0.92	2.78	1.44	0.73	1.41	2.49	0.76	1.77
August	4.00	0.90	2.55	1.85	0.70	1.50	2.14	0.72	1.61
September	3.57	0.87	2.32	1.48	0.73	1.44	1.60	0.73	1.49
October	2.17	0.80	1.95	2.17	0.70	1.50	0.00	0.00	0.00
November	2.43	0.84	2.09	1.21	0.58	1.08	0.30	0.07	0.16
December	2.11	0.87	2.19	2.57	0.82	1.75	0.52	0.26	0.49
Mean	**3.23**	**0.85**	**2.27**	**1.71**	**0.72**	**1.50**	**1.53**	**0.59**	**1.27**

Macroinvertebrates in the Nyabarongo River were examined and water quality in relation to their presence in chosen sites Kabirikarhaba, Cabwinw-Mwami and Ceshero were assessed using chemical, biological and diversity indices. From the analysis of the results, the biological condition of Kabirikarhaba site can be considered satisfactory because of the sampled aquatic organisms in BMWP raking. Therefore, the condition of Kabirikarhaba site is normal with a good quality requirement. Similarly, biological and chemical analyses at Cabwine-Mwami and Ceshero revealed a moderate or poor quality condition. The biodiversities at the two sites are poor and indicates the extent of organic pollution in the river where anthropogenic activities are carried out into the river. Detailed research should be carried out to further test the toxic effect of contaminant in fishes and other aquatic organisms in the river but also in the Lake Kivu where this river discharge the water. Biological indices (ASTP, BMWP, BI and EPT), chemical (IPO and LISEC) and diversity indices (MDI, SDI and SWDI) are effective tools in assessing the condition of a river ecosystem. Chemical indices are useful tools for a routine quality control but somehow costly and need trained people which can be a challenge in developing countries.

The different human activities along the river had influenced the physicochemical characteristics of the water in the river Nyabarongo. Macroinvertebrate need optimum characteristics of water in order to survive. The change observed in river Nyabarongo affected also the abundance and richness of the macroinvertebrate community in the river.

CONCLUSION

The chemical, biological and diversity indices indicated that Cabwine-Mwami site had slightly polluted water quality since it was located on the residential area where human perturbation and organic pollution was high. Kabirikarhaba site had a very good water quality since it was located far from residential area and with only a slight disturbance from the forest of Kahuzi Biega National Park. Ceshero site which received all water had a moderated water quality since it is also far from the residential area and the role of wetland for nutrient retention had reduced pollutant.

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