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# Evaluation of the state of riparian ecosystems in the city of Kinshasa by the quality of riparian strips: The case of the Bumbu River (DR Congo)

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## Abstract

The present study focused on the evaluation of the state of riparian ecosystems of the Bumbu River by the riparian strip quality index. The Riparian Quality Index (RQI) is a synthesis of information to assess the health of the riparian ecosystem along its course. Physical and chemical water quality analyses of this hydrosystem showed a slightly acidic pH (6.6 to 6.9), high conductivity (188 to 202µs/cm), a temperature around 26 °C and high turbidity (80 to 91 NTU), low dissolved oxygen (1.49 to 1.89 mg/l), nitrate, phosphates, BOD5 and COD had high average levels of 45.4 mg/l, 14.8 mg/l, 15.6 mg/l and 24.8 mg/l respectively. The examination of the spatial variation of this index according to the different stations shows that the quality of the riparian strips of the Bumbu River is weak to accomplish their ecological functions with an RBQI around 34.6 and 46.3. The herbaceous and cultivated strata occupied important proportions of the riparian strips of this hydrosystem.

**Keywords:** Bumbu; Riparian Ecosystems; Riparian Buffer Strips; Ecological Functions

## 1. Introduction

Nutrient accumulation in rivers is one of the most widespread ecological problems responsible for freshwater pollution worldwide [1]. But this is only the beginning of a long list of water-related problems. We can think of the drying up of rivers in different regions of the world due to global warming, the problems of erosion of banks linked to excessive deforestation, which has the effect of disrupting the habitats of aquatic fauna [2].

Faced with this magnitude of the problem, many countries such as the United States of America, Canada, Belgium, etc., have adopted a national policy to protect this unique resource, to manage it in a sustainable development perspective and thus to ensure the protection of public health and aquatic ecosystems [2].

The management of running freshwater requires a good knowledge of its state and degree of transformation. There are two different complementary approaches to answer these questions: the first is physico-chemical, it consists in characterizing the disturbances by their causes and, in this case, the presence of polluting elements, the second is biocenotic, it aims at characterizing the disturbances by their effects on the communities living in place [3].

The riparian zone is defined as the area that surrounds the lake from the shoreline (water/land interface) to 20 meters inland following the slope of the land [4].

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It represents a buffer zone between terrestrial and aquatic environments and serves as an important site for the biochemical processes that link them [5]. Riparian vegetation, commonly referred to as the riparian buffer, performs a multitude of functions necessary to maintain the biotic integrity of riparian ecosystems [6]. It is a key element for the control of the diffuse population to some extent in the retention and filtration of sediments, nutrients and contaminants transported by runoff [7].

Riparian vegetation and its root system also serve to control soil erosion caused by surface water runoff, wind and bank instability [8]. The canopy regulates stream temperature and productivity while the litter limits soil evaporation rates and stimulates the denitrification process [9].

Needle leaves and woody debris that fall into the water are an important source of nutrients and habitat for benthic and fish communities [6]. Finally, the presence of coarse woody debris in the aquatic environment stabilizes the hydrosystem and plays an important role in the retention of detrital particles and other organic materials [6].

The riparian quality index (RQI) provides a quick and comprehensive assessment of the ecological condition of the riparian habitat and its impact on the integrity of the aquatic environment [10].

The present study focuses on the evaluation of the quality of the riparian strips of the Bumbu River. In their natural state, these strips offer a full range of complex and diversified habitats conducive to the maintenance of biological communities [6]. They represent a key element for the control of non-point source pollution in watercourses because their vegetation cover serves to some extent to retain and filter sediments, nutrients and contaminants transported by runoff [11]. They with their root system also serve to control soil erosion caused by surface water runoff and shepherd stability [8].

The objective of the present study is to evaluate the quality of the riparian strips of the Bumbu River through the riparian strip quality index. Thus, it will be able to contribute to make available data that can be used for the analysis of the evolution of the health of this aquatic ecosystem and the development of the said river. The main objectives are to:

- To evaluate the physical and chemical quality of the Bumbu River
- To appreciate the quality of the riparian strips in order to note the influence of these on the water chemistry of this hydrosystem.

The interest of this study is that it characterizes the riparian strips of the Bumbu River and evaluates its ecological condition to allow a direct relationship between the quality of the habitat of the riparian ecosystem and that found in the watercourse.

### 1.1. Study environment

The Bumbu River constitutes the main hydrosystem of the Selembao commune. It has its source at 015° 15' 59'' East longitude and 04° 26' 18'' South latitude at an altitude of about 345 meters and is about 11 km long. According to Schum's classification [12], it is of order 3 and flows into the Funa River in the commune of Kalamu [13].

Its watershed is located largely in the hill area of Kinshasa and according to Van Caillié [14], it sits top to bottom on the following geological formations:

- reworked sandy layer ;
- more or less clayey sand (kaolinous) ;
- polymorphic sandstone ;
- soft white or pink sandstone;
- Altered sandstone shale belonging to the INKISI series [15].

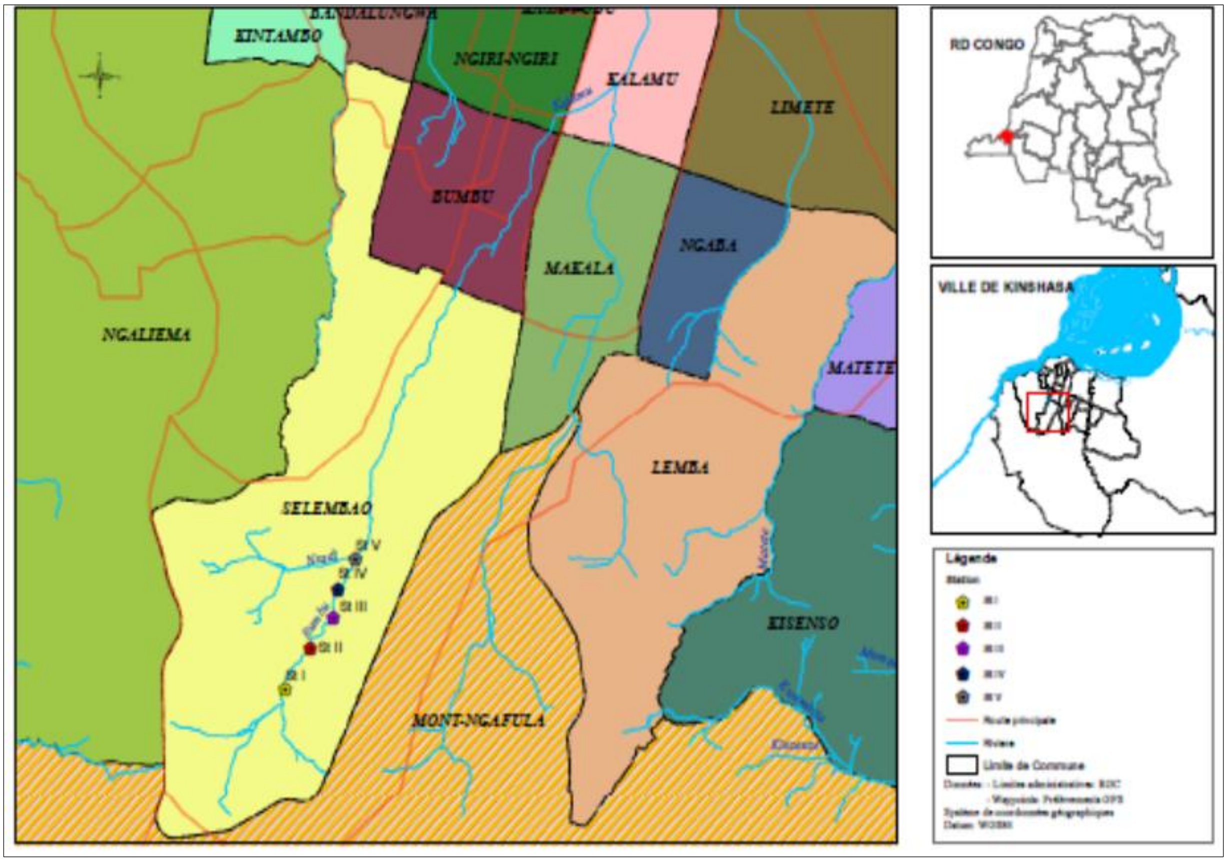


**Figure 1** Location of sampling stations and the Bumbu River

## 2. Methods

### 2.1. Physical and chemical characteristics of the biotope

The physical analyses of the water concerned temperature (°C), conductivity (µs/cm), turbidity (NTU) and Hydrogen potential (pH). These parameters were measured in situ using a Combo Hanna HI 98129 multiparameter probe.

The chemical analyses focused on dissolved oxygen (in mg/l), ammoniacal nitrogen ($NH^{+}_{4}$) (mg/l), nitrite ($NO^{-}_{2}$) (mg/l), nitrate ($NO^{-}_{3}$) (mg/l) and phosphate ($PO^{3-}_{4}$) (mg/l). Dissolved oxygen was measured using the WTW340i/SET multiparameter probe. The last four parameters were measured using a HACH DR/2400 spectrophotometer.

### 2.2. Riparian Quality Index (RQI)

Riparian strip quality is generally related to the biotic quality of a hydro system. The riparian buffer consisting primarily of vegetation is an intermediate zone between the terrestrial and aquatic environment [16]. The characterization and evaluation of its ecological condition allows a direct relationship between the habitat quality of the riparian ecosystem and that found in the rivers [10].

In the rivers studied, the five stations selected corresponded to the riparian strip sectors. Thus, an area of 100 m by 50 m was obtained on which the percentage of cover of each component was visually evaluated, the sum of cover having to equal 100%.

The data thus collected were combined to obtain information on the station [10].

For each station in the river, the Riverbank Quality Index (RQI) was calculated using the formula proposed by CBJC [17]

$$RQI = \frac{[\sum(\%i.Pi]}{10}$$

With:

i: nth component ;

%i: percentage of the station covered by the nth component;

Pi: weighting factor of the nth component (Appendix 3).

The different values of the Riparian Strip Quality Index (RSQI) were compared to the scale of the capacity of the riparian strip to perform its ecological functions [17]. Table 1 presents the riparian buffer rating scale.

**Table 1** Riparian buffer capacity rating scale [17]

| RQI | Capacity of the riparian buffer to perform its ecological functions |
|---|---|
| ≤19 | Very Low |
| 19 à 46 | Low |
| 47 à 58 | Medium |
| 59 à 74 | Good |
| 75 à 100 | Excellent |

### 2.3. Data analysis

The data referring to the physical and chemical parameters and the components of the riparian strips of this studied hydrosystem, were subjected to various statistical treatments. The method with simple variables was adopted due to the insufficient number of reference stations.

In addition to the different metrics inherent to the simple variable method, the data related to the riparian buffer components were correlated to the different abiotic parameters. And this correlation was performed using Principal Component Analysis (PCA).

Principal Component Analysis is a multifactorial analysis widely used in the processing of ecological data. It allows a simplified expression of the information contained in a multivariate table from a reduced number of variables [18, 16].

In this work, Principal Component Analysis was performed in order to establish a classification of the sampling stations according to their physicochemical quality and biotic variables. All data were first normalized (LOG (X+1)) and then centered reduced; the purpose of the normalization is to transform the distribution of raw data into a normal distribution. The transformed data are centered reduced to standardize the different environmental factors that are not expressed in the same order of magnitude.

Past (Paleontological Statistics version 2.16) software [19, 20, 21, 22, 23, 16] was used to determine the correlation between abiotic and biotic variables.

For the interpretation of the axes, variables with a contribution exclusively greater than the mean contribution (($> \frac{1}{\sqrt{p}}$; p denoting the number of variables) were retained [24, 16].

# 3. Results

## 3.1. Physical and chemical characteristics of the waters of the Bumbu River

### *3.1.1. Physical characteristics*

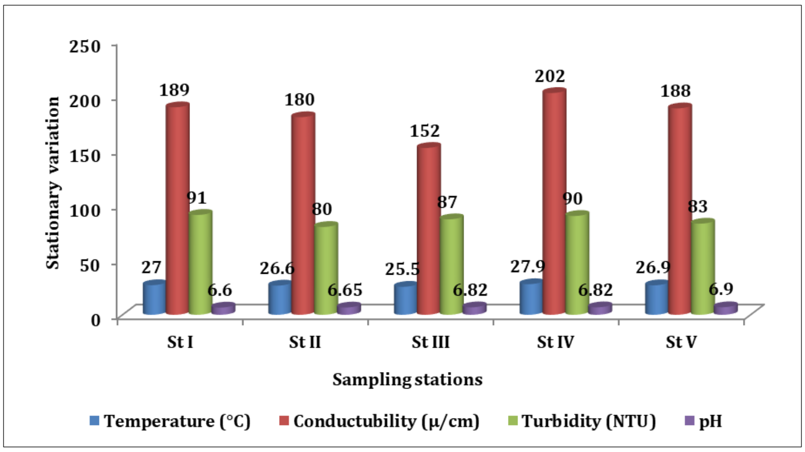


**Figure 2** Stationary variation Physical characteristics of water in the Bumbu dry season 2021

Figure 2 shows that in the Bumbu River, the highest water temperature and conductivity were recorded at the St IV station (27.9°C and 202µs/cm) and the lowest at the St III station (25.5°C and 152µs/cm). During the study period, the highest turbidity was observed at the St I station (i.e. 91UNT) and the St II station recorded the lowest (i.e. 80UNT). The highest pH value was measured at the St V station (6.9) and the lowest at the St I station (6.6).

### *3.1.2. Chemical characteristics*

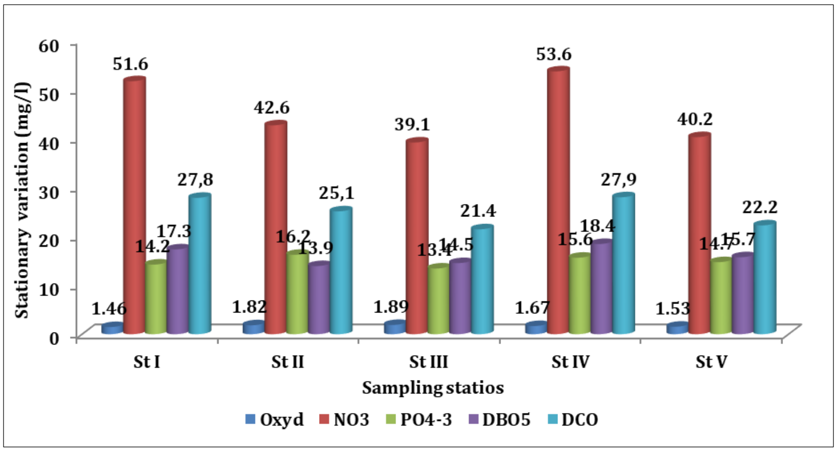


**Figure 3** Stationary variation Chemical characteristics of water in the Bumbu dry season 2021

Figure 3 shows that in the Bumbu River the highest dissolved oxygen content was observed at the St III station (1.89 mg/l) and the lowest at the St 1 station (1.46mg/l).

Regarding the nitrate level in the Bumbu River, the highest level was recorded at the St IV station (53.6mg/l) while the lowest was recorded at the St III station (39.1 mg/l).

The St II station recorded the highest phosphate levels (16.2mg/l) while the St III station recorded very low levels (13.4 mg/l).

The St IV station showed high biological oxygen demand (18.4mg/l) and chemical oxygen demand (27.93 mg/l) while the St II St III stations showed low biological oxygen demand (13.9mg/l) and chemical oxygen demand (21.4 mg/l) respectively.

### 3.2. Evaluation of the Riverine Quality Index (RQI)

**Table 2** Quality Index of the Bumbu River riparian zone in the dry season in 2021

| Stations | Riparian buffer components (%) | | | | | | | | RQI | Riparian capacity |
|---|---|---|---|---|---|---|---|---|---|---|
| | Forest | Shrub | Grass | Crop | Wasteland Lawn | Bare soil | Bedrock | Infr | | |
| St I | 0 | 5 | 40 | 50 | 0 | 5 | 0 | 0 | 37.6 | Low |
| St II | 0 | 0 | 70 | 30 | 0 | 0 | 0 | 0 | 46.3 | Low |
| St III | 0 | 0 | 70 | 30 | 0 | 0 | 0 | 0 | 46.3 | Low |
| St IV | 0 | 0 | 40 | 40 | 0 | 0 | 0 | 20 | 34.6 | Low |
| St V | 0 | 0 | 45 | 45 | 10 | 0 | 0 | 0 | 37.6 | Low |

Table 2 informs that in the dry season, the riparian strip is characterized by natural grasses that occupied proportions of 70% at the St II and St III stations, 45 at St V and 40% at St I and St IV; crops took proportions ranging from 50% at the St I station, 30% at St II and III, 40% at St IV and 45 at St V. Infrastructure occupied only 20% of the riparian buffer at the St 4 station. The capacity of this strip to perform its ecological functions is low from top to bottom. The highest riparian capacity index was recorded at the St III stations (RQI =46.3) and the lowest at the St IV station which had an RQI =34.6.

### 3.3. Correlations between riparian buffer components and physical and chemical

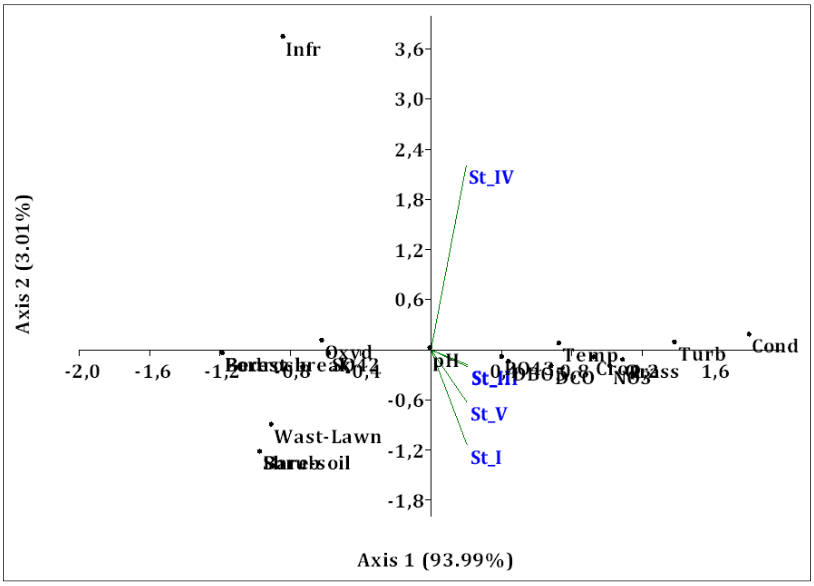


**Figure** 4 Correlations between riparian buffer components and physical and chemical parameters in the Bumbu River in the 2021 dry season

From Figure 4, it can be seen that two main axes (Axis 1 and Axis 2) were selected since they are responsible for 97% of the dispersion of the variables; Axis 1 having presented 93.99% of the total variance and Axis 2 3.01% of it.

The Principal Component Analysis of the riparian buffer components and the physical and chemical parameters during the dry season in the Bumbu River watershed, revealed a positive correlation between all the stations studied and axis 1.

Axis 1 is highly correlated with the following physical and chemical parameters and riparian buffer components: Temperature (r=0.72594), Conductivity (r=1.09), Turbidity (r=1.3837), Nitrate (r=1.0174), Phosphates (r=0.4011), BOD5 (r=0.43982), COD (r=0.68268), Crops (r=0.92523), and Grass (r=1.0891).

The following riparian buffer components: crops and natural grasses correlated positively with the following physicochemical parameters: Temperature, Conductivity, Turbidity, Nitrate, Phosphates, BOD5 and COD.

In terms of negative correlations, Temperature, Conductivity, Turbidity, Nitrate, Phosphates, BOD5 and COD were negatively correlated with the components Forest, Shrubs, Forest Cut, Bare Ground, Rochet Base and Infrastructure.

A positive correlation was observed between pH, dissolved oxygen and sulfate and the riparian buffer components forest, shrubland, forest cut, wildland, bare soil and bedrock.

## 4. Discussion

It is known that ecological factors have a determining role in the number and nature of species likely to cohabit in a given environment [25, 26] showed that the distribution of living organisms is largely influenced by the physical and chemical quality of the water (dissolved oxygen, temperature, pH, suspended solids, hardness, ammonia, etc. ....). Similarly, [25] emphasizes the role of hydrology as a structuring factor of aquatic ecology and also notes that hydrological variability resulting from the seasonal distribution of rainfall or inter-annual variability of precipitation has important consequences on the biology of species and on the dynamics of aquatic populations.

Temperature influences the metabolism (embryonic development, growth, respiration, reproduction,) and distribution of animal and plant species [27]. In the Bumbu, the increase in average water temperature (26.8°C in the dry season) could be explained by the thermal exchanges water-atmosphere and also of the shallow bed at the bottom of which the substrate is seen, the penetration of solar radiation is total in the vast majority of stations studied.

The values found in the five stations are close to those obtained by [28, 29, 30, 31]. These confirm that most tropical waters have a temperature greater than or equal to 25°C.

Regarding conductivity in the five stations, the high average value found (182.2(s/cm,) is the result of mineralization activity of organic matter by microorganisms and excessive discharges of wastewater containing mineral salts contained in soaps and detergents [32, 16].

As for turbidity, human activities in the Bumbu watershed have induced a significant turbidity whose average value during the study period was 86.2 NTU. The water coming from the concrete canals of the Heradie and Cité Verte districts, associated with the discharge of household waste of all kinds into this receptor, which is considered a dumping ground by the surrounding population, and the discharge of wastewater (black water and grey water) from the houses along the river, justify the turbidity of the waters of the Bumbu River. These values are also justified by the speed of flow of the water which drains numerous particles from the soils that reach the riverbed. These particles are generally found in the form of isolated grains [16]. Flocculation and aggregation of some of these particles occurs overall only when the flow velocity becomes low [33].

The average pH values recorded at the five stations are slightly acidic. The slightly acidic pH values recorded can be explained by the nature of the sandy-textured geological substrate through which this river flows; and by the decomposition of organic matter which releases carbon dioxide tending to acidify the waters [16].

The quantities of dissolved oxygen recorded in the different stations are justified by the important presence of aquatic vegetation in this river, the important speed of flow of its waters and the presence of eddies and cascades caused by water movements, justifying the permanent renewal of oxygen in this hydrosystem [34, 35, 16].

According to [36], the dissolved oxygen concentration varies daily and seasonally and it depends on many factors such as: water temperature, water agitation and nutrient availability. This justifies the differences observed between the stations in this hydrosystem. Dissolved oxygen is also related to turbidity. The latter disrupts the photosynthetic activity of aquatic vegetation by reducing the penetration of solar radiation into the hydrosystem, resulting in low dissolved oxygen supply by vegetation [37].

The decomposition of organic matter by microorganisms resulted in the ammonification ($NH_4^+$) of the organic matter. Almost all of $NH_4^+$ was used by nitrifying bacteria to produce their metabolic energy by converting ammonium to nitrite and the oxidation of the latter to nitrate [38, 39].

The high values of nitrate in the waters of this river can be justified by the use of synthetic fertilizers and manures, but also to deficient septic installations of riparians in the source areas of these hydrosystems [40].

The phosphate values recorded in the five stations of the Bumbu River are very important. [41] Estimates that the natural content (also called biogeochemical background) of $PO_4^{3-}$ in streams is generally less than 0.025 mg/l and depends mainly on the nature of the geological substratum. The high values observed in the studied hydrosystem can be explained by the domestic effluents discharged directly into this river [42].

The presence of sulfates in the five stations of the Bumbu River is related to the discharge of wastewater containing black water (containing excreta), grey water (containing detergents) and organic matter of various origins.

According to [43, 16], the decomposition of organic matter can occur through two processes:

- Aerobic, which leads to the direct reformation of sulfates $SO_4^{2-}$ ;
- Anaerobic, which goes through the sulfides $S^{2-}$ stage (storage form in reduced sediments).

The two processes are superimposed and are completed by exchanges of sulfur compounds. In anaerobic conditions, the sulfur cycle is entirely bacterial. Sulfides $S^{2-}$ arise from the reduction of sulfates $SO_4^{2-}$ by sulfate-reducing bacteria, the reduction of elemental sulfur by sulfo-reducing bacteria, the reduction of thiosulfate by thiosulfator-reducing bacteria and the bacterial decomposition of sulfur proteins [16].

When sulfates are assimilated by organisms, they are reduced and converted to organic sulfur compounds including some essential amino acids.

As for the cover of riparian buffer components, it does not vary much along the Bumbu River. The herbaceous strata and crops are the components mainly found on the banks of the Bumbu River.

The herbaceous stratum dominated in all sections of the Bumbu River, followed by crops, housing infrastructure, wasteland and shrub layer.

According to [9], in its natural state, the riparian strip generally has three vegetation layers consisting of forbs, shrubs and trees. This complex of natural riparian vegetation ensures the preservation of habitats and areas for the migration and existence of many species of mammals, birds, amphibians, reptiles and even some vascular plants [44].

The preservation of intact riparian buffer strips along the shoreline not only helps to maintain terrestrial biodiversity, but also aquatic biodiversity.

According to [10], the deterioration of the riparian strip affects the biotic integrity of the aquatic environment mainly through its effect on the complexity of the environment. This could be explained by the decrease in the frequency of woody debris in the sections of the Bumbu River located near the development of anthropogenic activities. The aquatic environment in these areas has become more homogeneous and less favorable for the maintenance of aquatic diversity.

With respect to herbaceous cover in natural environments, herbaceous plants are generally less effective than forests and shrubs in maintaining the stability and complexity of riparian habitats [45]. Herbaceous-dominated sites are thought to have higher sediment loads (bank instability, slump erosion, less in-stream habitat, resting shelters, and refugia (lack of ice jams and complexity), less in situ nutrient retention [45]. This is the case for the Bumbu River at all stations. The sediment load is higher and creates bank instability leading to erosion caused by landslides.

As for the cover by crops, agricultural practices increase the load of nutrients and contaminants caused by the frequent application of fertilizers and pesticides [8]. An increase in the percentage of riparian cover by crops can cause significant degradation of terrestrial and aquatic habitats and water quality in riparian ecosystems [9]. Stations in the Bumbu River where market gardening practices dominate have shown that the hydrosystem is unstable due to a high potential for bank erosion. This explains the positive correlations between crops and natural grasses with physical and chemical parameters Temperature, Conductivity, Turbidity, Nitrate, Phosphate, $BOD_5$ and COD.

With regard to fallow land, an increase in the frequency of leaves on the banks can lead to the clogging of watercourses, this can threaten the benthic and piscicultural life of aquatic environments [10].

As for anthropogenic infrastructure, it is usually a sign of the destruction of natural habitats and their degradation. It generally decreases the ability of the riparian system to support and maintain a balanced, well-integrated community of organisms and alters the composition, diversity and dynamics of the natural ecosystem [46].

According to [10], infrastructure influences variations in stream temperature, the alteration of tropical dynamics and the destruction of habitats due to clogging of substrates, can promote native productivity (primary productivity). This can sometimes lead to eutrophication.

Water conductivity is significantly related to riparian habitat quality. We find less clear and more conductive waters in places where the RBQI decreases due to shoreline exploitation (cultivation, residential infrastructure, etc.) [10]. The fragility of the banks in exploited areas can lead to an increase in the ionic load in the stream [47]. This explains the high values of conductivity in the studied stations.

Riparian vegetation also plays an important role in the regulation of phosphorus entering the stream. Like nitrate, the concentration of phosphorus can increase considerably with the presence of agricultural and residential environments [48]. This explains the increase in phosphate levels in the Bumbu. This explains the negative correlations observed in Figure 4 between phosphate and nitrate with the forest and shrub components.

According to [6], the direct uptake of nutrients such as nitrogen and phosphorus by riparian vegetation is an ecological factor that limits native stream production.

The values of physical and chemical parameters (Temperature, Dissolved Oxygen, Conductivity, pH, Turbidity, BOD5 and COD) and those of the riparian strip quality index were superimposed on those of the prediction model proposed by [16]. It was found that the studied hydrosystem is of lotic facies and is classified in the group of rivers of poor biological and ecological quality. This is justified by the fact that all the sampling stations of the Bumbu river presented low capacity of riparian strips to accomplish their ecological functions. This has had an impact on the water quality and bottom substrate of the river.

## 5. Conclusion

The diagnosis of the ecological status of a hydrosystem is mainly based on chemical and biological quality elements. A study combining chemical and biological tools in the medium, short and long term, can allow an effective and efficient monitoring of a hydrosystem.

The study of the quality of the riparian strips, as well as the physical and chemical quality of the waters of the hydrosystems of the city of Kinshasa, being incomplete, the knowledge of the factors favoring the degradation of the Bumbu River, can serve as a starting point for the monitoring of this river.

The absence of a wastewater collection system through a single pipe, coupled with ecological incivism and the demographic explosion, means that the hydrosystems of the city of Kinshasa serve as dumping grounds for all kinds of garbage. A mesological education based on the revalorization of household waste for the benefit of the population can be the beginning of a solution for the preservation of the rivers of the city of Kinshasa which are under strong anthropic pressure; while waiting for the implementation of an urban sanitation network.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

No conflict of interest.

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