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# Evaluation of the Content of Trace Metal Elements in the Waters of the Kipushi River and its Surroundings Areas

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## ABSTRACT
This study assessed the state of pollution of four trace metals (Cd, Pb, As and Co) in the Kipushi River during the dry and rainy seasons. To achieve this, monthly water samples were taken at fifteen sampling stations, selected primarily on the basis of mining and agricultural activities in the vicinity of each station. The results showed that, for cobalt, only two of the fifteen concentrations (13.3%) at the same two sites (13 and 14) in both seasons exceeded the WHO threshold. On the other hand, with regard to As, Cd and Pb, they reported that in the dry season, the last seven sites presented contents higher than the WHO toxicity thresholds for these three metals, i.e., 46.7%. In the rainy season, this observation remained for As and Cd; for Pb, only the last site was concerned, site 15.

**Keywords:** Kipushi River, pollution, ETM, water

## INTRODUCTION
In recent years, our attention has been drawn to several studies on the contamination of river water caused by mining activities (Tshibanda, 2012; Muteba et al., 2011; Chipeng, 2010; Kisanguka, 2010; Kitobo, 2009; Banza, 2003; Lootens and Lumbu, 1986). In the Democratic Republic of Congo (DRC), in the mining region of Katanga, metallic contamination of the ecosystem, due to the development of the mining industry and agricultural fertilizers, is a major threat to the purity of river surface waters.

Mining and metallurgical activities generate waste that pollutes soils, surface waters and aquifers through the leaching of solid waste and the migration of the pollutants they contain (SNC-Lavalin, 2003).

The aim of the present study is to enrich existing data on this contamination in the mining province of Haut-Katanga by measuring the levels of four trace metals (As, Cd, Pb and Co) in surface waters collected in and around the Kipushi basin and discharging into the Kafubu River.

## METHODOLOGY

### Location of the City of Kipushi
The mining town of Kipushi is located in the south of the Democratic Republic of Congo in province of Haut-Katanga, 600 meters from the Zambian border and 30 kilometers southwest of the city of Lubumbashi, in the Kafubu river basin. The city has an estimated population of 120,000. Like the rest of southern Katanga, Kipushi's climate is tropical. It is characterized by

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two seasons, a rainy season and a dry season. Several streams originating less than a kilometer from the underground mine to the southwest flow into the Kafubu River (Muteba, et al., 2011).

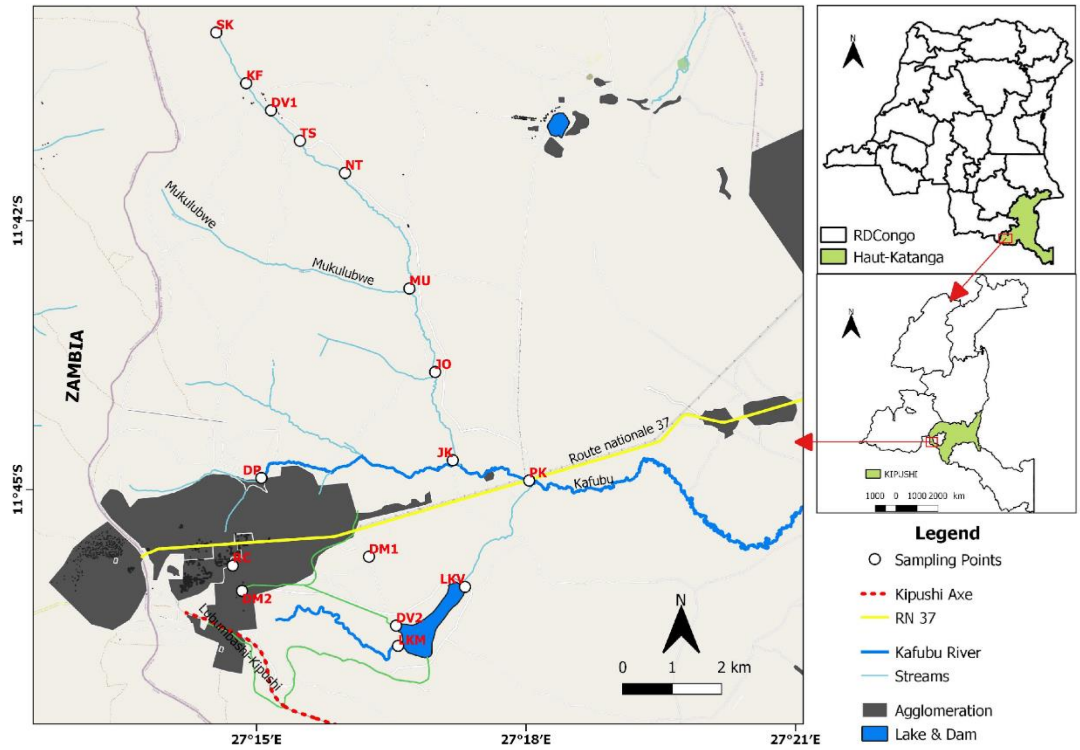



**Figure 1: Map of sampling sites**

## Sampling and Conditioning of Water Samples

Located mainly in the Kipushi river valley, the sampling sites were chosen in relation to the likely sources of changes in trace metal concentrations in the Kipushi river waters. Water sampling was carried out at 15 points chosen to highlight the pollutant potential of the liquid effluent and its impact on the Kipushi River, from the source to the junction with the Kafubu River.

Fifteen sites were selected for sampling in and around Kipushi during both the wet and dry seasons. These were chosen specifically because of the density of population activities and the location of mining companies. Water samples were collected over twelve campaigns during a period from August 2017 to July 2018. The frequency of sample collection was once a month, every fifteenth day of the month. Samples were taken from a depth of 15 to 20 cm in the river using 500 ml plastic bottles previously rinsed three times with distilled water to avoid any risk of biasing the results. Clearly labelled samples were then transported to the laboratory in a cooler at 4°C for analysis 24 hours after collection.

## Analysis Method

Our study focused on surface waters, which represent an excellent reservoir for chemical pollutants, particularly trace metals (TMEs) (Boucheseiche et al., 2002). We measured the metallic elements that describe the general quality of surface waters: As, Co, Cd and Pb.

TMEs were determined using ICP atomic emission spectrophotometry coupled to a Perkin Elmer mass spectrometer at the laboratory of the Congolese control office of Lubumbashi.

Various graphs have been produced to give a clearer view of the measurements and analyses carried out, and make it easier to comment on them easily. Descriptive statistics, including mean and standard deviation, were calculated. Similarly, the differences and variabilities in the distributions of TME concentrations in relation to the different seasons at different sampling sites are presented. In addition, tests were carried out to compare the mean levels of TMEs observed with WHO standards, in order to confirm or refute the hypothesis of surface water contamination at our study site.

## RESULTS AND DISCUSSION

### Presentation and Analysis of Results

Chemical analyses determined the average concentration of TMEs, relative to lead, cadmium, cobalt and arsenic in Kipushi river waters sampled during the dry and rainy seasons at the 15 sites.

The analysis results obtained are shown in Tables 1, 2 and 3 and Figures 1 and 2, based on one sample per month per site over two seasons.

**Table 1: Average TME levels (mg/L) in water during the rainy season**

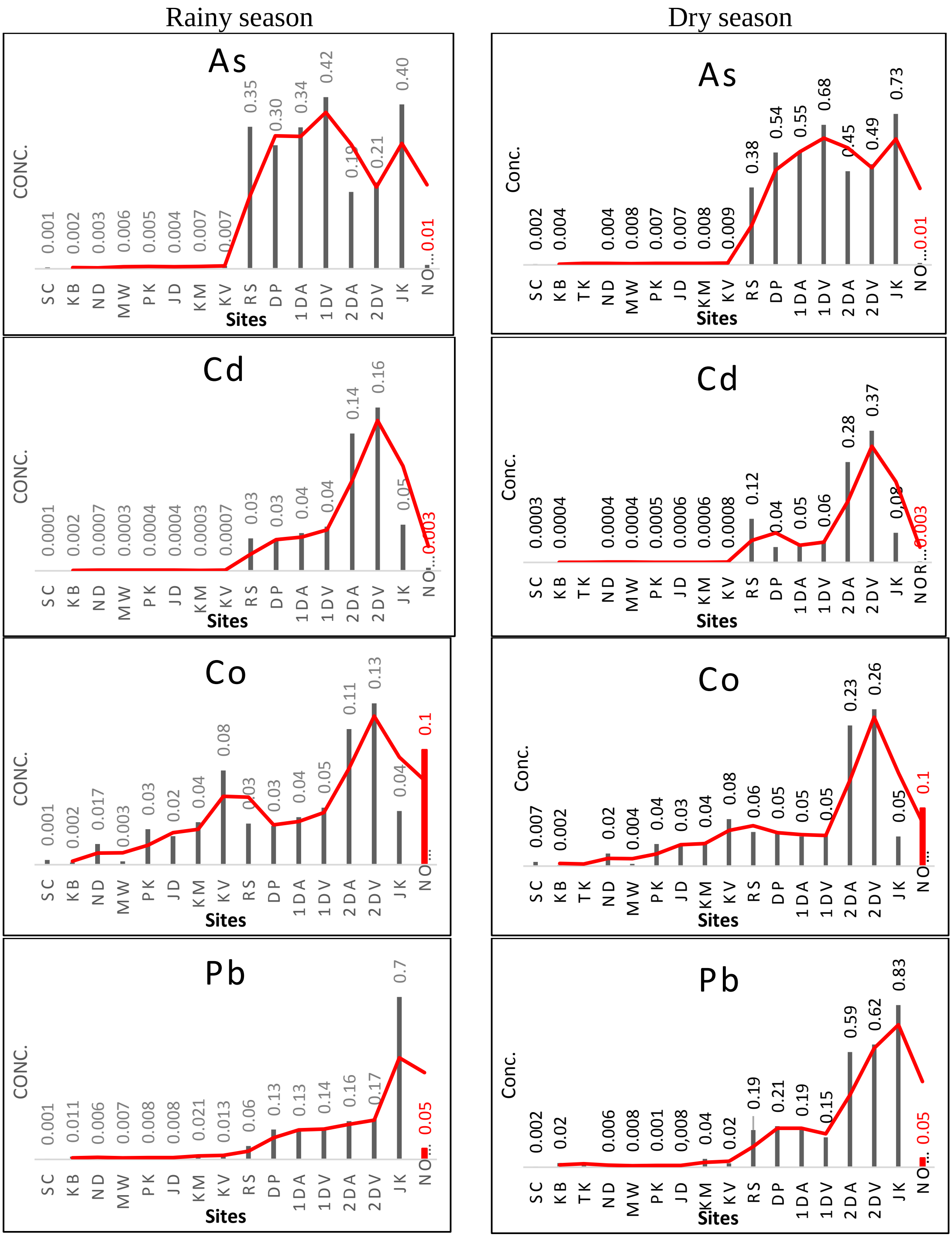
| N° | Site code | As | Cd | Co | Pb |
|---|---|---|---|---|---|
| 1 | SC | 0.001±0.001 | 0.0001±0.001 | 0.001±0.001 | 0.001±0.001 |
| 2 | KB | 0.002±0.002 | 0.0002±0.001 | 0.002±0.001 | 0.011±0.010 |
| 3 | ND | 0.003±0.001 | 0.0007±0.001 | 0.017±0.001 | 0.006±0.0001 |
| 4 | MW | 0.006±0.001 | 0.0003±0.004 | 0.003±0.001 | 0.007±0.0001 |
| 5 | PK | 0.005±0.004 | 0.0004±0.004 | 0.030±0.010 | 0.008±0.003 |
| 6 | JD | 0.004±0.001 | 0.0003±0.001 | 0.020±0.008 | 0.008±0.0001 |
| 7 | KM | 0.007±0.002 | 0.0007±0.001 | 0.040±0.003 | 0.021±0.010 |
| 8 | KV | 0.007±0.001 | 0.030±0.005 | 0.080±0.008 | 0.013±0.001 |
| 9 | RC | 0.350±0.060 | 0.030±0.005 | 0.030±0.004 | 0.060±0.040 |
| 10 | DP | 0.300±0.030 | 0.040±0.008 | 0.030±0.004 | 0.130±0.020 |
| 11 | 1DA | 0.340±0.140 | 0.040±0.010 | 0.040±0.003 | 0.130±0.040 |
| 12 | 1DV | 0.420±0.130 | 0.040±0.010 | 0.050±0.007 | 0.140±0.010 |
| 13 | 2DA | 0.190±0.190 | 0.140±0.110 | 0.110±0.050 | 0.160±0.070 |
| 14 | 2DV | 0.210±0.200 | 0.160±0.130 | 0.130±0.070 | 0.170±0.080 |
| 15 | JK | 0.400±0.200 | 0.050±0.040 | 0.040±0.007 | 0.700±0.440 |
| **Standards (WHO)** | | 0.01 | 0.003 | 0.1 | 0.5 |

Note. As: Arsenic Co: Cobalt Cu: Copper Cd: Cadmium Pb: Lead

**Table 2: Average TME contents during the dry season**

| N° | Site code | As | Cd | Co | Pb |
|---|---|---|---|---|---|
| 1 | SC | 0.002±0.001 | 0.0003±0.001 | 0.0007±0.001 | 0.002±0.0001 |
| 2 | KB | 0.004±0.003 | 0.0004±0.002 | 0.002±0.001 | 0.02±0.012 |
| 3 | ND | 0.004±0.001 | 0.0009±0.001 | 0.020±0.001 | 0.006±0.001 |
| 4 | MW | 0.008±0.001 | 0.0004±0.002 | 0.004±0.001 | 0.008±0.0001 |
| 5 | PK | 0.007±0.003 | 0.0005±0.002 | 0.040±0.010 | 0.01±0.005 |
| 6 | JD | 0.007±0.001 | 0.0006±0.001 | 0.030±0.030 | 0.008±0.001 |
| 7 | KM | 0.008±0.001 | 0.0006±0.004 | 0.040±0.007 | 0.04±0.007 |
| 8 | KV | 0.009±0.001 | 0.0008±0.001 | 0.080±0.008 | 0.02±0.004 |
| 9 | RC | 0.380±0.060 | 0.120±0.160 | 0.060±0.06 | 0.19±0.01 |
| 10 | DP | 0.540±0.080 | 0.040±0.008 | 0.050±0.06 | 0.21±0.05 |

| | | | | | |
|---|---|---|---|---|---|
| 11 | 1DA | 0.550±0.160 | 0.050±0.010 | 0.050±0.006 | 0.19±0.08 |
| 12 | 1DV | 0.680±0.120 | 0.060±0.010 | 0.050±0.005 | 0.15±0.02 |
| 13 | 2DA | 0.450±0.240 | 0.280±0.140 | 0.230±0.110 | 0.59±0.038 |
| 14 | 2DV | 0.490±0.250 | 0.370±0.170 | 0.260±0.120 | 0.63±0.43 |
| 15 | JK | 0.730±0.330 | 0.080±0.030 | 0.050±0.006 | 0.830±0.370 |
| **Standards (WHO)** | | 0.01 | 0.003 | 0.1 | 0.05 |




**Figures 1** **Figures 2**

**Figures 1 and 2: Average concentration of each TME during the rainy (Figures 1) and dry (Figures 2) seasons**

Analysis of Tables 1. 2 and Figures 1. 2 shows that the distribution of the four metals covered by our study is as follows:

- *In the rainy season*. arsenic and cadmium concentrations were below WHO thresholds for the four metals analyzed at the first eight sites (SC, KB, ND, MW, PK, JD, KM et KV). i.e. 53.3%. and above WHO thresholds for the last seven sites (RC, DP, D1M, D1V, D2M, D2V, JK). i.e. 46.7%. For cobalt, only two (13 and 14) of the fifteen sites are concerned. and for lead, only one site (1). This represents contents of 13.3% and 6.7% respectively.
- *In the dry season,* a comparison of the various metal concentrations covered by this study clearly shows that they are higher than those recorded in the rainy season. However, this time arsenic, cadmium and lead all belong to the category of metals whose concentrations are higher than WHO standards at the last seven sites (RC, DP, D1M, D1V, D2M, D2V and JK). As far as cobalt is concerned, despite the increase in its concentration, only the two sites (13 and 14) already reported during the rainy season have levels that do not comply with the standards consulted.

Given that the last seven sites (RC, DP, D1M, D1V, D2M, D2V and JK) were characterized by higher metal contents in the rainy season than those relative to the WHO standard thresholds. we have placed the pollution indices for the four metals analyzed in the rainy and dry seasons at the said sites in Table 3.

**Table 3: Seasonal pollution indices (PI) for sites**

| **N°** | **Stations** | **Rainy season** | | | | **Dry season** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | As | Cd | Co | Pb | As | Cd | Co | Pb |
| 09 | RC | 35 | 10 | <1 | 2.6 | 38 | 40 | <1 | 4.2 |
| 10 | DP | 30 | 10 | <1 | 1.2 | 54 | 13 | <1 | 4.2 |
| 11 | 1DA | 34 | 13.3 | <1 | 2.6 | 55 | 16.7 | <1 | 3.8 |
| 12 | 1DV | 44 | 13.3 | <1 | 3.4 | 68 | 20 | <1 | 3 |
| 13 | 2DA | 19 | **46.7** | **1.1** | 3.4 | **45** | **93.3** | **2.3** | **11.8** |
| 14 | 2DV | 21 | **53.3** | **1.3** | 14 | **49** | **123.3** | **2.6** | **12.6** |
| 15 | JK | 40 | 16.7 | <1 | **1.4** | **73** | 26.7 | <1 | **16.6** |

A major observation emerges from this third table of results: the number of pollution indices above 1 is greater than those below 1. in both dry and rainy seasons (Table 4).

**Table 4: Pollution indices above and below 1 in the rainy and dry seasons**

| **Season** | **IP>1** | | **IP<1** | |
|---|---|---|---|---|
| | Workforce | % | Workforce | % |
| Rainy | 23 | 82.14 | 5 | 17.86 |
| Dryer | 23 | 82.14 | 5 | 17.86 |

This primary consideration gives rise to three secondary findings:

1) First of all. Ace's PIs are not only the highest overall. they are also well above 1;

2) then, the remarkable peculiarity of the results from sites 13. 14 and 15:

- At sites 13 and 14, Cd PIs are the highest in Table 3 in both the rainy and dry seasons. while Co PIs is also higher than 1 in both seasons;
- At site 15, Pb PIs are also greater than 1 in both seasons;

3) finally, the TMEs corresponding to IPs below 1 concern Co and Pb in sites RC, DP, D1M, D1V et JK.

## DISCUSSION OF RESULTS

In our study, we limited ourselves to determining the concentration of the four most studied elements in surface waters in DR Congo: As, Cd, Co and Pb (Goussanou et al., 2018). Even at low concentrations, the ecological and health impact of these metals can be significant. Essential metals are also known to be essential trace elements (TMEs) in biological tissues for many cellular processes (Nkulu et al., 2007).

### a. Seasonal concentrations

Our results showed that concentrations of the metals analyzed were higher during the dry season than during the rainy season. This is a logical consequence of the increase in water quantity during the rainy season. This consideration can also be used to justify the fact that in the first eight sites. the concentrations recorded were below the WHO toxicity threshold (Khattabi et al., 2007).

### b. Concentration by site

In this study. we observed that TME content values are respectively low at the first eight sites (SC, KB, ND, MW, PK, JD, KM and KV) and high at the last seven (RC, DP, D1M, D1V, D2M, D2V and JK) in both seasons. These findings may be due to the distance separating the sites from the production plants and discharge storage facilities. The last seven are closer to the latter than the first eight.

### c. Particularities of metal content

With the exception of arsenic, the highest contents for all TMEs were observed at the last three sites (D2M, D2V and JK) during both dry and rainy seasons.

In addition, these contents are, as might be expected. higher in the dry season than in the rainy season. The fact that contents at sites 13 (D2M) and 14 (D2V) are the highest of all is due to the fact that these two sites are the closest to the plants and storage discharges.

Comparing our results with those in the literature. we found that our values were higher, lower or comparable to those reported by other researchers and concerned other study sites:

- For As. our results obtained during the rainy and dry seasons (0.42 mg/L and 0.73 mg/l) are respectively lower than those (8.4mg/l) of Kayembe et al., in 2023 on the Kamatanda River; but much higher than those found (0.0004mg/L) by Koya. in 2017 in Lake Tshangalele.
- For Cd. the concentrations we recorded during the dry season (0.36 mg/l) and the rainy season (0.16 mg/l) are far lower than those recorded by Katemo et al., 2010 (2.838mg/L) in Lake Lufira and those of Muteba et al., 2011 (1.42 mg/L) in the Kafubu River.
- For Co. the concentrations we recorded during both the dry and rainy seasons (0.26 mg/L and 0.13 mg/L) are here also lower than the values obtained by Kaniki. in 2021 (1.74mg/L) in the Kakanda River. those of Muyumba. in 2015 (1.32mg/L) in the Kafubu River and those of Kashimbo et al. in 2016 (0.61mg/L) in the Mulungwishi River.
- For Pb. our results for the rainy and dry seasons (0.69 mg/l and 0.83mg/l) are similar to those found (0.80 mg/l) by Koya. in 2017 in the Lufira. but are still higher than those of Nzapo et al., in 2018 (0.12mg/L) in the Malebo pool in Kingabwa and those of Baaissa and Reddjouh. in 2019 (0.3mg/L) in Algeria.

The result of this comparison is that the chemical composition of river water depends on several parameters specific to each watercourse. For example, the latter may be more polluted than the former due to mining activities.

### d. Pollution index (PI)

In the study area. PIs for the metals studied fluctuated from site to site and varied from season to season. The PIs for Co were below 1, while those for As, Cd and Pb were above 1(Tab3). As we know, the high values of these indices reflect an increase in the mobility of metallic elements based on the release. mobilization and suspension of metals in the aquatic environment (Fekhaoui. M et al., 1996). Thus, if the Cd and As PIs at the last seven sites were the highest in both seasons, this would seem to indicate that these deep-sea metals contained in discharges are a source of pollution in the waters of the Kipushi basin.

## CONCLUSION

The aim of the study was to analyze four TMEs (As, Cd, Co and Pb) in the waters of the Kipushi River in order to assess the contamination of the river and its environment. This will enable to highlight the risks of the excessive presence of these TMEs in the water and their impact on the health of aquatic plants, fish and above all humans throughout the tropical chain. The TMEs concerned in this study were analyzed by ICP-MS. In addition, the WHO standard for surface water quality was used as a reference.

Three types of results were obtained, Firstly, we found that, depending on the season, TME concentrations were higher in the dry season than in the rainy season. and attributed this to a decrease in water quantity in the dry season. We also showed that seven of the fifteen sampling sites had the highest concentrations. due to their close proximity to production plants and waste storage facilities. Finally, three metals, arsenic, cadmium and plomb, were characterized by their highest pollution indices in the rainy and dry seasons. Here too, the highest values were found at two of the three sites closest to the plants and discharge sites.

As can be seen, several avenues of study can be identified from the present investigations. including the exploitation of vegetation. sediments and fish present in the Kipushi River.

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