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Diagnosis of Wastewater Contamination by Metalic Trace Elements (MTE) in the Areas of Yopougon (South Abidjan) and Marcory, Koumassi (North Abidjan) from March to July 2021

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Abstract

Contamination of the aquatic environment by Metallic Trace Elements (MTE) is a major problem encountered in our environment today. In Côte d'Ivoire, in some municipals, residential and industrial areas in the city of Abidjan, waste water of worrying quantity is discharged into the rainwater drainage channels which flow directly into the Ebrié lagoon. In order to identify the origin of the pollution by metallic trace elements (MTE) transported by this water, samples of wastewater were collected and then analyzed. ICP-MS was used for MTE (Cu, Fe, Zn, Al, Pb, Cd) analyses and results were statistically processed in multivariate form using PCA and Excel. The results showed high concentrations of metals, with the exception of Cd. The typological structure represents 85.74% of the total information for the MTE. Plan F1 represents 63.90% of the variance and describes water pollution by copper (0.95), zinc (0.90), iron (0.84) and aluminum (0.84). Plan F2 represents 21.84% and describes the enrichment of water with lead (0.84). It seems more than necessary to make manufacturers aware of the need to install wastewater treatment systems in order to avoid their discharge into the environment.

Keywords

MTE, Wastewater, Typology

1. Introduction

Environmental pollution caused by wastewater discharges becomes a serious threat to the health of living beings [1]. Indeed, this water, which constitutes a reservoir of contaminants, is discharged into the lagoons without prior treatment [2] [3]. However, they can contain significant quantities of elements harmful to health, namely MTE [4]. The bioaccumulation and toxicity of metallic trace elements can, at high or low concentrations, be dangerous to biodiversity [5] [6]. This finding is also observed in Ivory Coast, more specifically in Abidjan. Indeed, previous study has been able to show the metallic contamination of certain aquatic species (fish, shrimp) in lagoon waters [7].

The municipals of Marcory, Koumassi and Yopougon, the study zones of this work, housed many industrial estates, especially that of Yopougon. These municipals have several networks of large open collectors of runoff water which flow into the Ebrié lagoon without prior treatment. The observation made today is that the drainage channel made for the evacuation of rainwater now serves as a reservoir for industrial and domestic wastewater. Indeed, textile, stationery, cosmetics and even soap industries have access to these underground channels or in the open. This study on the environmental pollution by MTE concerns above all the wastewater from the drainage canals communicating directly to the Ebrié lagoon. It aims to monitor the level of metal contamination (Zn, Pb, Cd, Cu, Fe, Al) in urban and industrial discharge sites in other to better understand their origin and their potential risk to the human and aquatic environment.

2. Materials and Analytical Methods

2.1. Materials

2.1.1. Study Area

The sites and sampling points were chosen according to the human activities that take place around these drainage canals and their natural outlet, the Ebrié lagoon.

The study sites are:

- Yopougon municipal, which extends over 153.06 km^2, is located in the north of the district of Abidjan and is bounded to the north by the municipals of Abobo and Anyama; to the south by the Ébrié lagoon; to the east by Attécoubé and to the west by Songon. Four points were chosen in this town according to their proximity to the textile, stationery, soap, oil and cosmetics industries.
- The Marcory and Koumassi mubicipals, which extends over 31.68 km^2, have sampling points dominated by anthropogenic activities (vehicle garage, hospital, fishing, etc.) and factories such as the electricity company and cocoa processing factory. Three points were chosen on these two sites.

These areas received wastewater discharges from industries and domestic discharges. The different sampling sites are shown in **Figures 1-3**.

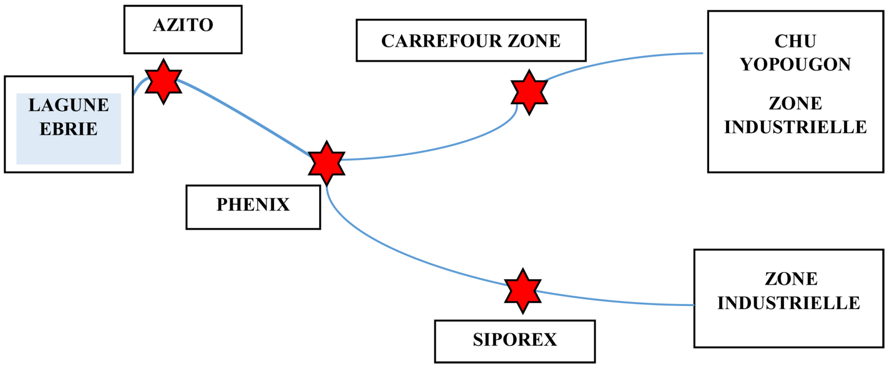

Figure 1. Yopougon sampling site.

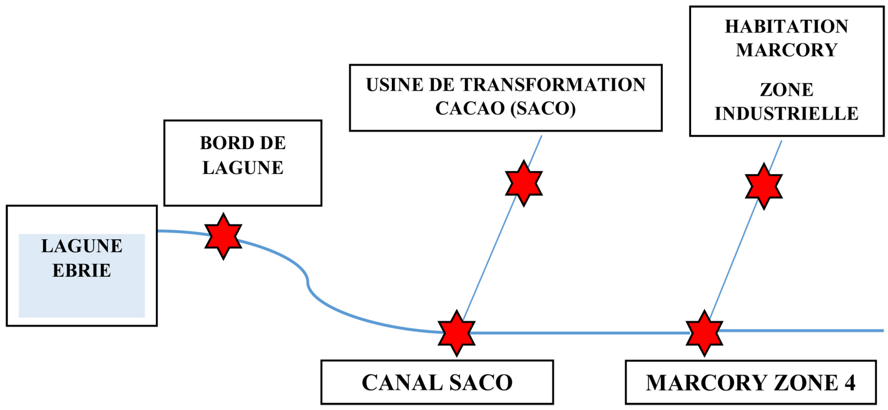

Figure 2. Marcory sampling site.

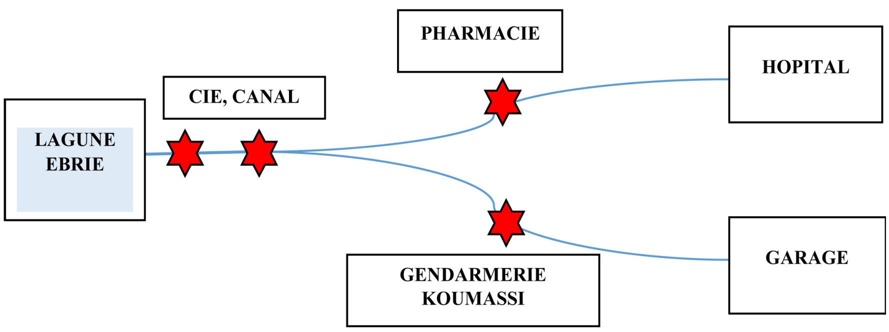

Figure 3. Koumassi sampling site.

2.1.2. Location of Stations

The different sampling stations were located using an MLR SP 12X GPS. The geographical coordinates are presented in Table 1.

2.1.3. Data Collection Time

For five months from March to July 2022, wastewater samples were collected using a 5 L capacity scoop, two samplings per month were performed between 8 a.m. and 2 p.m.

2.1.4. Sample Collection Method

- Sterile 1.5 L polyethylene bottles were used for storing water samples.

Table 1. Geographical coordinates of the sampling stations.

Collection stations	GPS Coordinates
CIE	N05˚28.268' W003˚96.742'
SACO	N05˚28.430' W003˚98.381'
BORD DE LAGUNE (BL)	N05˚28.313' W003˚98.458'
SIPOREX (SP)	N05˚35.805' W004˚07.429'
ZONE	N05˚35.578' W004˚08.475'
PHOENIX	N05˚34.454' W004˚07.948'
AZITO	N05˚30.429' W004˚07.707'

- A clean bucket, fitted with a rope, was used to collect samples from often very deep rain channels.
- Nitric acid (1 mL) was added to the samples for their preservation before any analysis.
- A cooler with ice packs was used to transport and maintain the samples at a temperature of around 4˚C [8].

2.2. Method

2.2.1. Preparation and Reading of the Sample

The preparation of the samples was carried out according to the ISO 11885 (2006) standard. The samples were first digested in a carbon oven with 40 ml in 20 ml of nitric acid (7 mol/litre) at 120˚C for 2 hours. The mixture was then filtered through pleated filter paper onto a 100 ml volumetric flask and topped up with distilled water to the mark of the flask. The final mixture was shaken well before being subjected to ICP-OES (optical emission spectroscopy/inductively coupled plasma) for reading by introducing the aspiration manifold into the flask.

2.2.2. Statistical Analysis

As part of this study, Principal Component Analysis (PCA) was used to make a typology of wastewater samples collected in three municipals of the city of Abidjan.

PCA is a technique for sorting variables and creating quantities that reduces the number of parameters needed to describe observations, while minimizing the loss of information. Although it is often used for descriptive purposes, it is paradoxically the probabilistic approach that is used and although it is a variable sorting technique, it is discriminating enough (with the usual precautions) to allow a sorting of observations [9].

3. Results and Discussion

3.1. Metal Concentrations of Liquid Effluents and Normative Values

The concentrations of MTE (Cd, Zn, Fe, Cu, Al and Pb) in the different study areas are presented in Table 2 and in Figure 4.

The iron concentrations in the wastewater from the various study sites except for the SACO site are 1.5 to 3 times higher than those of the US EPA (1000 µg/L). They are also 1 to 5 times higher than the New York standard (600 µg/L).

The concentration of Cu is 5 times higher than the effluents of US EPA and New York and 2 to 20 times higher than the value of some African countries (Nigeria and Tanzania).

The Cd concentrations observed on the BL and SACO sites are approximately 2 to 10 times higher than the New York standard values (0.6 µg/L) and are lower than the values for the US EPA, Tanzania and Benin City effluents in Nigeria. For Pb concentrations, they exceed the limits of the US EPA and New York but are lower than the limits of certain African countries. As for the Zn content, all the sampling points of the Yopougon site and that of SACO have concentrations above the limit values.

The presence of the metals studied such as Fe, Cu, Zn could come from anthropogenic activities in the study areas. Moreover, very high concentrations of these metals are observed in Yopougon. Their presence could be explained by the large number of industries present in this area, namely textile, stationery, cosmetics industries, fuel stations [10] from which they could be generated. The Marcory (SACO, BL) and Koumassi (CIE) areas have higher Pb and Cd contents. These high Pb and Cd values could be mainly due to the cocoa processing factories and vehicle-workshop present in these areas.

Table 2. Metal concentrations (µg/L) in effluents from some localities in the world and in Abidjan.

Site or Standard	Sample	Fe	Cu	Cd	Pb	Al	Zn	Reference
New York		600	63	0.6	5		-	[11]
Dar es Salaam (Tanzanie)		-	10	40	270		-	[12]
Benin City, Nigeria			194	72	125		174	[13]
USA Standard		1000	50	50	50	-	100	[14]
SACO	Effluent liquid	532.5	278.375	10.95	101.99	344.17	857.05	**Present study**
CIE		854.5	262.075	4.81	27.75	227.72	255.9	
BL		884.5	308.05	9.92	18.08	466.65	427	
SP		3026	2148.5	1.08	79.92	1126.5	2146.5	
ZONE		2418	245.25	0.8	34.85	224.25	566.75	
PHOENIX		2050	1984.5	2.03	53.75	1685.25	1282.5	
AZITO		1905	2157.5	2.29	61.45	1652.5	1170	

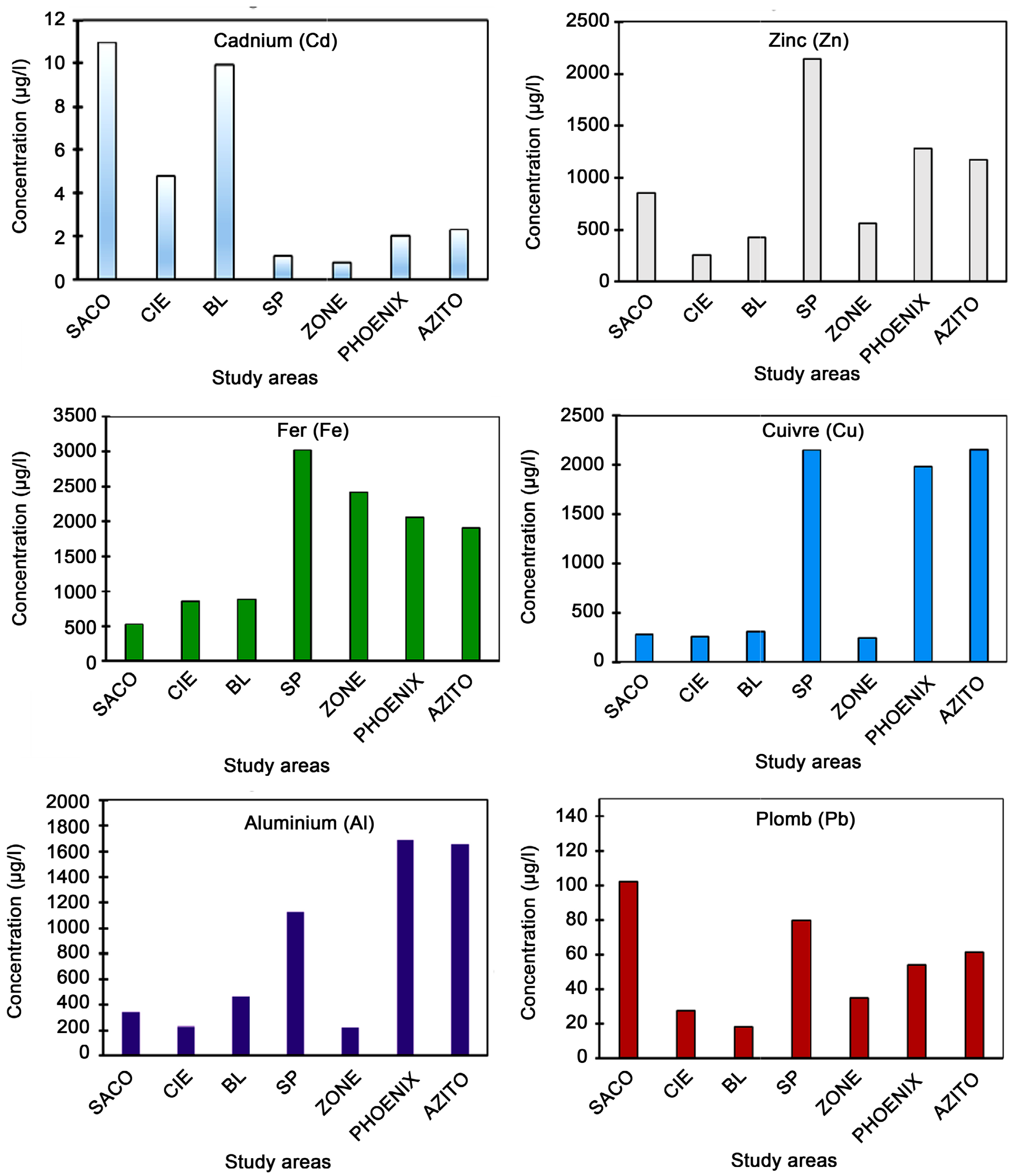

Figure 4. MTE (Cd, Zn, Fe, Cu, Al and Pb) concentrations in the study areas.

3.2. Typology of Wastewater from Sampling Sites

The variables, their codes and their correlations with the F1 and F2 axes are presented in Table 3. The two axes taken into consideration to describe the correlations between the metals alone hold 85.74% of the total information. In the correlation circle (**Figure 5**) and **Table 3**, axis 1 contributes 63.90% inertia. It is defined by copper (0.95), zinc (0.90), iron (0.84) and aluminum (0.84) on the positive side and by cadmium (−0.74) on the negative side. With an inertia of 21.84%, the second axis is defined by lead (0.84) on the positive side (**Table 5**).

According to the correlation matrix (**Table 4**), we observed that the correlations between the variables (Zn - Cd), (Fe - Cd), (Cu - Cd), (Al - Cd) with respective correlation coefficients of (−0.47), (−0.88), (−0.60) and (−0.48) are negative and therefore decreasing respectively. We also observed that among these four pairs of variables, two are negatively decreasing but strongly correlated, they are (Fe-Cd) with coefficient −0.88 as well as (Cu-Cd) with coefficient −0.60.

On the other hand, we noticed that there is a growing and strong correlation between the couples (Al-Cu) with the correlation coefficient of (0.95), then (Cu-Zn) whose correlation coefficient (0.84), followed by (Fe-Zn) with a correlation coefficient of 0.72. Average correlations are also observed including (Al-Zn), (Cu-Fe), (Pb-Zn) finally (Al-Fe) whose respective correlation coefficients are 0.67, 0.66, 0.62 and 0.49.

We also noticed that there is an increasing but weak correlation between (Pb-Cu (0.35)), (Pb-Al (0.26)), (Pb-Fe (0.1)) and (Pb-Cd (0.1)).

We then see that there is a significant correlation between copper, aluminum, zinc and iron. This explains why these elements could come from the same origin.

The factorial map of the sampling sites (**Figure 6**) associated with the circle of correlation of the variables (**Figure 5**), defines four groups. Group I composed of AZITO, PHOENIX and SP is characterized by a strong contamination in zinc,

Table 3. Distribution of the inertia between the two axes (F1 × F2) of the MTE measured in the wastewater studied.

	F1	F2
Clean Value	3.83	1.31
Variability (%)	63.90	21.84
Cumulative Percentage (%)	63.90	85.74

Table 4. Correlation matrix between the MTE measured on all the stations studied.

MTE	Cd	Zn	Fe	Cu	Al	Pb
Cd	1					
Zn	−0.47	1				
Fe	−0.88*	0.72*	1			
Cu	−0.60*	0.84*	0.66*	1		
Al	−0.48	0.67*	0.49	0.95*	1	
Pb	0.10	0.62*	0.10	0.35	0.26	1

Values in * are different from 0 to a significant level at $p < 0.005$.

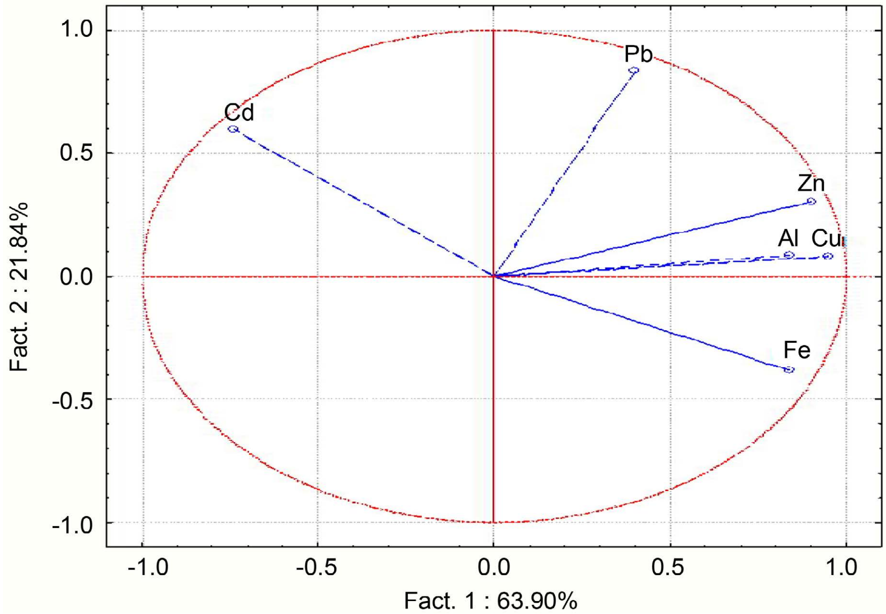

Figure 5. Circle of correlations of variables in the factorial plan F1 and F2.

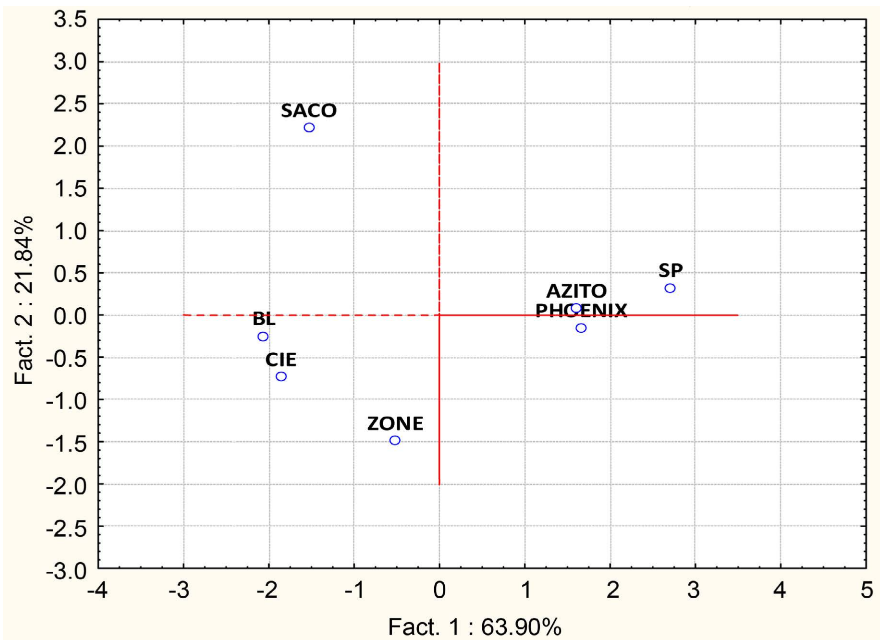

Figure 6. Factorial map of the sampling sites in the F1 and F2 factorial plane.

copper, iron and aluminum in the positive part of axis 1. Group II composed of BL and CIE which is characterized by a strong contamination in cadmium. Group III made up of SACO is characterized by a high lead contamination in the positive part of axis 2. To these three groups is opposed a fourth group (IV) made up only of ZONE and characterized by a very low contamination of metals.

The variables, their codes and their correlations with the F1 and F2 axes are presented in **Table 5**. The two axes taken into consideration to describe the

Table 5. Correlations between variables and factors.

Components	F1	F2
Cd	−0.74*	0.59
Zn	0.90*	0.31
Fe	0.84*	−0.38
Cu	0.95*	0.08
Al	0.84*	0.09
Pb	0.40	0.84*

Values in * are significant at $p < 0.005$.

correlations between the metals alone hold 85.74% of the total information. In the correlation circle (Figure 4 and Table 5), axis 1 contributes 63.90% of inertia. It is defined by copper (0.95), zinc (0.90), iron (0.84) and aluminum (0.84) on the positive side and by cadmium (−0.74) on the negative side. With an inertia of 21.84%, the second axis is defined by lead (0.84) on the positive side.

4. Conclusions

The waters of the Ebrié lagoon continue to be polluted by metals from the urban wastewater effluents that flow into it. Wastewater pollution has become increasingly worrying to the majority of large cities in developing countries, particularly in Abidjan. The Ebrié Lagoon, considered to be the largest area of brackish water in West Africa, remains and still remains under the threat of pollution from the wastewater discharge. Indeed, this work performed on the metal content (Fe, Pb, Cu, Cd, Zn, Al) contained in samples of wastewater, using an ICP OES allowed through the statistical tools PCA to show that the sampling points of the municipal of Yopougon have very high Fe, Cu, Zn and Al contents than the study points of Marcory and Koumassi which have high levels of Pb and Cd.

This study confirms on one hand, the state of pollution of the lagoon waters in MTE as mentioned by other authors and, on the other hand, shows that the zones with strong industrial activities are subjected to high contents of MTE. Awareness campaign to the manufacturers operating in these areas is essential. In the continuation of this study, innovative solutions will be proposed to the manufacturers for the elimination of MTE in wastewater before discharge into the evacuation channels.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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