Frothing and Froth Control in Copper Leach Washing and Purification Circuits

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Froth in copper leach circuits affects the process efficiency of many plants in the African Copperbelt region. With its natural hydrophobicity and floatability, talc is the most common cause of froth. Whether it is a direct copper ore leach system or a system that leaches the flotation tails or leach concentrates, foaming is the major issue. The strong froth formed in leach tanks, thickeners and in the counter-current decantation train makes operations more difficult as it prevents operators from seeing the surface changes and reduces leaching tank capacity. The foam also carries solids as fines in suspension and they are carried into the solvent extraction through the pregnant leach solution, contributing to the crud formation. Traditional methods of using water or raffinate spray bars are not very effective if the volume of froth increases and they have other disadvantages, as well. This study shows the effectiveness of a novel chemical solution on controlling froth in an acidic leach system. KemFoamX 9980 breaks down froth and prevents the generation of froth in acid leach system. The study shows the compatibility of the KemFoamX 9980 with downstream solvent extraction and its non-persistent or degradation in acid exposure. The study was carried out in copper acid leach systems that are heavily affected by froth generated by different mechanisms.

INTRODUCTION

Many plants in the African Copperbelt region have a common problem of froth in acid leach systems. Froth affects the feedwell, overflow launders and the counter-current decantation (CCD) thickener surfaces. This gives rise to a multitude of problems.

There are various causes of froth in the leach system, but the most common is talc. Talc is the common component of gangue mineral that is naturally floatable because of its ~90% hydrophobicity (Mälhammar, 1990; Morris *et al*., 2002). The grinding and milling of talc results in both hydrophobic and hydrophilic surfaces (Mälhammar, 1990; Yehia *et al*., 1999; Morris *et al*., 2002). The hydrophobic surface of talc is exposed after treatment with acid (Yang *et al*., 2006; Zdrálková *et al*., 2013). Carbonaceous materials are another cause of froth problems. An integrated system that leaches flotation tailings to recover mineral losses from flotation often has active residual floatation reagents and other hydrophobic carbonaceous material. Therefore, these materials tend to be the primary causes of froth problems during leaching of the flotation tailings.

Over the years, the quality of ore has deteriorated, resulting in more ore with talceous or carbonaceous material. The unstable copper price has also forced mines to focus on improving process efficiency, while increasing the production throughput to remain profitable.

Talc and other fine solids often attach to the surface of the bubbles in the froth. This increases flocculant consumption (non-ionics in particular) because these chemistries attach to the talc on the bubble surface (Steenberg, 1982; Mackenzie, 1986; Nagaraji *et al*., 1987; Morris *et al*., 2002). Optimising flocculant consumption is an important aspect to improve operational efficiency.

Froth can also carry fine solids into the solvent extraction (SX) process where it forms crud. The buildup of the crud at the bottom of the SX settlers reduces capacity of the settlers and reduces efficiency. The process of removing this crud is expensive and may require putting the settlers off-line. Sometimes special crud treatment equipment or a system is required to reclaim expensive reagents (Sole and Tinkler, 2015). Process efficiency can be improved by reducing crud in SX by minimising solids carryover to SX. Controlling froth in the CCD thickeners is an economic way by which the amount of solids carried over downstream can be reduced.

Froth problems in Counter-Current Decantation Thickeners and Control Measures

Froth is commonly encountered in the CCD thickeners and some froth is always visible on the thickeners. Talc stabilizes the froth, helping it build up to form a crust on the thickener surface. Figure 1 shows fresh froth overflowing from the feedwell and building up on top of the old froth on the thickener surface. This makes it difficult to observe and adjust the flocculant dosing in the feedwell in the event there is blockage on the flocculant pipeline or there is inadequate mixing velocity at the dosing point. This can result in poor overflow clarity as observed in Figure 1B. Furthermore, fine solid particles that are carried by the froth eventually block the launder (Figure 1C), affecting production.

Figure 1: Froth covers the feedwell, launder and thickener surface and the fine particles it carries eventually blocks the launder.

There are two traditional methods of controlling froth. One approach is to add raw water or raffinate to the thickener surface through spray bars to knock down the froth (Figure 2A). The main drawback of using raw water is that it upsets the pH and water balance of the system. Raffinate can block the spray nozzles and the mist from the sprays corrodes the thickener bridge, leading to structural problems and resulting in health and safety issues. The second approach is to frequently flood the

thickener so that the froth spills out onto the thickener bund area, which would then be pumped back into the feedwell (Figure 2B). Flooding the thickener creates a hazard on the ground and is laborious as it requires many hours of cleaning.

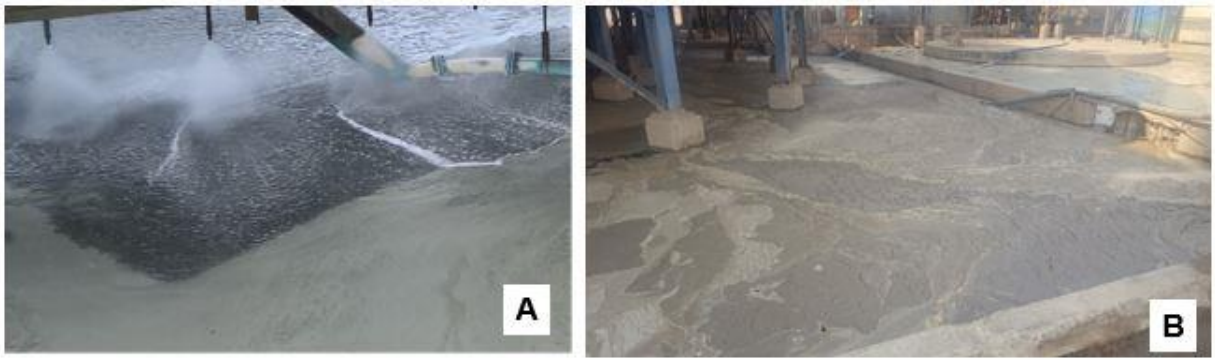

Figure 2: Current traditional methods used to control froth in acidic system.
Picture A demonstrates spraying the froth using raffinate or raw water.
Picture B demonstrates flooding the thickener and spilling the froth into the thickener bund.

Application of defoaming and antifoaming chemistry in leach systems has been a challenge due to the sensitivity of the downstream SX process and because most chemistries cannot function well in low pH systems. This study provides a chemical solution to froth treatment in an acid copper leach system. The chemistry, referred to as KemFoamX 9980 in this study, is a blended product acknowledged for its effective foam control properties (Edward *et al*., 1961).

Direct application of KemFoamX 9980 in leach discharge slurry prevents the generation of froth and breaks down from what is already formed. Furthermore, the study shows that KemFoamX 9980 is compatible with downstream SX process and is non-persistent because it degrades on continuous exposure to acid environments. A flocculant (Superfloc® N100) was used in this study to stimulate solid–liquid separation in the thickeners during the experiments.

Based on findings from the laboratory experiments, the product was applied in the field and results from those trials are also presented.

PROTOCOLS AND RESULTS

Defoaming Effectiveness

The antifoaming and defoaming ability of KemFoamX 9980 was evaluated using leach discharge slurry (LDS) from the leach tank. The slurry was diluted with pregnant leach solution (PLS) from 30% down to 12% solids to allow for proper mixing and froth generation. The experiment was done using 1 L graduated static cylinders filled to 700 mL. Using a plunger (a perforated stainless steel disc attached to a handle), five strong strokes of mixing were performed to the cylinder to generate froth. The test cylinder without a defoamer was used as a negative control. The tests using KemFoamX 9980 were performed at 2 mg/L 5 mg/L, 10 mg/L and 50 mg/L dosages. Dosages from 2 to 10 mg/L are typical economic levels and 50 mg/L was the maximum selected to see the possible effect of excess dosage. After 5 minutes of standing, photographs were taken to compare the froth levels generated. The second test set was repeated identically as described above, but after five minutes of standing 10 g/t of Superfloc® N100 was added, followed by five strokes of mixture using the plunger to mix solids with flocculant then allowed to stand another five minutes before photographs were taken for comparison. Froth height was from 700 mL mark to 1000 mL mark. As little as 2 mg/L of KemFoamX 9980 reduced the froth height down to 700 mL mark. Therefore, the study did not consider quantifying froth heights at varying dosages of KemFoamX 9980. The flocculant dosage was chosen

by balancing the amount required to settle the solids while avoiding excess flocculant in the clear phase.

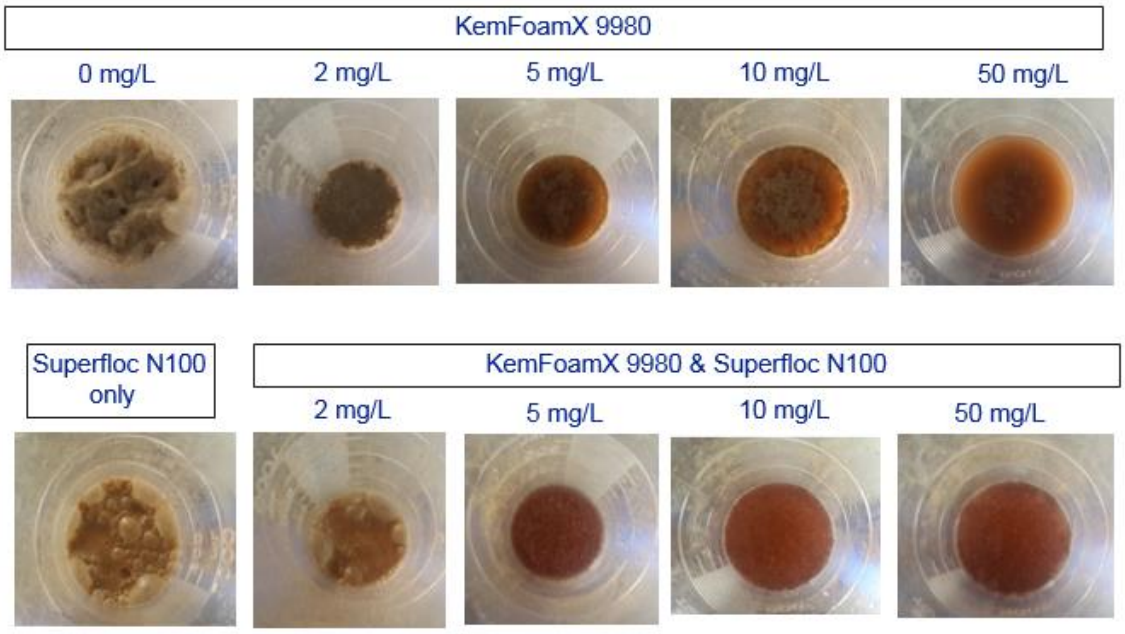

Figure 3: Effect of KemFoamX 9980 on froth inhibition and degradation. Addition of Superfloc® N100 assists to capture the fine particles in suspension and improves the clarity. The images are photograph captures from the top of the cylinders five minutes after adding the products. The control experiment with 0 mg/L KemFoamX 9980 shows stable froth on surface. Dosage of Superfloc® N100 was constant at 10 g/t across the bottom raw.

Different defoamer chemistries were evaluated on their ability to prevent froth or foam in the leach circuit, as described in the experimental procedure. KemFoamX 9980 has shown the ability to work as an antifoam and also defoaming of already formed froth.

KemFoamX 9980 Evaluation at Varying Dosages

From Figure 3, it can be shown that KemFoamX 9980 breaks down with as little as 2 mg/L dose. Froth in the cylinder with no KemFoamX 9980 was stable. After dosage of 2 mg/L to 50 mg/L, little to no froth was observed; however, KemFoamX 9980 does not have the ability to settle the solids that were suspended in froth and the addition of flocculant is required for that function. The breaking of the froth allows Superfloc® N100 flocculant to capture the fine solids that were suspended by foam and settle them through the flocculation process. The bottom row of Figure 3 shows the cylinders after addition of KemFoamX 9980 and Superfloc® N100. The suspended fines were settled by Superfloc® N100 flocculant and a clear surface was observed.

KemFoamX 9980 Evaluation on Different Ores

Slurries from different acid leach plants in the Copperbelt region were compared as Slurry X and Slurry Y (Figure 4). Froth was generated as described earlier, KemFoamX 9980 (10 mg/L) was applied to kill the froth generated. The addition of Superfloc® N100 settled the solids, including the fine solids material that was suspended by froth, thereby giving good clarity of the clear phase. The application of Superfloc® N100 alone showed a slightly reduced level of froth. This is because non-ionic polymeric flocculant and other polymeric chemistries absorb to the talc or froth surface (Steenberg, 1982; Mackenzie, 1986; Nagaraji *et al.*, 1987; Morris, 2002). Hence, an increase in flocculant consumption is generally observed in systems with talceous material or excessive frothing. It was also

observed that the clarity of the PLS following the addition of KemFoamX 9980 was better, compared with the clarity given by the addition of Superfloc® N100 by itself.

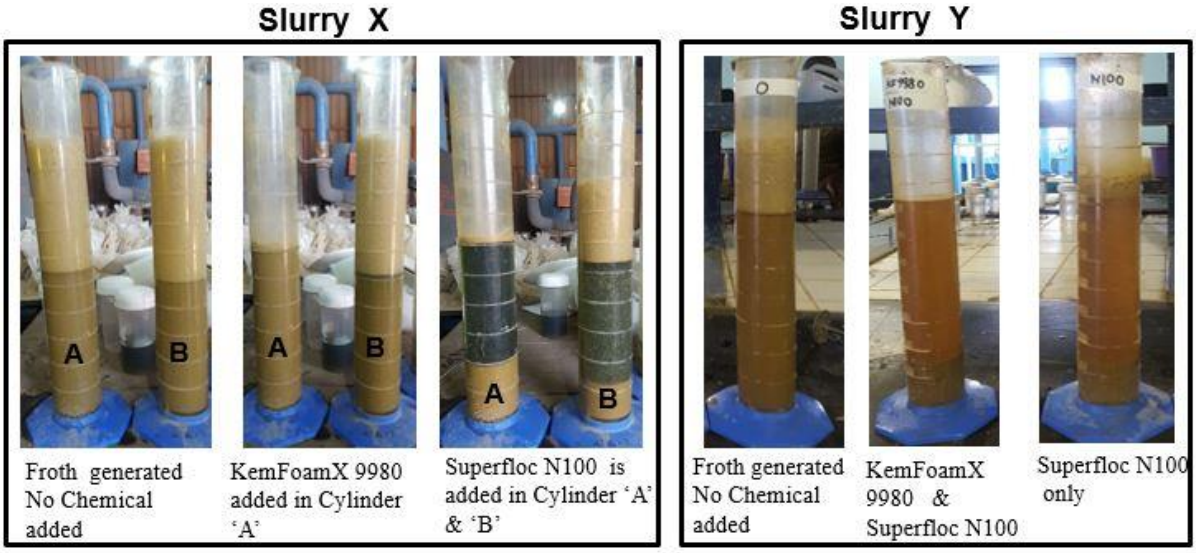

Figure 4: Effect of KemFoamX 9980 on slurries from two different acid leach plants in the Copperbelt region.

Product Persistence

Degradation of the product was determined based on the loss of efficiency after exposure in the acid media for up to 24 h. A graduated 1 L static cylinder filled up to the 700 mL mark with 12% solids slurry was dosed with KemFoamX 9980. Dosages of 0 mg/L, 5 mg/L, 10 mg/L and 20 mg/L KemFoamX 9980 were used because they are economic and were shown to work well. Froth was generated as described above after different exposure times up to 24 h (*t*0; *t*1; *t*2; *t*24) using a plunger. The time taken for the generated froth to clear was noted. The control was the cylinder without any KemFoamX 9980. The time (seconds) taken for the generated froth to clear was plotted against the exposure time (hours). A second test was done to assess if the actives from the KemFoamX 9980 could be carried through to the SX system.

KemFoamX 980 Behaviour in Acid Leach Slurry

The persistence of a chemical in a non-acidic system is a cause for concern to downstream processes and the environment. The efficiency of KemFoamX 9980 decreases when exposed to acid leach solution over a prolonged period of time. The product efficiency was determined based on time taken to breakdown the generated froth. Without KemFoamX 9980 (0 mg/L), the time taken for the froth to break down was 25 s. At dosage of 5 mg/L to 20 mg/L, the time taken for the froth to break down increased over a period of 24 h, indicating the decrease in efficiency to break the froth.

Immediately after dosage *t*(0), the froth was broken down in less than 5 s, despite the difference between 5 mg/L and 20 mg/L dosing rates. This suggests that a dosage of 5 mg/Lis sufficient to break the froth. Degradation of a dosage of 5 mg/L was almost complete in 24 h, indicated by a difference in time compared with 0 mg/L at *t*24.

Product Transport

An additional test was performed to understand the transport of KemFoamX 9980 actives through the CCD system. This was demonstrated by dosing 10 mg/L of the KemFoamX 9980 in leach slurry and mixed. Solid–liquid separation was performed using Superfloc® N100 in a 1 L static cylinder. After separation, the liquid phase was decanted into fresh leach discharge slurry while the underflow was re-suspended in fresh PLS.

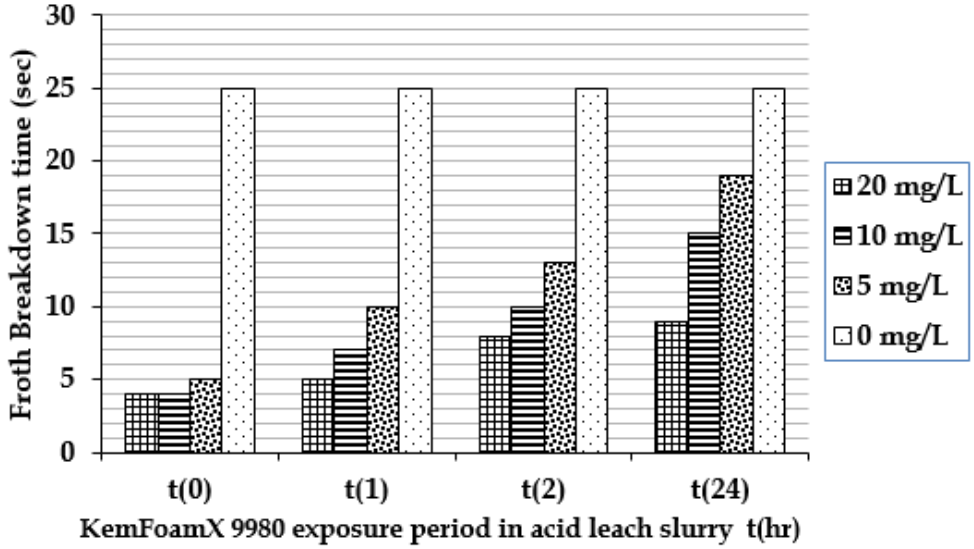

Figure 5: Product effectiveness of exposure time in acid leach slurry.

KemFoamX 9980 settles with solids in the thickener

The cylinder with underflow solids re-suspended in fresh PLS was able to break down the generated froth in 5 s. The cylinder with overflow that was decanted into fresh leach discharge slurry was able to break down the froth in 25 s (similar time with 0 mg/L dosage of KemFoamX 9980). This demonstrates that there is little chance for the product to be carried through PLS to the downstream process.

Solvent Extraction Compatibility

Solvent extraction compatibility of the KemFoamX 9980 was evaluated using a method where 30 vol. % solution of ACORGA OPT5510 was prepared. A synthetic PLS containing 6 g/L of copper and 3 g/L of iron at a pH of 2 was prepared. A 30 g/L copper and 150 g/L sulphuric acid synthetic electrolyte was also prepared. KemFoamX 9980 was added to PLS in increasing dosages of 2 mg/L, 3 mg/L, 4 mg/L, 5 mg/L, and 10 mg/L. Similarly, KemFoamX 9980 was added to the electrolyte in 5 mg/L and 10 mg/L dosages using a micro-syringe. To test if solids and flocculant would affect phase disengagement time (PDT), 1 L of synthetic PLS was thoroughly mixed with 120 g of soil. KemFoamX 9980 was dosed at dosages of 5 and 10 mg/L and further mixed. Then 21 g/t of Superfloc® N100 flocculant was dosed to settle the solids. For the PDT determinations, an overhead stirrer with a 1 L measuring beaker (with baffles) was used to agitate the organic and aqueous phases. The organic and aqueous phases were mixed in organic-continuous mode at a volumetric ratio of 1:1 for 3 minutes and PDT measured. The same sample was then mixed in aqueous-continuous mode to determine if KemFoamX 9980 behavior could affect phase continuity. The concentrations of copper and iron in both aqueous and organic phases was also studied.

Compatibility of KemFoamX 9980 with solvent extraction process

The impact of upstream additives affects the physical and chemical performance of the downstream process. Additives like flocculants and floatation reagents affect SX interfacial characteristics if their dosages are not properly controlled. The interfacial tension affects the transfer of copper ions across an aqueous–organic interface. Since KemFoamX 9980 is surface active, it has crucial influence on the interfacial tension. Therefore, test work was performed to determine the interfacial tension at varying KemFoamX 9980 dosages. It was determined that there was no effect on copper transfer or phase disengagement expected at this value of interfacial tension reduced by a maximum of 3 dynes/cm. Figure 6 shows that even at 10 mg/L dosage, the change in interfacial tension was below this limit.

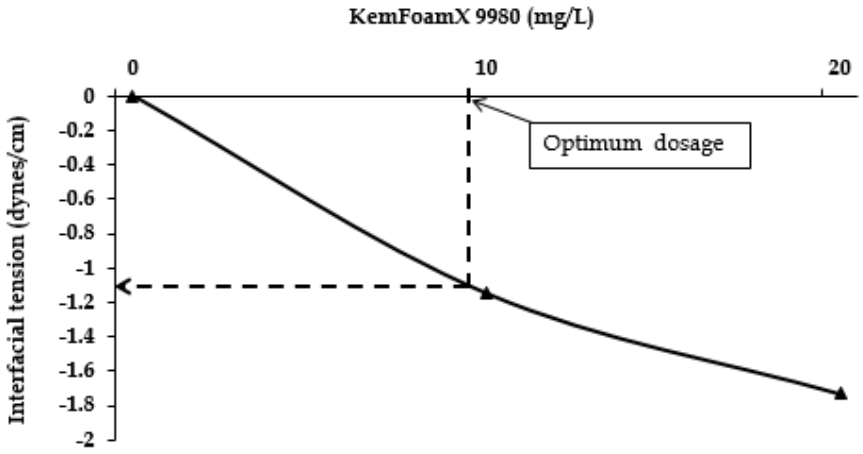

Figure 6: Effect of KemFoamX 9980 addition on interfacial tension.

The recommended dosage is between 5 mg/L to 10 mg/L, with a maximum dosage of 20 mg/L. The dosing point is directly in the feedwell or in the leaching tanks. KemFoamX 9980 is insoluble in the aqueous phase and tends to settle with solids in the thickener. Consequently, little to no excess or spillage is expected to be carried over into the PLS, but this test confirms that minimal adverse effects occur.

The phase disengagement process is influenced by the sedimentation and coalescence behavior of the droplets. Such droplets are influenced by interfacial tension and strength of the interfacial film. The test work was performed by direct addition of the KemFoamX 9980 into the PLS to stimulate a worst-case situation of overdosing. Figure 7 shows that there is insignificant change in the PDT for both organic- and aqueous-continuous mixing.

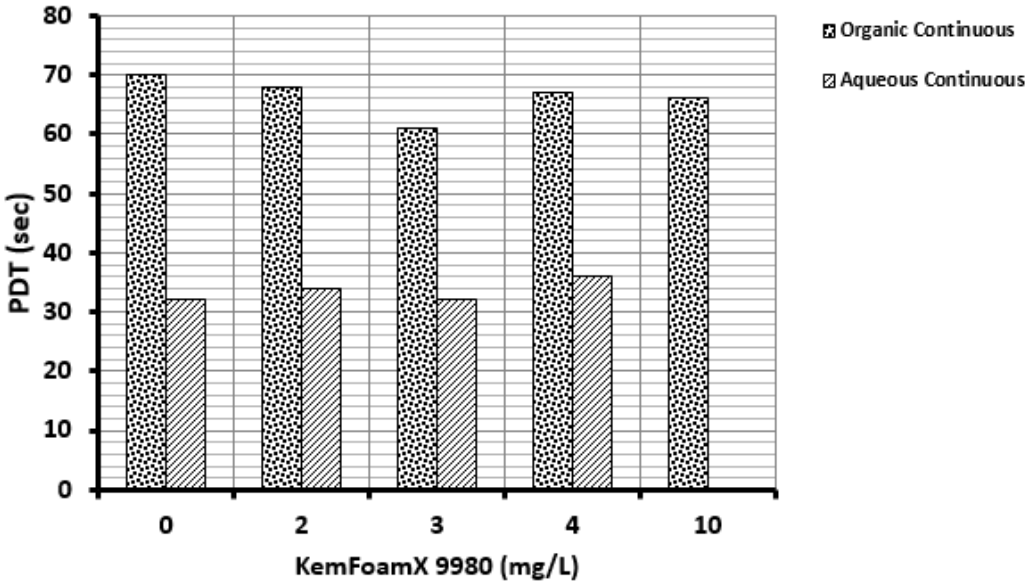

Figure 7: The effect of KemFoamX 9980 on phase disengagement time.
The variation is not significant and other factors may also course the variation.

Interfering chemicals can reduce the effectiveness of extractants on copper ion transfer across an aqueous–organic interface. Modified and non-modified aldoxime–ketoxime extractants like LIX 984N, ACORGA OPT 5540 and OPT 5510 are commonly used in the African Copperbelt (Sole and Tinkler, 2015). KemFoamX 9980 was tested on the effect on copper ion transfer. The results of organic and aqueous analysis of copper concentration after phase disengagement are shown in Figures 8 and 9, respectively. It can be seen that there is almost no change in the concentration in both phases across the full range of dosages. These results mean that there was no evidence that suggests KemFoamX 9980 interference with copper ion transfer across the organic–aqueous interface.

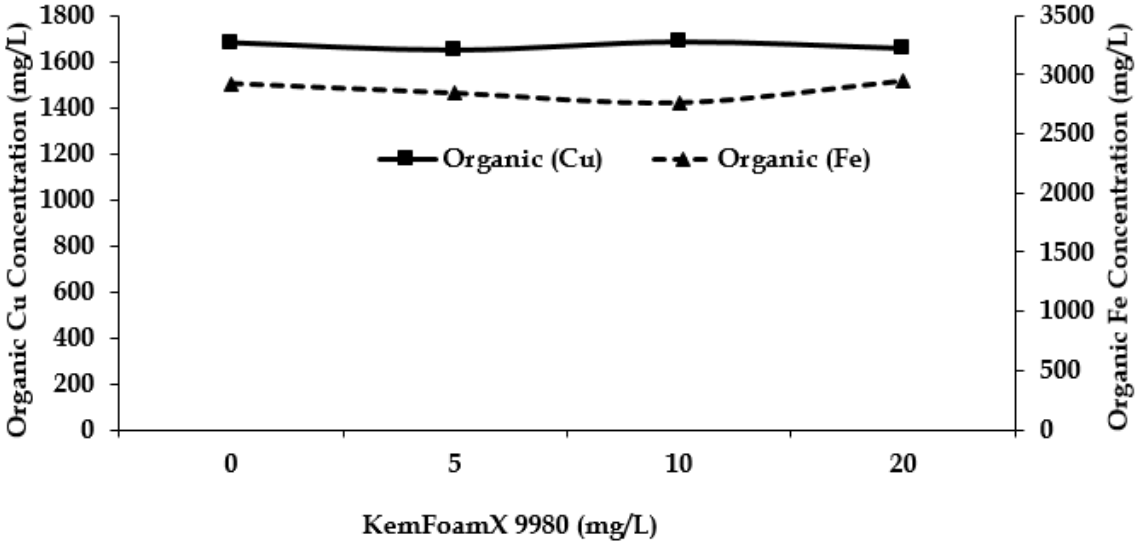

Figure 8: Organic-phase analysis of copper and iron concentartions after phase disengagement.

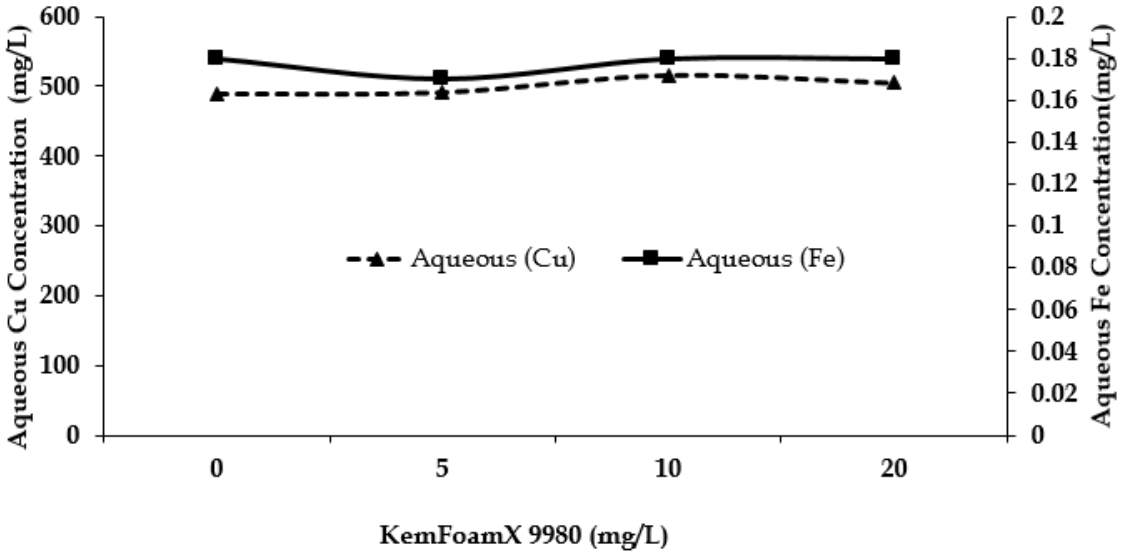

Figure 9: Aqueous-phase analysis of copper concentartion after phase disengagement. The concentrations of copper and iron in the aqueous phase are not affected by KemFoamX 9980 dosage.

FIELD RESULTS

Post-Leach Counter-Current Decantation Thickener Application

Based on the laboratory testing, KemFoamX 9980 was applied at 5 mg/L directly in the feedwell. Froth on the feedwell launder was considerably reduced within minutes of dosing the product. The edges of the feedwell began to appear (Figure 10A). After 30 mins of dosing KemFoamX 9980 (5 mg/L), the feedwell was clear, no new froth was being generated and the froth on the thickener feedwell surface degrades (Figure 10B and 10C). The crust on the thickener surface that had been building for some days began thinning (Figure 10D).

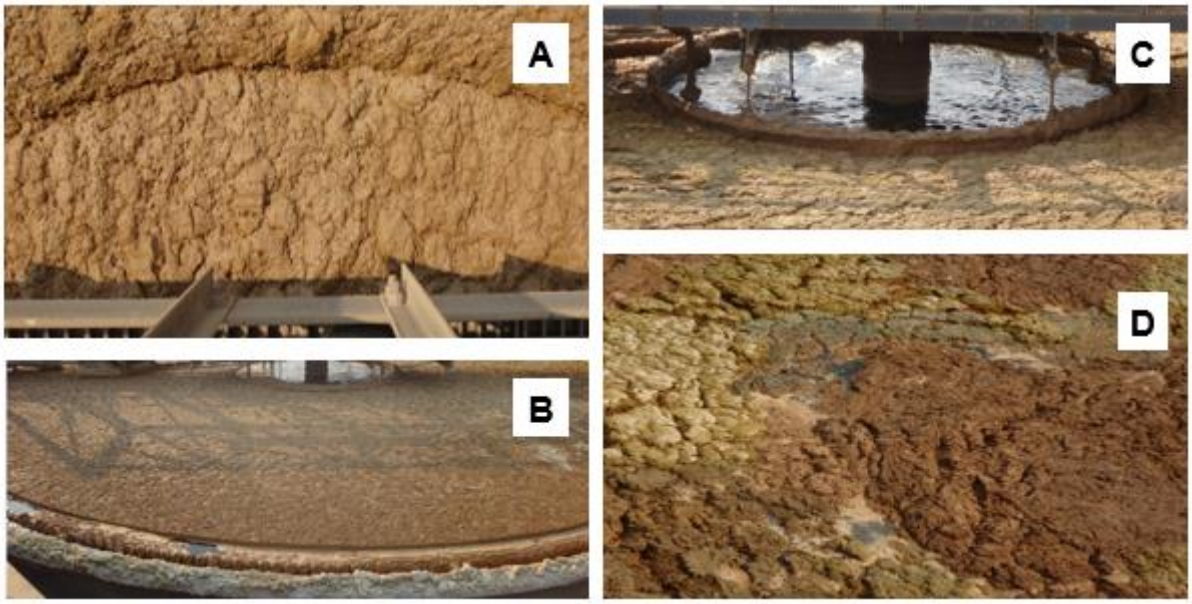

Figure 10: Field results from KemFoamX 9980 addition into feedwell.

KemFoamX 9980 is Effective in Acid System Only

KemFoamX 9980 is specially formulated for antifoaming and defoaming in an acid system. It is effective at pH < 3, making it an ideal solution for froth in leaching tanks and CCD trains; however, at pH > 3, the product has a frothing tendency, particularly if physical conditions of frothing are present.

Increasing the dosage of KemFoamX 9980 when pH > 3 results in an increase of froth; however, increasing the dosage of KemFoamX 9980 when pH < 3 results in a complete breakdown of froth.

Provided frothing conditions are present, carryover of excess active product downstream that has high pH may possibly cause frothing (Figure 11)The CCD train has pH < 2 and average excess free acid of 2–3 g/L. Excess free acid and high dissolved metals destroy the active ingredient of the product, hence its loss of efficiency over 24 h.

CONCLUSION

The chemical means of froth control, as demonstrated by application of KemFoamX 9980, has shown to be more effective when compared with traditional physical and mechanical methods. Furthermore, laboratory studies showed that the product does not have any adverse downstream effects. When KemFoamX 9980 was dosed into the leach discharge receiving thickener feedwell, it proved to effectively knock down the existing froth on the thickener and feedwell surface. It was also shown to prevent formation of new froth in the feedwell. Froth was not formed in the subsequent feedwell because the product settled out with the solids and continued to suppress froth formation.

The feedwell surface was visible and it could be seen how the flocculant was mixing by observing the mixing velocity. The overflow PLS from the thickener can be visually inspected for the presence of pin-flocs scaling off from the high mud-bed level.

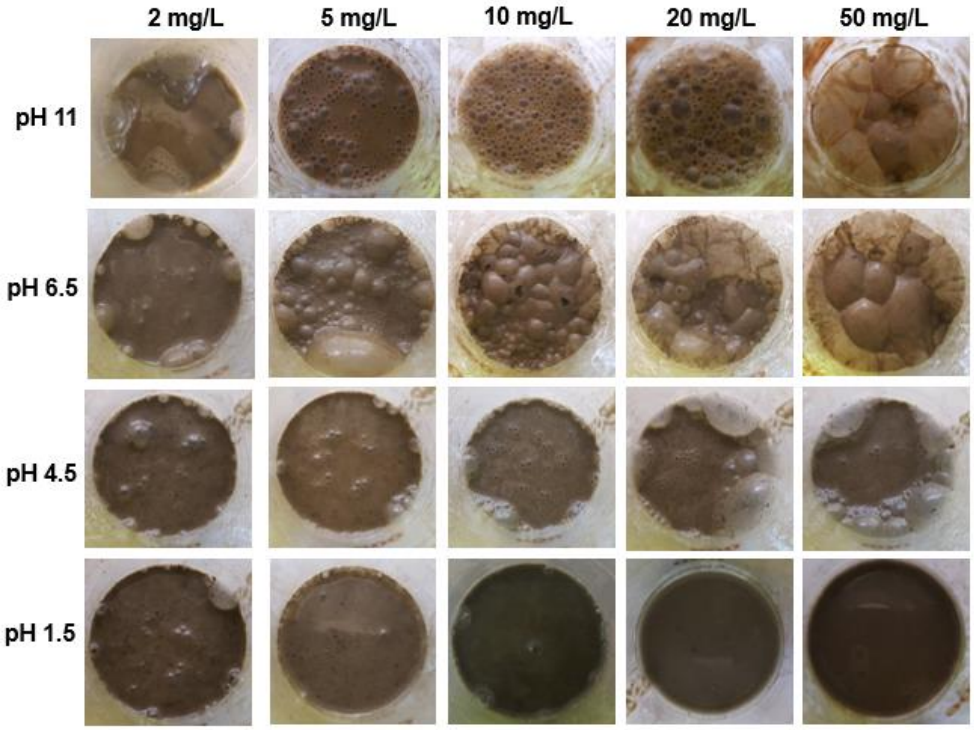

Figure 11: The frothing tendency of KemFoamX 9980 in pH > 3. The product is specially formulated for defoaming and antifoaming in acid media of pH < 3.

Long-term application of KemFoamX 9980 can allow accurate measurement of total suspended solids (TSS) reduction in PLS and subsequent reduction of crud volumes in SX; however, this was not within the scope of this study and will be considered for future study that includes a full prolonged plant trial for the potential benefits to be fully evaluated, followed by a complete evaluation of the impact of the chemical on the plant processes and operations.

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