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Impact of Treated Wastewater on The Leaching of a Copper and Cobalt Ore: A Study by the Katanga Mining Company in Lubumbashi, Democratic Republic of Congo

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Abstract: Katanga mining company has storage basins for the water used in the production of cobalt hydroxides. This used water is neutralized before being discharged back into nature. This research study examines the treatment of this used water with a view to its recycling during the leaching of the Copper-cobalt ores.

After the physicochemical characterization of the water samples and their chemical characterization of the water samples and their chemical, mineralogical and granulometric analysis, the tests for treatment of the used waters were carried out with the help of calcium carbonate, quicklime, active carbon, cationic resin and combinations involving quicklime, active carbon and an ion-exchange resin .Following the treatment of the used water concerned, leaching tests of the heterogenite were carried out under the real hydrometallurgical operating conditions of Katanga mining company .

The results obtained have shown that the recycling of this used water influences the performance of the heterogeneity teaching. Indeed, the best results were obtained during the treatment of the used water 2 g of quicklime and 1 g of active carbon. Under thesis conditions, the concentrations of impurities such as Cu, Co, Fe, Zn and Cr have significantly decreased in the used water, the pH of which has been 6.46. As for the heterogeneity teaching tests, the best performances were obtained during total recycling (100 %) of the treated water with an acidity, time and density of 130 g/L, 6h and 1.25 respectively. Under thesis conditions, leaching yields of 81.95% Cu and 86.08%Co were achieved, compared to the performances of the teaching with feed water (85.32% Cu and 88.01% Co).

Thesis heterogeneity teaching performances allow considering the treatment and recycling of the used water as not recycling of the used water as an interesting alternative that not only makes it possible to sustainably manage the water resources of SOMIKA, but also to reduce the environmental footprint of its hydrometallurgical process and to release more water for use in the environment of the recycling is integral , without disturbance on the whole mineral processing circuit at Katanga mining company .

Keywords: *Recycling, Treatment, Processing, Hydrometallurgy, Performance, Neutralization.*

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I. INTRODUCTION

Mining industry researchers rely on the extraction of significant quantities of metals present in water, particularly through hydrometallurgy. This process is widely used in mines, particularly in the Zambian region of the Democratic Republic of the Congo, where the Katanga Mining Company is located.

In this context, cobalt is produced using hydroxides from ores containing copper-bearing elements and other substances located in the Lubumbashi Valley. Cobalt extraction involves steps such as mineral separation, as well

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as cobalt purification through a dehydration and filtration process, which takes place under the influence of wastewater, requiring storage in basins. This wastewater management is essential to preserve the environment while enabling cobalt production.

The treatment of wastewater and cobalt hydroxides from copper ores and other substances present in the Lubumbashi Valley plays a crucial role. Copper and cobalt production involves the implementation of solutions for the ores, as well as the purification of cobalt by extraction using methods using cobalt in the form of hydroxides. These processes must also take into account wastewater management, which requires adequate storage.

However, the recycling of this wastewater has not yet been sufficiently studied, which poses a challenge for the industrial sector of the Katanga Mining Company. This project aims to analyze the impact of wastewater in the hydrometallurgical operations of the Katanga Mining Company and to evaluate the effects of its recycling on the performance of heterogenite leaching. The objective is to guide future initiatives concerning the sustainable use of the Katanga Mining Company's hydrometallurgical resources.

The environmental impact of the hydrometallurgical plants of the Katanga Mining Company. To achieve this, wastewater samples were characterized based on various parameters, including chemical, mineralogical, and environmental aspects. Subsequently, treatment tests were carried out on this water using activated carbon and calcium, as well as calcium hydroxide, with an emphasis on the predominant role of the chemical elements present. The results show that activated carbon and cationic resin, used to reduce heavy metal concentrations, play a key role in optimizing ion exchange processes. The objective is to reduce the heterogeneity of wastewater and improve the efficiency of the hydrometallurgical plants the Mining Company of Katanga, as well as the water supply.

II. MATERIALS AND METHODS

➢ *Results of Sample Characterization*

The characterization of samples consisting of wastewater, feed water from the hydrometallurgical plants the mining company of Katanga and heterogenite led to the results presented and interpreted below.

- *Results of the Physicochemical Characterization of Water Samples*

Table 1 shows the results of the physicochemical characterization of wastewater and feed water from the hydrometallurgical plants of the Mining Company of Katanga.

Table 1 Physicochemical Characteristics of the Water Samples Analyzed

Setting	Water supply	Wastewater
TDS	330 ppm	0.25 g/L
pH	7.91	7.56
Cu	29 ppm	0.15 g/L
Co	-	2.17g/L
Mn	60 ppm	1.11g/L
Zn	21 ppm	0.25 g/L
Cr	-	0.16 g/L
Ca	540 ppm	1.90 g/L
Mg	360 ppm	9.62 g/L
Fe	887 ppm	1.58 g/L

Reading the results in Table 1 shows that the pH of the feed water of the Katanga Mining Company plants (7.91) and that of the waste water are slightly alkaline and close to neutrality. However, the feed water of the plants has a low salinity compared to that of the waste water where appreciable concentrations of different chemical elements analyzed were observed. This presence of chemical elements justifies their treatment.

- *Results of Chemical Characterization of Heterogenite*

The results of the chemical analysis of the heterogenite are presented in Table 2 below.

Table 2 Chemical Composition of Heterogenite

Elements	Cu	Co	Fe	Mn	Zn	Cr	Cd
Content (%)	0.53	1.82	16.81	1.41	0.004	0.02	0.03

The results in Table 2 reveal that the sample contains elements at varying levels. Iron, cobalt and manganese are present at significant levels, unlike other chemical elements analyzed.

- *Results of Mineralogical Characterization of Heterogenite*

Microscopic observation of the heterogenite sample under transmitted and reflected light revealed the presence of the following minerals:

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- ✓ Heterogenite: aCoO.bCo $_2$O$_3$. cCuO.dH$_2$O;
- ✓ Limonite: Fe$_2$O$_3$.nH$_2$O. pFeO (OH)nH$_2$O;
- ✓ Dolomite: CaMg ($_{CO3}$) $_2$;
- ✓ Quartz: SiO$_2$.

These results confirm the significant contents of iron, cobalt and manganese provided by the chemical analysis of the sample where the respective minerals carrying these chemical elements are found.

- *Results of the Granulometric Characterization of Heterogenite*

The results of the granulometric characterization of the heterogenite sample are presented in Table 3 and illustrated in Figure 1.

Table 3 Granulometric Characteristics of the Heterogenite Sample

Granulometric range (µm)	Mass (g)	Mass distribution (%)	Cumulative mass distribution (%)
+212	6.70	1.34	1.34
-212+150	10.60	2.12	3.46
-150+125	16.45	3.29	6.75
-125+106	26.15	5.23	11.98
-106+90	21.30	4.26	16.24
-90+75	22.40	4.50	20.74
-75	396.10	79.26	100
Total	499.70	100.00	

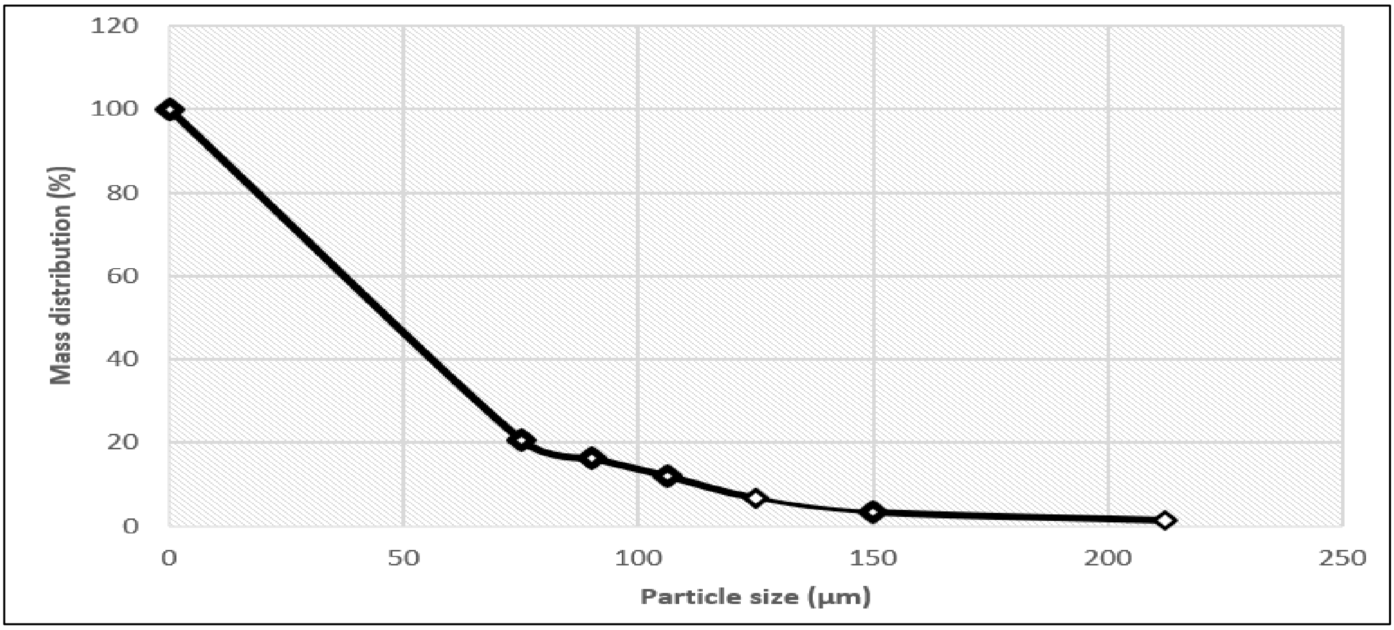

Fig 1 Mass Distribution as a Function of Particle Size

The heterogenite sample submitted for analysis contains approximately 21% of 75 µm sieve rejects. On the other hand, 79% of the particles are smaller than 75 µm. These results show that it is not necessary to grind this sample.

- *Results of the Treatment of Wastewater from the Mining Company Katanga*

It is important to remember that the aim of this treatment was to eliminate by precipitation and adsorption as many ions as possible of the chemical elements observed in the wastewater from the Katanga Mining Company.

- *Result of Wastewater Treatment using Calcium Carbonate*

This treatment was carried out by varying the mass of calcium carbonate added to the wastewater to be treated. The results of this treatment are shown in Table 4 below.

Table 4 Evolution of the Physicochemical Characteristics of Wastewater as a Function of the Mass of Calcium Carbonate

Mass of CaCO$_3$ (g)	Cu (ppm)	Co (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)	That (ppm)	Mg (ppm)	pH	TDS (ppm)
0.5	0.63	100	520	630	4.00	1.75	510	2610	7.0	230
1	0.59	97	510	600	3.87	1.67	530	2610	7.25	170
2	0.56	97	450	600	3.75	1.72	560	2620	7.38	240
3	0.21	96	430	540	0.90	1.27	700	2560	7.52	260

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Analysis of the results in Table 4 reveals that the concentrations of metal ions present (Cu, Co, Fe, Mn, Zn, Cr and Mg) decrease with the increase in the mass of calcium carbonate added to the wastewater.

- ✓ pH and TSD increase with the mass of calcium carbonate and this means that the wastewater becomes alkaline and salinity increases due to the presence of calcium and carbonate ions;
- ✓ The pH of the water seems to stabilize around 7.5 despite the addition of carbonate. Carbonate ions form insoluble compounds in water. These compounds are precipitated due to their solubility constants and consume the carbonate ions, preventing a rise in pH.
- ✓ Although the concentrations of metal ions decrease significantly in wastewater by precipitation with the reagent used, it still becomes a little harder due to the increase in its calcium ion concentrations.

- *Wastewater Treatment Using Calcium Hydroxide*

The wastewater treatment was carried out by varying the mass of calcium hydroxide and the test results are shown in Table 5.

Table 5 Evolution of the Physicochemical Characteristics of Wastewater as a Function of the Mass of Calcium Hydroxide (ppm)

Mass of Ca (OH) $_2$ (g)	Cu (ppm)	Co (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)	Ca (ppm)	Mg (ppm)	pH	TDS (ppm)
0.5	0.34	1280	490	260	3.23	1.91	460	2560	7.05	300
1	0.34	724	470	240	3.2	1.77	510	2430	7.35	250
2	0.32	610	440	210	1.95	1.42	750	729	7.51	230
3	0.31	530	430	210	-	1.35	768	540	7.65	220

The results presented in Table 5 show a decrease in the concentrations of ions of chemical elements (Cu, Co, Fe, Mn, Zn, Cr and Mg) and TDS as a function of the mass of calcium hydroxide added to the wastewater. This decrease is related to the precipitation of metal ions in the presence of hydroxide ions contained in the water. Furthermore, the concentration of calcium ions increases as with the mass of calcium hydroxide added. The best results were observed when the concentrations of the chemical elements in the treated water approached those of the feed water of the Mining Company Katanga, except for the following elements: Co (pH = 7.8 to 8.2), Mn (pH = 8 to 10.5), Mg (pH = 9.5 to 10.5) and Ca (pH = 12.4). Despite the increase in pH, these elements did not reach the acceptable values allowing the precipitation of the ions of these metals. The stabilization of the pH at 7.56 despite the addition of lime, is due to the consumption of hydroxide ions by the cations present in the water. Indeed, the addition of hydroxide ions promotes the formation of insoluble compounds, which precipitate in the form of hydroxide. This precipitation process is accompanied by the elimination of hydroxide ions, thus contributing to the stabilization of the pH.

- *Result of Wastewater Treatment with Activated Carbon*

The treatment of wastewater by adsorption of chemical element ions with activated carbon led to the results shown in Table 6.

Table 6 Evolution of the Physicochemical Characteristics of Wastewater with the Mass of Activated Carbon

Activated carbon (g)	Cu (ppm)	Co (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)	Ca (ppm)	Mg (ppm)	pH	TDS (ppm)
0.5	0.12	98	590	570	3.01	1.45	610	690	5.21	240
1	0.03	96	550	590	4.37	1.37	520	610	4.44	260
2	0.091	97	530	590	2.25	1.6	580	620	5.18	300
3	0.02	87	570	580	0.36	1.91	890	670	5.00	320

➢ *Analysis of the Table Results:*

- *Findings*

✓ *Best Results Achieved:*

The best performance was recorded with 1 g of activated carbon, due to significant removal of Cu, Co, Fe, Zn, Cr, Ca ions and TDS.

✓ *Water pH:*

The pH of the water obtained is 4.44, which indicates a decrease due to adsorption by activated carbon, particularly in the absence of dissolved oxygen in the water. In fact, the presence of activated carbon causes the suspension of oxygen ions, which promotes the conversion of oxygen into hydroxyl ions.

Table 7 Evolution of the Physicochemical Characteristics of Wastewater with the Mass of the Ion Exchange Resin.

Cationic resin(g)	Cu (ppm)	Co (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)	Ca (ppm)	Mg (ppm)	pH	TDS (ppm)
0.5	0.55	95	520	580	3.5	1.52	500	2610	7.45	170
1	0.11	96	530	550	2.12	1.48	450	2580	7.34	220

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2	0.61	114	510	420	0.74	1.16	350	2570	6.19	250
3	0.36	117	490	400	0.95	1.07	360	2540	6.40	280

Results obtained using the cationic resin show that increasing the exposure time leads to an increase in the concentration of copper and cobalt, as indicated by the conductivity tests (Fe, Cr and Ca) as well as a decrease in pH (6.19). This suggests that the resin fixes the metal ions present in the water. The increase in the levels of iron and other heavy metals in the water is noteworthy.

Overall, the results in Tables 5 and 6 reveal that wastewater treatment with cationic resin is less effective compared to the use of activated carbon. The latter is capable of reducing the concentration of hydronium ions, while decreasing the levels of calcium and calcium carbonate.

Wastewater treatment tests were also carried out with 1 g of activated carbon and varying the mass of quicklime used, are presented in Table 8.

Table 8 Evolution of the Physicochemical Characteristics of Wastewater Treated with 1 g of Activated Carbon and Different Masses of Quicklime

Quicklime(g)	**Cu (ppm)**	**Co (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Cr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**pH**	**TDS (ppm)**
0.5	0.36	14.25	0.806	4.48	0.039	0.236	809	600	6.87	90
1	0.15	14.04	0.581	3.62	0.032	0.205	855	580	7.45	120
2	0.06	13.37	0.201	3.29	0.018	0.079	862	490	7.76	200
3	0.40	12.75	0.199	3.13	0.014	0.042	955	330	9.87	230

- *Analysis of the Results in Table 8 Reveals that:*
  - ✓ Optimal wastewater treatment is achieved with 2 g of quicklime and a pH of 7.76, which corresponds to a level close to that of the feed water of the Katanga Mining Company.
  - ✓ At this concentration, an increase in pH, TDS and calcium concentration is observed.
  - ✓ The significant presence of calcium and magnesium makes the water hard, which can influence the performance of ore leaching and subsequent processing operations such as solvent extraction.

Table 9 Physicochemical Characteristics of Wastewater Treated with 1 g of Cationic Resin and Different Masses of Quicklime

Quicklime(g)	**Cu (ppm)**	**Co (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Cr (ppm)**	**Ca (ppm)**	**Mg (ppm)**	**pH**	**TDS (ppm)**
0.5	0.23	13.25	0.802	5.11	0.033	0.214	448	800	7.06	180
1	0.12	13.02	0.788	4.39	0.046	0.170	617	780	6.48	110
2	0.09	12.25	0.573	3,811	0.091	0.043	780	600	6.46	407
3	0.06	11.12	0.172	3,502	-	0.020	956	480	9.56	240

- *Analysis of the Results Obtained Shows that:*
  - ✓ pH and TSD increase with the addition of quicklime to wastewater. The best results are observed with 2 g of lime, reaching a pH of 6.46, which indicates an increased magnesium concentration.
  - ✓ Elements such as copper, cobalt, iron, manganese, zinc and chromium are also present in the treated water, although in minimal traces.
  - ✓ The results show that with 1 g of activated carbon and 2 g of quicklime, optimal performance is obtained. This combination appears to be the most effective for treating wastewater, due to its efficiency in leaching heterogenite.

➢ *Results of Heterogenite Leaching Tests*

The influence of acidity on heterogenite dissolution was studied during leaching tests, carried out for 4 hours at an ambient temperature of 27 °C. The tests were carried out at a constant pH of 1.25 and 1.5 respectively, varying the acidity to 110 g/L, 130 g/L and 150 g/L. The results of these tests are presented in Table **10 and** Figures **5 and 6**.

Table 10 Results of the Influence of Acidity on the Solubilization of Copper and Cobalt

Acidity (g/L)	**Solubility Cu g/L)**	**Co solubility (g/L)**	**Cu yield (g/L)**	**Co yield (g/L)**
110	6.69	10.44	73.31	75.7
130	9.82	13.01	82.42	85.02
150	7.53	12.67	75.25	82.67

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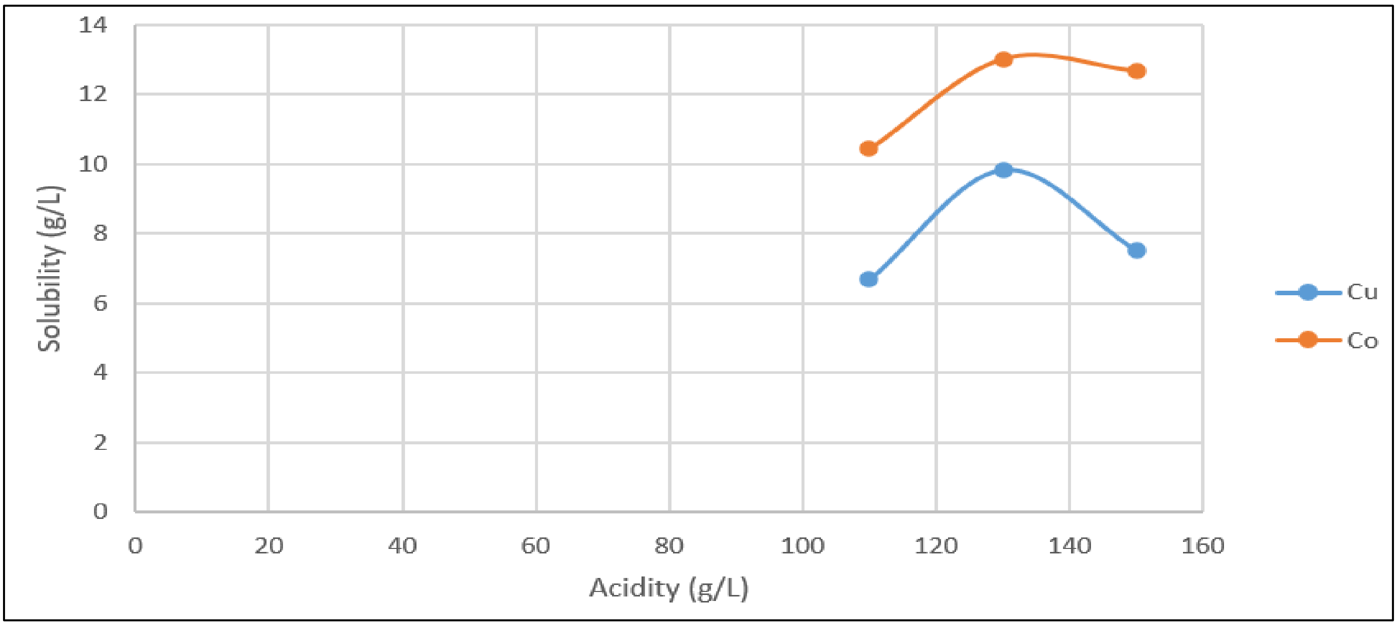

Fig 2 Solubility of Copper and Cobalt as a Function of Acidity

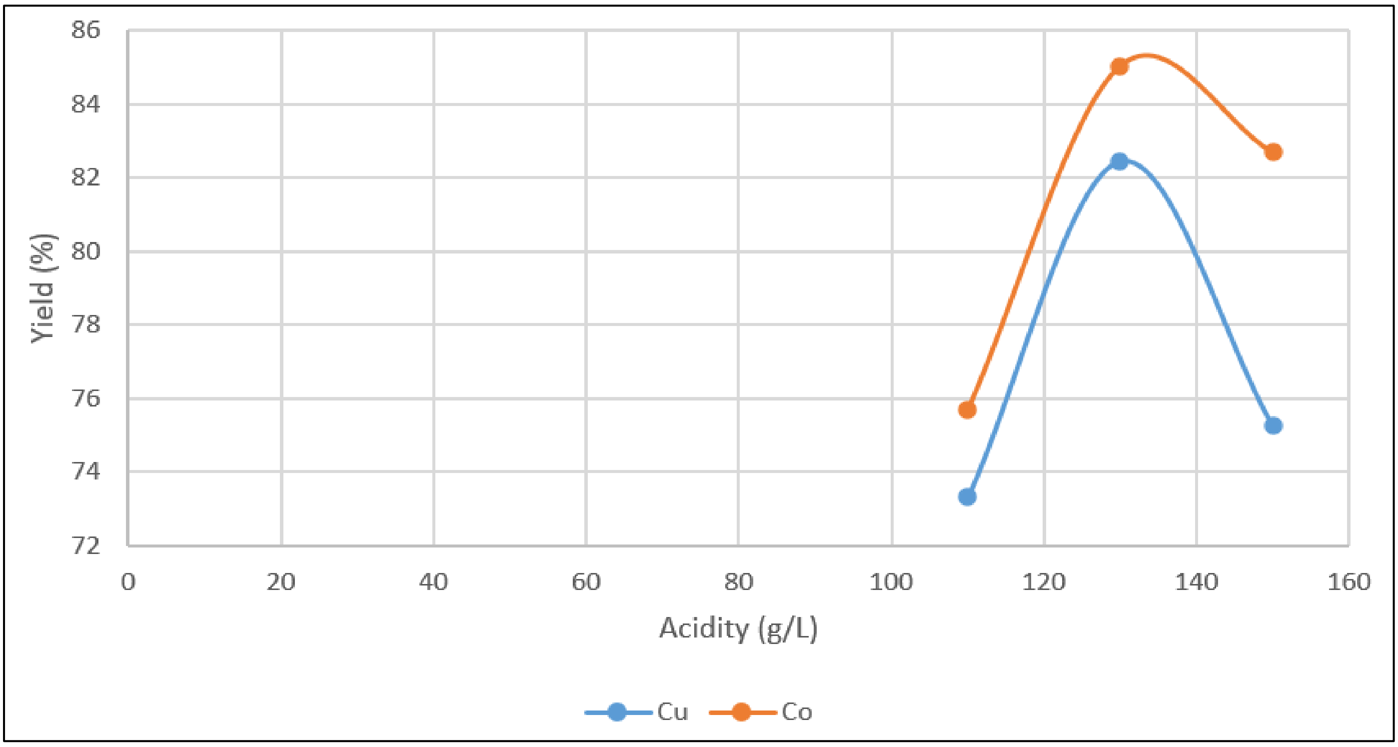

Fig 3 Solubilization Yield of Copper and Cobalt as a Function of Acidity

Analysis of the results in **Table 10** shows that the maximum concentrations of copper and cobalt are 9.82 g/L and 13.01 g/L, respectively, depending on the acidity conditions. Indeed, the tests indicate that the solubilization efficiencies are 82.42% and 85.02%, respectively, at an acidity of 130 g/L.

The curves in **Figures 2 and 3** reveal that increasing acidity beyond 130 g/L is accompanied by a significant decrease in solubility and solubilization efficiency. This decrease in results is due to the adverse effect of excessive acidity, which can lead to impurities affecting copper and cobalt concentrations. Under these conditions, we can conclude that the optimal acidity is 1.5, corresponding to sulfuric acidity.

➢ *Influence of Time*

Further heterogenite leaching tests were carried out at room temperature (27 °C) with varying time (2 to 6 hours), for a sulfuric acid concentration and density of 130 g/L and 1.25, respectively. The results of these tests are presented in **Table 11** which illustrates Figures 4 and 5.

Table 11 Results of the Influence of Time on the Solubilization of Copper and Cobalt

Time (hour)	Solubility Cu g/L)	Co solubility (g/L)	Yield Cu (g/L)	Yield Co (g/L)
2	7.76	11.32	77.8	79.1
4	10.32	12.96	83.25	82.97
6	10.76	14.26	84.76	87.21

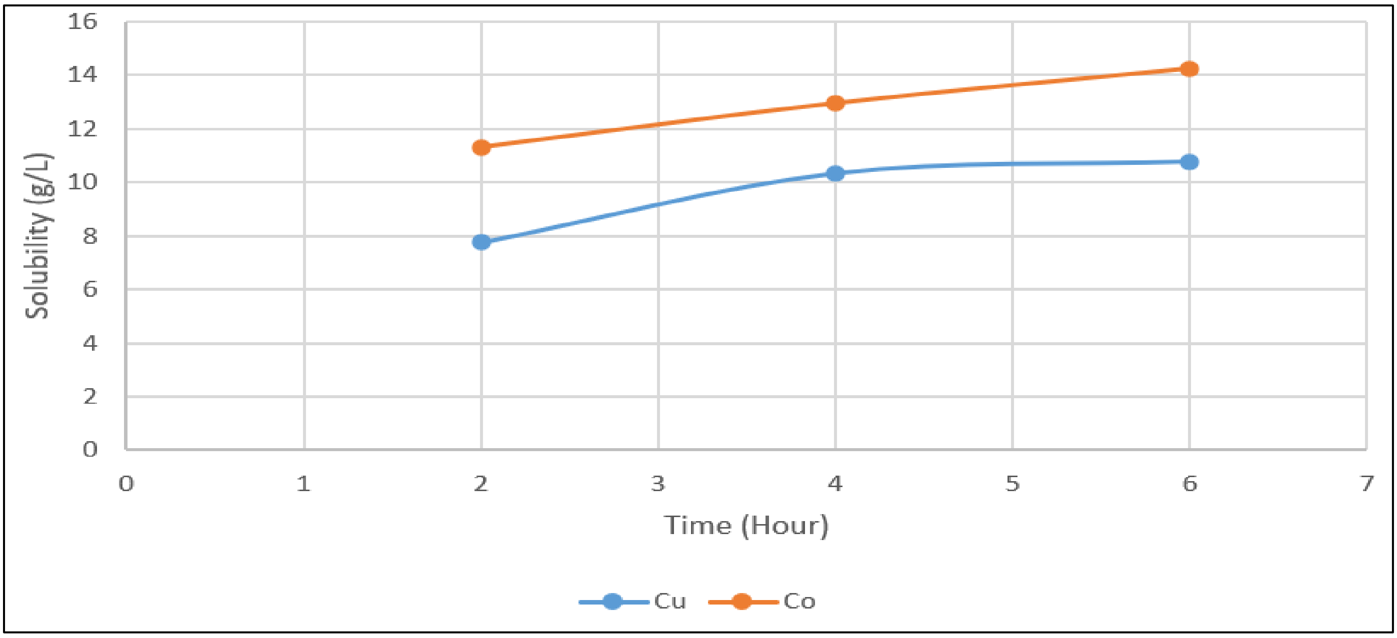

Fig 4 Solubility of Copper and Cobalt as a Function of Time

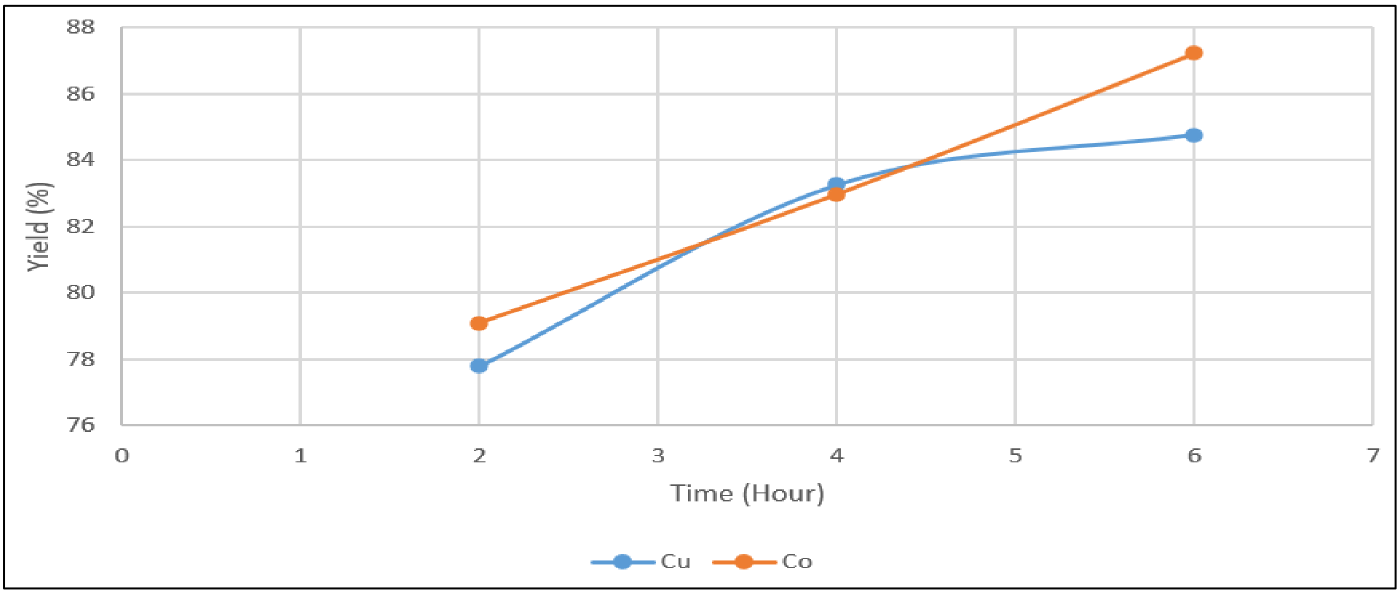

Fig 5 Solubilization Efficiency of Copper and Cobalt as a Function of Time

- *The Results Obtained Allow us to Make the Following Observations:*

✓ The best dissolution of copper and cobalt is observed after 6 hours of leaching with respective yields of 84.25% and 87.21%;

✓ Beyond 6 hours, a decrease in solubilization efficiency is expected due to acid depletion, which limits dissolution.

✓ Given the evolution of the degree of dissolution of copper and cobalt as a function of the increase in reaction time, it becomes important to take into account the influence of time in the context of the study of heterogeneity and activation time.

➢ *Influence of Pulp Density*

The heterogenite leaching tests were carried out by varying the pulp density (from 1.20 to 1.30), for a sulfuric acid concentration, a reaction time and a pH equal to 130 g/L. The results of these tests are presented in **Table 12,** illustrated schematically in Figures 6 and 7.

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Table 12 Results of the Influence of Density on the Solubilization of Copper and Cobalt

Density	Solubility Cu g/L)	Co solubility (g/L)	Cu yield (%)	Co yield (%)
1.2	6.73	11.97	74.3	80.32
1.25	9.05	13.45	81.96	86.08
1.3	5.73	11.03	67.3	78.26

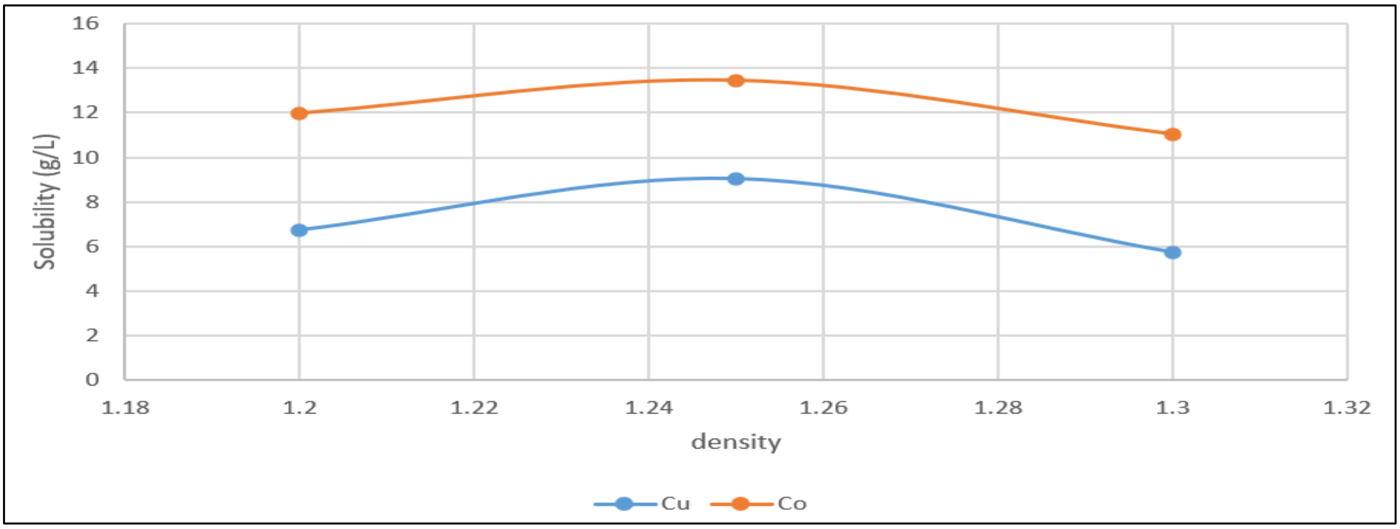

Fig 6 Solubility of Copper and Cobalt as a Function of Pulp Density

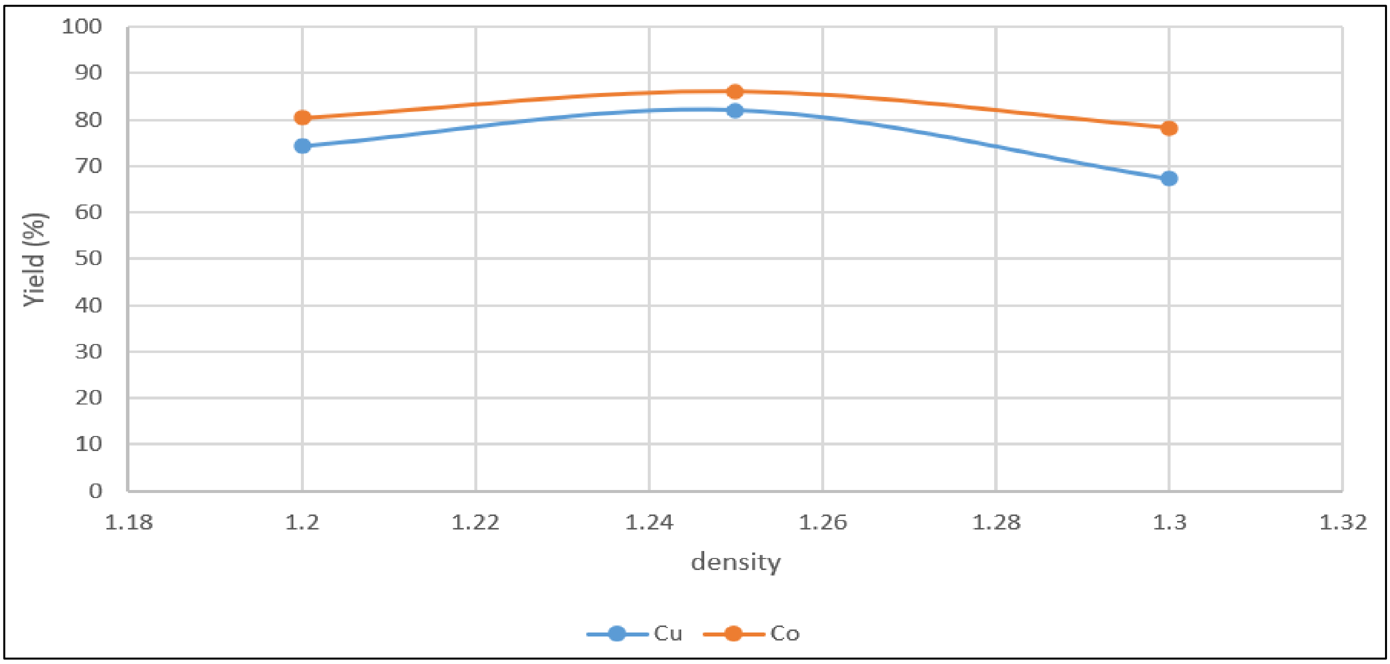

Fig 7 Solubilization Efficiency of Copper and Cobalt as a Function of Time

- *It Emerges from the Analysis of the Results Recorded in Table 13 that:*

✓ The best dissolution of copper is obtained with a pulp density of 1.25, i.e. the solubilization yields of copper and cobalt reach 81.96% and 86.08% respectively.

✓ These results show that the solubility as well as the solubilization yields of copper and cobalt increase with the density of the pulp up to 1.25 beyond which the yield may no longer be as favorable.

✓ Often, the density of the pulp subjected to leaching is generally between 25% and 40% by weight of solids. A very concentrated pulp, i.e. containing more than 40% of solids, can lead to proven mineral losses (Corneille and Masson A., 1973).

➢ *Leaching Results with Feed Water*

This heterogenite leaching test was carried out under the following conditions:

- Acid: 130 g/L;
- Time: to be specified
- Density: 1.25;
- pH: 1.5

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Table 13 Results of Copper and Cobalt Dissolution from Heterogenite with Feed Water

Essay	Cu solubility g/L)	Co solubility (g/L)	Cu yield (g/L)	Co yield (g/L)
1	10.97	14.76	85.32	88.01

It is clear from the analysis of the results in Table 14 that the type of water used influences the performance of heterogenite leaching, i.e. the solubility of metals and their solubilization yields. The performance of heterogenite leaching obtained using feed water from hydrometallurgical plants is notable. In this case, the solubility of copper reaches 10.95 g/L and that of cobalt 14.76 g/L. With a respective yield of 85.32% Cu and 88.01% Co. The feed water of the units the Mining Company Katanga therefore served as a reference for assessing leaching performance.

For the treated wastewater, heterogenite leaching carried out under reference conditions led to a copper solubility of 9.05 g/L and 13.45 g/L for cobalt, with a respective yield of 81.96% Cu and 86.08% Co. This demonstrates that the leaching of copper minerals treated with the hydrometallurgical waters of the Katanga mining company is significantly more efficient.

III. CONCLUSION

The integration of wastewater treatment and recycling from the copper-cobalt ore leaching process at the Mining Company of Katanga represents a significant step forward in a sustainable and innovative approach. This study highlighted several key aspects:

- 1.Physicochemical analysis: Wastewater and feed water of the factories showed high concentration of elements such as Cu, Co, Mn, Cr, Zn, Ca, Mg and Fe with pH varying from minimum value to maximum value. These parameters are essential to assess the impact of water.

- 2. Characterization of heterogenite: The analysis reveals a marked heterogeneity in the chemical composition, with variations ranging from 1.41% to 1.82% for certain elements, highlighting the importance of treatment adapted to this variability.

- 3. Chemical reactions: The results showed that the treated wastewater acts as a reactant in precipitation and adsorption processes, thus enabling efficient recovery of heavy metals and reduction of pollution.

- 4. Leaching and recycling: The leaching process was optimized to recover heterogenite, with an efficiency reaching up to 90.5% for some metals. This demonstrates the importance of recycling strategies in sustainable resource management.

In summary, this research highlights the need for integrated water resource management in the Mining Company Katanga, promoting practices that reduce environmental impact while maximizing resource recovery.

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