

Evaluation of Solid Matter in Suspension in Atmospheric Air in the City of Boma, Republic of the Congo

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Abstract

The objective of this study on the evaluation of solid matter suspended in the atmospheric air of the city of Boma, DR Congo, is to identify and quantify the solid atmospheric pollutants that the atmosphere deposits on surface waters. Indeed, this study presents two interests, one on the risk of water pollution in Kalamu and the other on the knowledge of atmospheric pollutants in the environment. After 30 days of exposure, water samples collected from these sensors were analyzed in the laboratory using spectrophotometers and other laboratory equipment and techniques. Gravimetry allowed us to determine the solids concentration. The R software then allowed us to analyze the results to compare them with international regulatory values. The spatio-temporal monitoring of the physicochemical parameters of water from its sensors gives us less satisfactory results on the following sites: site no. 1: 745.244 mg/m², site no. 2: 561.60 mg/m², site no. 3: 859.893 mg/m² and site no. 5: 979.861 mg/m², taking into account the international standard for the residential environment which is set at 500 mg/m². Concerning metallic trace elements, the analysis results are also alarming and can be summarized as follows: Aluminum (Al) with a result which varies between 50.12 mg/l to 60.96 mg/l, Lead (Pb) 3.21 mg/l to 41.12 mg/l and Zinc (Zn) 3.02 mg/l to 7.12 mg/l. Indeed, this study is carried out in the rainy season; taking into account the weather conditions of the city of

Boma, from one season to another; these results may be different for the dry season; on this, a study is underway on the same objectives during the dry season, in order to correlate the results between the two seasons.

Keywords

Assessment, Solid Matter, Suspension, Atmospheric Air, Boma

1. Introduction

Outdoor air pollution in Africa is expected to worsen if action is not taken quickly. Economic growth, population growth, unplanned urbanization, and a lack of environmental regulation could exacerbate the effects on the environment and human health. (Ali Abbas et al., 2003) Air pollution, particularly fine particulate matter (PM) pollution, is the second leading risk factor for death after malnutrition in sub-Saharan Africa and the leading environmental risk factor for death in North Africa, representing a greater risk than unsafe water, poor sanitation, and poor hygiene (Murray et al., 2022).

Air quality has become a major health issue in urban areas in recent years. Human activities release a large number of pollutants into the atmosphere, which have a direct impact on climate change and human health. These activities lead to ecosystem degradation (Adams & Kanaroglou, 2016).

Air quality assessment refers to any method used to measure, calculate, predict, or estimate pollutant concentrations or their deposition on the ground. Air quality assessment is therefore carried out using a set of complementary methods (emission factors, modeling, etc.), of which measurement is one of the essential components, but not the only one (AWAC, 2025).

Watercourses flowing through urban areas are exposed to several types of pollution generated by human activities. These activities and the pollution they generate are all the more pronounced because the individual pursuit of profit, without regulation, prevents the prevention and treatment of these negative externalities, leaving them to the community (Kakundika et al., 2019).

Water is an essential element for life and for the real and sustainable socio-economic development of a country. It is therefore necessary to have a better understanding of existing water resources, especially information concerning:

1) The vulnerability of resources to a possible factor; 2) The measures necessary to develop, manage, and protect resources (Belghiti et al., 2013). The Kalamu River, the main waterway of the city of Boma, has become a disposal site for various municipal wastes. Yet, the water from this river is used by the population of Boma for various household chores and for swimming (Wanga et al., 2014).

Few studies on the health impact of air pollution have been conducted in Africa compared to other geographic areas; a review of the academic literature suggests that there have been no epidemiological studies assessing long-term exposure to particulate air pollution and mortality for African populations (Greenstone &

Hasenkopf, 2023). The importance of air pollution stems from the critical role air plays in sustaining life as we know it on Earth. Poor air quality negatively impacts human health and the broader environment. Its consequences are not only health, ecological, and economic, but also human: having access to quality, clean air should be a fundamental right (AWAC, 2025).

While numerous studies have addressed the overall consequences of air pollution, few have investigated its impact on surface water pollution. Thus, the aim of this study is to assess the quality of suspended solids in the atmospheric air that falls on the waters of the Kalamu River per square meter per day; a means of determining the influence of this pollution on the quality of surface waters. Two specific objectives will allow us to assess this air pollution by solid particles on the surface waters of the said river: Measure the quantity of solid particles in the atmospheric air, and calculate the quantity of solid particles that are deposited on a surface area of one square meter.

2. Presentation of the Study Environment

The study was conducted in Boma, located in the southwest of the country, on the banks of the Congo River (latitude between 3° and 5° south, longitude between 11° and 13° east, and at an altitude of at least 500 m). It is 470 km from the city of Kinshasa, 120 km from Matadi (the capital of Kongo Central), and 110 km from the coastal city of Moanda. This city is crossed by the watershed of the Kalamu River, a tributary of the Congo River. The Kalamu River rises in a rural forest at an altitude of 300 m, from where it descends to 181 m in the savannah. In the urban area, the Kalamu drains three municipalities (Kalamu, Kabondo, and Nzadi) before flowing into the Congo River near the port of Boma. Its watershed has an area of 68.84 km² and a perimeter of 44.36 km (Figure 1) (Mananga et al., 2025).

To visualize the study area, we have in Figure 1 the geolocation of said city; and in Figure 2, it is the geolocation of the sites where the sensors are placed.

Figure 1 is a map of the city of Boma in the Kongo Central province of the Democratic Republic of Congo. It is located in the southwest of the country, on the banks of the Congo River. Its area was 62 km² in 2012, but with time and the city's expansion, this area has increased significantly. It is now approximately 100 km² (Mairie de la ville Boma, 2020; Mananga et al., 2025).

The table above shows the geographic coordinates of each point where a sensor is placed; the five coordinates indicate the five sites where our sensors are located. Each site is represented by two values, one for South Latitude and the other for East Longitude.

Based on the geographic coordinates of each monitoring site, we represent the five sites on the geographic map of the city of Boma using remote sensing. Figure 2 represents these points at different sites where the sensors are placed, allowing us to achieve the objective of this study. Five sensors are located along the Kalamu River, which flows through the city from its confluence with the Congo River. These sites are: Site 1, named CVM Bridge; Site 2, City Bridge; Site 3, Boulevard; Site 4, Stadium Bridge; and Site 5 Nibak.



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3. Materials and Methods

3.1. Materials

To conduct this study, five sites were identified along the Kalamu River, as shown in **Table 1**. These sites served as locations for dust collectors, taking into account several criteria, including safety and the types of activities (industrial and road traffic). They are characterized by industrial activity related to chemical fertilizers, associated with the activities of shipping companies such as CVM (Seaways Company) and SCPT (Port and Transport Trade Company), as well as the influence of illegal dumps. Road traffic, along with other general commercial activities that contribute to the emission of transport-related pollutants (particularly nitrogen oxides and particulate matter), was also a factor in site selection.

Table 1. Geographic coordinates of monitoring points around the Kalamu River.

N°	Sites	South Latitude	East Longitude
S1	CVM BRIDGE	5°51'22.638"S	13°2'57.162"E
S2	CITY BRIDGE	5°51'5.73"S	13°3'14.55"E
S3	BOULEVARD	5°50'47.751"S	13°3'19.147"E
S4	STADIUM BRIDGE	5°50'28.914"S	13°3'32.598"E
S5	NIBAK	5°50'17.964"S	13°3'40.44"E

- Presentation of **Image 1(a)** and **Image 1(b)** from sensors of solid pollutants in the air around the Kalamu River.

Five solid pollutant sensors are installed on the banks of the Kalamu River in Boma, to assess air quality. These sensors make it possible to measure, by physico-chemical analysis, the quantity of solid pollutants that the atmosphere deposits on a surface.

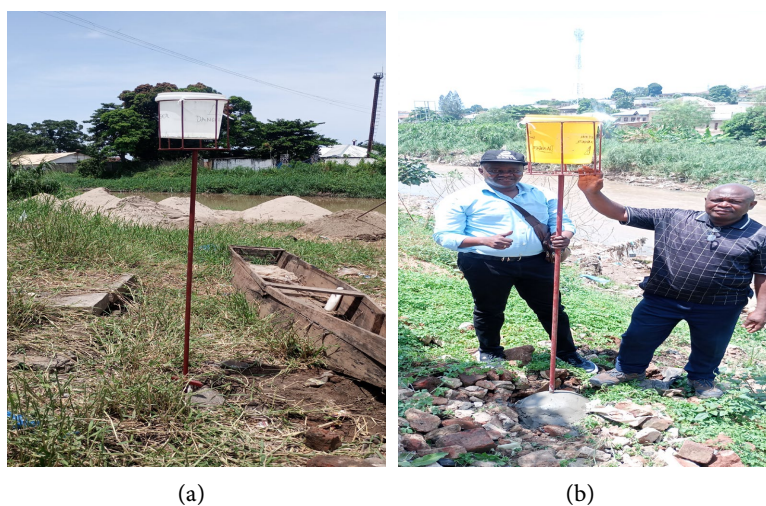


Image 1. (a) and (b): Photos taken during the installation of dust sensors in Boma: Prof J. P Mfwamba and Faustin F. Mananga/2025.

Image 1(a) and **Image 1(b)** are field photos; these are the dust sensors that we had placed along the Kalamu River in Boma; these sensors allowed us to identify and quantify trace metal elements, but also those of suspended solid particles.

3.2. Methods

3.2.1. Diagram of the Experimental Approach

Data Collection

The schematic of the experimental approach for data collection, see **Figure 3**, enabled us to achieve our objective; accordingly, three samples were taken during three months of the year 2025, i.e., four months from March to June 2025; this is a period of the rainy season in the Democratic Republic of Congo in general and in the city of Boma in particular; this period was chosen for the influence of precipitation.

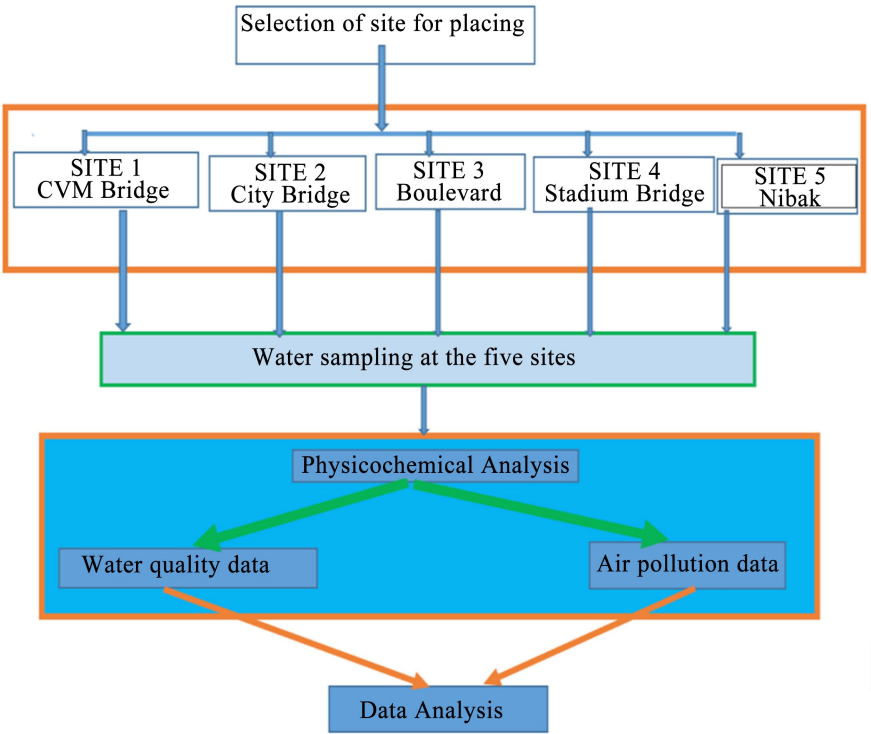


Figure 3. Diagram of the experimental approach for data collection.

The first sample was taken on April 10, 2025, the second on May 10, 2025, and the last on June 10, 2025. The duration of exposure of our sensors before sampling was 30 days, i.e., one month.

Wet deposition includes several processes and we generally distinguish wet deposits associated with precipitation (rain, snow, hail) and occult wet deposits associated with the impact of cloud droplets on a mountain or the sedimentation of fog droplets. Wet deposits by precipitation are overall the most important. During precipitation, two main processes contribute to wet deposition. On the one hand,

particles act as condensation nuclei for cloud drops (which can then become raindrops) and the pollutants present in these particles are therefore incorporated into these drops. On the other hand, gaseous or particulate pollutants are captured by cloud or rain drops in the cloud. Gaseous pollutants are captured by dissolution in the aqueous phase. Particulate pollutants are captured when the particle collides with a cloud or rain drop. These processes take place in the cloud and are generally considered to constitute “rain-out”. Furthermore, precipitation will wash away some of the pollutants present between the earth’s surface and the base of the cloud. This leaching occurs for gaseous pollutants that are soluble in water and for particles that collide with raindrops (Christian Seigneur, 2018).

3.2.2. Analytical Methods

Physicochemical analyses of the water samples from the sensors were carried out in the laboratory of the University of Kinshasa (laboratory of the Department of Environment of the University of Kinshasa); one liter (1 L) of water was taken from each sensor for various laboratory analyses.

Calcium hypochlorite, or $\text{Ca}(\text{ClO})$, does not have a direct suppressive effect on trace metals, but its reaction in aqueous media can change the oxidation state of some metals, potentially affecting their solubility and mobility. Calcium hypochlorite increases the pH of water, which can promote the precipitation of metals in the form of hydroxides. In addition, the presence of calcium can influence the mobility of certain trace metals by adsorption on calcium carbonate or phosphate precipitates. Calcium hypochlorite is a strong oxidizing agent. It can oxidize certain metals (e.g., iron, manganese) and precipitate metals as insoluble oxides or hydroxides under high pH conditions; but, in the context of our study, Calcium hypochlorite did not influence the pH, taking into account the recorded pH value. On this, monitoring the pH value of the water collected in the sensors is important to determine the influence of this preservative.

3.3. Analyses Performed

1) TME Content in Water

The water samples were analyzed using Inductively Coupled Plasma Mass Spectroscopy (ICP, VARIAN brand). The objective was to determine the TME (trace metal element) concentrations in these waters, taking into account the device’s detection limits set for each metallic element. These are: Fe, Mn, Al, Ca, Cu, Hg, Pb, in order to determine the concentrations of trace metal elements present in the air.

2) Physicochemical Parameters

In the water samples, the physicochemical parameters to be analyzed were: pH, turbidity, color, T.A, TAC, T° , TSS, and OM.

MES and OM will allow us to calculate the daily rate of suspended matter in solid particles from atmospheric air falling within a 1 m² perimeter of the Kalamu River using the following formula:

$$T_{me} = \frac{MES + OM}{\frac{SC}{N_j}}$$

T_{me} : Daily rate of suspended matter;

N_j : Number of days;

SC: collector surface;

MES: suspended matter;

OM: organic matter.

The total mass of suspended matter is found by adding the suspended matter and the organic matter.

For the daily rate is calculated by the Total Soluble Mass in mg, divided by the number of days and the surface. The values found are in mg/m^2 .

The surface area of the collectors is expressed in cm^2 or m^2 . It allows you to measure the space inside the circle. The surface area of our collectors is equal to 498.5 cm^2 ; this value is found using the following formula:

$$A = \pi \times r^2$$

where:

- A represents the area of the circle in m^2 ;
- π (pi) is a mathematical constant whose approximate value is 3.14;
- r is the radius of the circle in meters; it is the distance between the center of the circle and any point on its circumference.

For this study, the surface area of the collector used is: 0.0314 m^2 .

3.3.1. Quality Assurance

To ensure the reliability of the results, field blanks were collected and analyzed in parallel with the exposed samples to control for any contamination related to handling or transport. Repeat samples were included in the protocol to assess the reproducibility of the measurements and detect any potential analytical variations. ICP analyses were performed with specific detection limits for each trace metal; for example: $0.01 \mu\text{g}/\text{m}^3$ for lead (Pb), $0.005 \mu\text{g}/\text{m}^3$ for cadmium (Cd); but also for the daily level of suspended matter, according to the standards of the Republic of South Africa (RSA), which sets this level at $500 \text{ mg}/\text{m}^2$ in residential areas and $1200 \text{ mg}/\text{m}^2$ for industrial areas.

3.3.2. Software Used

Statistica 7.1 software was used to perform Principal Component Analysis (PCA), a correlation analysis between the different variables found after laboratory analysis.

Excel (2013) was used to organize the data into tables and generate graphs to visualize the distribution and assess the degree of pollution at each site for the entire study period.

ArcGIS (Geographic Information System) software was used to analyze the geographic coordinates, map them, and present the study area. For the laboratory analysis results, an evaluation will be conducted to determine the quantity of solid

particles falling on a given surface of the Kalamu River, also comparing these results to international standards established by the World Health Organization (WHO). The results will be processed using R software for multivariate analysis: Principal Component Analysis (PCA) to better understand the relationships between the different measured variables and identify the underlying factors influencing pollutant concentrations.

4. Presentation of Results

1) First-month results: March 10 to April 10, 2025

a) Analyse en Composantes Principales (ACP)

In **Figure 4**, we present the results of physico-chemical analysis of the samples taken from the solid sensors for the first month of the study; these results were then processed by Principal Component Analysis (PCA); PCA reveals two major poles:

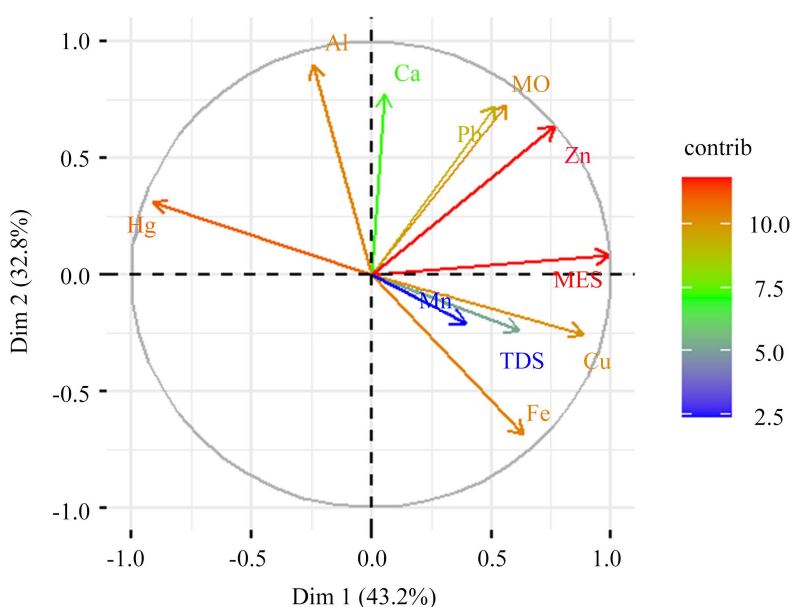


Figure 4. Circle of correlations and variation in the concentration of the analyzed elements in first month.

- i) Metallic/mineral pollution (TSS, Pb, Zn, Cu, Fe, TDS) → axis Dim1.
- ii) Organic/calcium content (OM, Ca) → axis Dim2.

Some variables (Hg, Al, NO_3) play a secondary role. This structure is consistent with the correlation matrix, which shows strong correlations between metals and relative independence of Ca/OM, and with hierarchical ascending classification (HAC), where sites rich in TSS/Pb/Zn cluster together while those marked by Ca/OM or low concentrations stand out.

✚ Main axes:

- PC1: positively correlated with Iron, Mercury, TSS, and Organic Matter; this indicates an axis of metallic and organic pollution.

- PC2: correlated with Al, Ca, Cu, and TDS; these represent an axis of mineralization.
- PC3: correlated with Manganese and Cu, with a secondary axis linked to specific metals.

 Site locations:

- Points 2 and 4: negative values for PC1 indicate that the sites are less polluted.
- Points 3 and 5: positive values for PC1 indicate that the sites are polluted.
- Point 1: intermediate, marked by Cu and TSS.

The variables near the circle are well represented by PC1 - PC2:

- Iron, Hg, TSS, and MO are strongly correlated with PC1.
- Al, Ca, Cu, and TDS are also strongly correlated with PC2.
- Pb and Zinc are poorly represented by PC1 - PC2.

b) Hierarchical Ascending Classification (HAC) of sites

Figure 5 is the dendrogram which allows us to present the relationships of similarity and hierarchical grouping between the different sites, according to the results of physico-chemical analysis. The dendrogram indicates the existence of two classes: Class 1, which groups together sites 3, 1, and 5. These sites are likely associated with variables from the first and second quadrants: OM, Zn, Pb, SS, Cu, Iron, etc., suggesting mixed pollution (organic and metallic) typical of urban and agricultural areas. Since site 4 is a little further away, it could have a slightly different pollutant load (e.g., less Zn or more SS). It can be considered a subclass of this first class. Class 2 groups together sites 2 and 4. These sites could be influenced by the isolated variables Hg (third quadrant) or Ca (fourth quadrant). This indicates specific or natural pollution, distinct from the previous group.

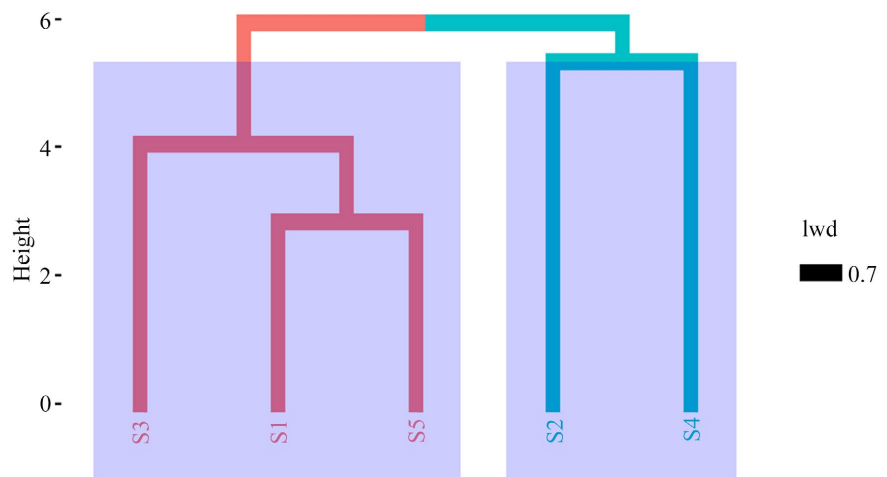


Figure 5. Dendrogram of the sites; for the Hierarchical Classification of sites. Legend: S1 (CVM Bridge); S2 (City Bridge); S3 (Boulevard); S4 (Stadium Bridge); S5 (Nibak site).

- Cluster 1: Points 2 and 4 are less polluted but more mineralized sites.
- Cluster 2: Points 1 and 5 are also polluted sites, with high metal and organic content.

- Point 3: isolated, intermediate between the two groups.

The CHA highlights a clear polarization of sites:

- Sites with a high metal/mineral load (S1, S3, S5), indicative of anthropogenic pollution or industrial inputs.
- Sites with an organic/calcium profile (S2, S4), reflecting more natural conditions or distinct organic inputs.

2) Results for the second month (From April 10 to May 10)

a) Analyse en Composantes Principales (ACP)

In **Figure 6**, we present the results of physico-chemical analysis of the samples taken from the solid sensors for the first month of the study; these results were then processed by Principal Component Analysis (PCA); PCA reveals:

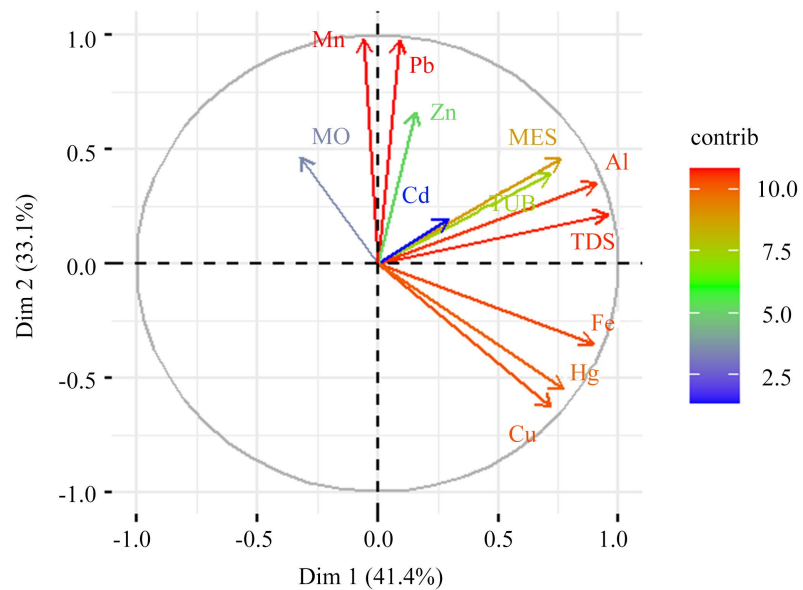


Figure 6. Correlation circle and variation in the concentration of the analyzed elements.

- Variables with similar orientations (MES-Pb-Zn-Cu-Fe-TDS) are positively correlated; they move together and define a profile of metal-contaminated sites.
- Variables with opposite orientations (e.g., MES/Pb vs. MO/Al) are negatively correlated; they distinguish contrasting site profiles.
- Variables near the center (Hg) do not provide structure and can be considered non-discriminating.

All variables are located in the first two quadrants of the correlation circle. Cu and Fe almost touch the correlation circle; Cd, very short, followed by Tds, Al, TUB, and MES are found in the first quadrant. However, Zn, superimposed on Hg and accounting for almost half of the Hg, followed by Pb and Mn. MO, slightly shorter than the previous parameters, completes the second quadrant.

Correlations are shown on:

- The variables MES, TDS, Al, Pb, Cu, and Zn are strongly correlated with each other and well represented by PC1.
- The variables Mo and Cd show weaker contributions, indicating a lesser im-

portance in structuring the principal axes.

- The variables Fe and Mn occupy an intermediate position, suggesting moderate correlations.

b) Hierarchical Ascending Classification (HAC) of sites

Figure 7 is the dendrogram which allows us to present the relationships of similarity and hierarchical grouping between the different sites, according to the results of physico-chemical analysis of the second month of study on the evaluation of solid pollutants in atmospheric air near the Kalamu River.

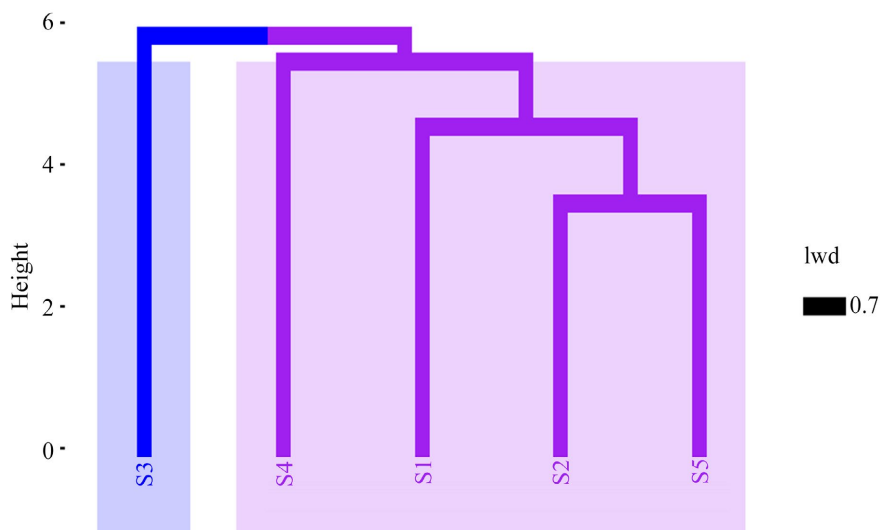


Figure 7. Hierarchical Classification of Sites (Dendrogram of the sites). Legend: Site 1 (CVM Bridge); Site 2 (City Bridge); Site 3 (boulevard); Site 4 (Stadium bridge); Site 5 (nibak).

This hierarchical classification reinforces the relevance of PCA and provides a solid basis for scientific discussion and the planning of environmental interventions.

The hierarchical classification of sites groups them as follows:

- The CHA confirms the structure highlighted by the PCA and the correlation matrix.
- Metallic/mineral cluster: S1, S2, S5 (strong correlations between TSS, Pb, Cu, Zn, Fe, and TDS).
- Specific cluster: S4 (organic/Al profile, low metallic contamination).
- Unique site: S3 (influenced by TDS and Fe, clearly distinct from the others).
- This hierarchical classification illustrates the diversity of pollution profiles between sites and allows us to link the statistical dimensions (PCA) to the concrete groupings.

3) Results for the third month (May 10 to June 10)

a) Principal Component Analysis (PCA)

We present the results of physico-chemical analysis of the samples taken from the solid sensors for the third month of the study in **Figure 8**; by Principal Component Analysis (PCA); this is to present in a clearer way the physico-chemical variations of each element found in the atmospheric air near the Kalamu River in Boma.

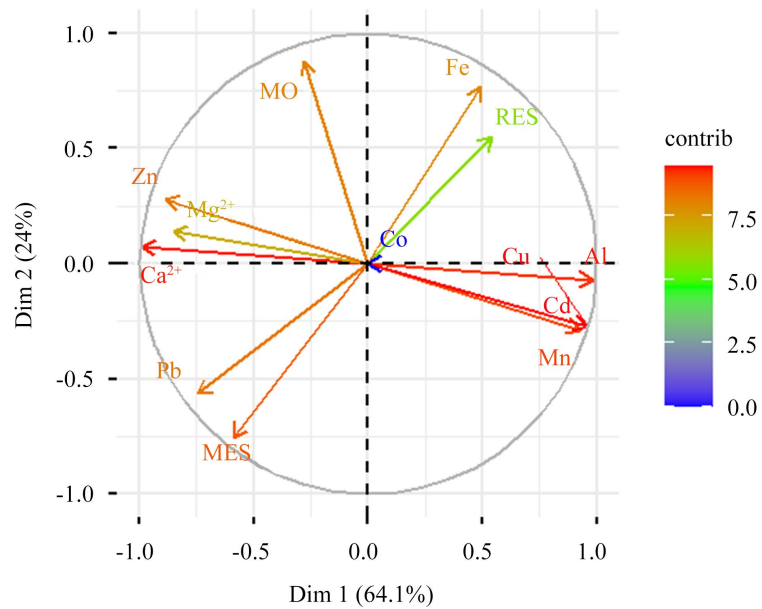


Figure 8. Circle of correlations and variation in the concentration of the analyzed elements in third month.

Two major poles structure the base:

- i) Metallic/mineral pollution (Dimension 1).
- ii) Organic load and aluminum (Dimension 2).

Variables oriented in the same direction are positively correlated (e.g., TSS-Pb-Cu-Zn-Fe-Cd-Mn-Ca²⁺-Mg²⁺-Co).

Variables oriented in opposite directions (e.g., TSS/Pb vs. OM/Al/RES) are negatively correlated, reflecting contrasting site profiles.

Variables near the center do not provide significant structuring.

➤ **Opposite or Weakly Correlated Variables**

Based on our analysis, some elements represent a particularity related to their correlation. We cite the following: Fe, Cd, and Mo: their arrows are shorter or oriented differently.

- Fe and Cd appear less well represented in this plane, which means they contribute to other dimensions (Dim 3, Dim 4, etc.).
- Mo is nearly orthogonal to the other metals, suggesting independence or a different source.

➤ **Interpretive Synthesis**

Two main groups of parameters emerge:

- i) Suspended metals and particles (Pb, Mn, Zn, suspended solids, TUB) → probably related to discharges or erosion.
 - ii) Dissolved elements (Al, TDS, Cu) → related to mineralization or groundwater sources.
- Directional contrasts (e.g., Pb vs. Mo) indicate inverse behavior: where Pb is high, Mo tends to be low, and vice versa.

Potential sources: Industrial/urban activities, runoff, erosion—co-mobilization

of metals with particles.

- Limitations: Constant mercury (Hg) excluded from interpretations; small sample size ($n = 5$) limits statistical robustness; need for temporal replications.

b) Hierarchical Ascending Classification (HAC) of sites

The dendrogram represents a hierarchical classification of sites based on their physico-chemical similarities; for **Figure 9**, we present the results of physico-chemical analysis from the third month of the study on the evaluation of solid pollutants in atmospheric air near the Kalamu River.

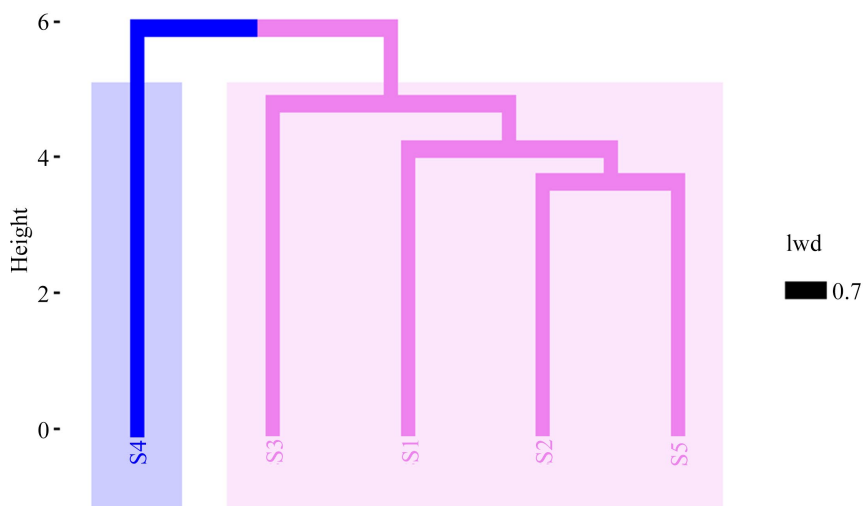


Figure 9. Hierarchical Classification of Sites (Dendrogram of the results). Legend: S1 (CVM Bridge); S2 (City Bridge); S3 (Boulevard); S4 (Stadium Bridge); S5 (nibak).

- It groups the five sites numbered from 1 to 5 according to their level of similarity.
- The vertical axis indicates the level of dissimilarity: the higher the junction, the more different the sites.

CHA confirms the structure highlighted by PCA and the correlation matrix:

- Metallic/mineral cluster: S1, S2, S5 (and partially S3).
- Specific cluster: S4, characterized by a higher organic and aluminum content, and lower metallic contamination.

Cluster 1: These three sites are clustered very early, indicating a strong similarity between their physicochemical profiles. This may reflect:

- A common source of pollution or disturbance.
- Geographic or hydrological proximity.
- Similar environmental conditions (e.g., use, substrate).

Cluster 2: Sites 4

Site 4 forms a second homogeneous group, distinct from the first. Their grouping suggests:

- A different chemical composition from Cluster 1.
- Perhaps an area less impacted or influenced by other factors (e.g., agricultural

vs. urban).

Final Merger: Clusters 1 and 2.

The junction between the two groups occurs at a high level of dissimilarity, confirming that:

- The groups are clearly distinct.
- There is a marked difference between the two sets of sites.

Implications for Analysis and Planning.

➤ **Strategic synthesis**

Table 2 helps us to determine, according to their grouping, the source of the trace metal elements found in the water samples taken from the sensors, and to present suggestions for interventions to deal with each group of this pollutant in the atmosphere.

Table 2. Intervention to combat pollution.

Quadrant	Dominant variables	Probable type of pollution	Suggested intervention
I	Al, MO, Zn, Pb	Urban/domestic mixed	Sanitation, discharge control
II	MES, Cu, Fer, Tds, Mn	Particulate/agricultural	Soil management, effluent control
III	Hg	Spécifique industrielle	Targeted surveillance, traceability
IV	Ca	Naturelle/géologique	Background monitoring, no emergency

4.1. Metal Trace Element (MET) Content

These results demonstrate the presence of metal trace elements in the atmospheric air in the city of Boma; the concentration of Al, Pb, and Zinc in all samples indicates that effluents from electronic waste disposal techniques in the bins erected along the Kalamu River are loading the atmospheric air with these metal elements.

The other MEs found in the samples after analysis vary from one point to another; however, points 2 and 3 yield lower results than the other points. This is likely due to the lack of industrial activity and the absence of illegal bins near these dust collectors.

The waters of the Kalamu River constitute a water supply source for multiple services; therefore, the MEs levels were compared to the WHO drinking water reference values.

The zinc levels in the various samples, although higher than the threshold concentration of approximately 4 mg/l, except for point 4 where the level is below the normal threshold; Water containing zinc at concentrations above 3 - 5 mg/l may appear opalescent and form a greasy film when boiled. Zinc imparts an undesirable astringent taste to water at a threshold concentration of approximately 4 mg/l (in the form of zinc sulfate).

The aluminum level is very worrying at all points, this indicates a high input of aluminum into the waters of the Kalamu River; the presence of aluminum at con-

centrations above 0.1 - 0.2 mg/l often leads to consumer complaints due to the deposition of aluminum hydroxide flocks and the intensification of the discoloration of the water due to iron.

For copper content, point 4 still stands out with a level below 1 mg/l. However, no value in any of the points exceeds 5 mg/l, as a value above 5 mg/l imparts color to the water and an unpleasant bitter taste. Although copper can impart a taste to water, it should be tolerated at the health-based guideline value of 2 mg/l.

As for iron, the iron content in our samples is above 0.3 mg/l. An iron taste is usually not noticeable at concentrations below 0.3 mg/l, although turbidity and discoloration may develop.

Manganese at concentrations below 0.1 mg/l is usually acceptable to consumers. Even at a concentration of 0.2 mg/l, manganese will often form a coating on pipes that can detach as a black precipitate. However, under certain conditions, manganese can be present at concentrations above 0.1 mg/l and can remain in solution for a longer period compared to its usual solubility in most drinking water. Based on our results, point 2 has an acceptable content of 0.25 mg/l.

The mercury content at the various points also remains above the WHO threshold of 0.006 mg/l; the results of our analyses give values between 0.01 and 0.02. On the other hand, for total dissolved solids, the taste of water with a total dissolved solids (TDS) level below approximately 600 mg/l is generally considered good; for this study, the upper value found after analysis is 169.12 mg/l and the lower value 92.5 mg/l; thus, we find that the values found are below the threshold considered.

By **Figure 10** presented, we present the correlation circle in trace metallic elements in all the sites, where the sensors are placed, this, based on physico-chemical analysis results. The ETM projection analysis shows a distribution of elements along the two main dimensions (Dim1 and Dim2), which capture 37.5% and 32.6% of the data variance, respectively:

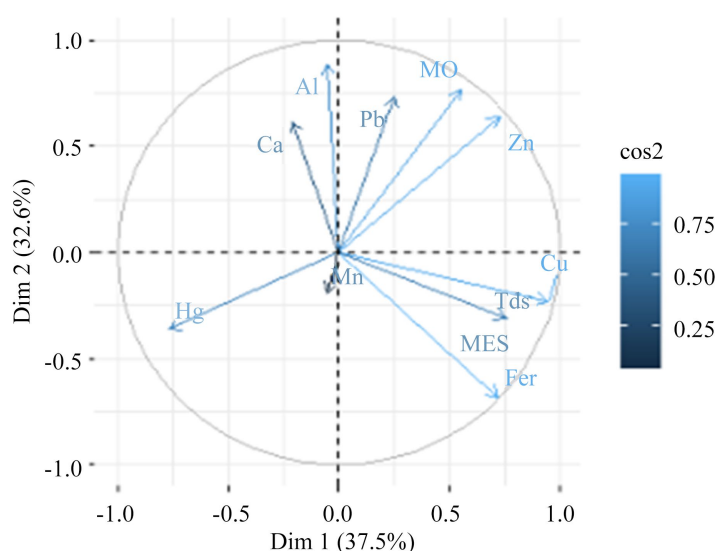


Figure 10. Circle of correlations of ETM concentration.

First quadrant: (Pb, Mo, Zn) the close proximity of OM and Zn to the circumference suggests that they are strongly influenced by Dim1 and Dim2. Pb, being slightly shorter, could indicate a lesser contribution to these dimensions, but remains associated with this trend. This distribution can be interpreted as elements related to anthropogenic activities, such as electronic waste or vehicle emissions.

Second quadrant: (Cu, TDS, TS and Fe): These elements show a correlation in this space, indicating a possible common origin. The presence of Iron and Suspended Solids (SS) suggests an influence from corrosion processes or sources loaded with solid particles. Cu and TDS (Total Dissolved Solids) may reflect pollution related to industrial or urban effluents.

Third quadrant: (Mn and Hg): Mn, with a short vector close to Dim1, appears to be little influenced by Dim2 and may have a more uniform distribution or be less correlated with other parameters. Hg, in light blue and with a longer vector, appears to be strongly influenced by these dimensions, possibly indicating a specific source such as mining or the incineration of certain industrial waste.

Fourth quadrant: (Ca and Al): Their close proximity to Dim1 means that they are mainly explained by this dimension. Ca is often linked to geological processes or the influence of hard water, while Al may be associated with suspended particles or soil erosion phenomena.

In summary, the projection highlights clusters that reflect natural or anthropogenic influences on the distribution of trace elements.

4.2. Assessment of Solid Matter Particles

Assessment for the study period

Table 3 presents the results of the gravimetric analysis of samples from all sites; this allows us to calculate the quantity of solid pollutants in the atmospheric air which is deposited in a given surface of the Kalamu River during 24 hours. The regulatory limit value is set at 500 mg/m² in residential areas, represented by the red bar, and at 1200 mg/m² in industrial areas, represented by the gray bar in the graph below. Note that the blue bar represents the variation in deposit concentrations at different sites (**Figure 11**).

Table 3. Results of analyses for precipitation.

SITES	Total Insoluble Mass (mg)	Total Soluble Mass (mg)	Total Mass (mg)	Surface area in m ²	Number of days	Daily rate of suspended matter (M/S/d) mg/m ²
RESULTS OF THE FIRST MONTH ANALYSIS						
SITE 1	750	0.02	750.02	0.0314	30	745.244
SITE 2	529	0.03	529.03	0.0314	30	561.6
SITE 3	810	0.02	810.02	0.0314	30	859.893
SITE 4	190	0.01	190.03	0.0314	30	201.73
SITE 5	923	0.03	923.03	0.0314	30	979.861

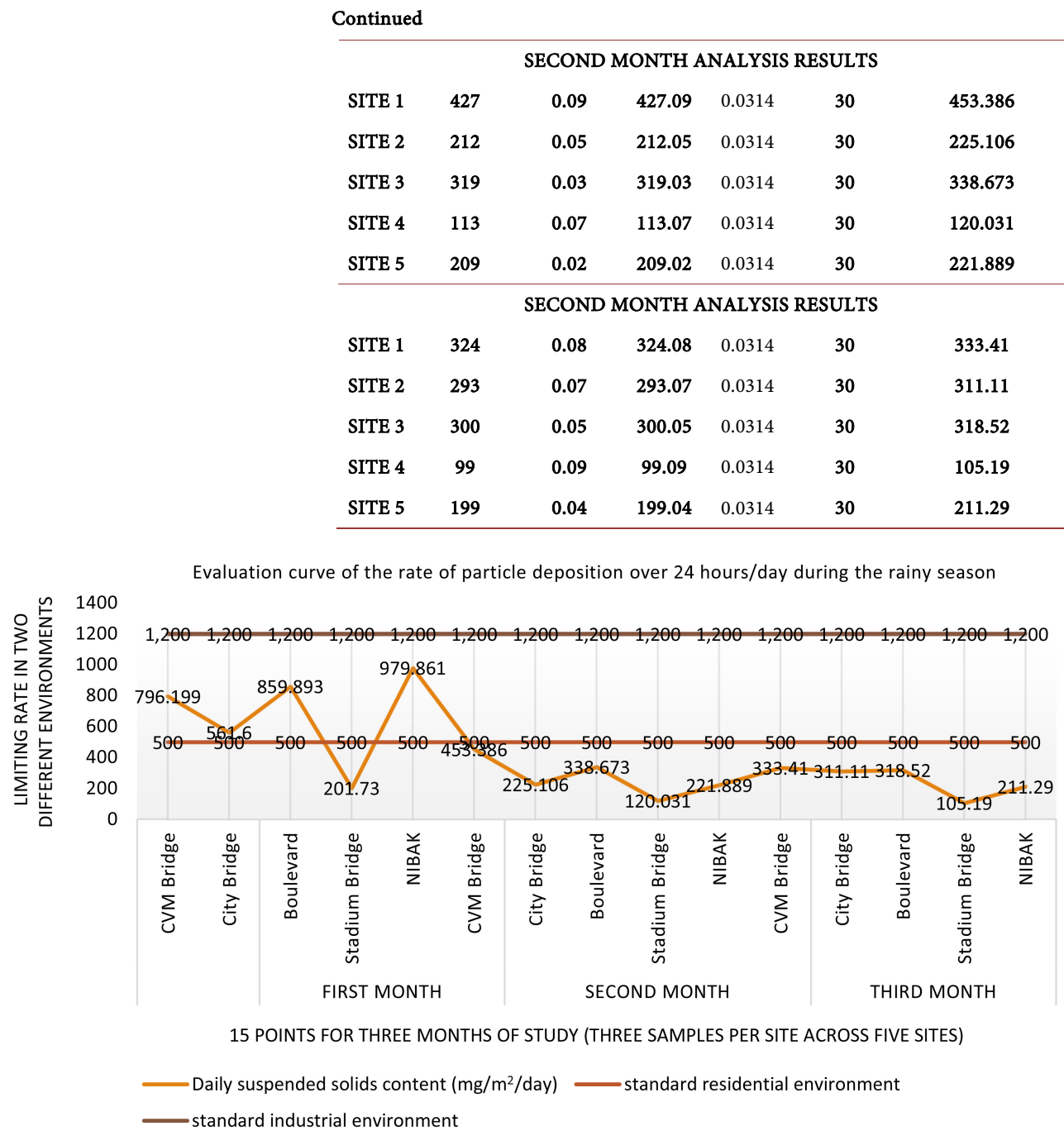


Figure 11. Concentration of solid deposits at the various air quality assessment sites.

The concentration of solid deposits in the different air quality assessment sites in the city of Boma over 24 hours is presented in **Figure 10**; This figure shows us the variation between sites for the three months of our study. Indeed, the graph shows fifteen points throughout this study. Of these, four (4) points have a concentration that exceeds the regulatory value in the maximum value for residential areas, but below the maximum value for industrial areas. These points were recorded during the first study period, i.e., from March 10 to April 10, 2025. These

results indicate the level of air pollution during this period in the city of Boma. On the other hand, eleven other points during the second and third periods, and one point from the first period, indicate that air quality is satisfactory, given the curve, which is two lines below the regulatory thresholds.

5. Discussion

The CEPA Federal-Provincial Working Group on Air Quality Objectives and Guidelines stated that particulate matter is a unique constituent of the atmosphere in that it is not defined based on its chemical composition. It can include a wide variety of chemical species: organic and elemental carbon compounds; silicon, aluminum, and iron oxides; trace metals; sulfates; nitrates; and ammonia.

The expression “you can’t protect what you don’t know” highlights the need to improve knowledge with the aim of moving toward sustainable management of the environment and natural resources (Christian, 2018). We note that for some time now, the Kalamu River at Boma has been of interest to scientists, some of whom complain about its quality and the damage it causes during floods; Water quality around the world has deteriorated significantly in recent years due to uncontrolled industrial discharges and the intensive use of chemical fertilizers in agriculture. These produce chemical changes in the water, making it unfit for its intended uses. Rouabhia and Djabri (2010) regarding the physicochemical quality of Kalamu, Vuni Simbu Alexis et al. (2024) note that the water of the Kalamu River is polluted. Comparing the results obtained between two seasons, it appears that the rainy season carries the greatest amount of fecal matter into the river. They report that urban leaching appears to be the main cause.

Same author Alexis Vuni Simbu et al. Will study the elements for assessing a watershed for a river contract: Case of the Kalamu in Boma, they state that in the Kalamu River watershed, population growth has been accompanied by the misuse of water, soil, and plant resources. Human activities in the watershed are highly varied, likely to create environmental pollution problems.

Hydro-qualitative diagnosis of the waters of the Kalamu River watershed in Boma, Central Kongo, DR Congo (2024) by the same author Vuni Simbu Alexis et al. (2022). These authors monitored water quality, a study conducted; physicochemical and bacteriological parameters were monitored at nine sampling sites from the upstream to its mouth and subjected to analyses. Human activities in the watershed are indeed very varied; they have led to the occupation of space up to the major bed and are therefore likely to create environmental pollution problems.

Physicochemical and bacteriological analyses highlighted the relationship between human activities and the physicochemical and bacteriological quality of water bodies, particularly at certain sites. Microbiological analyses of total coliforms in the water ranged from 3000 to 70,000 mg/l, fecal coliforms from 1400 to 85,000 mg/l, and *Escherichia coli* from 300 to 20,000 mg/l. The results of the physicochemical analyses show that the waters of the Kalamu River in Boma are more sensitive to pollution. This pollution is manifested, among other things, by flood-

ing affecting the local population and by chemical disturbances in the water (Vuni et al. 2024; Wanga et al., 20214). Wanga et al. (2015) had carried out a study on the Physico-chemical quality of the waters of the Kalamu River of Boma. The results showed the following characteristics, color (93.83 Pt Co/l), temperature (29.95°C), pH (7.34), conductivity (72.42 μ S/l), turbidity (48.33 NTU), TDS (46.4 mg/l), suspended solids (45.5 mg/l), dissolved oxygen (6.47 mg/l), O₂ saturation (84.58 mg/l), NH₄⁺ (0.16 mg/l), Ca²⁺ (214 mg/l), Mg²⁺ (106.11 mg/l), Pb²⁺ (70.41 mg/l), Cd²⁺ (20.49 mg/l), Cl⁻ (58.9 mg/l), Al³⁺ (3.03 mg/l), BOD₃ (18.5 mg O₂/l), COD (61.04 mg/l), PO₄³⁻ (76.28 mg/l), NO₃⁻ (111.44 mg/l), and SO₄²⁻ (7.61 mg/l). Calcium hypochlorite is a strong oxidizing agent. It can oxidize certain metals (e.g., iron, manganese) and precipitate metals as insoluble oxides or hydroxides under high pH conditions; but, in the context of our study, Calcium hypochlorite did not influence the pH, taking into account the recorded pH value.

All authors who have studied the water quality of the Kalamu River show that these waters are polluted. No author points to atmospheric air pollution as a source likely to pollute the waters of this river. Indeed, taking into account (Rosillon et al., 2013), who stated that improving water quality aims to control the different types of pollution at their source in order to restore the potential of aquatic environments and protect surface and groundwater resources, we wanted to study air pollution and its influence on surface water pollution, the case of the Kalamu River in Boma, D. R. Congo. This study shows the results which confirm the contribution of atmospheric air pollution to the waters of the Kalamu River, the monthly rate of suspended matter: site n°1: 745.244 mg/m², site n°2: 561.60 mg/m², site n°3: 859.893 mg/m², site n°4: 201.730 mg/m² and site n°5: 979.861 mg/m²; taking into account the international standard on the standard in residential environments which is set at 500 mg/m² per day and the standard in industrial environments at 1200 mg/m² of solid particles per day; the results presented by our study show that, of the five sites, only site n°4 which is within the standard in both cases, on the other hand, the other four sites, present results which are higher than the standard in residential environments but lower than the standard in industrial environments.

6. Conclusion

The objective of this study on the evaluation of solid matter suspended in the atmospheric air of the city of Boma, DR Congo, is to identify and quantify the solid atmospheric pollutants that the atmosphere deposits on surface waters, as in the case of the Kalamu River. The exploitation of the waters of this river is intense, with increasing needs linked to population growth and the accelerated development of economic activities, particularly agricultural. Indeed, this study presents two interests, one on the risk of water pollution in Kalamu and the other on the knowledge of atmospheric pollutants in the environment.

The results of this study determine the quantity of pollutants that flow into an area of 1 m² of the Kalamu River, but also indicate the health risks that the popu-

lation runs in this environment. From a health point of view, the analysis results indicate the presence of trace metal elements in atmospheric air, in quantities less acceptable for the population, ETMs such as: Al, MO, Zn, Pb, Cu, Iron, Hg and Ca, these are of different origins, Mixed urban/domestic, Particulate/agricultural, Industrial specific, Natural/geological; the maximum and minimum values of each ETM are as follows: Aluminum (Al) with a result which varies between 50.12 mg/l and 60.96 mg/l, Lead (Pb) 3.21 mg/l to 41.12 mg/l and Zinc (Zn) 3.02 mg/l to 7.12 mg/l.

From the point of view, protection of resources, the results of the analyzes allow us to quantify the pollutants which discharge into an area of 1 m² during one day in each site: site 1: 745.244 mg/m², site 2: 561.60 mg/m², site 3: 859.893 mg/m², site 4: 201.730 mg/m² and site 5: 979.861 mg/m²; taking into account the international standard for residential environments, set at 500 mg/m², and the standard for industrial environments at 1200 mg/m² of solid particles. That being said, the Interventions that we suggest are as follows: Environmental sanitation, control of discharges (waste bin management), soil management, control of effluents, targeted surveillance, traceability and in-depth monitoring. Based on these results, we state that atmospheric air pollution has an impact on the water quality of the Kalamu River.

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Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

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