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COPPER AND COBALT RECOVERY FROM TAILINGS LEACH PLANT SOLUTIONS-A CASE OF A LEACH PLANT ON THE COPPERBELT OF ZAMBIA

By

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ABSTRACT

Tailings leach plant final tailings solution phase contains typically 0.5 gpl Copper and 0.05 gpl Cobalt. Depending on the ore treated, it may contain other impurities such as Nickel, Manganese etc. in varying concentrations. All these are neutralized using quick lime and or rock lime along with the acid and disposed off. However, if part of the solution component is recovered, it is possible to recover the metallic components and subject the product to beneficiation processes in an economically viable manner.

Hence, the solution component was recovered from the tailings leach plant on the Copperbelt of Zambia and subjected to precipitation where the solution was reacted with three precipitation reagents i.e. Quick lime, Sodium Carbonate and Sodium Hydroxide. In the first instance, pH was varied between 5 and 10, residence time between 1 and 7 hrs, and reagent concentration between 10 – 50 gpl to establish the optimum operating conditions for the process. The optimum pH, residence time and reagent concentration obtained were 8.5, 2 hrs and 40 gpl respectively. At the optimum operating conditions, tests were conducted and financial evaluation carried out to determine the most economical reagent.

The results obtained showed recoveries higher than 80 % for both Copper and Cobalt for the three reagents with precipitate Copper grade ranging from 12 - 25 % and Cobalt 1 - 2.5 % depending on feed grades in solution. It is worth noting that the precipitate produced is amenable to the Smelter Process and or Cobalt Plant for both Copper and Cobalt recovery.

Financial evaluation shows that this process is viable with NPV over five years for Lime at \$ 68 million, Sodium Carbonate at \$ 51 million and Sodium Hydroxide at \$ 55 million at LME Cu \$ 6,000/t and Co \$ 30,000/t. To fully implement this work, the capital expenditure required is \$ 10 million for installation of paste thickeners, precipitation vessels, filtration equipment and pumps. Hence, from the NPV values obtained, it can be concluded that Lime gives the highest NPV of the 3 reagents. Other than Copper and Cobalt recovery from tailings leach plant final tails, this method can be used in treatment of various waste water streams for metal recovery.

Keywords: tailings, recovery, precipitation, precipitate, NPV (Net Present Value), LME (London Metal Exchange)

INTRODUCTION

Tailings Leach Plant by design treats tailings from Concentrator (where ore crushing, milling and floatation are carried out) through a leach process. Tailings from concentrator at 30% solids are first dewatered in a thickener where solids contents is raised to 60% solids. After thickening, material is pumped to leach vessels where it is repulped to 30-35% solids using raffinate from SX then contacted with concentrated Sulphuric Acid and pH maintained at 1.8. The acid reacts with the acid soluble component of the Copper in the ore to form a Copper Sulphate solution termed as Pregnant Liquor Solution (pls) and is taken through stages of washing. Tailings leach plant material flow is summarised in figure 1 below.

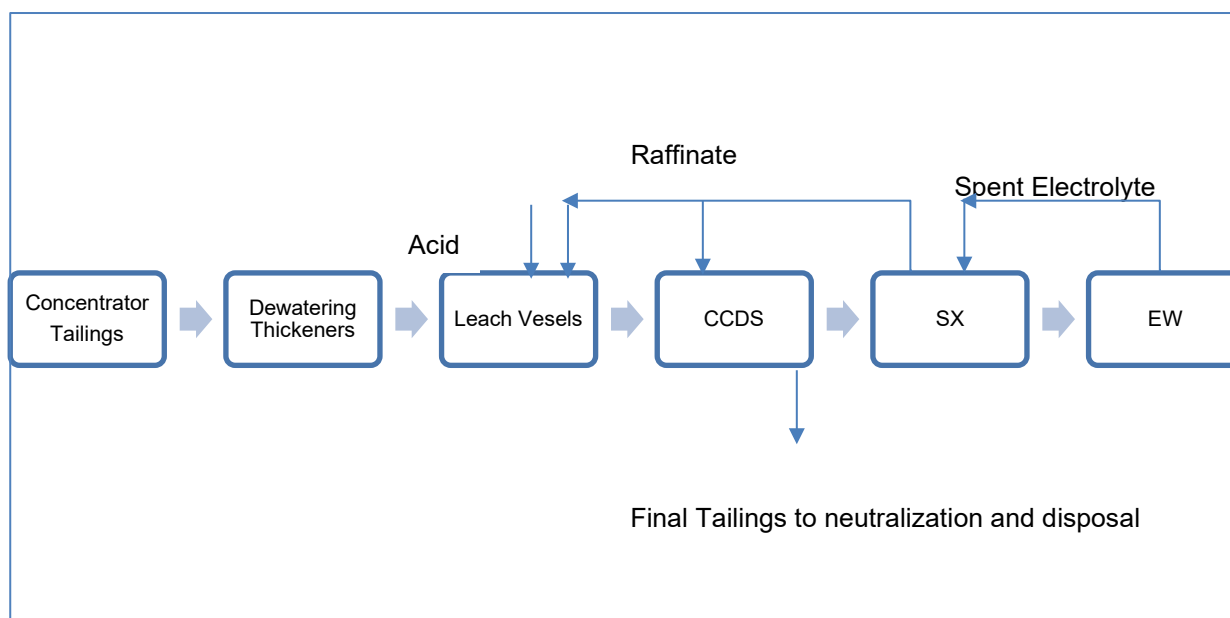


Figure 1: Leach Plant Schematic Flow Sheet

At the washing stage, Copper rich slurry is counter currently contacted with low Copper raffinate from the solvent extraction plant in counter current decantation thickeners (CCDs). CCDs are solid-liquid separation vessels where slurry of a given density/percent solids (typically 30%-60%) is fed in the middle of the vessel and the solid phase is collected at the bottom as a high density slurry underflow while the liquid phase is collected as an overflow. In the process the raffinate carries away the Copper and is transformed into pls and pumped to the solvent extraction plant (SX). At the Solvent Extraction Plant Copper is preferentially extracted by contacting pls with Organic with a high affinity for Copper producing an advance solution which is then pumped to the Tankhouse for Cathode production. The process investigated has five washing stages. The final CCD Underflow at 50-60% solids is disposed of after neutralization to the Tailings Dam.

Final tailing (both the solution and solids phase) contain Copper and Cobalt as shown in table 1 below. This Copper is typically disposed of to the tailings dam disposal site.

Table 1: Final CCD Underflow Assays

Solid				Solution	
TCu %	ASCu %	TCo%	ASCo	Cu gpl	Co gpl
0.60	0.05	0.025	0.025	0.50	0.02

Copper and Cobalt Recovery Options from Final Tailings

A number of investigations have been carried out to establish potential to recover Copper economically. One of such works (Credo Nguni et al, 2012) showed that Copper recoveries of up to 24% can be achieved on flotation of final CCD underflow slurry. No work was done targeting recovery of Copper and Cobalt from the solution phase. This paper focus on recovery of Copper and Cobalt from the solution phase of final tails using the precipitation method. The investigation established the optimum pH for both Copper and Cobalt recovery, optimum reagent concentration, the commercial viability of the process and the most viable reagent.

PROBLEM STATEMENT

At flow rates of 2000m³/hr., over 300 tons of Copper and 12 tons of Cobalt from the solution phase, 6700 tons Copper and 248 tons Cobalt from the solid phase are disposed to the tailings dam per month. There is need to recover some the Copper and Cobalt to realize value from the resource that has been mined at great cost.

EXPERIMENTAL PROCEDURE

The experiment was carried out as per flow sheet in figure 2 below.

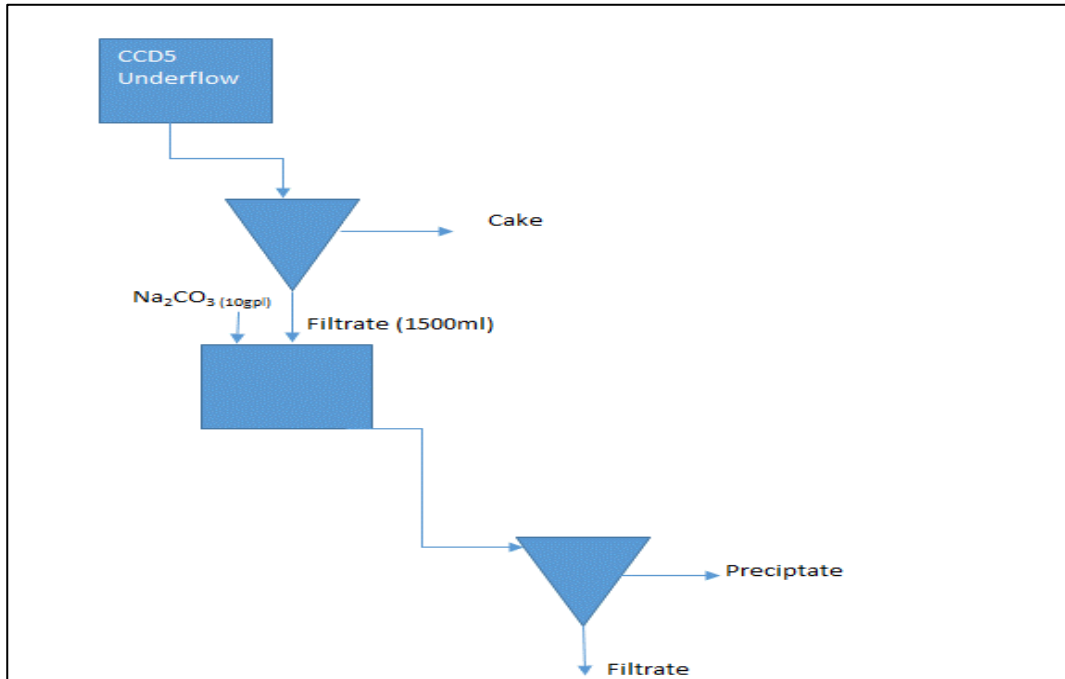


Figure 2: Precipitation flowsheet

Final CCD underflow slurry was filtered and the solution measured to 1500ml of the filtrate and used as Feed Filtrate for precipitation. The Feed Filtrate was transferred to a beaker, initial pH and temperature measured and recorded. Precipitation reagent solution (10gpl sodium carbonate solution) was filled in a burette and titration started while monitoring the pH in the beaker using a pH meter. Precipitation reaction time was maintained at 07hrs at different pH (5, 6, 7, 7.5, 8, 8.5, 9, 9.5, and 10). At the end of the reaction time, the precipitation mixture was filtered. Both the cake and the filtrate were analysed to establish metal constituents. Results obtained were analysed and the graph plotted to establish optimum pH. Subsequent tests were done at the established optimum pH (8.5). At pH 8.5, different reagent concentrations (10gpl, 20gpl, 30gpl, 40gpl, 50gpl) were tested. At 40gpl reagent concentration, residence time 2hrs, pH 8.5, different reagents (sodium hydroxide and quick lime) were tested and results recorded.

RESULTS AND DISCUSSION

pH versus Recoveries

Precipitation involves formation of a salt that is insoluble in water. It involves creating conditions that will lead to preferential formation of such a salt.

In the Final CCD solution phase, Copper is in the form of Copper Sulphate (CuSO₄), Cobalt as Cobalt Sulphate (CoSO₄). Both Sulphates are soluble in water at ambient temperature and pressure. However solubility of hydroxides of these metals in water at the same conditions vary with pH as per figure below.

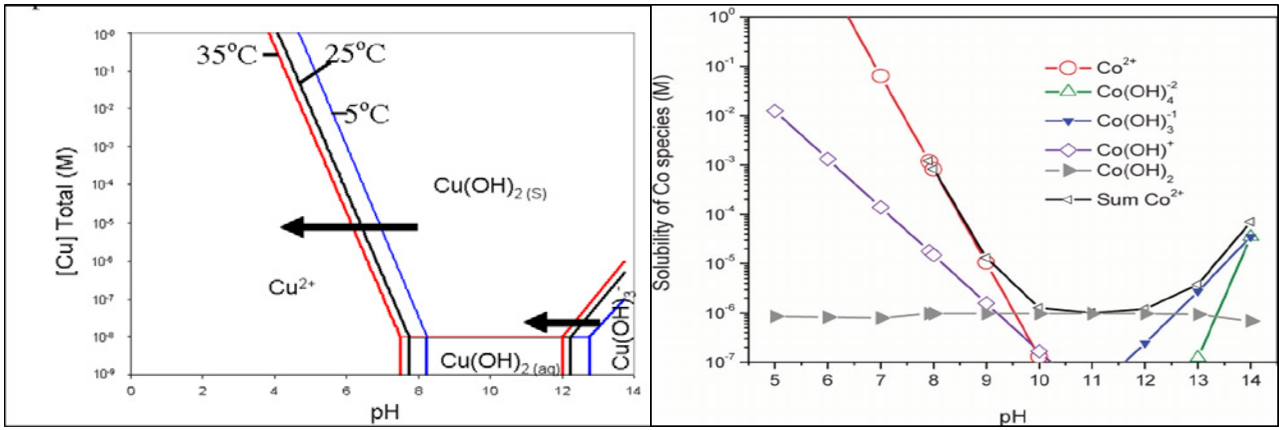
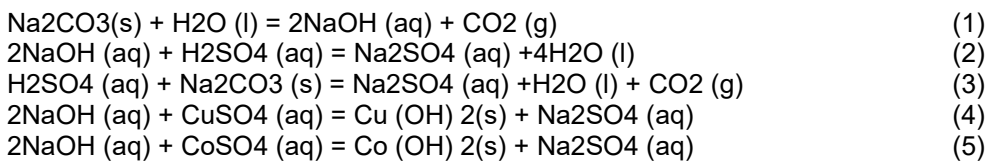


Figure 3: Copper and Cobalt Solubility Variation with pH

Copper hydroxide solubility is lowest from pH 7.5 to 12 while Cobalt hydroxide solubility is lowest at pH 10 to 12. To effectively recover these two metals from solution through precipitation, pH must be raised to between 7.5 and 12.

A number of reagents (Sodium Carbonate, Sodium Hydroxide and Quick Lime) can be used to form Hydroxides of both Copper and Cobalt. Sodium Carbonate was tried as the first reagent and the following reactions normally occur.



When Sodium Carbonate is hydrolysed, reaction (1) takes place converting the carbonate to hydroxide. The hydroxide then reacts with Sulphuric Acid in a neutralization reaction (2). Residue Sodium Carbonate is used in reaction (3). After all the acid has reacted, conditions are suitable for reaction (4) and (5) to occur. The Cobalt Hydroxide and Copper Hydroxide can then be filtered from solution as precipitates.

From results obtained, pH varies with recoveries as shown in figure 4 below.

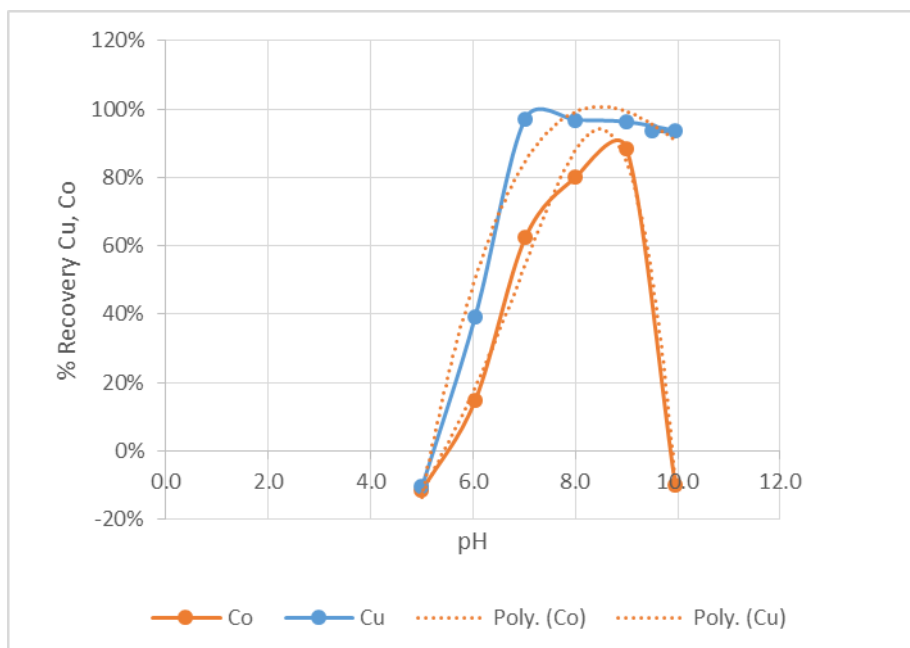


Figure 4: pH vs Cu, Co recovery

Figure 4. Shows that both Copper and Cobalt recoveries increase with increase in pH. Copper precipitates at pH 6-7 and remains a precipitate at higher pH values. Cobalt precipitates at pH 6.5-9 and remains a precipitate up to pH 9. At pH higher than 9, Cobalt Hydroxide redissolves in water due to creation of pockets of high pH values in the reactor. The solubility curve for Cobalt has a higher gradient compared to that of Copper. The

graph shows a point of inflation at pH 8.5. Therefore the optimum pH stands at 8.5 with recoveries of Copper at 96% and of Cobalt at 88%. At pH lower than 7, neutralization reactions occur preferentially (KG Fisher and LG Treadgold, 2009). At pH higher than 7, precipitation of the two metals occurs.

Reagent Concentration versus Recoveries

Sodium Carbonate concentration varies with recoveries as shown in figure 5 below.

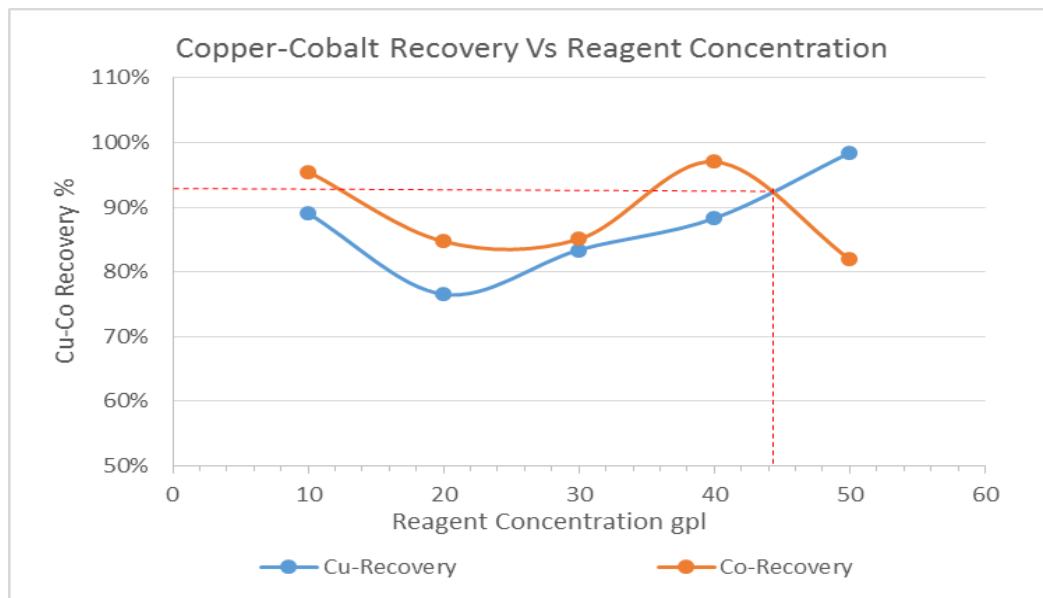


Figure 5: Copper and Cobalt recoveries

Cobalt recovery decreases with increase in Sodium Carbonate concentration. High concentrations of reagents will result in portions of high pH (9-9.5) in the reactor at which point Cobalt hydroxide redissolves into solution. Copper recovery increases with increase in Sodium Carbonate concentration as Copper hydroxide remains insoluble at higher pH values. The graph shows both Copper and Cobalt recoveries combined are optimum at 44gpl (approx. 40gpl), 93% Copper and 93% Cobalt.

Optimum Reaction Time

Figure 6 below shows variation of Copper and Cobalt recovery with reaction time

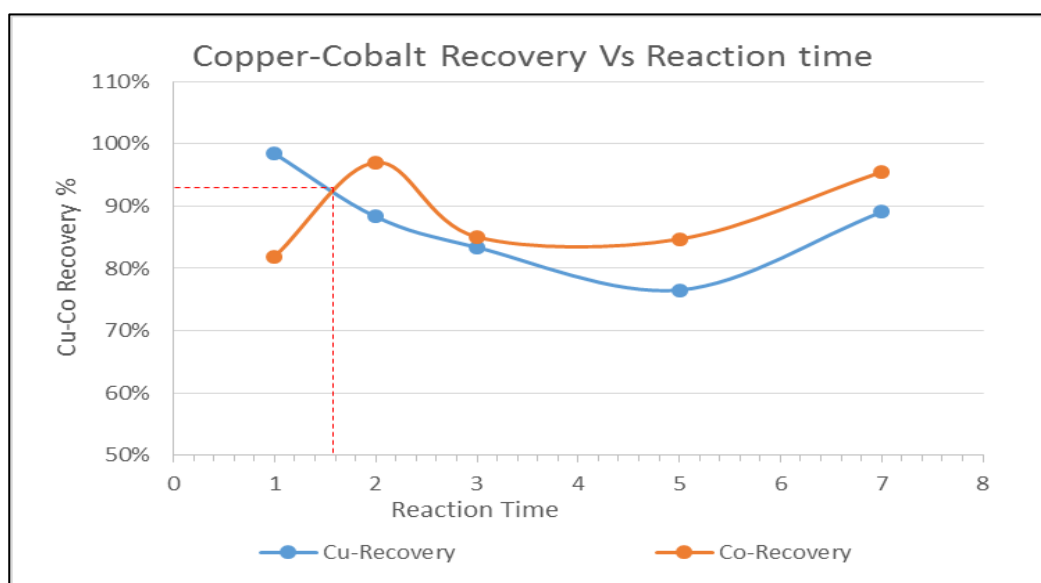


Figure 6: Variation of Copper and Cobalt recovery with reaction time

Figure 6 shows that optimum residence time is 1.6hrs (Approximately 2hrs). This is equivalent to 93% and 93% Copper and Cobalt respectively.

Precipitate Grade

Precipitation product Copper and Cobalt grade are dependent on feed grades as shown in figure 7 below.

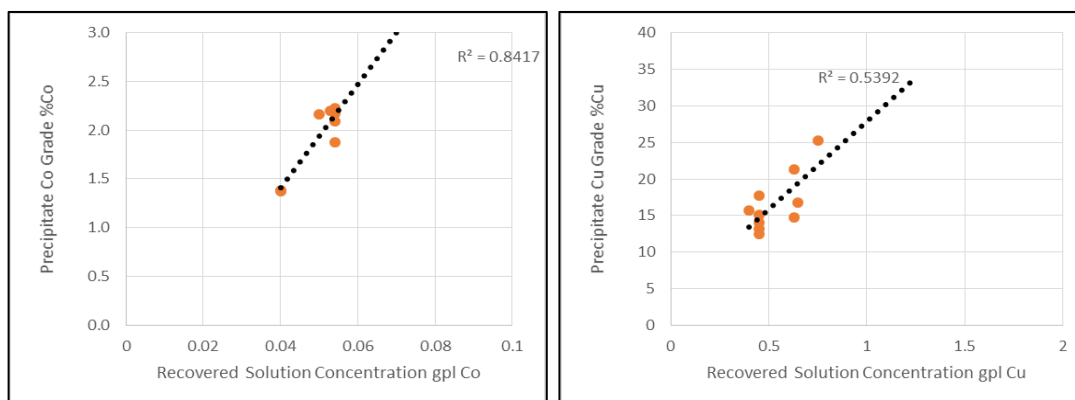


Figure 7: Copper and Cobalt product grades with solution feed grade

Figure 7 shows that Copper in feed at 1gpl will produce precipitate with Copper grades of 25%. Cobalt grades in feed of 0.06gpl (60ppm) produces precipitate of 2.5% Cobalt grade. This product is amenable to a smelter treatment route. The smelter should have a Cobalt recovery option producing an alloy as the final product. The product is also amenable to a Cobalt refinery process where Copper and Cobalt can be redissolved and separated.

Selection of the subsequent processing option (whether smelter or Cobalt plant) is a financial feasibility consideration. In the interest of this paper, it is assumed the product will be treated through the smelter route.

Precipitation Reagent Comparison

Three different reagents were tested and the table below shows recoveries at optimum parameters: pH 8.5, 40gpl reagent concentration, 2hrs residence time.

Table 2: Precipitation Reagent Comparison

Reagent	Reaction time	pH	Reagent Concentration	Consumption	Recovery	
				Reagent/ TCu	Cu	Co
			Gpl	T/TCU	%	%
Sodium Carbonate	2	8.5	40	11.3	88%	97%
Lime	2	8.5	40	6.0	95%	87%
Sodium Hydroxide	2	8.5	40	2.7	100%	84%

Sodium carbonate produced recoveries of 88% and 97% Copper and Cobalt respectively. Quick lime had recoveries of 95% and 87% Copper and Cobalt respectively. Sodium hydroxide had 100% and 84% Copper and Cobalt respectively. The preferred reagent rests in an economic evaluation. The product is amenable to both the smelter and Cobalt refinery treatment option regardless of the reagent used. In the case of Lime, gypsum is produced which becomes a fluxing agent at the smelter.

FINANCIAL VIABILITY ANALYSIS

As shown in the above discussion, Copper and Cobalt can be recovered from solution using precipitation. The Table below provides a summary of financial evaluations. Net Present Value (NPV) and Payback Period will be used as the basis for financial viability and decision making.

Key financial evaluation assumptions:

- Precipitation product is treated at the Smelter.
- Recovery; 100% Copper, 65% Cobalt.
- Payables 100% Copper, 40% Cobalt.

Capex includes: Solution recovery vessels (paste Thickeners 4), repulping vessels, pumps, precipitation reactor, filtration equipment, mechanical, civils and electrical works.

Table 3: Precipitation Reagents Comparison

Description	UOM	Lime	Sodium Hydroxide	Sodium Carbonate
Feed Dry Solids	tpd	45,000	45,000	45,000
Feed Cu grade Tcu	%	0.90%	0.90%	0.90%
Feed Co grade	%	0.02%	0.02%	0.02%
Cu Leach Efficiency Tcu	%	43.5%	43.5%	43.5%
Co Leach Efficiency Tco	%	8.0%	8.0%	8.0%
Precipitation Recovery Cu	%	95%	100%	88%
Precipitation Recovery Co	%	87%	84%	97%
Cu Recovered	tpa	4,466	4,686	4,137
Co Recovered	tpa	156	151	174
LME Cu	\$/t	6,000	6,000	6,000
LME Co	\$/t	30,000	30,000	30,000
Reagent Price Delivered	\$/t	140	750	300
Opex	\$mIn/a	(4.35)	(9.15)	(7.32)
EBIDTA	\$mIn/a	21.43	17.80	16.79
CAPEX	\$mIn	(10.00)	(10.00)	(10.00)
Payback	months	6	7	7
NPV over 5 years	\$mIn	68.32	55.23	51.61

Using Sodium Carbonate as the precipitation agent produces Copper and Cobalt recovery of 88% and 97% respectively with NPV of \$51.61 million. Sodium Hydroxide recovers 100% Copper and 84% Cobalt-has NPV over 5 years \$55.23million. Quick Lime on the other hand produces Copper and Cobalt recovery of 95% and 87% respectively with NPV \$68.32million. Quick Lime has better NPV in comparison with all other reagents. Pay back for the three reagents is as follows, 6, 7, 7 months for Quick Lime, Sodium Hydroxide and Sodium Carbonate respectively. All three are very attractive with payback less than 1 year.

Lime is readily available in Zambia while Sodium Carbonate and Sodium Hydroxide have to be sourced from neighbouring countries or from the Far East. Lime therefore offers more benefits of the three reagents.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The work carried out established that the solution phase of final tailings is amenable to precipitation using different precipitation reagents with Copper and Cobalt recoveries above 80%. The conditions for optimum recovery of both Copper and Cobalt are: pH 8.5; residence time 2hrs; precipitation reagent concentration 40gpl.

The precipitation process is financially viable when any of the three reagents (Quick Lime, Sodium Hydroxide and Sodium Carbonate) are used. Quick Lime gave highest NPV among the three (Quick Lime (\$68 million), Sodium Hydroxide (\$55 million) and Sodium Carbonate (\$51million)) investigated reagents.

Recommendations

All leach plants should consider adopting this processing option prior to disposal of final tails. It can also be used in waste water treatment where there is presence Copper and Cobalt.

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