Effect of dissolved oxygen levels on benthic macroinvertebrates community in rivers tributaries of Lake Kivu, South Kivu, DR Cong

Ndahama N., Matembera B.[2], Bakulikira M[1]/Polepole N.[1], Bugoma M[1].BishwekaC., Bagalwa M.[3*]

[1]Centre de Recherche en Sciences Naturelles de Lwiro, Département de l'Environnement, République Démocratique du Congo
[2]Centre de Recherche en Sciences Naturelles de Lwiro, Département de Documentation, République Démocratique du Congo
[3]Centre de Recherche en Sciences Naturelles de Lwiro, Département de Biologie, Laboratoire de Malacologie, République Démocratique du Congo

***Correspond author: mashibagalwa@gmail.com**

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Abstract
Protection and conservation of natural environments, especially water quality, has become a major concern and even a main focus in development programs over the last decade. In order to know the sensitivity of macroinvertebrates to the variation of dissolved oxygen in a human disturbed natural environment, a study was undertaken in the rivers of the Lake Kivu basin including Nyabarongo, Cirhanyobwa and Lwiro during one year. Following the differences in tolerance of aquatic species, 7 classes of dissolved O_2 were selected and ranked as follows: 0-2 mg/L; 2 - 4 mg/L; 4 - 6 mg/L; 6 - 8 mg/L; 8 - 10 mg/L; 10 - 12 mg/L and 12 - 14 mg/L. Harvested species were identified and counted by dissolved O_2 class. Species identified in ecosystems were considered tolerant to this amount of dissolved O_2. The species *Perlinella drymon* and *Palpamyia tibialis* were found in the dissolved O_2 class of 14-12 mg/L, a non-polluted medium while the species *Tabanu sp.*, *Biomphalaria pfeifferi*, *Symbiocladius aquitan* and *Haemopis sangsuga* are found in the classes dissolved O_2 ranging from 4-2 mg/L to 2-0 mg/L. These sites are polluted and the species present are tolerant to the decrease of dissolved oxygen.

1. Introduction

The sensitivity of rivers refers globally to the ability of an ecosystem to adjust to different types of natural and / or anthropogenic pressures without losing its attributes and functions, without any notable change in its biotic and abiotic characteristics (St-Hilaire et al., 2017). Macro-invertebrates form an important link in the food chain and many of them also participate in the decomposition of organic matter. They are a very diverse class whose species have varying degrees of tolerance for changes in their environment. They are therefore indicators of choice for assessing the health of a water ecosystem (Mariam et al., 2015).

Normally in a watercourse, the great diversity of benthic macroinvertebrates is observed in unpolluted areas (Derwiche et al., 2010). Each macroinvertebrate also has preferences for the conditions prevailing in the river. By observing the diversity and abundance of the various macroinvertebrates communities, information is obtained on the state of a watercourse and its immediate environment (Moisan, 2010).

The increase of anthropogenic activities in an environment is a threat to aquatic ecosystems in general in the world, in the Democratic Republic of Congo, and especially in the province of South Kivu. These effects are characterized by water eutrophication, a dramatic decrease in dissolved oxygen levels, and sedimentation leading to high turbidity (Bagalwa 2006; Bagalwa and Kubuya 2009).

Dissolved oxygen is one of the most important indicators of the degree of water pollution and measures the concentration of dissolved oxygen in the water. It is essential for aquatic life and the degradation of biodegradable pollutants allowing self-purification. It also participates in the majority of chemical and biological processes in the aquatic environment. The average level in unpolluted surface water is 6 mg/L and hardly exceeds 10 mg/L (Derwiche et al., 2010). Two critical levels from which effects on fauna are observed have been identified (Aminot and Kérouel, 2004).

Macro-invertebrates are the bio-indicators mostly used in the determination of the state of health of the corns because they are ubiquitous and easy to harvest in large numbers. They have a quick reaction to environmental changes and are relatively sedentary. In addition, they have a large number of species and the range of sensitivity to environmental stresses varies according to the taxonomic group of water quality as well as substrate (Mokofi et al., 1991). Environmental monitoring of rivers consists of using different tools to assess the health status of rivers (Lounaci, 2014). For this, physicochemical approaches are used consisting of comparing the concentrations of pollutants measured in water with criteria recognized as providing protection for the aquatic environment (Derwiche et al., 2010), but also, bacteriological approaches (fecal coliforms) and biological (diatoms, macroinvertebrates and fish).

Anthropogenic activities in river basins only degrade the quality of the waters of its rivers (Luu et al., 2007). Macro-invertebrates have the advantages of having a longer life cycle of a few months to a year and they have a wide range of trophic level and pollution tolerance, relatively easy to sample, but they are sensitive to modification of habitat, the presence of organic matter and changes in dissolved oxygen. Nevertheless, new synthetic methods that include both physicochemical and biological components pursue this ideal and are already in use worldwide (Anonymous, 2014).

Among the material used for biological analyzes, benthic macroinvertebrates are the most frequently cited (Foto et al., 2011). Previous studies in this region demonstrate the problems of river water pollution due to anthropogenic activities (Bagalwa 2013; Ndahama et al., 2013).

In the river, each organism has particular requirements (Oxygenation, nature of the bed, temperature ...). Confronted with a point or chronic pollution, certain animal species will disappear and others will develop. Thus, by studying the animal communities of the river, it is possible to show the existence of a disturbance and to evaluate the quality of the water according to the concentration of dissolved oxygen.

Thus, in order to develop a management tool based on a standardized method the determination of the live macroinvertebrate species in the different sites, their classes of dissolved O_2 and their abundance of abundant species in each site as well as their tolerance in O_2 will be the subject of this study.

2. Material and Methods

2-1. Description of study area

The investigations were carried out in three rivers including Nyabarongo, Cirhanyobwa and Lwiro having their sources in the Kahuzi-Bièga National Park at over 2000 m altitude (Marlier, 1954). This area is between 28º45' to 28º85' East Longitude and 2^0 00' to 2º30' South Latitude. The Nyabarongo River is located 50 km north of the city of Bukavu, separating the Irhambi/ Katana sub-county and Kalehe and is part of the tributary streams of Lake Kivu (Marlier, 1954). It flows into Lake Kivu through Irambo Bay. The Lwiro

River is part of the tributaries of Lake Kivu. It is located on the eastern flank of Lake Kivu, between latitudes 2°15' and 2°30'S and longitudes 28°45' and 28°85'E. Its headwaters are in the Kahuzi-Biega National Park mountain region, at an altitude of 2 000 m. It flows to Lake Kivu through Kakondo Bay (Bagalwa, 2013) passing through heavily populated areas. Cirhanyobowa River is also located in the same region between the two rivers and are also a main tributary river of Lake Kivu. These rivers are used upstream and downstream by the local population for its various basic needs including drinking, watering animals, washing clothes and cooking utensils, swimming, etc. (Bagalwa, 2006). They flows into a cultivated area to pour into Lake Kivu through the large marsh of Ceshero, Kakondo and Mubunga (Marlier, 1954).

Vegetation on the edge of its rivers are cultivated savannas that have replaced the *Albizzia grandibracteata* forest (Baluku, 1987, Bagalwa and Baluku, 1997), and all along their route, the banks are colonized mainly by a community of hygrophilous to *Pennisetum purpureum*, *Cyperus latifolia*, *Fragites mauritianus* and food crops like *Musa sp*, *Manihota utilisima*, *Phaseolus vulgaris*, *Zea mays*, *Ipomea batatas*, *Saccharum officinarum* and *Xanthosoma sagitifolia*. The climate in this region is of the humid tropical type whose dry season extends from June to August and the rainy season from September to May. The annual average temperature is 22 ° C and the annual precipitation is greater than 1500 mm/year (Bagalwa et al., 1998). The population density around this river is 360habitants per km2 and the catchment area is 141 km^2. Thus, the sampling sites were chosen according to their accessibility all year long.

2-2. Determination of the amount of dissolved oxygen in selected river sites

To determine the amount of dissolved oxygen in the study sites, the Winkler method was used. The water to be analyzed was maintained and field-fixed, titrated with 0.025N thiosulfate and the amount of dissolved O_2 expressed as mg/l (Golterman et al., 1978, APHA, 2005).

2-3. Harvesting and identification of live macroinvertebrate species at different sites

The macroinvertebrate harvest was carried out in the three rivers (Nyabarongo River, Cirhanyobwa River and Lwiro River) in the West Lake Kivu Basin using the standard man-time harvest method. Thus, 3 sites in each of the rivers were selected from upstream to downstream and sampled once a month for one year. Macro-invertebrate harvest was done by scraping the banks and bottoms with a 30 cm circumferential flutter for ten minutes (Olivier and Scheiderman, 1956). The contents of the net were poured into a plastic bucket and then sorted on a tray using tongs (Cunha et al., 1997).

The identification of macroinvertebrates was carried out in the laboratory of Malacology, Department of Biology, Centre de Recherche en Sciences Naturelles de Lwiro, Democratic Republic of Congo using the keys proposed by Brown, (1994); Micha and Noiset, (1982); Tachet and Noiset, (1980). The observation of the small structures was made using a binocular loupe X 10 objective. The counting was done in petri dishes. The specimens thus identified are kept in formalin in the Malacology laboratory. The number of species by dissolved oxygen class was grouped for count according to the number of times the species was found during the study period.

2-4. Determination of dissolved oxygen classes and species abundance at each site

Seven classes of dissolved O_2 were determined: 14-12 mg/L; 11.9 - 10 mg/L; 9.9 - 8 mg/L; 7.9 - 6 mg/L; 5.9 - 4 mg/L; 3.9 - 2 mg/L; 1.9 - 0 mg/L. The choice of these classes was dictated by the differences in tolerance of aquatic species (Mariam et al., 2015; Moisan, 2010). For each class, the species found were counted and the abundant species were noted with their number. These species were considered tolerant to this amount of dissolved O_2. Their presence in the site and the biotope was then documented to know the life cycle of the species (Ammar et al., 2010). The species found throughout the year and/or more than 50 % of the year in the site was considered tolerant, 8 - 10 mg/L of dissolved O_2.

3. Results

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Environmental monitoring of freshwater pollution based on the sensitivity of benthic macroinvertebrates for the change in dissolved oxygen in the wild was monitored for one year in each of the rivers. Thus, the following results were found in each of the rivers. Table 1 presents the result of the Cirhanyobwa River.

Table 1: Sampling in the Cirhanyobwa River

Dissolved Oxygen Classes	**Taxa**	**Abundance**
14 – 12 mg/L	*Perlinella drymon* *Palpamyia tibialis* *Gorgodius robustus*	12 7 10
11,9 – 10 mg/L	*Pleastriola sp* *Corrixa sp.*	10 10
9,9 – 8 mg/L	*Polycentropus sp.* *Pseudogrion sp.*	6 10
7,9 – 6 mg/L	*Cleon sp.* *Baetis sp.* *Caenis sp.*	6 7 8
5,9 – 4 mg/L	*Nepacinerea sp* *Nemoura venosa*	5 5
3,9 – 2 mg/L	*Tabanu satratus* *Biomphalaria pfreifferi*	7 5
1,9 – 0 mg/L	*Tubifera sp* *Tipula ignobilis,* *Haemopis sangsuga* *Syrphide sp*	7 7 7 7

The first table of the Cirhanyobwa River shows that the species *Perlinella drymon* has a high abundance 12 in the dissolved O_2 class of 14-12 mg/L and the dissolved oxygen class of 5.9 - 4 mg/L of which abundance was minimal (5 samples) for the *Nepacinerea sp* and *Nemoura venosa* species while the class of 1.9-0 mg/L has 5 species more resistant to freshwater pollution including *Tubifera sp.*, *Tipula ignobilis*, *Haemopis sangsuga* and *Syrphide sp.* As for the Nyabarongo River, the result is shown in Table 2 below.

Table 2. Sampling in the Nyabarongo River

Dissolved Oxygen Classes	Taxa	Abundance
14 – 12 mg/L	*Cryptocerus punctulatus* *Perlinella drymon* *Potamon sp.* *Progomphus obscuris* *Gorgodius robustus*	11 6 10 5 12
11,9 – 10 mg/L	*Isogenus fluminea* *Pleastriola sp*	7 6
9,9 – 8 mg/L	*Pseudogrion* sp. *Heptagenia sp.* *Iron humeralis*	10 7 9
7,9 – 6 mg/L	*Cleon sp.* *Baetis sp.* *Caenis sp.* *Aeschna sp.*	8 7 8 6
5,9 – 4 mg/L	*Tabanu satratus* *Biomphalaria pfreifferi*	7 5
3,9 – 2 mg/L	*Nepacinerea sp* *Pleastriola sp*	8 6
1,9 – 0 mg/L	*Tubifera sp.* *Chaoborus albipes* *Symbiocladius equitans* *Haemopis sangsuga* *Tubifex sp.*	7 6 5 5 5

As for Table 2 of the Nyabarongo River, it appears that the dissolved O_2 class of 14-12 mg/L shows the presence of the 5 species including the species *Gorgodius robustus* with a great abundance (12) that the others and the species *Progomphus obscuris* is less represented with abundance (5). For the dissolved O_2 class of 1.9-0 mg/L there are 5 species grouped in 3 abundances, 7 for the species *Tubifera sp.*, 6 for *Chaoborus albipes* and 5 respectively for the species *Symbiocladius equitans*, *Haemopis sangsuga* and *Tubifex sp*. For the Lwiro River, the result is shown in Table 3 below.

Table 3. Sampling in the Lwiro River

Classes d’O_2 dissous	Espèces	Abondance
14 – 12 mg/L	*Gorgodius robustus* *Potamon sp.* *Nymphura makulalis*	11 10 7
11,9 – 10 mg/L	*Pleastriola sp* *Progomphus obscuris*	10 8

9,9 – 8 mg/L	*Pseudogrion sp.* *Coenagrion sp.*	10 10
7,9 – 6 mg/L	*Cleon sp.* *Baetis sp.* *Caenis sp.* *Aeschna sp.* *Rhytrogenia sp.*	10 10 8 10 6
5,9 – 4 mg/L	*Nepacinerea sp* *Heptagenis sp.*	8 6
3,9 – 2 mg/L	*Biomphalaria pfreifferi* *Palpomya sp.*	5 10
1,9 – 0 mg/L	*Tubifera sp.* *Tipula sp.* *Pschoda sp.* *Haemopis sangsuga*	7 8 7 7

It is apparent from Table 3 of the Lwiro River that the dissolved O_2 class of 14-12 mg/L has a high abundance (11) of the *Gorgodius robustus* species than the other classes and the other species. Also, the finding is that for the O_2 class dissolved from 3.9 to 0 mg/L, the species *Biomphalaria pfeifferi* and *Haemopis sangsuga* are less compared to other species with an abundance (5). Table 4 presents species of macroinvertebrates bioindicators of the quality of dissolved oxygen in the three rivers

Table 4. Bio-indicator species for the quality of dissolved oxygen in the three rivers

Classes d'O_2 dissous	**Espèces**
14 – 12 mg/L	*Gorgodius robustus* *Potamon sp.* *Perlinella drymon*
11,9 – 10 mg/L	*Pleastriola sp*
9,9 – 8 mg/L	*Pseudogrion sp.*
7,9 – 6 mg/L	*Cleon sp.* *Baetis sp.* *Caenis sp.*
5,9 – 4 mg/L	*Nepacinerea sp*
3,9 – 2 mg/L	*Biomphalaria pfreifferi*

1,9 – 0 mg/L	*Tubifera sp*. *Hemoepus sanguisuga*, *Chironomus sp*. *Tubifex sp*.

Table 4 discusses bioindicator species for the dissolved oxygen quality of the three study rivers and shows that the class 14-12 mg/L is represented by 3 species including *Gorgodius robustus*, *Potamon sp* and *Perlinella drymon*, and for classes 11.9-10 mg / L (*Pleastriola sp*); 9.9-8 mg/L (*Pseudogrion sp*.); 5.9 - 4 mg/L (*Nepacinerea sp*) and 3.9 - 2 mg/L (*Biomphalaria pfeifferi*) represent respectively one species. As for the class of 7.9-6 mg/L is represented by 3 species (*Cleon sp*, *Baetis sp*, *Caenis sp*).

We also notice the presence of a crustacean like *Potamon sp* that cannot live in polluted waters and the presence of mosquito larvae species like chironomids, called: towards vases, which adapt very well in polluted waters as sewers and so, the class 1.9 - 0 mg/l is represented by the species *Tubifera sp*, *Hemoepus sanguisuga*, *Chironomus sp* and *Tubifex sp*.

4. Discussion

This study focused on the sensitivity of benthic macroinvertebrates and the variation of dissolved oxygen in a human disturbed natural environment in South Kivu, DR. Congo provided, after field investigations. For the Cirhanyobwa River, the species *Perlinella drymon* has a high abundance 12 in the dissolved O_2 class of 14-12 mg/L and the class of 1.9-0 mg/L has 5 species more resistant to pollutant pollution. Freshwater macroinvertebrates including *Tubifera sp*, *Tipula ignobilis*, *Haemopis sangsuga* and *Syrphide sp*. For the Nyabarongo River, the dissolved O_2 class of 14-12 mg/L shows the presence of the 5 species of which the species *Gorgodius robustus* with a large abundance (12) that the others and the species *Progomphus obscuris* is less represented with an abundance (5). For the Lwiro River, the dissolved O_2 class of 14-12 mg/L has a high abundance (11) for the *Gorgodius robustus* species than the other classes and the other species and the species *Biomphalaria pfeifferi* and *Haemopis sangsuga* are less abundant. Compared with other species with an abundance (5) in the O_2 class dissolved from 3.9 to 0 mg/L. These results coincide with those of Moisan, (2010), because in these studies, it has shown that for a long time, the observation of various benthic macroinvertebrate has led to the assessment of the quality of surface water. Thus some communities are pollo-resistant (*Chironomus sp*, *Eristalis sp* larvae, *Asellus sp*, *Lymnaea natalensis*, ...) or pollo-sensitive (*Ephemera sp* larvae, *Sialis*, ...) found in the rivers compared to the species communities as found in France by Moisan (2010). Several researchers have been led to propose biotic indices based on the assessment of species richness and reflecting the quality of surface water (Vernaux and Tuffery, 1967). Isopod crustaceans such as *Potamon sp*, as well as Pulmonate gastropods such as *Biomphalaria pfeifferi* are also high-performance bio-accumulators of freshwater pollution found in the Nyabarongo River similar to Crustacea species found in Bangui by Mokofi et al., (1991). The results of Derwiche et al., (2010) on dissolved oxygen concentrations, which together with pH values represent one of the most important water quality parameters for aquatic life, are similar to this study in tributaries of Lake Kivu. The class 14- 12 mg/L is represented by 3 species including *Gorgodius robustus*, *Potamon sp* and *Perlinella drymon* and the class of 11.9-10 mg/L by the specie *Pleastriola sp*; the class of 9.9-8 mg/L by *Pseudogrion sp*; the class of 5.9 - 4 mg/L by *Nepacinerea sp*) and the class of 3.9 - 2 mg/L by *Biomphalaria pfeifferi* species. As for the class of 7.9-6 mg/L is represented by 3 species (*Cleon sp*, *Baetis sp*, *Caenis sp*). We also notice the presence of a crustacean like *Potamon sp*, which cannot live in polluted waters and the presence of mosquito larvae species like chironomids, called: towards vases, which adapt very well in waters polluted as sewage and so, the class 1.9 - 0 mg/L is represented by the species *Tubifera sp*, *Hemoepus sanguisuga*, *Chironomus sp* and *Tubifex sp*.

According to Moisan, (2010), dissolved oxygen concentrations are one of the most important water quality parameters in that they are essential for aquatic life and for the degradation of biodegradable pollutants that allow self-purification. Dissolved oxygen concentration varies daily and seasonally because it depends on many factors such as the oxygen partial pressure of the atmosphere, the water temperature, the salinity, the penetration of light, the agitation of the atmosphere water and nutrient availability (Anonymous, 2011). This dissolved oxygen concentration is also a function of the oxygen depletion rate of the medium by the activity of aquatic organisms and the processes of oxidation and decomposition of the organic matter present in the water. Overall, the higher dissolved oxygen concentration is close to saturation, the greater the ability of the river to absorb pollution (self-purification process) is large. A value of less than 1 mg/L of O_2 indicates a state close to the anaerobic, compared to the results found in these three rivers including the Cirhanyobwa River, the Nyabarongo River and the Lwiro River. This condition occurs when the oxidation processes of mineral waste, organic matter and nutrients consume more oxygen than is available. Low dissolved oxygen content in water causes high solubility of toxic elements that are released from sediments. This was observed in site 2 in Nyabarongo comparatively to the results of Derwiche et al., (2010) for groundwater analyzes. A value of 1 to 2 mg/L of O_2 indicates a highly polluted freshwater; and a content of 4 to 6 mg/L of O_2 characterizes a good quality water according to the results obtained. Thus, according to (Anonymous, 2015), levels higher than the natural content of oxygen saturation indicate eutrophication of the medium resulting in intense photosynthetic activity.

Fourteen species of pollen-sensitive macroinvertebrates including *Gorgodius robustus*, *Potamon sp*, *Perlinella drymon*, *Pleastriola sp*, *Pseudogrion* sp, *Cleon sp, Baetis sp, Caenis sp, Nepacinerea sp*, *Biomphalaria pfeifferi*, *Tubifera sp, Hemoepus sanguisuga*, *Chironomus sp* and *Tubifex sp* are found. For the species *Gorgodius robustus*, which is often found at a location with a dissolved oxygen class of 14-12 mg/L, it shows that the environment is not polluted and this is consistent with the studies of (Moisan, 2010; Bagalwa et al., 1998) in Quebec, which show that levels above oxygen saturation indicate eutrophication resulting in intense photosynthetic activity.

For the other species *Tubifera sp*, *Tipula ignobilis*, *Haemopis sangsuga*, *Syrphiae sp* (*Eristale sp*) whose dissolved oxygen classes vary between 4-2 and 2-0 mg/L, this shows that the environment is more polluted and that the species are more resistant than freshwater pollution. In a region whose rivers have a dissolved oxygen variation of 1 to 4 mg/L, it shows one of the highly polluted site but reversibly proven rivers by the results obtained and also according to the results found by Foto et al., (2011) in Cameroon when assessing the diversity of benthic invertebrate macro-populations in an human disturbed natural environment water in a tropical environment.

The concentration of dissolved oxygen can be expressed in mg/L of O_2 or in % of saturation in oxygen (the relation between these 2 values is a function of the temperature). Some orders of insects as the beetles, the dipterans, the hemipterans ones are difficult to apprehend because they have both terrestrial representatives and aquatic representatives (Lounaci, 2014).

5. Conclusion

Environmental monitoring of freshwater pollution based on the sensitivity of benthic macroinvertebrates for the change in dissolved oxygen in the wild was monitored for one year in three rivers. In fact, for the class of dissolved O_2 14-12 mg/L, depending on the abundance, the species *Gorgodius robustus*, *Potamon sp* and *Perlinella drymon* are considered tolerant and indicative of an unpolluted water while the species *Tabanus atratus* and *Biomphalaria pfeifferi*, whose dissolved oxygen classes vary between 4-2 and 2-0 mg/L, prove that the environment is more polluted. The species in the families of Dipterae, Syrphidae, Tabanidae and Tipulidae are more resistant to freshwater pollution and prefer areas of maximum pollution in organic matter according to the findings of the three rivers.

However, it is important to ensure regular monitoring of these ecosystems and to put in place appropriate protection and management measures for the uses that are expected of them. The establishment of an index testifying the general quality of the environments (quality of the habitat and environment) is desirable. Thus, the determination of biodiversity centers (from upstream to downstream) are essential tools for determining the properties of concentrations of dissolved O2. The development of distribution maps of the inventoried fauna will make it possible to identify areas of interest for conservation.

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