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Research Article

Vulnerability of the Functional Organization of the Aquatic System of the Matete River in Kinshasa

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Abstract: The objective of this work is to study the vulnerability of the vertical and longitudinal dimension of the functional organization of the ecosystem of the Matete river in Kinshasa. The results obtained during this study show that the flood period is an important contributor to metallic elements. However, it offers a toxic habitat to the species that live there and could directly influence their development, in particular, the electrical conductivity varies between 262±23.1 and 415±7.1 µS/cm before the rain and from 276±4.6 and 417±5.7 µS/cm after rain; phosphorus of 0.011±0.001 mg/L and 0.325±0.07 mg/L before rain and 2.7±0.2 mg/L and 8.6±1.1 mg/L after rain; nitrite 0.001±0.000 mg/L and 0.12±0.016 mg/L before rain and 1.899±0.089 mg/L and 4.501±0.815 mg/L after rain; nitrate 0.4±0.2 mg/L and 7.1±0.1 mg/L before rain and 5.4×101±0.1 mg/L and 7.8×101±1.8 mg/L after rain; potassium of <0.1×102± <0.1 mg/L before rain and 17.70.6 and 207.2±0.4 mg/L after rain; manganese 0.5±0.4 mg/L and 9.1±0.1 mg/L before rain and <1.0±<0.2 and 399.9×101±905.6 mg/L after the rain; iron <0.1×101±<0.8 mg/L and 119.5×103± 3054.5 mg/L before rain and 21.5±0.7 and 140.8×101± 29.5 mg/L after rain; calcium of <0.1×101±<0.1 and 22.1±0.1 mg/L before rain and of 49.1± 0.1 and 472.8 ±3.7 mg/L after rain; aluminum <2.0×101±<1.4 mg/L and 173.5×101± 67.5 mg/l before rain and between <2.0×101±<1.2 and 286.5×101±133.9 mg/L after rain; cadmium <0.00020 ±<0.00002 mg/L and 2.4±0.3 mg/L before rain and <2.0±<0.1 mg/L and 50.5±12.8 mg/L after the rain. In addition, the bioavailability of these metals and the physicochemical characteristics of the aquatic environment would be the key factors in the transfer of these metals from the abiotic environment to the biotic environment.

Keywords: Metallic trace elements, vulnerability, functional organization, Matete river, Kinshasa.

1. Introduction

The use of chemicals is today an essential factor in the development of our society and contributes to the economic prosperity of many regions. Since the 1930s, the world production of chemicals has increased 400 times. Plastics, preservatives, detergents, paints, etc. are doing us countless services. However, some substances can have significant harmful effects on the environment and on human health, even at low doses (WHO, 2005 cited by Kusonika, 2016). The physical alterations made to watercourses are numerous and diverse: succession of numerous sills and dams, water diversion, recalibration and rectification of small and medium-sized rivers, protection of banks and extraction of aggregates. They have contributed to a decline in the general quality of rivers, both morphological and ecological. This deterioration results in a decrease in biodiversity, to the detriment of the most sensitive species, or in a disturbance of the characteristic populations of a watercourse. It is recognized

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that one of the major problems of this century is the prevention of the quality of the environment. Indeed, releases of substances of natural or synthetic origin constitute one of the most important factors of degradation of the biosphere by man. However, aquatic ecosystems, direct receptors of these discharges, reveal high rates of pollutant concentration greater than natural loads (Pery *et al.*, 2002). The Matete River is a natural receiver of wastewater from domestic and industrial sources and also an important crossroads for metallic trace elements. These high concentrations of metallic trace elements contribute to the instinct of certain aquatic species (plants and animals). However, these metallic trace elements vulnerable influences the functional organization of this ecosystem.

The overall objective of this study is to study the vulnerability of the vertical and longitudinal dimension of the functional organization of the ecosystem of the Matete river in Kinshasa. To do this, we have focused on the specific objectives below:

- ✓ Measure and determine the physicochemical parameters of this river;
- ✓ Determine the influence of metallic trace elements on the functional organization of this ecosystem;
- ✓ Produce a decision support tool to contribute to the sustainable management of the aquatic resources of the Matete river.

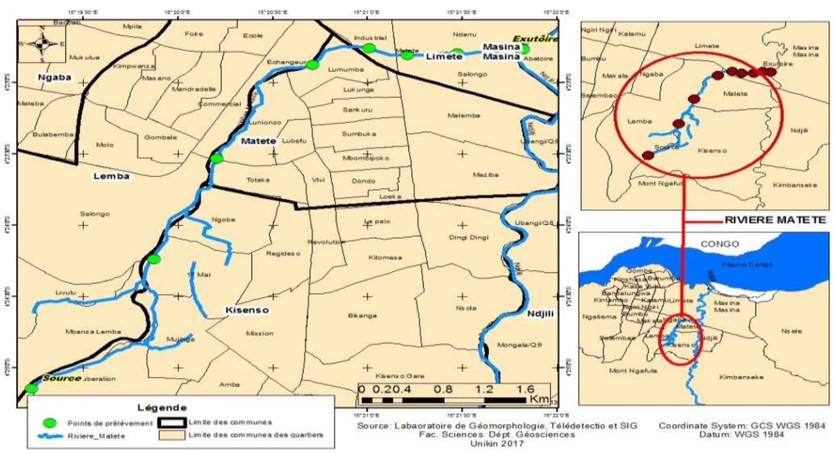
2. Material and methods

In situ, pH, temperature and dissolved oxygen were measured at each sampling. The other physicochemical parameters, in particular nitrates, nitrites, phosphorus, turbidity, manganese, iron, identification and the content of metallic trace elements, etc., were analyzed at the central analysis laboratory (LCA) of CGEA/CREN-K, at the OCC/Katanga laboratory and at the Régideso/Kingabwa central laboratory.

2.1 Sampling, labeling and identification

The samples collected consisted of water from the Matete River (see Map 1.). Water samples were taken every morning of two seasons (rainy and dry season) from different places in the Matete River (from source to outlet). After each collection, the water samples were placed in 1.5 liter plastic bottles which were washed beforehand, rinsed with tap water and then with distilled water and water from the river to be analyzed. These were labeled and placed in a cooler at a temperature of 4^0C and transported to the laboratory for analysis.

2.2 Sample collection sites



Map 1. Illustration of the digital mapping of the sample collection sites of the Matete river in kinshasa

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3. Results

3.1 Characterization of water samples from the Matete river

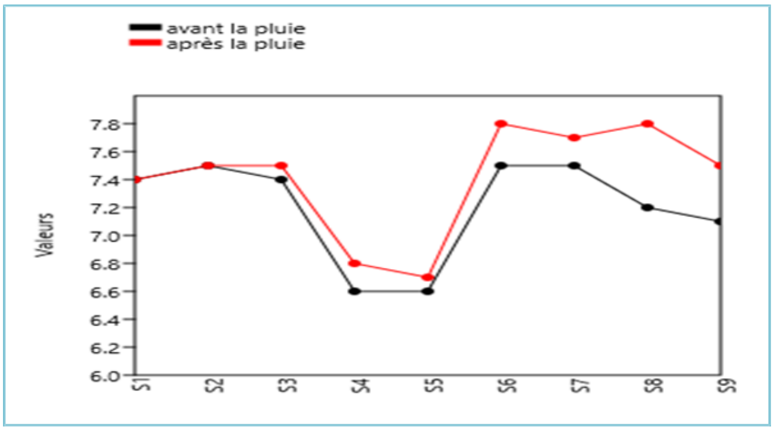

Figure 1. pH variation of the Matete river before and after the rain

The results obtained on the pH of the different samples from the Matete river vary between 6.6±1.2 and 7.5±2.0 before the rain and 6.7±0.6 and 7.8±1.1 after rain ($p = 0.05 \leq 0.05$).

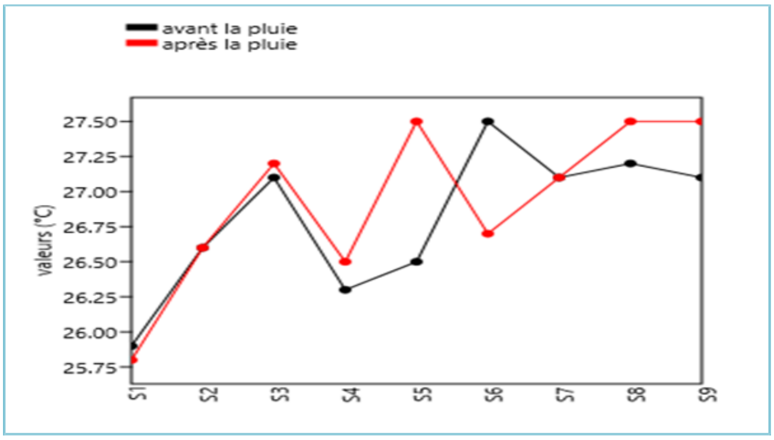

Figure 2. Temperature variation of the Matete river before and after the rain

The temperature values of the samples from the Matete River oscillate between 25.9±1.1^{0}C and 27.5±1.9^{0}C before the rain and 25.8±0.9 ^{0}C and 27.5±2.1^{0}C after rain ($p = 6.6486 \times 10\text{-}9 \leq 0.05$).

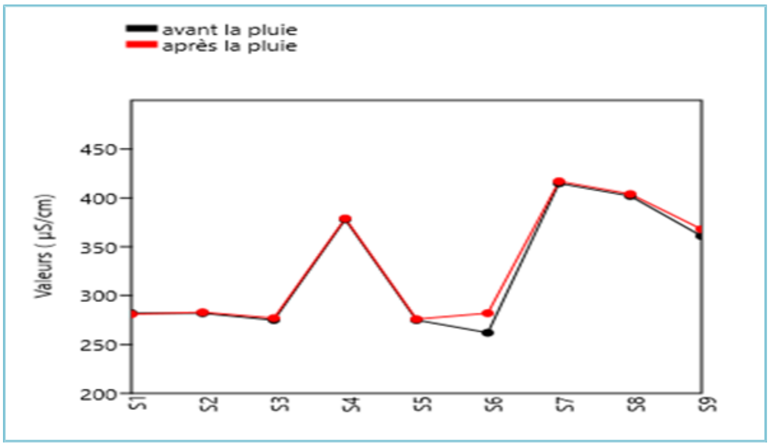

Figure 3. Change in conductivity of the Matete river before and after rain

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The values obtained on the electrical conductivity of the different samples of the Matete river vary between 262±23.1 and 415±7.1 µS /cm before the rain and between 276±4.6 and 417± 5.7 µS/cm after rain (p = 0.05 ≤ 0.05).

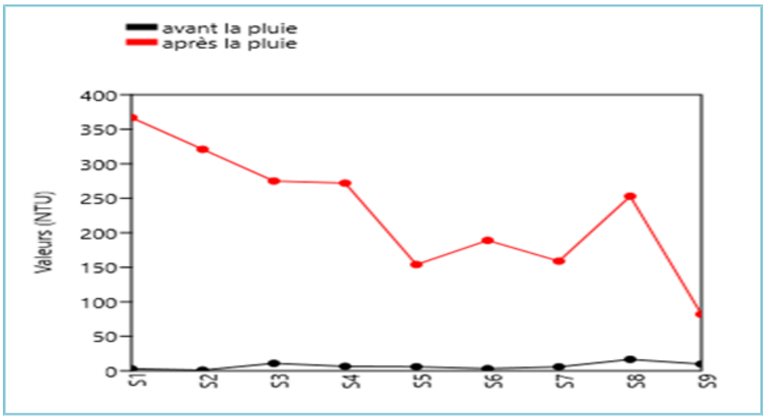

Figure 4. The turbidity values of the different water sampling sites of the Matete river

The turbidity values of different water samples from the Matete River oscillate around 1.03±0.01 NTU and 16.6±1.30 NTU before rain and between 8.2×101±4.98 NTU and 3.67×102±13.88 NTU after rain (p = 2.3477×10-9≤0.05).

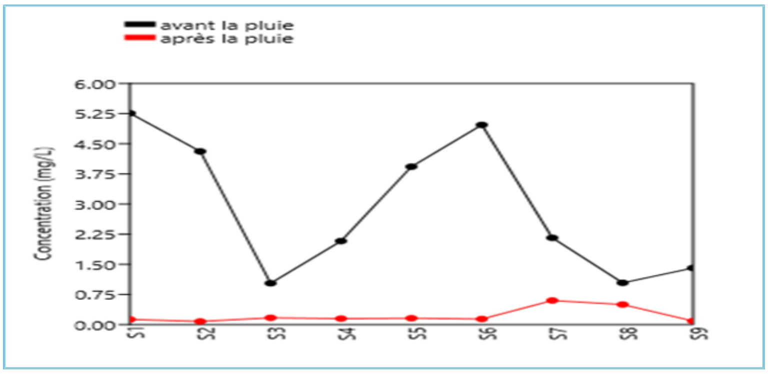

Figure 5. The dissolved oxygen values of the different water sampling sites of the Matete River

The dissolved oxygen results of water samples from the Matete River hover around 1.03± 0.24 mg/L and 5.26±0.23 mg/L before rain and between 0.08 ±0.02 mg/L and 0.6±0.2 mg/L after rain (p = 3.356×10-8≤0.05).

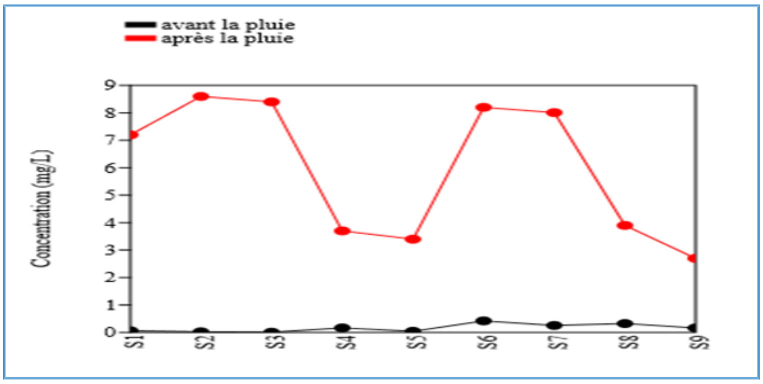

Figure 6. The phosphorus values of the different water sampling sites of the Matete River

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The phosphorus results for water samples are between 0.011±0.001 mg/L and 0.325±0.07 mg/ L before rain and between 2.7±0.2 mg/L and 8.6±1.1 mg/L after rain (p = 8.208×10-14≤ 0.05).

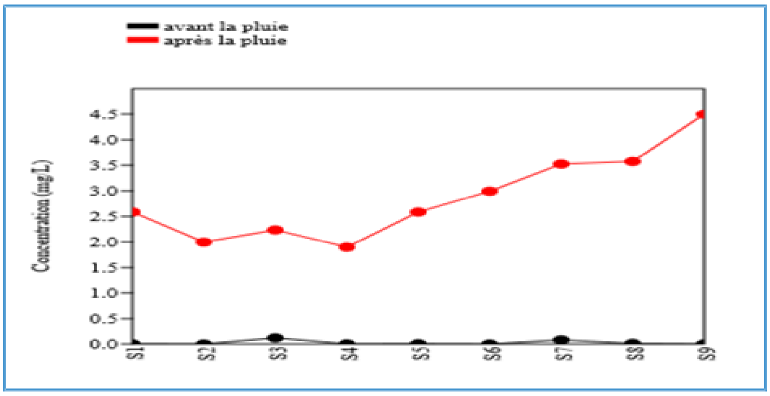

Figure 7. The nitrite values of the different water sampling sites of the Matete river

The nitrite values of the Matete River water samples range from 0.001±0.000 mg/L to 0.12± 0.016 mg/L before the rain and from 1.899±0.089 mg/L and 4.501±0.815 mg/L after the rain. rain (p = 1.6689×10-19≤0.05).

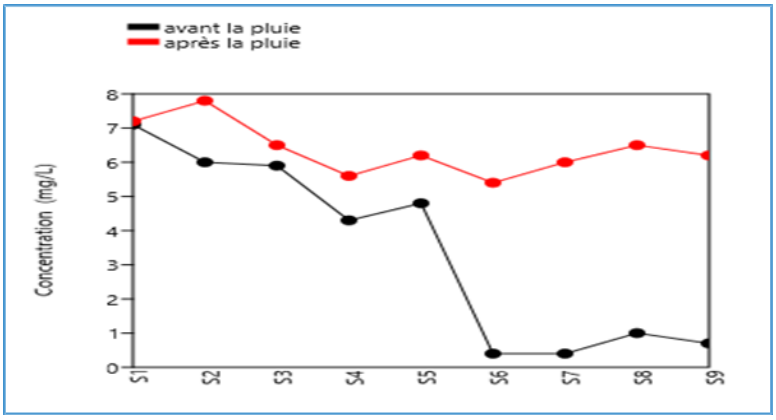

Figure 8. The nitrate values of the different water sampling sites of the Matete river

The nitrate values of the water samples from the Matete River are at the interval of 0.4±0.2 mg/L and 7.1±0.1 mg/L before the rain and between 5.4×101±0.1 mg/L and 7.8×101±1.8 mg/L after rain (p = 0.0001835≤ 0.05).

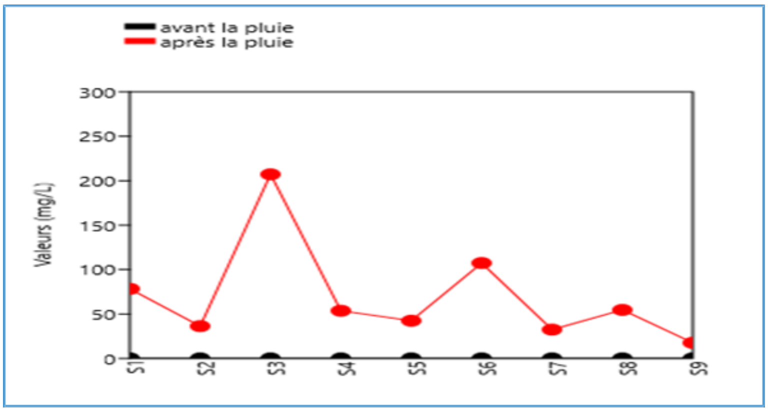

Figure 9. The potassium values of the different water sampling sites of the Matete river

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Potassium measurements in river water samples reveal a concentration around <0.1×102± <0.1 mg/L before rain and 17.7±0.6 and 207.2±0.4 mg/L after rain (p = 1.7491×10-5≤ 0.05).

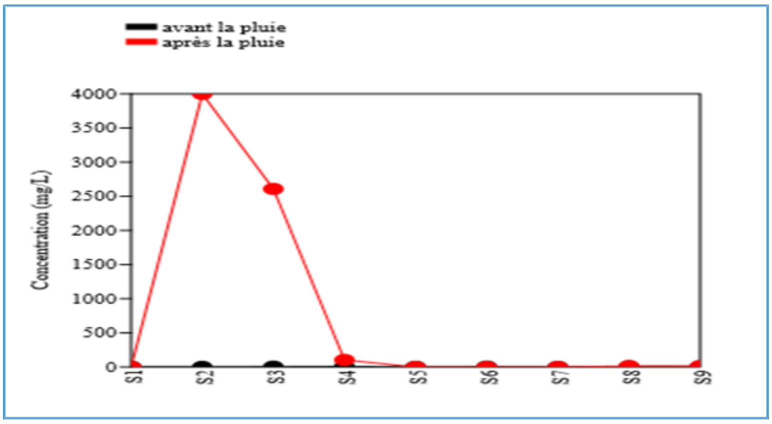

Figure 10. The manganese values of the different water sampling sites of the Matete river

The manganese content in the water of the Matete river oscillates between 0.5±0.4 mg/L and 9.1±0.1 mg/L before the rain and <1.0±<0.2 and 399.9×101±905.6 mg/L after rain (p = 0.04685047≤0.05).

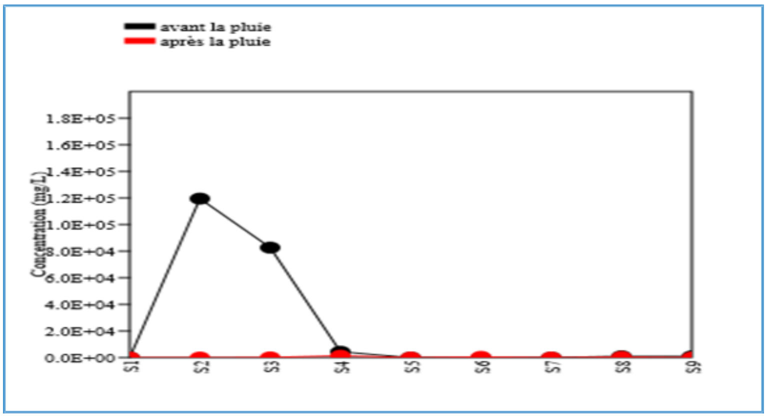

Figure 11. The iron values of the different water sampling sites of the Matete river

The iron values in the water samples from the Matete River are between <0.1×101±<0.8 mg/ L and 119.5×103±3054.5 mg/L before rain and 21.5±0.7 and 140.8×101±29.5mg /L after rain (p = 0.04934238≤0.05).

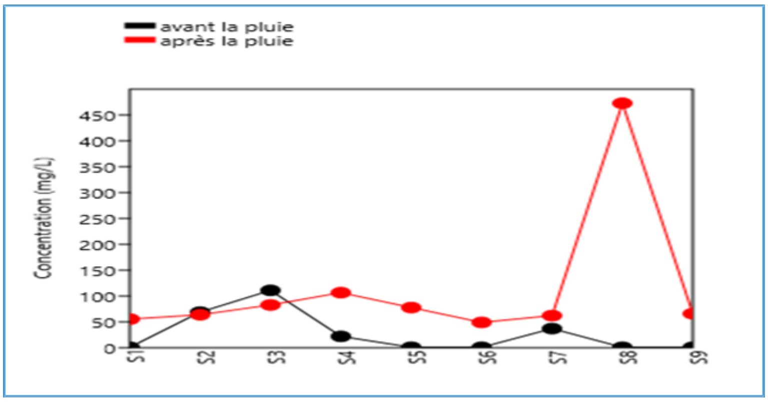

Figure 12. The calcium values of the different water sampling sites of the Matete river

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The calcium content in the water samples from the Matete River is in the range of <0.1×101± <0.1 and 22.1±0.1 mg/L before rain and 49.1±0.1 and 472.8±3.7 mg/L after rain (p = 0.05099203≤ 0.05).

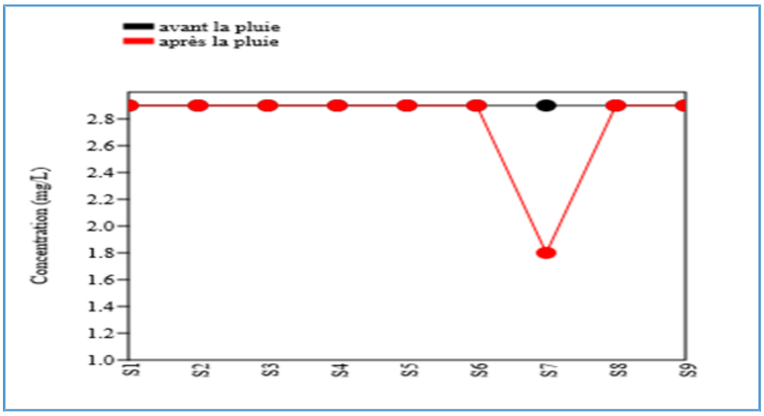

Figure 13. The cobalt values of the different water sampling sites of the Matete river

Before rain, cobalt values are in the range of <3.0±<0.4 mg/L and between 1.8±0.0 and <0.3× 101±<0.4 mg/L after rain (p = 1.3003×10-19≤ 0.05).

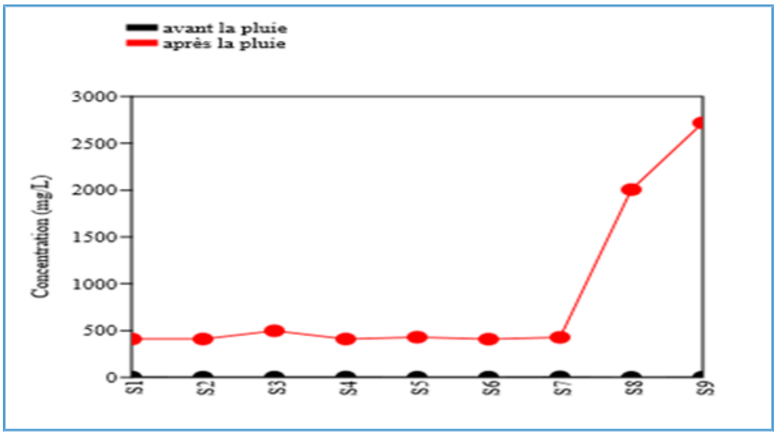

Figure 14. The nickel values of the different water sampling sites of the Matete river

The nickel content of water samples from the Matete River is 0.00052±0.0 mg/L and 5.8±0.2 mg/L before rain and between 40.9×101±28.6 and 271.9×101±66.1 mg/L after rain (p = 0.00069229≤0.05).

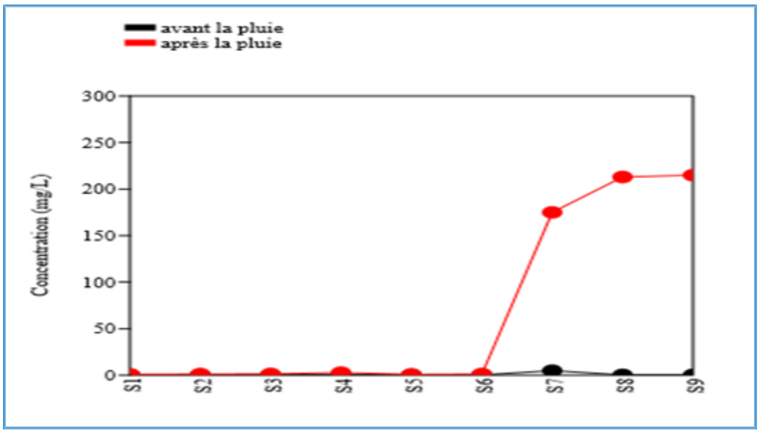

Figure 15. The zinc values of the different water sampling sites of the Matete river

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The zinc values in the different water samples are around <0.5±<0.1 mg/L before the rain and between 0.9±0.1 and 21.5×101±9.6 mg/L after rain (p = 0.04992386≤0.05).

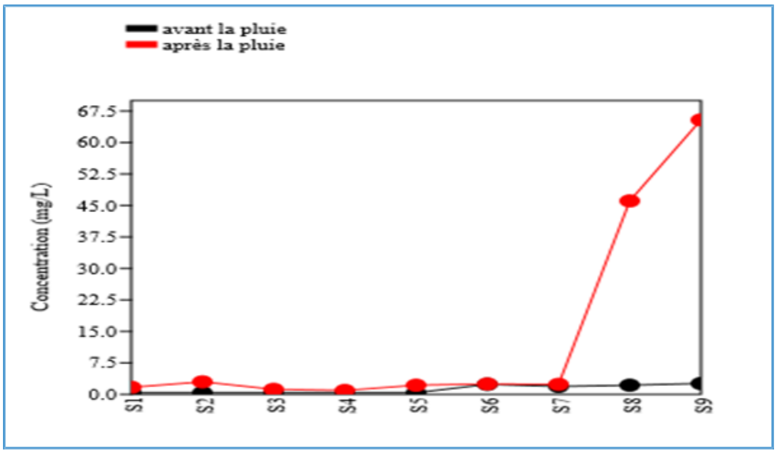

Figure 16. The copper values of the different water sampling sites of the Matete river

The copper assay data in the different water samples vary around <0.5±<0.1 and 2.6±0.2 mg/L before rain and between 0.95±0.05 and 65.4±4.7 mg/L after rain (p = 0.03508048≤ 0.05).

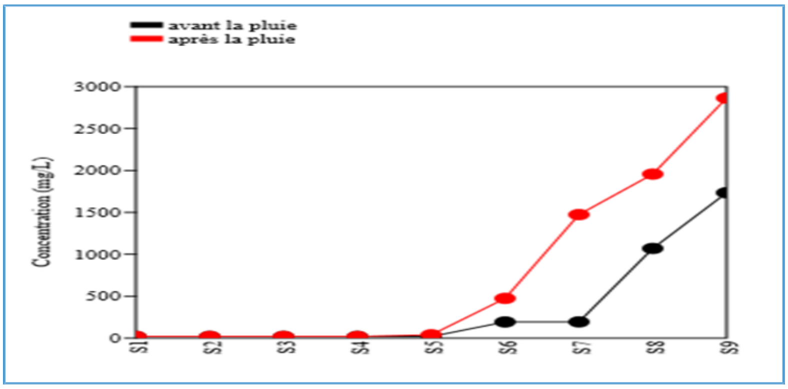

Figure 17. The aluminum values of the different water sampling sites of the Matete river

The aluminum values in the different water samples are between the values <2.0×101±<1.4 mg/L and 173.5×101±67.5 mg/L before the rain and between < 2.0×101±<1.2 and 286.5×101 ±133.9 mg/L after rain (p = 0.05854919≤0.05).

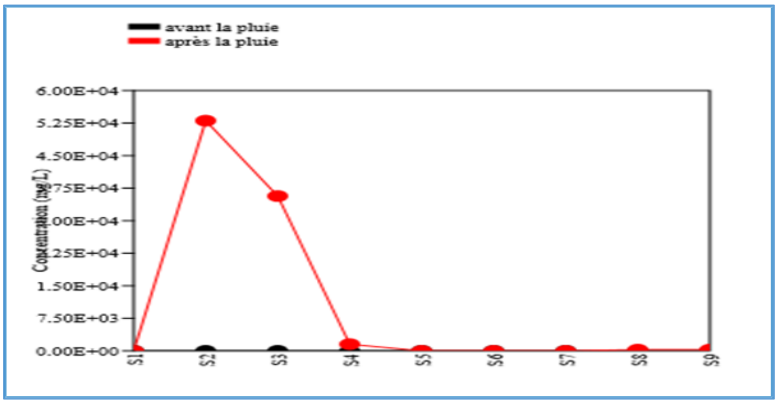

Figure 18. The chromium values of the different water sampling sites of the Matete river

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The chromium content in water samples from the Matete River is between <1.0±<0.0 and 4.0 ±0.3 mg/L before rain and between <1.0±<0.1 mg / L and 530.5×102±1690.2 mg/L after rain (p = 0.04762886≤0.05).

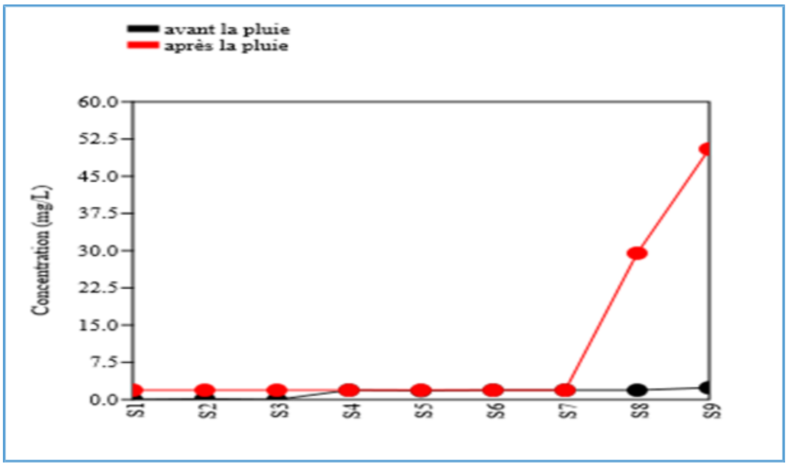

Figure 19. Cadmium values from the different water sampling sites of the Matete river

Cadmium values in river water samples are around <0.00020±<0.00002 mg/L and 2.4±0.3 mg/L before rain and <2.0±<0, 1 mg/L and 50.5±12.8 mg/L after rain (p = 0.03950648≤ 0.05).

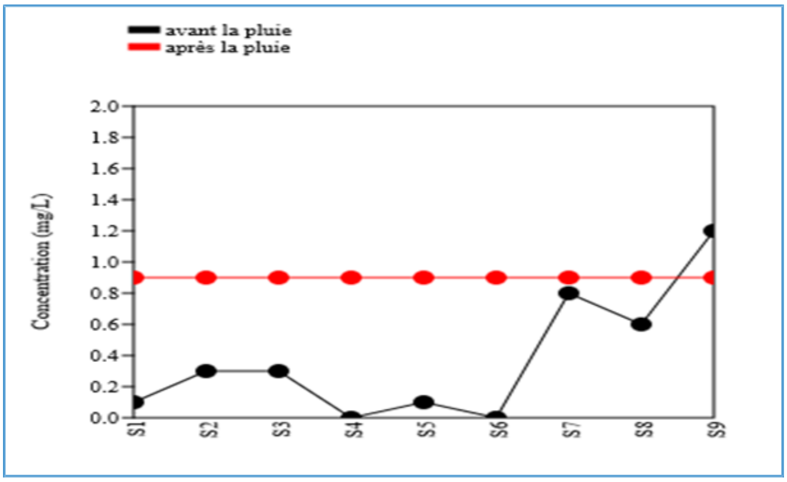

Figure 20. The lead values of the different water sampling sites of the Matete river

Lead concentrations in water samples from the Matete River hover around <0.00008±<0.0 mg/L and 1.2±0.3 mg/L before rain and values around <1.0±<0.1mg/L after rain (p = 8.4927 × 10-7≤0.05).

4. Discussion

Under the natural conditions of the Matete River, this aquatic ecosystem has pH values between 6.6±1.2 and 7.5±2.0 in the dry season and 6.7±0.6 and 7.8±1.1 in the rainy season. These values comply with WHO guidelines (1972) where the pH is set at 6 and the variation observed is due to the way in which residents and industrialists consider the river to be a landfill or a public trash can. The pH of the medium is a good tracer of photosynthetic activity in surface waters. The pH in the water column increases during periods of high primary production. Indeed, during the assimilation of CO_2 by plants, the CO_2 concentration decreases. The temperature values of the samples from the Matete River oscillate respectively

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around 25.9±1.1^{0}C and 27.5±1.9^{0}C before the rain and 25.8±0.9 ^{0}C and 27.5± 2.1^{0}C after rain. This is not surprising because the Matete River is in a tropical area. The solubility of aluminum and certain metallic trace elements is increased in the presence of complexing ligands in acidic or alkaline medium (pH<6 or >8).

The ambient temperature also influences the speciation of aluminum and, therefore, its solubility in the environment. Species are expected to remain in their most toxic form at higher pH if the temperature is low (2^{0}C), compared to the higher temperature of 20^{0}C (Howells *et al.*, 1990). Therefore, at 2^{0}C and a pH value <5.7, aluminum is mostly found as Al^{+3}. The dissolution of minerals generally increases with temperature, but the solubility of aluminum does not, which decreases. Climate change could explain up to 10% of the decrease in aluminum concentrations in Czech lakes (Skjelkvåle, 2003). The data obtained for the electrical conductivity of the different samples vary between 262±23.1 and 415±7.1 µS/Cm before rain and between 276±4.6 and 417±5.7 µS/Cm after rain.

The turbidity values of different water samples from the Matete River oscillate around 1.03± 0.01 NTU and 16.6±1.30 NTU before rain and between 8.2×101±4.98 NTU and 3.67×102± 13.88 NTU after rain. They show a high turbidity of the analyzed water which is higher than the international guidelines set at values <5 NTU, in particular at the sites S3, S4, S5, S7, S9 and S8 before the rain and in all the sites after the rain. These results confirm those of Aguiza Abai *et al.*, (2014) who worked on monitoring the physico-chemical and bacteriological quality of the waters of Ngaoundéré, Cameroon. These variations obtained can be explained by the lack of a treatment plant for wastewater from leaching of agricultural, industrial and urban land in the North-East and East-South part of the Mont-Amba district and the products of erosion.

From the Mbanza-Lemba district, Municipality of Kisenso, banks of the same river and the anarchic occupation along the Matete aquatic ecosystem. While it is in high demand by aquatic species as an ideal habitat for their survival. These values could disrupt photosynthetic activity and cause disruption to the proper functioning of this lake ecosystem. Thus, the results of the dissolved oxygen of the Matete river are around 1.03±0.24 mg/L and 5.26±0.23 mg/L before the rain and between 0.08±0.02 mg/L and 0.6±0.2 mg/L after rain. Under these conditions, the Matete river is considered as a dumping ground for waste and/or a natural wastewater treatment plant.

Phosphorus results for water samples are between 0.011±0.001 mg/L and 0.325±0.07 mg/L before rain and between 2.7±0.2 mg/L and 8.6±1.1mg/L after the rain. The farming environments along this river on one side, the landfills and the connection of toilets on the other side could testify to its presence in this ecosystem. Given its importance, Correll (1998) adds that the development of primary production is dependent on many parameters, the most determining being phosphorus, since it is considered to be the limiting nutrient for the growth of phytoplankton in water continental.

Compared to the values of the trophic state thresholds of water bodies proposed by Galvez-Cloutier (2002), the Matete river is in the margin between a eutrophic and hyper-eutrophic watercourse with values around 35-100µg/l and also greater than 100 µg/L. On the other hand, its surface is less populated by aquatic flora due to the action of aluminum, iron and calcium. However, nutrients are not bioavailable for the growth and development of aquatic plants. Hence, the disappearance of certain species from water bodies. While the Nitrite values of the river Matete oscillate between 0.001±0.000 mg/ L and 0.12±0.016 mg/L before

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rain and from 1.899±0.089 mg/L and 4.501±0.815 mg/L after rain and those of nitrate are at the interval of 0.4±0.2 mg/L and 7.1±0.1 mg/L before the rain and between 5.4×101±0.1 mg/L and 7.8×101±1.8 mg/L after rain.

Potassium measurements in river water samples reveal a concentration around <0.1×102±<0.1 mg/L before rain and 17.7± 0.6 and 207.2± 0.4 mg/L after rain. The artificial shores of residences, septic systems, illegal dumps, road ditches and wash water from agricultural environments are potentially important sources of these nutrients in the Matete aquatic ecosystem with a real impact on its biodiversity. The controls of these elements in the aquatic environment affect algal growth (algal bloom) and could also contribute to the reduction of aquatic species. This is what Brown and McLeay (1975) observed on juvenile rainbow trout (*Oncorhynchus mykiss*) which exhibited a 20% methemoglobin level for a nitrite concentration varying from 0.05 to 0.10 mg/L and 80% for a concentration of 0.10 to 0.20 mg N-NO_2 L/t, which is likely to induce sub-lethal effects.

Smith and William (1974) add that it is also possible that fish poisoned by nitrite succumb to a toxic reaction from nitrite rather than methemoglobinemia. Although the toxicity responses of nitrite and nitrate have been studied in different organisms for a number of years, the diversity of the results demonstrates that each species reacts differently. In addition, the toxicity of nitrite on different aquatic organisms is influenced by different environmental factors such as calcium, pH etc.

The manganese content in the water of the Matete river varies between 0.5±0.4 mg/L and 9.1± 0.1 mg/L before the rain and <1.0±<0.2 and 399.9×101±905.6 mg/L after rain. In general, manganese is present in natural surface waters, either in solution or in suspension, at concentrations below 0.05 mg/L. It is present in more than a hundred common salt and mineral compounds found in rocks, soils and at the bottom of rivers.

Most commonly, manganese is found in the form of manganese dioxide, carbonate or silicate. On the other hand, those of iron are between <0.1×101±<0.8 mg/L and 119.5×103±3054.5 mg/L before the rain and 21.5±0.7 and 516.7±14.6 mg/L after rain. These results are higher than the normative values for the prevention of contamination of water and aquatic organisms set at 0.05 mg/L and 0.3 mg/L respectively. At these levels, the Matete lake ecosystem presents a danger to aquatic life. Very widespread, iron ranks 4th among the elements of the earth's crust. It is widely used in metallurgy and its secondary uses in chemistry are very varied. Surface water can contain up to a few mg/L of iron originating from leaching from crossed land or industrial pollution (pharmacy, steel industry, etc.) and agricultural land.

On the other hand, manganese is often used in the manufacture of alloys, electric batteries and pesticides. The effects of iron, as well as manganese, are special because they are essential metals. They can nevertheless be toxic in high concentrations. Iron is used by the cell as a cofactor for the synthesis of genetic material, the immune system or the transport of oxygen (Lim *et al.*, 2000; Nordberg *et al.*, 2014). An iron deficiency will therefore be harmful for an organism, just like its excess. Even though this element is easily regulated by the body, an excess of iron can lead to the formation of many hydroxyl radicals, cell and tissue damage, lipid peroxidation, etc. (Debnath *et al.*, 2012).

Manganese is important for the body (MnO_2/ Mn^{3+}). It is an essential metal since it acts as a cofactor for several enzymatic activities, particularly related to phosphorylation, antigen synthesis and the antioxidant system with SOD (Michiels *et al.*, 1994; Goyer and Clarkson, 1996). Like iron, its excess or deficiency can be harmful to organisms. However, the vulnerability of this structure can be seen in a reduced number of these trophic levels.

Regarding the calcium content in the water samples from the Matete river, the results are in the range of values <0.1×101±<0.1 and 22.1±0.1 mg/L before rain and 49.1±0.1 and 472.8± 3.7 mg/L after rain. Calcium is an alkaline earth metal extremely widespread in nature and in particular in limestone rocks in the form of carbonates. In addition, its presence in the form of calcium oxide in the waters of the Matete River could come from effluents from buildings, paper mills, water treatment, etc.

Cobalt values in water samples from the Matete River are in the range of <3.0±<0.4 mg/L and between 1.8±0.0 and <0.3×101±<0.4 mg/L after rain. These values are above the guide value for freshwater environments set at 8 µg/L (Cicad, 2006). Cobalt is an essential microelement which, when present in too high concentrations, can be toxic for living organisms. The exchangeable fraction of cobalt in continental aquatic ecosystems is low. This element is frequently associated with manganese dioxide. However, its solubility can be increased in an acid-prone environment (low pH) or in the presence of organic ligands (Atsdr, 2004), which form neutral or negatively charged complexes with cobalt. On the other hand, during massive resuspension of anoxic sediments, it can be emitted into the water column.

Martino *et al.*, (2002) observed dissolved cobalt concentrations in the range of 2 to 4 µg/L in the zone of maximum turbidity of the Mersey Estuary. In addition, those of Nickel are 0.00052±0.0 mg/L and 5.8±0.2 mg/L before the rain and between 40.9×101±28.6 and 271.9×101±66.1 mg/L after rain. These values are higher than the surface water quality criteria for metals in fresh water set at 0.07mg/L (Berube, 1991), except at site S8 before the rain (0.00052mg/L) which is lower than the standard used. These results are superior to that of Léger (1991) who reported that nickel concentrations were generally less than 2 mg/L in several thousand samples taken from rivers and lakes from 1973 to 1990 everywhere in the Atlantic provinces.

Zinc values are around <0.5±<0.1 mg/L before rain and between 0.9±0.1 and 21.5×101±9.6 mg/L after rain. These data are lower than the described criteria of 5.0 to 7.4 mg/L (Berube, 1991) and, while they are higher than the S7, S8 and S9 values after rain. In addition, copper data vary around <0.5 ±<0.1 and 2.6±0.2 mg/L before rain and between 0.95±0.05 and 65.4± 4, 7 mg/L after rain. These values are relatively lower than the criteria used in sites S1, S2, S3, S4 and S5 before the rain and S3 and S4 after the rain, on the other hand they are higher than the standard set of 1.0 to 1.3 mg/L at sites S6, S7, S8 and S9 before the rain and S1, S2, S5, S6, S7, S8 and S9 after the rain.

The presence of copper in this environment comes mainly from erosion of dikes and surrounding environments contaminated by agricultural and industrial activities and from wastewater discharges which still contain copper. Beyond a concentration of 25 µg/L of copper, the balances within the different communities are profoundly modified: Thus certain populations are in sharp decline (Gomphonema for phytoplankton, Trichocerca for zooplankton, *Gammarus pulex* in macroinvertebrates, *Lemna minor* in macrophytes for example) while others are increasing (like Nitschia for phytoplankton, *Callitriche platycarpa* in macrophytes, Trichospherae for zooplankton, Chironomidae in invertebrates).

The aluminum values in the different water samples are around <2.0×101±<1.4 mg/L and 173.5×101±67.5 mg/L before rain and between <2.0×101±<1.2 and 286.5×101±133.9 mg/L

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after rain. The presence of this element in the Matete river would be due to the texture and structure of its bed and to repetitive episodes of erosion in the surroundings. High concentrations of aluminum in the Matete river could acidify the environment and lead to the bioavailability of certain heavy metals (lead, cadmium, chromium, etc.) and also responsible for the decrease in the availability of nutrients necessary for aquatic plants by accelerating of sedimentation (coagulation) process of the Matete river.

Unlike Foy *et al.*, (1978) who show that aluminum interferes with the accumulation, transport and action of Ca, Mg, P, and K during various metabolic processes in plants. On the other hand, it stimulates that of manganese (Roy *et al.*, 1988). In addition, excess manganese in the plant increases its competition with iron (Hopkins, 2003). The chromium content is <1.0±<0.0 and 4.0±0.3 mg/ L before rain and between <1.0 ±<0.1 mg/L and 530.5×102±1690.2 mg/L after rain. The normative value of chromium is set at 0.05 mg/L. As a result, the Matete river has values above the criteria for the preservation of aquatic life in all of its sampling sites and during the two seasons of the year.

On the other hand, the cadmium values in the river are around <0.00020±<0.00002 mg/L and 2.4±0.3 mg/L before the rain and <2.0 ±<0.1 mg/L and 50.5± 12.8 mg/L after rain. These values are higher than the criteria for preserving the quality of life of the aquatic environment set at 0.005 mg/L and on the other hand they are lower than the S1 and S3 sites before the rain. On the other hand the lead concentrations of the Matete river oscillate around <0.00008 ±<0.0 mg/L and 1.2±0.3 mg/L before the rain and around <1.0± <0.1mg /L after rain. These data are above the normative value set at 0.01mg/L, except, at the site S4 (0.00008mg/L) and S6 (0.00059mg/L) before the rain. However, this ecosystem provides a toxic habitat for the species that live there and could directly influence their development.

The results corroborate those of Musibono (1999) who worked on the seasonal variations of hexavalent chromium (Cr IV), copper (Cu), lead (Pb) and zinc (Zn) dissolved in four urban rivers in Kinshasa (DRC) and analyzed the ecological impacts. Under these conditions, organisms may or may not adapt and therefore respond differently to the presence of these contaminants, especially since the potential effect of metals on living organisms may be in trace amounts. In addition, the bioavailability of these metals and the physicochemical characteristics of the aquatic environment would be the key factors in the transfer of these metals from the abiotic environment (sediment, water, suspended matter) to the biotic environment.

5. Conclusion and Perspectives

The aim of this study was to study the vulnerability of the vertical and longitudinal dimension of the functional organization of the ecosystem of the Matete river in Kinshasa. This vulnerability has been studied through the understanding of the behavior of metallic elements (iron, manganese, zinc, copper, cobalt, nickel, aluminum, chromium, cadmium and lead) mainly emitted by natural phenomena and anthropogenic activities and are currently present in the Matete aquatic ecosystem. The approach proposed to achieve this goal has combined observational and experimental methods and the implementation of molecular absorption spectrophotometric determination techniques and X-ray fluorescence.

After analysis, the results of this study are carried out in dry weather (before the rain) and in flood (after the rain). As a result, the flood period is an important input factor for metallic elements. However, it provides a toxic habitat for the species that live there and could directly influence their development. Hence, organisms may or may not adapt and therefore respond differently to the presence of these contaminants, especially since the potential effect of metals on living organisms may be in trace amounts. In addition, the bioavailability of these metals and the physicochemical characteristics of the aquatic environment are key factors in the transfer of these metals from the abiotic environment (water, suspended matter) to the biotic environment.

In conclusion, we affirm the hypothesis according to which the Matete river represents a natural receiver of wastewater from domestic and industrial origins and also an important crossroads of metallic trace elements. These high concentrations of metallic trace elements contribute to the instinct of certain aquatic species (plants and animals). However, these metallic trace elements vulnerable influences the functional organization of this ecosystem. In view of the above, we recommend that the authorities do the following:

- ✓ Pretreat and control industrial effluents before they are released into the receiving environment;
- ✓ Apply the urban wastewater management policy in order to preserve the quality and balance of the receiving ecosystem;
- ✓ Continue research on the vulnerability of metallic trace elements in the structural-functional organization of the aquatic system of rivers in Kinshasa.

Conflicts of interest

The authors declare no conflicts of interest.

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