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Research Article

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Abstract
Cirhanyobowa River in D.R. Congo, is extensively used as washing and drinking water source by surrounding population as well as by gorillas. The study was carried out in three sites on Cirhanyobowa River to evaluate the effect of landuse (forest, mining and agricultural) on Cirhanyobwa River water quality. Surface water temperature, DO, BOD_5, nitrogen and phosphorus were measured, and aquatic macroinvertebrates collected monthly for a period of one year and measured according to standards analytical and biological methods. Results have shown changes in water quality for the forest, mining and agricultural sites but slight changes in number of taxa at the forested and mining sites with respectively 43 and 42 species; and significant changes in agricultural site with 27 species. Chemical and physical parameters measured at the three sites did not seem sufficient to account for all observed differences in macroinvertebrate communities, suggesting some unmeasured toxicity. It was established that there is water quality deterioration along Cirhanyobwa River due to surrounding population anthropogenic activities.

Key words: Cirhanyobowa River, Landuse, Macroinvertebrates, Toxicity, Water quality.

INTRODUCTION

Numerous studies have demonstrated the effects of land-use change on erosion and sediment loading patterns in aquatics ecosystems (Dearing *et al*., 1987; O'Hara *et al*., 1993; Alin *et al*., 1999; 2002). Increased sedimentation has detrimental impacts on biodiversity and ecological integrity in aquatic communities (Detenbeck *et al*., 1999).

Changes in landscape due to activities such as agriculture, silviculture, fishing, urban sprawl and transportation infrastructure have been recognized for some time as one of the major causes of the loss of biodiversity planet-wide. Agricultural development and mining activities provides both subsidies (positive effects) and stresses (negative effects) to rivers and streams ecosystems. The extent of soil degradation, the losses of potential agricultural production and the decrease in the water quality are relatively known for Africa (Kitaka *et al*., 2002). Human activities threaten biodiversity in a number of ways including habitat loss, the introduction of exotic species, changes in climate and biogeochemical cycles, pollution, and over-harvesting. Of these, habitat loss is blamed for causing the vast majority of current biodiversity loss (Wilcove *et al*., 1998).

In mineral rich countries such as the Democratic Republic of Congo, mining is among activities that contribute to financial income. One major concern is the effect of anthropogenic activities such as mining, agriculture and urbanization on the esthetics, economic viability, safety health and biodiversity. Human activities are now a major force affecting the ecosystem of the earth (Vitousek *et al*., 1997). The excess of sediment loading due to these anthropogenic activities in the water column can impact aquatic organism in a variety of ways. It has been noticed that sediment in suspension reduces light penetration and thereby photosynthetic rates while settling sediment may completely blanket benthic algae or reduce the nutritional value of detritus (Cohew *et al*., 1993).

In DRC, information on the physical and biological processes characterizing the cycle of nutrients is scare and fragmentary (Bagalwa, 2006). Data of rivers chemistry and aquatic biota are periodically collected by scientist for specific objectives. There have been no surveys, to estimate annual nutrients interring in rivers by runoff and their impact on aquatic biota. Degradation of water quality, depletion of water resources and loss of aquatic biodiversity are prominent features of the environmental landscape requiring urgent attention at global and national scales. The landscape in the Democratic Republic of Congo (DRC) has been transformed by agriculture. Extensive clearing and drainage of the wetlands has caused changes in floodplain hydrology, destruction of wetlands, and loss of biodiversity (Armour *et al.,* 2004). Off-farm export of major riverine contaminants including nutrients, sediments and agricultural chemicals has resulted in deterioration of water quality in catchments of different rivers of the DRC, causing degradation of riverine ecosystems and damage to the aquatics biodiversities (Baker, 2003; Armour *et al.,* 2004).

The Cirhanyobowa River water is extensively used by surrounding population for agriculture, washing and as the main drinking water source for gorillas as well as for people living in some villages where the river crosses. A systematic study on the river water quality is of great necessity and significance. Earlier we reported the elemental concentration of physico-chemical parameters in Cirhanyobowa River water (Bagalwa and Kubuya, 2009). Studies of the major sources of nutrients in rivers and streams in the Democratic Republic of Congo in different agro-ecological zones suggested that human intervention may be a cause of excessive enrichment in surface waters (Bagalwa, 2005; Bagalwa, 2006). This study on the river Cirhanyobowa assesses the effect of land use change (deforestation, agriculture, mining and urbanization) on water quality and aquatic macroinvertebrates.

MATERIALS AND METHODS

Study Area

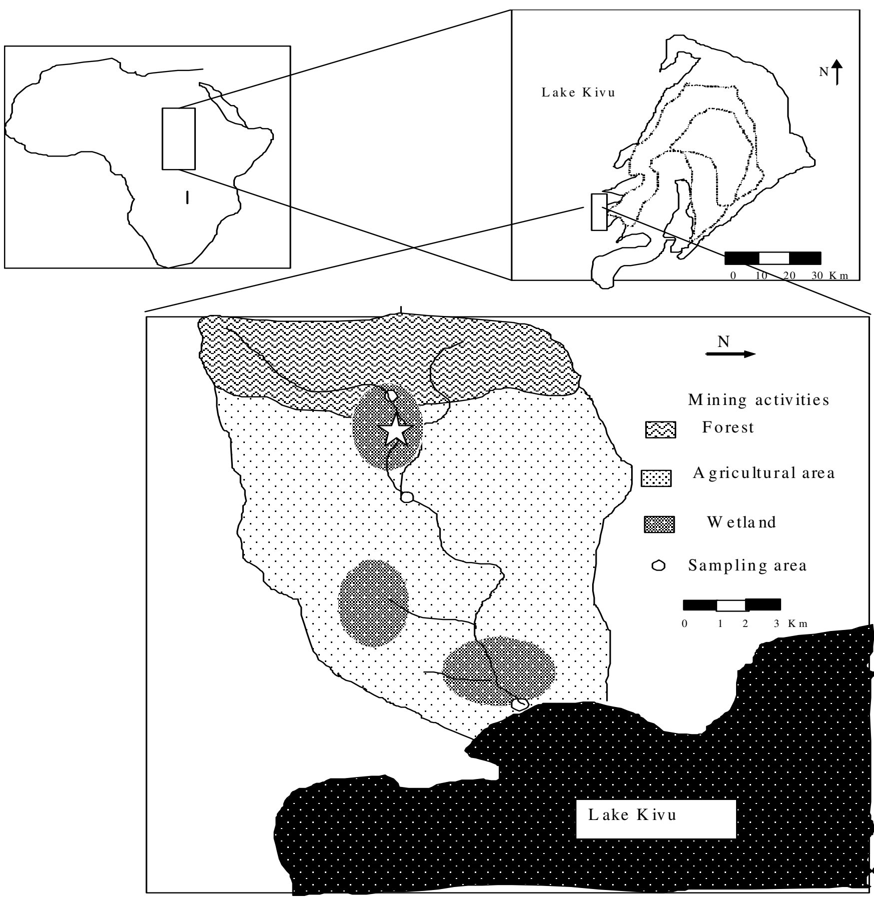


Figure 1. Map of Cirhanyobowa River, its location in the lake Kivu basin, Great lakes of Africa

The study was carried out at three sites (Figure 1) basing on the accessibility throughout the year. The site 1 was located at the bridged of the Kahuzi Biega National Park (1959 m altitude AMSL; 02°11'2'0"S and 028°47'02.9"E). No human activities are done near the site. It is chosen as an upstream control site. The middle canal is covered by macrophytes such as *Pennisetum purpureum* Schumarch. The second site was 500 m after artisanal mining station (1941 m altitude AMSL; 02°11'40.7" S and 028°47'36.2" E). This site is the mid-channel site within a mining and agricultural sector where maize, green beans and cassava are grown. Water at this site is used for bathing and washing animals. The substratum are constitute of stones and mud. And the third site was located at the downstream of the river at 500 m of the edge of the lake (1463 m altitude AMSL; 02°10'43.9'' S and 028°52'15.2'' E). The site is used for fishing, bathing and washing closes. This site is located in a wetland before entering Lake Kivu.

The catchments above each site are dominated by steep (<3°) hilly topography underlying by sedimentary sandstones and siltstones soils are predominantly volcanic where volcanic ash deposits. Except the site downstream which is located in the wetland where topography is a plain. Irrigated sugarcane fields are major cropping system in this site. The substratum is composed of mud, due to the decomposition of mud, as well as sedimentation. The vegetation around this site comprises *Cynondon dactylon* and *Pennisetum purperum*.
Average annual rainfall in the region is 1500 mm and mean air temperature 19°C (Baluku, 1987; Bagalwa and Baluku, 1997). Due to the high population density (more than 350 inhabitant per square kilometer), land is intensively used. Seventy percent of the land is used for agriculture and 20 % for other activities; irrigated sugarcane field located in the swamp area, covering about 10 %.

Sampling protocol

Water sampling and analyses

The three stations were sampled from January 2009 to September 2009, in order to cover both the rainy season (January–May- September) as well as the dry season (June–August), and to compare values. Surface water temperature, DO, five-day Biological Oxygen Demand (BOD_5), nitrogen and phosphorus were measured, following the procedures described in Golterman *et al*. (1978), ALPHA (1981), and Wetzel and Likens (2001).

On each occasion, samples were collected at midday. Water was collected at a depth of 5cm, near midstream. The temperature was measured using a mercury thermometer. At each station, two water samples were collected in pre-washed glass bottles, for the measurement of DO and BOD_5. After fixation in the field, DO was determined, following the iodometric Winkler's method (Golterman *et al*., 1978). BOD_5 was measured as the decrease in DO after incubation in the dark at 20°C for five days. Other water samples were taken in 1l bottles at the same time, for other chemical analyses. Suspended solids (mg l^{-1}) were estimated by filtration through analytical filter paper (Whatman 589, 185µm pore size), which was dried at 105°C and pre-weighed. Various forms of dissolved and particulate phosphorus and nitrogen were analyzed following the standard methods for water examination (Wetzel and Likens, 2001). All measurements were made in duplicate.

Data were analyzed using a two-way ANOVA test for differences between sites, between months, and site month effects.

Macroinvertebrate sampling

The benthic macro-invertebrates were collected using a standard form hand-net of 30 cm wide, 20 cm high and 50 cm long with mesh size of 500 µm. They were collected along the river stretch in a stream direction with an effective sampling effort of 10 minutes per person (Olivier and Scheiderman, 1956). The presence of stones in the river bed and water plants were taken in the hand-net and washed in a bucket to collect macro-invertebrate attached. The collected organisms were stored and preserved in formalin 4 % on the field. Species Identification was made at the malacology laboratory using the determination keys of Needhan and Needham (1962), and Micha and Noiset (1982). If the species were not fund in the key, the identification was restricted to the family or genus level.

RESULTS AND DISCUSSION

Throughout the entire study period mean concentration of most parameters investigated in the three sites of the Cirhanyobowa River were significantly different. For most parameters the mean concentration determined in the site 1 markedly exceeded those found in other sites in the river. But the site 3 located downstream had high values than in the site 2 (Table 1).

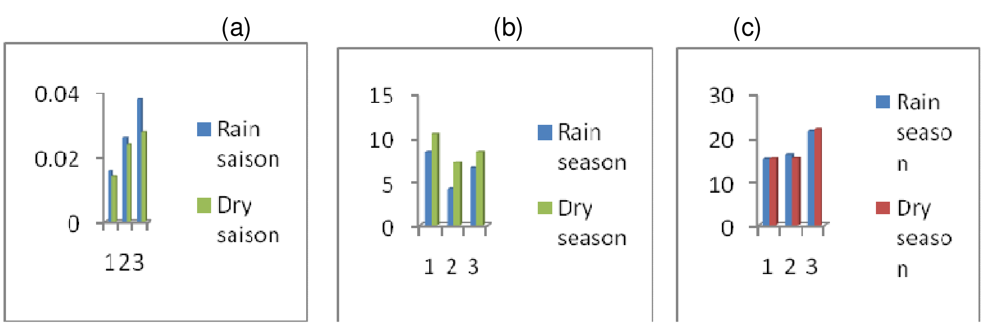
Table 1: Mean values (± SD) of physicochemical parameters in three sites of Cirhanyobowa River (*) difference statistically significant, p<0.001.

Parameters		Site 1	Site 2	Site 3	Significant differences
Temperature	°C	15.38 ± 0.07	16.27 ± 0.2	21.67 ± 0.34	***
Dissolved oxygen	mg/L	8.05 ± 1.6	4.8 ± 0.54	5.66 ± 0.91	**
BOD_5	mg/L	0.96 ± 0.69	1.95 ± 0.72	2.43 ± 1.1	
Reaction	pH	8.057 ± 1.6	4.8 ± 0.54	5.66 ± 0.91	*
Total Phosphorous	µmole/L	0.55 ± 0.47	0.96 ± 0.42	0.79 ± 1.1	
Soluble Reactive Phosphorous	µmole/L	0.168 ± 0.14	0.32 ± 0.31	0.32 ± 0.26	
Total Nitrogen	µmole/L	25.17 ± 16.33	19.5 ± 15.8	29.68 ± 23.3	
Ammonium	µmole/L	6.4 ± 5.69	5.21 ± 4.35	7.0 ± 6.39	
Nitrate	µmole/L	8.4 ± 10.84	8.32 ± 10.85	8.12 ± 10.34	
Suspended solid	mg/L	0.015 ± 0.001	0.025 ± 0.001	0.033 ± 0.007	

The average nutrient concentrations gradually decrease with the course of the river due to the specificity use of the river. The quality of organic matter exported by the river is quite different at each site. The site is near the Kahuzi-Biega National Park, where no anthropogenic activity is carried out; site 2 is located after the artisanal mining station where the riverbed change each time due to mining operation. Sediment inundation resulting from mining exploitation and other activities such as agriculture can be noticed; this is among the most immediate and important damaging activity for littoral and sub-littoral communities. This was also fund by Cohen *et al.* (1993). Increases in suspended sediment loads that are carried by mining activities alter rocky benthic habitats in several ways: increased turbidity can act by reducing light penetration and so decrease benthic primary productivity. Incoming sediments may also bind or release nutrients or toxins, altering energy flows through communities. In this case the poorly decomposable dissolved organic matter decreases the concentration of analyzed nutrients, i.e. nitrogen and phosphorus forms. The microbiological decomposition of organic matter is probably affected by the length of time the flowing water remains in the riverbed (Moss, 1988; Zielinski *et al.,* 2003). There was, however, no significant relationship between land use and nutrient concentration (TP, SRP, TN, NO_3^- and NH_4^+) in the three sites. This was also found in 17 streams in Maine, U.S.A. (Huryn *et al.*, 2000).

In the site 3, an increase in the concentration of total phosphorus can be observed; this can be attributed to the decomposition of mineral organic complexes transported from the runoff. In the upper sector (site 1) of the river, the nitrification and transformation of nitrogen from ammonia to nitrate occur. At the site 3 the increase in the concentration of major parameters except BOD_5 was observed. This can be explained by the discharge of the river and anthropogenic activities along the river. Owing to the considerable self-purification potential of the river, the quality of the water is distinctly improved with distance along the river.

A distinct seasonal variability of chemical parameters was recorded in the Cirhanyobowa River water (Fig. 2).



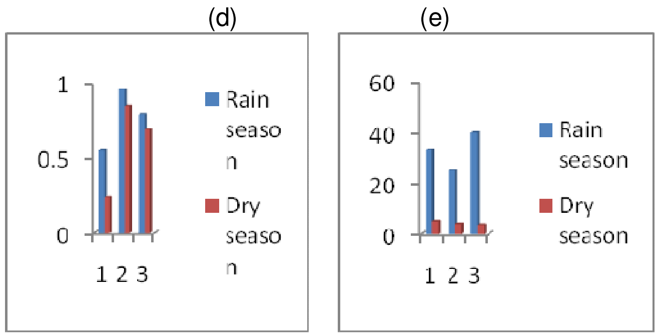


Fig 2: Seasonal variation of some chemical parameters in the three sites (Site 1, Site 2 and Site 3) of Cirhanyobowa River.

(a) Suspend solid
(b) pH
(c) Temperature
(d) Total Phosphore
(e) Total Nitrogen

Rain season differs from the remaining season of the sampling period to the greatest degree due to the inflow of great loads particularly in the nutrients and suspended solids. Suspended solid concentrations were greatest at the site 3 and during the rainy season.

Differences in water chemistry across the river sites are statistically significant. Phosphorus and nitrogen are important nutrient carrier in the downstream ecosystems. This can intensify the eutrophication process in the Kivu Lake. Water flow increase during floods increases concentration of chemical parameters in the river although the increase was less pronounced in the site 3 where the load of biogens is neutralized by the wetland. The monthly variations of some parameters (Dissolved Oxygen, Total Phosphorous and Total Nitrogen) are presented in Figure 3 of the three sites in the Cirhanyobowa River (Fig. 3).

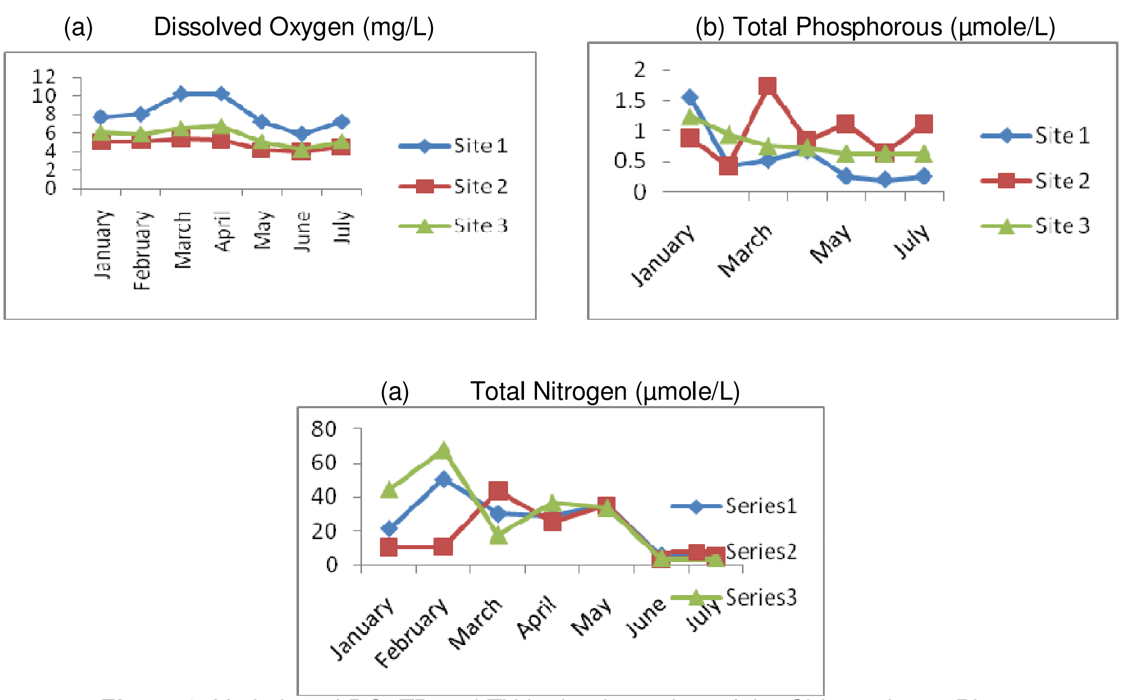


Figure 3: Variation of DO, TP and TN in the three sites of the Cirhanyobowa River.

Benthic invertebrate communities have long been used as tools to assess the effects of anthropogenic stressors on water quality in the temperate regions. Table 2 shows the composition and distribution of macroinvertebrate in the three sites of Cirhanyobowa River.

Table 2: Composition, distribution and frequency (%) of macroinvertebrate in the three sites of Cirhanyobowa River

Taxa	Site 1		Site 2		Site 3	
	N° of individuals	Frequency (%)	N° of individuals	Frequency (%)	N° of individuals	Frequency (%)
E. Arthropods						
Cl. Insects						
O. Dictyoptera						
F. Panasthiidae						
Cryptocercus punctulatus	6	44.4	0	0	0	0
O. Plecoptera						
F. Nemeuridae						
Nemeura sp	13	11.1	0	0	0	0
F. Perlidae						
Specie 1	35	44.4	2	11.1	0	0
Perlinella drymo	47	77.7	20	66.6	0	0
F. Perlodidae						
Isoperla holochlora	8	33.3	0	0	0	0
O. Tricoptera						
F. Hydropsychidae						
Hydropsyche simulanus	143	55.5	42	88.8	10	22.2
F. Philopotamidae						
Chimarra aterrima	22	11.1	10	44.4	21	55.5
Polycentropus sp	8	55.5	0	0	0	0
F. Lepidostomatidae						
Lepidostoma sp	241	100	108	66.6	5	11.1
F. Phyganeidae						
Agrypia vestita	0	0	4	33.3	7	33.3
F. Helicopsychidae						
Helicopsyche borealis						
F. Leptoceridae	0	0	0	11.1	2	33.3
Leptocerus Americana						
Triaenodes tarda						
Leptocella albida	3	22.2	5	33.3	1	11.1
	5	33.3	6	22.2	4	33.3
	23	88.8	0	0	0	0
O. Ephemeroptera						
F. Baetidae						
Caenis sp	8	66.6	0	0	0	0
Baetis sp	146	44.4	254	55.5	46	44.4
Adenophlebia sp	50	66.6	62	77.7	36	55.5
F. Heptagenidae						
Heporous sp	1	11.1	1	0	0	0
Iron humeralis	11	77.7	3	22.2	0	0
Rhithrogena sp	14	77.7	2	11.1	0	0
F. Ephemerola						
Specie 2	5	55.5	1	11.1	0	0
F. Coenidae						
Specie 3	0	0	4	44.4	6	33.3
F. Platyceremidae						
Ancantrela sp	0	0	19	44.4	20	44.4
O. Odonata						
F. Coenagrionidae						
Pseudogrion sp	0	0	95	88.8	174	100
F. Aechnidae						
Aeschna sp	8	55.5	19	33.3	8	11.1
F. Libellulidae						
Tachopteryx thoreyi	49	66.6	10	66.6	19	55.5
Cordulia sp	0	0	2	22.2	12	66.6
F.Gomphidae						

Progomphus obscuris	55	66.6	38	88.8	30	88.8
O. Coleoptera						
F. Psephenidae						
Psephenus herricki	5	22.2	1		0	0
F. Elmidae						
Stenelmis lateralis	17	66.6	8		0	0
F. Gyrinidae						
Gyrinus notatore	11	55.5	8		1	11.1
F. Dytiscidae						
Specie 4	3	33.3	0		0	0
F. Haliplidae						
Haliplus triopsis	0	0	2		0	0
Nocterus sp	1	11.1	0		0	0
F. Hydrophilidae						
Hydrobius friscipes	7	44.4	0		0	0
F.Corixidae						
Corixa sp	1	11.1	35		0	0
F. Amphizoidae						
Amphizoa lecontei	1	11.1	1		0	0
O. Diptera						
F. Chironomidae						
Chironomus tentans	0	0	7	55.5	9	33.3
F. Psychodidae						
Psychoda sp	23	77.7	27	66.6	3	11.1
F.Similidae						
Simulius venastum	399	77.7	3	22.2	0	0
F. Ceratopogonidae						
Palpomyia tibialis	19	66.6	0	0	0	0
O. Hemiptera						
F. Mesovelidae						
Mesovelia sp	0	0	20	55.5	5	33.3
F. Pleidae						
Plea striola	41	88.8	19	22.2	0	0
F. Gerridae						
Gerris lacustris	0	0	8	11.1	0	0
F. Nepidae						
Nepa cinerea	0	0	1	11.1	0	0
F. Velidae						
Velia cuneus	7	44.4	8	33.3	0	0
F. Naucoridae						
Pelocoris fermoratus	0	0	21	22.2	1	11.1
O. Megaloptera						
F. Sialidae						
Sialis sp	2	22.2	9	22.2	0	0
Cl. Arachnidae						
O. Areneides						
F. Agyronectidae						
Agyronecta sp	23	66.6	56	77.7	0	0
F. Mideopsidae						
Mideopsis orbicularis	4	33.3	0	0	0	0
Cl. Cristacea						
O. Decapoda						
F. Potadomidae						
Potagetum sp	13	66.6	0	0	0	0
O. Isopoda						
F. Asselludae						
Assellus aquaticus	8	44.4	3	22.2	0	0
E. Annelida						
Cl. Oligocheta						
O. Lumbriculida						
F. Lumbriculidae						

Lumbriculus inconstans	10	66.6	2	11.1	12	22.2
Cl. Huridinae O. Rhynchobdellida F. Glossiphonidae Glossiphonia complanata	20	66.6	8	55.5	0	0
E. Nemathelminthe Cl. Gordiace O. Gordiidea F. Nematomorpha Gordius sp	2	11.1	3	22.2	0	0
E. Mollusca Cl. Gasteropoda O. Basommatophora F. Lymnaeidae Lymnae natalensis Lymnae collumella F. Planorbidae Biomphalaria pfeifferi Bulinus truncatus Segmentorbis kempi	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	4 3 9 4 2	11.1 11.1 33.3 33.3 22.2
Total	43		42		27	

Sixty-one taxa were identified during 9 months of sampling in the Cirhanyobowa River. 43 (71.67 %) taxa were collected from the site 1, while 42 (70 %) from the site 2 and 27 (45 %) from site 3. The taxon richness was highest in site 1 and lowest in site 3. Site 2 has the same taxon richness than site 1. This difference is due to anthropogenic activities which affect macroinvertebrate presence (Victor and Onomivbori, 1996). The mining activities and agriculture around the riverbank are responsible for the disappearing of some species sensitive to pollution in sites 2 and 3. The total number of taxa is not significantly different at the sites 1 and 2 but significantly at the site 3 (Kruskal wallis test, P< 0.05).

All physical and chemical conditions indicative of water quality were variable fluctuating during the sample period in the three sites. Same parameters were high in the site 1 and less in the sites downstream as far as dissolved oxygen and nitrate are concerned but others were high downstream. Since changes in water quality conditions directly influence the structure and composition of Cirhanyobowa River macroinvertebrate. Monthly variation of some chemical parameters (DO, BOD_5) demonstrated that these two parameters influenced the composition of macroinvertebrate (Fig. 4 and Fig. 5).

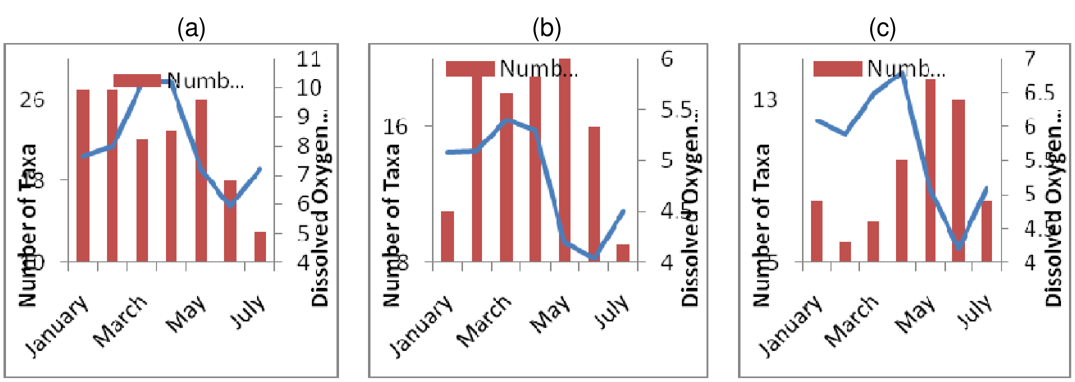


Fig. 4: Monthly variation of DO and number of taxa in the three sites of Cirhanyobowa River.

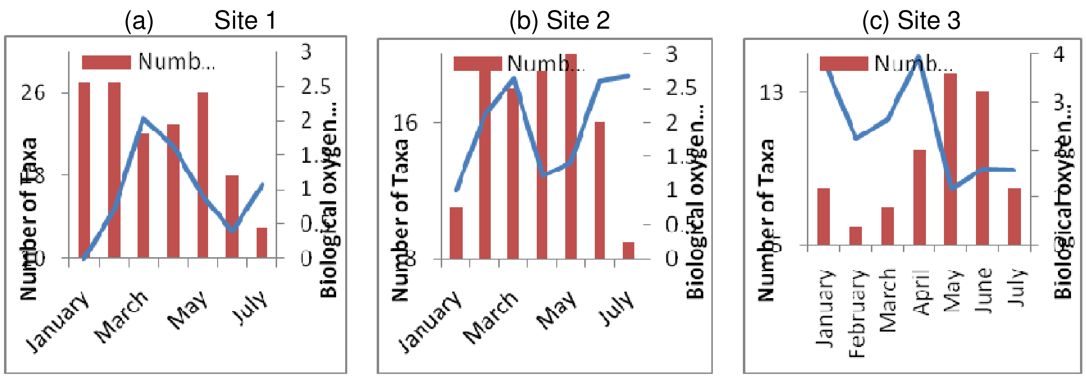


Fig. 5: Monthly variation of BOD_5 and number of taxa in the three sites of Cirhanyobowa River.
(a) Site 1 (b) Site 2 (c) Site 3

The intolerant species found in site 1 was absent in site 2 even if the number of taxa was similar. Macroinvertebrate taxa richness and the number of unique macroinvertebrate species (found at only one site) indicated moderate stress (Fair water quality) around the forested site and severe stress (Poor water quality) at the agricultural and mining site. At the agricultural site, declines in taxa richness within intolerant groups were partially offset by increases within tolerant groups as also documented by David and Grawford (1994); this is the case of Ephemeroptera and Gasteropoda in the Cirhanyobowa River.

CONCLUSIONS

The mining site had the highest abundance values, indicating enrichment. The agricultural site, however, was characterized by low species richness for most groups and very low abundance values. Dominant macroinvertebrate groups shifted from Plecoptera at the forested site, to Ephemeroptera and Gasteropoda at the agricultural site, and Ephemeroptera to Hemiptera at the mining site. Chemical and physical parameters measured at the three sites did not seem sufficient to account for all of the observed differences in the macroinvertebrate communities; it will be interesting to investigate other unmeasured parameters to explain the difference observed in macroinvertebrate communities in the Cirhanyobowa River.

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