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Study of the ability of two Ivory Coast clays to clean up effluents from a chemical production units

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Abstract: The problem of industrial pollution is growing in developing countries as more and more factories are built. Most factories use highly toxic chemicals, which are excellent reservoirs of metals. The aim of this study is to clean up industrial effluents from chemical production plants in the Yopougon industrial zone in Abidjan, using two clays from Côte d'Ivoire. To achieve this objective, physicochemical parameters such as pH, conductivity, turbidity and metal content in the effluent were measured. Lead, cadmium, arsenic and manganese levels exceeded the different surface water limit values recommended by the WHO. The technique of adsorption of trace metals on Bingerville (BIN) and Katiola (KAT) clays was applied to clean up these industrial effluents. Treatment of the wastewater with the clays generally showed a reduction in pollutant levels. Elimination of the various metals in effluent decreased in the direction Hg > Cr > Co > Mn > Cu > Ni > Zn > Cd > Pb > As. Mercury is the metal that adsorbs best on clays. KAT clay adsorbs metals better than BIN clay.

1. Introduction

Industrial effluents and their impact on our living environment remain a reality, and a medium- and long-term threat to the quality of surface waters and soils. The problem of industrial pollution is becoming more acute in developing countries, as more and more factories are being built (El Abdouni *et al.*, 2021); (Manisalidis *et al.*, 2020). Most factories use highly toxic chemicals, which are excellent reservoirs of metals. Like many developing countries, Côte d'Ivoire is not immune to this scourge. Indeed, the success of its agriculture, the mainstay of its economy since independence, has motivated the various Ivorian governments to base their industrial policy on the valorization of raw materials. Ivorian industry experienced strong growth between 1960 and 2023. From just forty units in the 1950s, by 1994 it had grown to nearly 8,000 companies (Dongo *et al.*, 2013). Its proportion of Gross Domestic Product (GDP) rose from 6% in 1960 to 16% in 1989. In 2019, industry accounted for 23.2% of Gross Domestic Product (GDP) (Coulibaly *et al.*, 2022) , (Banque Africaine de Developpement, 2020). Over 73% of industry is concentrated in the south of the country. In Abidjan, 45% of industry is concentrated in Yopougon, 20% in Koumassi and 20% in Port-Bouët (Dongo *et al.*, 2013). The municipality of Yopougon in the District of Abidjan is home to one of the world's largest industrial zones. The process of transforming raw materials and cleaning installations and tools after production requires the use of

a lot of water. Industrial wastewater is sometimes discharged untreated into surface waters, contaminating them with chemical species. Studies have shown that industrial effluents are contaminated by metals (Blais, *et al.*, 1999); (Deghles, *et al.*, 1999); (Hayé *et al.*, 2007). Against this backdrop, industrial effluent needs to be cleaned up. In recent years, several pollution control methods have been developed. Techniques commonly used to remove chemical species from water include chemical precipitation, adsorption, lime coagulation, ion exchange, reverse osmosis... ; (Aaddouz *et al.*, 2023); (Hamid *et al.*, 2019); (Moonis, *et al.*, 2008). Among these techniques, the adsorption of pollutants by less expensive, available, and easily usable adsorbents such as clays is of great interest (Bailey *et al.*, 1999) (Mockovčiaková, *et al.*, 2010). A number of research projects have shown that clays possess interesting adsorbent properties (Ouakouak and Youcef, 2016) (Mimanne *et al.*, 2014). In addition, Côte d'Ivoire has many clay material sites that can be used to protect the environment (Andji *et al.*, 2001). In view of the above, the aim of this work is to depollute effluents from chemical production units in the Yopougon industrial zone (Abidjan) by adsorption on Ivory Coast clays. This study, carried out in natural effluents, will enable us to truly appreciate the competitive adsorption between chemical species. This work is intended as a contribution to effluent depollution, with a view to improving surface water quality.

2. Materials and methods

2.1 Materials

2.1.1. Industrial effluents

The industrial effluents for this study originated in the city of Abidjan, in the commune of Yopougon, at 5°36'39' north latitude and 4°08'08" west longitude (Figure 1). The samples were taken from a wastewater drainage canal in the Yopougon industrial zone, which discharges into the Ebrié lagoon. This area is home to industries manufacturing cosmetics, soap, cooking oil, etc.

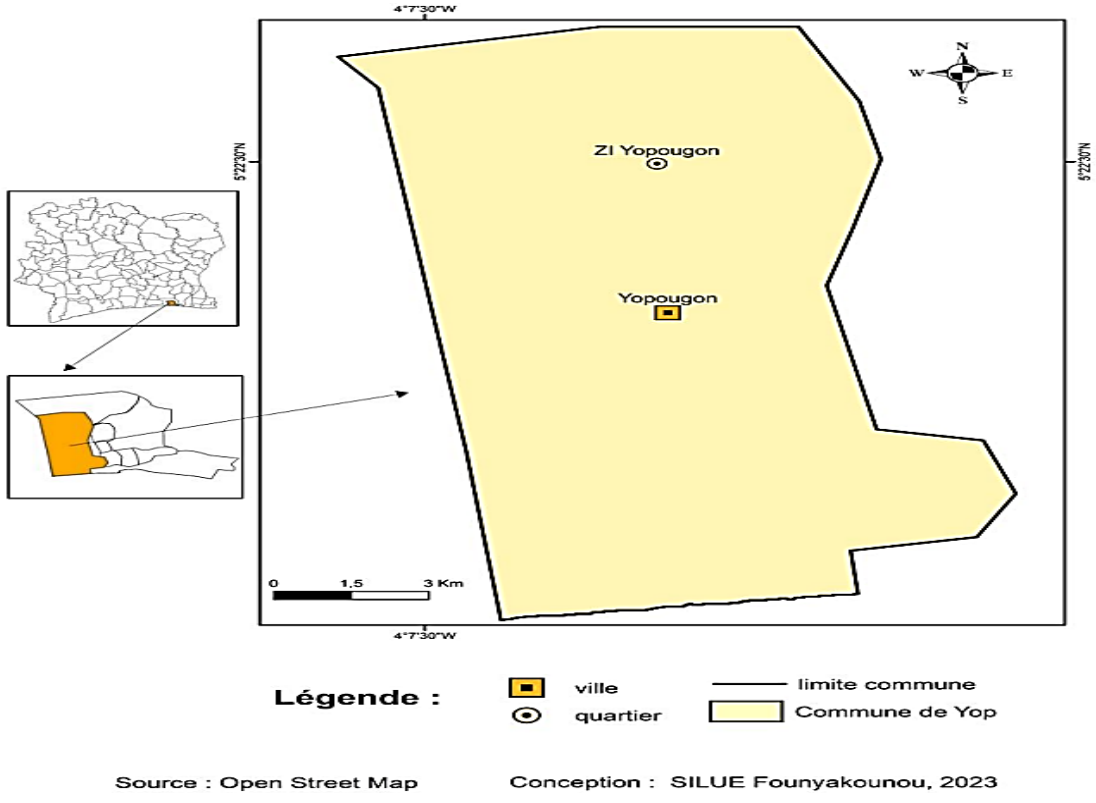

Figure 1. Location of study area

2.1.2. *Clay materials*

The clays used in this study are referenced BIN and KAT (**Figure 2**). The BIN clay was extracted at 5°18' north latitude and 3°50' west longitude at Bregbo in the town of Bingerville in the Autonomous District of Abidjan. The KAT clay comes from the town of Katiola in the Hambol region of northern Côte d'Ivoire, at 8°08' north latitude and 5°06' west longitude. The main characteristics of these clays are listed in **Table 1** (mineralogical composition, specific surface area and cation exchange capacity) below.

Figure 2. Images of clay samples BIN (a) and KAT (b)

Table 1. Mineralogical composition and physicochemical properties of BIN and KAT clays (Kouadio *et al.*, 2022)

Sample	% Kaolinite	% Illite	% Smectite	% Quartz	% Goethite	CEC (meq/100g)	S_{BET} (m^2/g)
BIN	52.21	6.23	-	17.50	15.71	6.2	31.7
KAT	48.08	3.55	20.14	6.11	16.86	35.47	48.5

2.2. *Methods*

2.2.1. *Industrial effluent sampling*

Sampling points were selected on the basis of their potential to reflect metallic pollution. Two samples were taken at the site. The first sample was taken upstream of the discharge channel (close to the companies responsible for the effluent) and the second sample was taken downstream (where the effluent comes into contact with other liquids such as toilet water). Effluents were sampled using half-litre (500mL) glass bottles. These bottles were thoroughly rinsed with 10% hydrochloric acid, then twice with distilled water. Samples were taken with hands protected by sterile gloves to avoid contamination. Samples were immediately stored on ice in a cooler and taken to the laboratory. Prior to analysis, the effluent was kept at 4°C in a refrigerator to prevent any degradation. A total of two (02) water samples were collected (**Figure 3**). Samples Z_1 and Z_2 represent effluent upstream and downstream of the discharge channel respectively.

2.2.2. *Effluent analysis*

Parameters such as pH, conductivity, turbidity and trace metal concentrations were measured. Water pH was measured using a HANNA HI 2211 pH meter. Conductivity was determined using a HANNA

HI98192 “EC/TDS/NaCl/Resistivity” conductivity meter. A HANNA HI98713 turbidity meter was used to determine turbidity. Metals in the water were determined using a Perkin Elmer Optima 2100 DV induction plasma-coupled optical emission spectrometer (ICP-OES). The metals analyzed were: mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As), copper (Cu), nickel (Ni), zinc (Zn), chromium (Cr), cobalt (Co) and manganese (Mn).

Figure 3. Effluent samples from the industrial zone (Z_1 and Z_2)

2.2.3. Adsorption study

A part of each effluent was treated with each of the two clays (BIN and KAT). A clay mass of 1.25g was introduced into a 250 mL beaker containing 125 mL effluent. The clay-to-liquid ratio was 10g per liter. Mixtures were agitated at 600 rpm for 90 minutes using a DWB MS-PB magnetic stirrer at room temperature. Following agitation, the mixture was placed in test tubes and centrifuged at 6000 rpm for 15 minutes. The supernatant liquid was then collected for chemical compound analysis by ICP-OES to determine residual trace metal concentrations. The removal of chemical species by clays was assessed by calculating the adsorption capacity Q ($Q = \frac{C_0 - C_t}{m} V$) and percentage elimination R ($R = \frac{C_0 - C_t}{C_0} * 100$). **Figure 4** summarizes the metal adsorption protocol. The Z_1 and Z_2 effluents treated with Bingerville clay are denoted Z_{1BIN} and Z_{2BIN} respectively. Z_{1KAT} and Z_{2KAT} represent respectively Z_1 and Z_2 effluents treated by Katiola clay.

3. Results and Discussion

3.1 Physicochemical properties of industrial effluents

Figure 5 shows the results obtained for pH, conductivity and turbidity, before and after clay treatment.

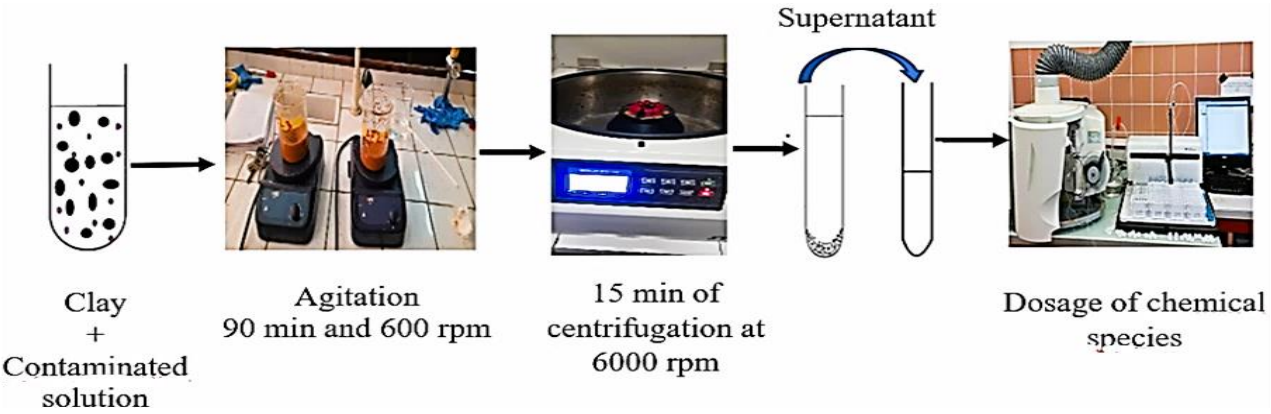

Figure 4. Metal adsorption protocol

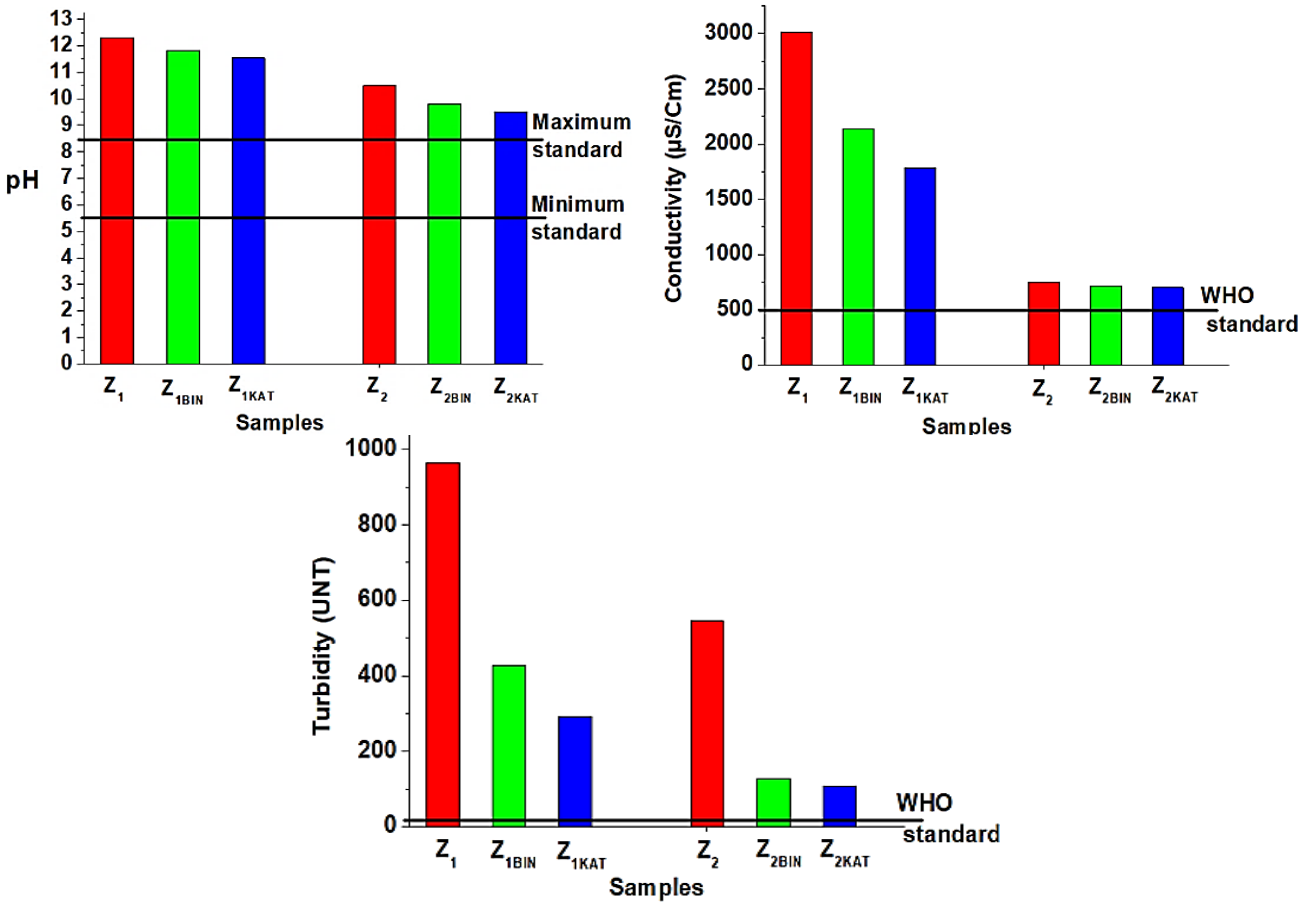

Figure 5. pH, Conductivity and Turbidity of water sample before (Z_1 and Z_2) and after clay treatment (Z_{1BIN}, Z_{1KAT}, Z_{2BIN} and Z_{2KAT})

3.1.1. Hydrogen potential (pH)

pH values ranged from 9.5 to 12.83. The pH values of Z_1 samples ranged from 12.30 to 11.54 after treatment with clays. As for Z_2 effluents, after treatment with clays, pH values ranged from 10.5 to 9.5. These values clearly show that these liquid wastes are basic (pH > 7). The basicity of the effluents is thought to be due to discharges from a soap production plant close to the sampling site. Treatment of this effluent with clays reduced the pH somewhat. However, the values still do not comply with the Ivorian standard, which suggests that pH values for industrial effluent should be between 5.5 and 8.5. This result shows that treatment of these effluents by adsorption on clay is not totally effective in obtaining a pH that complies with the national standard. Further treatment is therefore necessary.

3.1.2. Conductivity

Untreated effluent Z_1 has a high conductivity (3014 µS/cm), which is 4 times that of Z_2 (750.9 µS/cm), although the latter is high. Effluent treatment with clays has considerably reduced the conductivity of Z_1 (from 3014 µS/cm to 2138 µS/cm with Bingerville clay and to 1786 µS/cm with Katiola clay). While Z_2 conductivity decreased slightly (from 750.9 µS/cm to 716 µS/cm with Bingerville clay and to 702 µS/cm with Katiola clay). Z_1 conductivity fell from 3014 to 2138 and 1786 µS/cm with Bingerville and Katiola clays respectively, a reduction of 29% and 57%. The conductivity of sample Z_2 was reduced from 750.9 µS/cm to 716 µS/cm with Bingerville clay and to 702 µS/cm with Katiola clay, i.e. a reduction of 4% and 6% respectively. Before or after treatment with clay, the conductivities of the effluents studied were higher than the WHO standard for drinking water (500 µS/cm) (Hadzi, *et al.*, 2015). The high conductivity values of raw effluents prove that these industrial effluents contain large quantities of ionic compounds (Ouabou, *et al.*, 2014).

The higher conductivity obtained in Z_1 suggests that the upstream effluent (closer to the companies responsible for industrial discharges) is more ion-laden than the effluent sampled downstream, which is in contact with toilet water (Z_2). The decrease in conductivity after treatment with clays would be due to the reduction of ions in solution caused by their adsorption to the surface of the clays.

3.1.3. Turbidity

The turbidity of effluent Z_1 (965 NTU) is significantly higher than that of Z_2 (545 NTU). The clay treatment significantly reduced the turbidity values of both effluents. The turbidity of Z_1 was reduced from 965 NTU to 428 NTU with BIN clay and to 291 NTU with KAT clay, a reduction of 55 and 69% respectively. As for Z_2, turbidity decreased from 545 NTU to 127 and 108 NTU respectively with BIN and KAT clays, a reduction of 76 and 80%. Turbidity values before and after treatment remain above the WHO recommended standard for drinking water (Hadzi, *et al.*, 2015). The reduction in turbidity can be seen in **figure 6**, with darker colors for untreated raw effluent and lighter colors for clay-treated samples. This significant reduction in turbidity can be interpreted as an adsorption of dissolved substances in the effluent onto the clay surface (Djaani and Amer, 2020). The greater reduction in turbidity obtained with Katiola clay is in line with the conductivity results and is due to its greater adsorption properties.

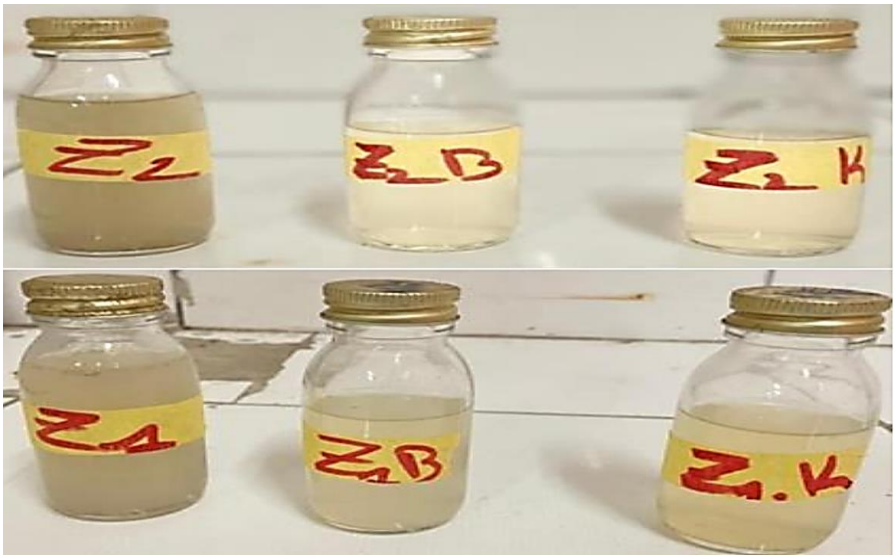

Figure 6. Industrial effluent samples before (Z_1 and Z_2) and after clay treatment (Z_{1BIN}; Z_{1KAT}; Z_{2BIN} and Z_{2KAT})

3.1.4. Trace metal content in untreated effluent

ICP analysis of industrial effluents revealed the presence of heavy metals such as mercury, lead, cadmium, arsenic, copper, nickel, zinc, chromium, cobalt and manganese. **Table 2** shows metal concentrations in untreated samples Z_1 and Z_2. Concentrations of lead, arsenic, chromium, manganese, nickel, zinc, copper, mercury and cobalt in raw samples Z_1 and Z_2 are 31.6 and 22.6 µg/L; 10.5 and 12.3 µg/L; 17.9 and 13.2 µg/L; 177.0 and 34.5 µg/L; 48.7 and 10.8 µg/L; 78.9 and 22.3 µg/L; 65.4 and 17.8 µg/L and 3.2 and 1.7 µg/L respectively. These various levels are generally below the maximum limits recommended by the national discharge standard for industrial effluents, which are 500 µg/L for lead, 50 µg/L for arsenic, 500 µg/L for chromium, 1000 µg/L for manganese, 500 µg/L for nickel, 2000 µg/L for zinc, 500 µg/L for copper and 10 µg/L for mercury (MEF (Ministère de l'Environnement et de la Foret), 2008).

Table 2. Metal content (Pb, Cd, As, Cr, Mn, Ni, Zn, Cu, Hg and Co) in µg/L in raw effluent Z_1 and Z_2

	Pb	Cd	As	Cr	Mn	Ni	Zn	Cu	Hg	Co	Total
Z_1	31.6	16.4	10.5	17.9	177.0	48.7	78.9	65.4	3.2	17.3	466.9
Z_2	22.6	18.1	12.3	13.2	34.5	10.8	22.3	17.8	1.7	20.3	173.6
National reject standard (MEF (Ministère de l'Environnement et de la Foret), 2008)	500	10	50	500	1000	500	5000	500	10	-	

However, lead and arsenic levels in Z_1 and Z_2 are higher than their WHO surface water limit of 10 µg/L (Bempah and Ewusi, 2016). Cadmium levels in Z_1 and Z_2 (16.4 and 18.1 µg/L respectively) exceed both its industrial effluent discharge standard (10 µg/L) and its surface water limit value (3 µg/L). Manganese levels in Z_1 and Z_2 are respectively above and below its surface water limit value (100 µg/L). Cobalt levels in Z_1 and Z_2 are respectively below and above its limit value (20 µg/L). For all the metals studied, the total content in sample Z_1 was 466.9 µg/L, compared with 173.6 µg/L for effluent Z_2. The higher metal contents obtained in effluent Z_1 compared to Z_2 are in agreement with the conductivity results. This observation confirms that the Z_1 sample is more ion-laden than the Z_2 effluent. The relatively high metal contents in the effluents studied show that these liquids are generally contaminated and should not meet surface waters (lagoons, rivers, etc.) before treatment.

3.1.5. Trace metal content in treated effluent

Tables 3 and **4** show, respectively, metal concentrations in samples Z_1 and Z_2 before and after treatment with BIN and KAT clays, as well as adsorption capacities (Q_{BIN} and Q_{KAT}) and removal percentages (R_{BIN} and R_{KAT}). Metal content results are also shown in **Figures 7** and **8**. Clay treatment had varying effects on pollutant concentration. Lead levels rose to 30.6 µg/L with the BIN clay, versus 29.7 µg/L with KAT for effluent Z_1. For sample Z_2, lead concentrations fell to 18.3 and 15.8 µg/L respectively after treatment with BIN and KAT. The rate of lead concentration reduction in Z_1 was 3.2% for the BIN clay versus 6% for the KAT clay, representing adsorption capacities of 0.1 and 0.2 µg/g respectively. In sample Z_2, the percentage lead reduction is 19% for BIN and 30.1% for KAT, i.e. adsorption capacities of 0.4 and 0.7 µg/g respectively.

Table 3. Metal content in Z_1 industrial effluent before and after treatment (Z_{1BIN} and Z_{1KAT}), percentage removal and clay adsorption capacity

	Pb	Cd	As	Cr	Mn	Ni	Zn	Cu	Hg	Co	Total
Z_1	31.6	16.4	10.5	17.9	177.0	48.7	78.9	65.4	3.2	17.3	466.9
Z_{1BIN} (µg/L)	30.6	10.3	12.7	10.8	143.0	45.2	70.6	63.6	2.8	16.3	405.9
R_{1BIN} (%)	3.2	37.2	-21.0	39.7	19.2	7.2	10.5	2.8	13.7	5.8	13.1
Q_{1BIN} (µg/g)	0.1	0.61	-0.22	0.71	3.4	0.35	0.83	0.18	0.04	0.1	6.1
Z_{1KAT}(µg/L)	29.7	17.5	11.6	11.3	110.0	44.3	65.8	59.7	1.9	13.4	365.2
R_{1KAT} (%)	6.0	-6.7	-10.5	36.9	37.9	9.0	16.6	8.7	41.1	22.5	21.8
Q_{1KAT}(µg/g)	0.2	-0.1	-0.1	0.7	6.7	0.4	1.3	0.6	0.1	0.4	10.2

Table 4. Metal content in industrial effluent Z_2 before and after treatment (Z_{2BIN} and Z_{2KAT}), percentage removal and clay adsorption capacity

	Pb	Cd	As	Cr	Mn	Ni	Zn	Cu	Hg	Co	Total
Z_2	22.6	18.1	12.3	13.2	34.5	10.8	22.3	17.8	1.7	20.3	173.6
Z_{2BIN}(µg/L)	18.3	15.9	8.8	9.1	29.6	7.2	17.4	10.5	0.1	12.8	129.6
R_{2BIN}(%)	19.02	12.2	28.7	31.4	14.2	33.1	22.0	41.0	94.8	36.9	25.3
Q_{2BIN}(µg/g)	0.43	0.22	0.35	0.41	0.49	0.36	0.49	0.73	0.16	0.75	4.4
Z_{2KAT}(µg/L)	15.8	13.8	7.0	7.4	20.3	5.9	13.2	9.8	0.1	9.9	103.2
R_{2KAT}(%)	30.1	23.8	42.9	43.6	41.2	45.5	40.8	45.1	95.8	51.4	40.6
Q_{2KAT}(µg/g)	0.7	0.4	0.5	0.6	1.4	0.5	0.9	0.8	0.2	1.0	7.0

In the Z_1 effluent, cadmium content fell by 37.2% for BIN, giving an adsorption capacity of 0.6 µg/g. However, for the KAT clay, a 6.7% increase of cadmium content was observed. As for sample Z_2, cadmium content decreased by 12.2% for BIN versus 23.8% for KAT, with adsorption capacities of 0.2 and 0.4 µg/g respectively. The initial arsenic content in sample Z_1 increased by 21% after treatment with BIN clay and by 10.5% after treatment with KAT. However, in sample Z_2, this concentration decreased by 28.7% for BIN and 42.9% for KAT, representing adsorption capacities of 0.4 and 0.5 µg/g respectively. Treatment of effluent Z_1 with BIN and KAT reduced chromium concentration by 39.7% and 36.9% respectively, giving adsorption capacities of 0.7 µg/g for both clays. As for sample Z_2, the percentage reduction of chromium was 31.4% for BIN and 43.6% for KAT, with adsorption capacities of 0.4 and 0.6 µg/g respectively. The initial manganese concentration in sample Z_1 decreased by 19.2% and 37.9% after treatment with BIN and KAT respectively, representing adsorption capacities of 3.4 and 6.7 µg/g. In sample Z_2, this content decreased by 14.2% after treatment with BIN and 41.2% after treatment with KAT, an adsorption capacity of 0.5 and 1.4 µg/g respectively. Nickel was removed from Z_1 at 7.2% and 9% after treatment with BIN and KAT respectively, representing an adsorption capacity of 0.4 µg/g for both clays. However, in the Z_2 effluent, the BIN clay adsorbed 33.1% nickel compared with 45.5% with the KAT clay. The adsorption capacity of BIN and KAT is 0.4 and 0.5 µg/g respectively, relative to nickel removal. BIN and KAT clays adsorbed 10.5% and 16.6% of the initial zinc content respectively in sample Z_1, representing adsorption capacities of 0.8 and 1.3 µg/g. In sample Z_2, 22% and 40.8% of the initial zinc concentration is removed by the BIN and KAT clays respectively.

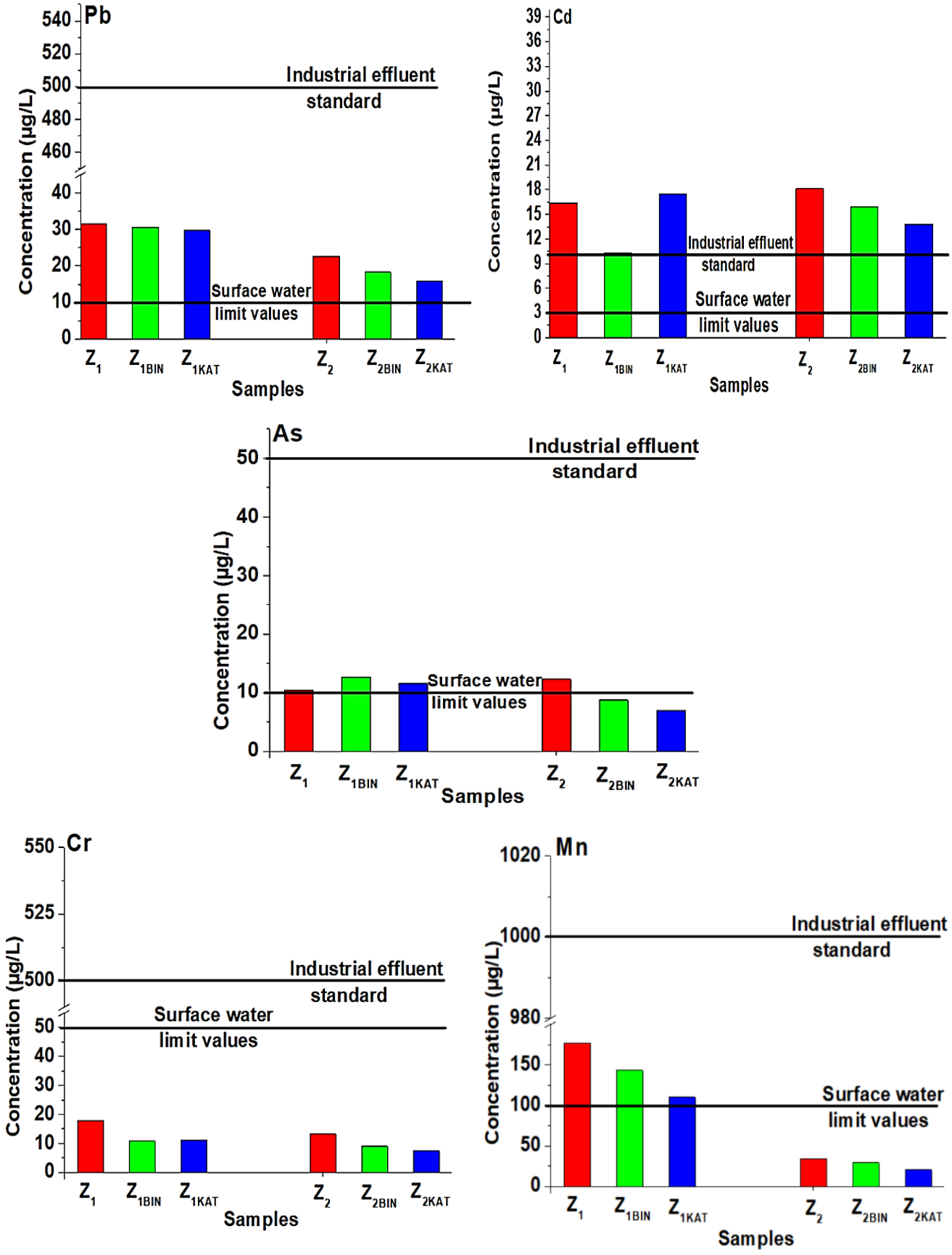

Figure 7. Concentration of Pb, Cd, As, Cr and Mn in liquid waste before (Z_1 and Z_2) and after treatment with the clays BIN (Z_{1BIN} and Z_{2BIN}) and KAT (Z_{1KAT} and Z_{2KAT})

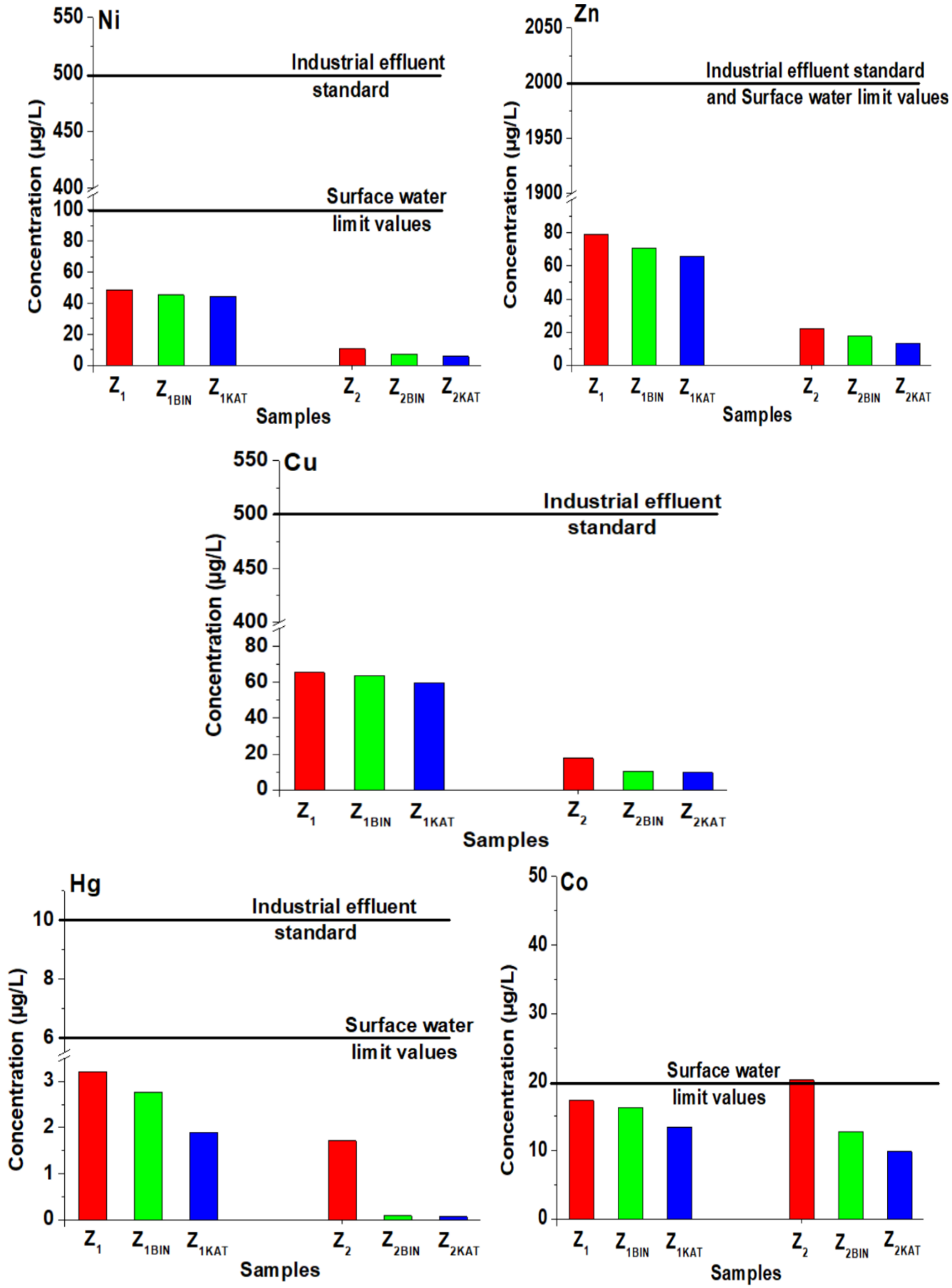

Figure 8. Concentration of Ni, Zn, Cu, Hg and Co in liquid waste before (Z_1 and Z_2) and after treatment with the clays BIN (Z_{1BIN} and Z_{2BIN}) and KAT (Z_{1KAT} and Z_{2KAT})

The adsorption capacity of BIN and KAT in Z_2 is 0.5 and 0.9 µg/g respectively, relative to zinc removal. The copper reduction rate in the Z_1 effluent is 2.8% after treatment with BIN versus 8.7% for KAT, with an adsorption capacity of 0.2 and 0.6 µg/g respectively. On the other hand, after treatment with BIN and KAT, the copper content in Z_2 decreased by 41% (0.7 µg/g) and 45.1% (0.8 µg/g) respectively. The adsorption capacities of BIN and KAT clays for mercury removal in Z_1 are 0.04 µg/g (13.7% reduction) and 0.1 µg/g (41.1% reduction) respectively. For sample Z_2, the mercury concentration reduction rate is 94.8% (or 0.2 µg/g) for BIN clay and 95.8% (or 0.2 µg/g) for KAT clay. As for cobalt concentration, in effluent Z_1, the initial content is reduced by 5.8% by BIN clay and by 22.5% by KAT clay. The adsorption capacity of BIN and KAT clays in the Z_1 sample is 0.1 and 0.4 µg/g respectively. However, treatment of the Z_2 effluent with the clays reduced the cobalt concentration by 36.9% for BIN and 51.4% for KAT, representing adsorption capacities of 0.8 and 1 µg/g respectively.

For all metals studied, the total content in sample Z_1 fell from 466.9 µg/L to 405.9 µg/L after treatment with BIN clay, a reduction of 13.1%, versus 365.2 µg/L with KAT, a reduction of 21.8%. As for effluent Z_2, the total content decreased from 173.6 µg/L to 129.6 µg/L with BIN, versus 103.2 µg/L with KAT. Pollutant levels in Z_2 dropped by 25.3% and 40.6% after treatment with BIN and KAT clays respectively.

Although metal concentrations in effluent have generally been reduced by treatment with clays, they are still above their different limit values, except for arsenic and cobalt concentrations in effluent Z_2. The reduction in metal content in effluent after treatment is due to the binding of these pollutants to the clay surface. Clays are known for their ability to eliminate toxic metals and other pollutants from wastewater (Zhao *et al.*, 2023). This efficiency is due to their large specific surface area, their cation exchange capacity and their negative charge, which give them a high adsorption capacity *(Kouadio et al.*, 2024).

The results show varying degrees of adsorption of metals from effluent. Pollutant removal efficiency depends on both the clays and the nature of the metals. In general, Katiola clay has higher pollutant adsorption capacities than Bingerville clay. Indeed, this clay is rich in 2:1 minerals such as smectites (20.14%), unlike Bingerville clay, which contains mainly kaolinite (52.21%), a 1:1 mineral. The composition of the two clays gives the KAT sample (S_{BET} = 48.5 m2/g and CEC = 35.5 meq/100g) greater adsorbent properties than BIN (S_{BET} = 31.7 m^2/g and CEC = 6.2 meq/100g) (Kouadio *et al.*, 2022). The mineralogical and physico-chemical characteristics of these two clays explain their difference in pollutant removal. Moreover, the best removal efficiencies are obtained for mercury, followed by chromium, cobalt, manganese, copper, nickel, zinc, cadmium, lead and arsenic. Of the ten metals, mercury adsorbs preferentially to clays, ahead of the other nine. Arsenic is the least adsorbed of the metals studied. Like this work, several studies have reported cases of preferential adsorption. AL-Hamandi et al. found in their research that in multi-element systems, competition between various metals caused preferential adsorption (AL-Hamandi *et al.*, 2024). In a similar vein to the present study, they showed that adsorption was best for copper, followed by zinc and finally cadmium. Unlike the present study, in their work, lead was the best adsorbed. This difference may be linked to the pH of the solutions to be depolluted and the nature of the ions to be eliminated. As the effluents studied (Z_1 and Z_2) are basic, the surface of the clay in solution is negatively charged due to the deprotonation of the silanol and aluminol groups at the edges of the sheets ($-SiOH + OH^- \Leftrightarrow -Si-O^- + H_2O$ and $-AlOH + OH^- \Leftrightarrow -Al-O^- + H_2O$) (Kouadio *et al.*, 2024). Consequently, an electrostatic repulsion is established between the arsenic compounds, which are oxyanions, and the negatively charged clay surface, thus

justifying the low arsenic adsorption rate. Moreover, this observation could explain the arsenic desorptions observed in the Z_1 effluent. The differences in adsorption between metal cations could be explained by their different affinities with clays. Indeed, at higher pH, some metal cations are adsorbed on the edges of clay particles, forming either monodentate or bidentate complexes (Li *et al.*, 2024) (Srivastava *et al.*, 2005).

4. Conclusion

The specific aims of this study were to determine the metal content in industrial effluents and to assess the adsorption capacity of clays from two Côte d'Ivoire towns (Katiola and Bingerville), in the removal of species contained in these wastewaters. Firstly, the studies involved analyzing wastewater from an effluent discharge canal in the Yopougon industrial zone in the city of Abidjan. Two samples were taken upstream and downstream of this effluent discharge canal. The analyses consisted in determining physicochemical parameters such as pH, turbidity, conductivity and levels of trace metals (Hg, Pb, Cd, As, Cr, Mn, Cu, Zn, Co, Ni). Secondly, the sampled effluents were treated by adsorption on clays from Bingerville (BIN) and Katiola (KAT).

The analyses carried out revealed that the effluents sampled were basic, with high conductivity and turbidity values. The effluent is polluted with metals. Levels of lead, cadmium, arsenic, manganese and cobalt are all above the different surface water limits recommended by the WHO. Wastewater treatment has generally shown a reduction in metal levels due to the adsorption of these chemical species to clay surfaces. Mercury is the most adsorbed, with a removal rate of 95.8%. Metal removal rates in effluent are generally higher after treatment with Katiola clay. The high adsorption capacity of KAT clay is linked to its mineralogical composition (20.14% smectite), its greater specific surface area and its high cation exchange capacity. For all metals, the removal rate is less than 50% (ranging from 13.1 to 40.6%). Although the adsorption technique is effective, a clay material with a higher adsorption capacity, such as iron- or aluminum-bridged clays, would be needed to remove more and more trace metals.

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