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WATER QUALITY CHANGE DUE TO THE MINE BACKFILLING AND ITS POSSIBLE RESPONSE TO TALC FLOTATION

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Abstract: A study was carried out in the framework of international R&D Project to determine the effect of water quality changes due to mine backfilling on talc flotation performance. The influence of two types of cemented paste backfill (Shotcrete and backfill) on flotation process water was investigated using the indoor soaking method, and the water quality was evaluated through water chemistry analysis, in addition to measuring pH, conductivity, and zeta potential as a function of soaking time. At the same time, talc batch flotation tests were performed using a KHD Humboldt Wedag lab cell for a period of 20 minutes. Soaking water at different soaking times was used as a process water for flotation, and tap water was also used to establish a reference response. Based upon the experimental results from the talc flotation and the several water quality parameters measured in the soaking water, conclusions were drawn.

Keywords: *paste-backfilling, water quality, flotation, zeta-potential, pH, conductivity*

1. INTRODUCTION

Mineral processing operations generate the so-called “mine tailings”, which are by-products in the form of fine gangue particles ranging from 1 to 600 µm in size and mixed with process water and potentially some chemical reagents. Tailings are characterized as being economically unfeasible to process since they contain low amounts of valuable minerals. The composition of tailings is dictated by the nature of the processed ores along with the separation techniques adopted. Traditionally, tailings are discharged in slurry form into tailings ponds for the purpose of solid separation from wastewater under gravity influence. The recirculation of solid-free wastewater for mineral processing operations leads to the accumulation of solids over time, and the management of such solids poses many challenges in terms of storage, stability, and safety, in addition to the negative environmental impacts [1].

Cemented paste backfill (CPB) is one of the various tailings management methods that have been increasingly used nowadays in order to limit finite resource consumption and prevent environmental pollution. The CPB method follows the trend of environmental protection and the current environmental regulations, and it is described as being a safe storage, economical method to handle tailings. The CPB method is carried out according to the following steps: (I) It starts with storing the tailings underground, so no surface disturbance is generated. (II) The created paste has colloidal water-retention capabilities, which means that leachate generation is greatly reduced [2]. The main goal of using CPB is the formation of monoliths that serve as geotechnical supports for underground mine cavities. However, CBP can offer the prevention of air intrusion into tailings, which is important in the case of sulfide ores to limit their oxidation rate [3].

A survey by MEND [4] has reported that only a few studies have been carried out at that time to reveal the impact of using the cemented paste tailings on the surface and groundwater quality. The report also elaborated that the focus of the existing studies has been on the strength of the paste in addition to the type of additives used. It is unclear whether the paste technology has long-term effects on environmental stability from a geochemical standpoint, and whether it poses a risk of polluting underground water, which may endanger local people's water consumption or lead to process water variation for water-dependent enterprises such as flotation plants. What is clearly known is that there is an upward trend in the site-specific evaluation of paste characteristics of newly proposed mines in recent years, which is attributed to the increase in awareness of the backfill potential to generate contaminant plumes in the long term and the possibility of affecting ground and/or surface water.

A more recent study by [5] has reported that geochemical tests of cemented paste tailings have shown that the use of 3% binder as an additive to oxidized tailings greatly reduced the mobility of all evaluated constituents. The study also concluded that the release of all metal ions tested was controlled by diffusion and that cemented paste used as backfill would have no adverse or measurable effect on water quality, although certain species migration may have taken place.

Talc is a phyllosilicate mineral that is made up of hydrated magnesium sheet-silicates and has the formula $Mg_3Si_4O_{10}(OH)_2$. It is made up of two layers of silica tetrahedral bound together by octahedral brucite in a two-dimensional sheet structure. The surface area of talc is divided into two parts: the basal cleavage faces and the margins. Because there is no charged group on the face surface, the talc faces are thought to be non-polar and hydrophobic, but the edges are hydrophilic due to the presence of charged ions (Mg^{2+} and OH^-) [6].

Paper, plastic, paints, polymers, rubber, fertilizers, pesticides, ceramics, and cosmetics are just a few of the sectors that employ talc. To eliminate contaminants from talc, flotation is the favored concentration method. Particle size, pH, collector dosage, depressant dosage, pulp density, and frother dosage, as well as ionic strength and type of available electrolyte in the process water, all influence talc flotation [6]. For most of the metallurgical processes, water is considered an essential medium, which may influence the efficiency of the mineral processing. A thorough understanding of the effects of process water on the various mineralogical processes is thus required. The flotation technology as a process for mineral beneficiation is greatly influenced by the quality of the process water. The precise reasons for these effects are not fully understood. It was reported that water pH, dissolved solids, organic hydrocarbon reagents, and dissolved oxygen affect the natural hydrophilic qualities of the gangue materials present with the ore so that the gangue is activated and floats in the ore concentrate, which results in adverse effects on the flotation process selectivity [7].

2. EFFECTS OF PROCESS WATER QUALITY ON FLOTATION

The efficiency of the flotation process is directly affected by the quality of the process water, as it plays a significant role in flotation. Therefore, it is essential to recognize and monitor the quality of process water to avoid any adverse effects on mineral flotation processes [8]. It is of paramount importance to understand the influence of water quality, such as the effect of electrolyte levels, to ensure that the water quality and the chemistry of reagents are controlled to guarantee optimum mineral flotation performance.

2.1. The effect of electrolytes on flotation reagents

Reagents are used in flotation by adding them to the flotation pulp. They are added to carry out certain roles, such as manipulating the pulp chemistry and enhancing the differences in mineral surface hydrophobicity, to create suitable flotation performance. It has been proven that it is essential to evaluate the reagent's behavior as a whole and to assess its effects on both the pulp and froth phases [9].

Polymer adsorption on the surface of talc mineral and the consequent depression of naturally floatable gangue are influenced by many factors. These factors include the type of the polymer, concentration, molecular weight, pH, ionic strength, and the degree of substitution. Many studies have been performed for the purpose of investigating the effects of ions present in the process water on the naturally floatable gangue. These investigations have shown that with the existence of Ca^{+2} and Mg^{+2} cations, the activity of a depressant such as carboxymethyl cellulose (CMC) on the talc is improved, pointing out that the solution ionic strength has a critical role in the adsorption of the CMC on the surface of talc. On the other hand, these ions have a damaging effect as they activate the unwanted gangue or depress the valuable mineral. For that, it is of paramount importance to comprehend the depressant behavior used for targeting the naturally floatable minerals in the case of using process water with high ionic strength to be able to optimize the pant performance [10].

[11] has reported that in the presence of Ca^{+2} and Mg^{+2} ions, maximum talc recovery has been obtained. It was suggested that these ions were enhancing the frother adsorption on talc surfaces, increasing the floatability.

2.2. The effect of solution pH on the flotation process

Depending on the water source, various amounts of dissolved solids exist, and thus the pH of the process water may vary. The slurry pH influences the surfactant hydrolysis, the mineral surface charge, and the degree of ionization in the solution. Eventually, the pH of the solution affects the flotation process and its selectivity by enhancing or impeding the adsorption of the surfaceactive agent at the mineral-water interface [12].

If the pH of the solution is in the alkaline region, then metal ions tend to hydrolyze and precipitate in the form of hydrophilic metal hydroxides, carbonates, or sulphates. The precipitation takes place when their concentrations exceed their solubility limits, resulting in the formation of a hydrophilic barrier to collector adsorption on mineral surfaces [13]. In the literature, the most cited cations causing species precipitation are calcium, iron, and aluminum ions. These have detrimental effects on mineral recovery and grade. It has been reported that these multivalent ions result in depressing coal flotation in the pH region of metal hydroxide precipitation [14].

Generally, talc floatability is not affected by pH, but there is a negative correlation between talc suspension coagulation and pH. It should be noted that the surfaces of talc particles have a net-negative charge, and the zeta-potentials of the talc surface reduced as the pH increased. Talc has the lowest solubility at pH 9.4; by lowering pH, the negative charge of talc decreases, and its solubility enhances. As a result, pH may affect talc floatability. Talc floatability is diminished to varying degrees in acidic and alkaline solutions [6].

2.3. The effect of electrolytes on froth stability

The mineral recovery and grade achieved by the flotation process depend to a great extent on the froth phase stability and structure. The degree of froth stability depends on the type and concentration of the used frother along with the nature and amount of the suspended particles, in terms of size and floatability [15].

It has been reported that the froth phase stability tends to increase as the ion concentration in water increases, which is a consequence of the rise in the stability of the aqueous layer between air bubbles. Water recovery has been linked to the stability of the froth and it was concluded that as the froth stability increases, more water will be recovered in the flotation concentrate. Moreover, the increase in the ionic strength led to an increase in the solid and water recovery, which was linked to the increase in the froth stability [16].

The authors [16] also compared the effects of increasing the frother dosage along with increasing the ionic strength and reported that there is a possibility of varying the frother dosage and the ionic strength of the solution to achieve specific solids and water recoveries for a certain type of operation.

2.4. Electrolytes on the mineral-water interface and the electrical double layer

The chemical composition and the structure of the mineral surface, along with the nature of the electrical double layer, governs the ions' adsorption at the mineral-water interface. Adsorption can be of physical or chemical nature. Physical adsorption involves the counter ions in the double layer, while chemical adsorption is in the form of chemical reactions between the adsorption species and the ions comprising the mineral surface, which is termed chemisorption [17].

The metal ions present in the process water have the potential to change the particles' surface charge, which results in affecting the particles and waste gangue interactions or the interactions between particles and reagents. This leads to inefficient particle–bubble attachment and can affect the stability of the particle–bubble aggregates [18].

Zeta potential value changes due to the ion adsorption onto the mineral surface either by physical or chemical sorption. Moreover, the value of zeta potential can be lowered by changing the concentration of potential-determining ions or by increasing the ionic strength of the solution. If high electrolyte concentrations are present in a solution, the surface charge of particles may change due to the adsorption of cations onto the surface of these particles, which leads to a strong attraction between the particles [17]. This was demonstrated by [19], as it was reported that the adsorption of Ca^{+2} and other metal ions onto the surfaces of particles led to a decrease in their negative surface charge, which resulted in detrimental effects on the adsorption of xanthates onto galena, thus low recovery of galena by flotation.

This paper presents an experimental study conducted through water sampling, quality analysis, and batch flotation tests using talc, to reveal the potential for species migration from cemented paste backfilling specimens containing tailings towards the soak water and the possible influence of these species on the yield, grade, and recovery of talc flotation.

3. MATERIALS AND METHODS

3.1. Overview

The experimental test work was comprised of batch flotation tests using soaked water from two tubs containing two different types of cylindrical solid specimens representing the cemented paste (Shotcrete and Backfill) contained tailings and immersed in tap water. Moreover, the water quality of the soaked water was explored by taking samples and analyzing them for pH, zeta potential, and conductivity using a laser light-scattering BROOKHAVEN instrument (ZetaPALS), in addition to chemical analysis (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) to reveal the water chemistry and species migration.

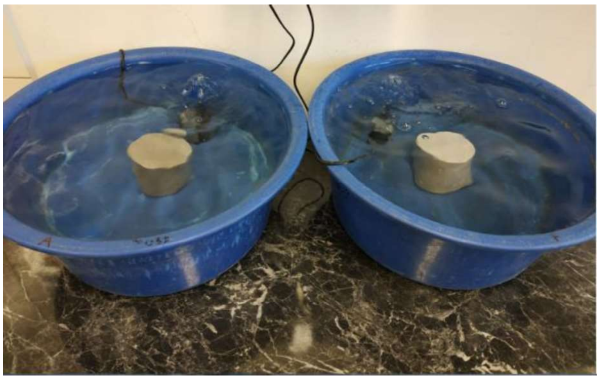


Figure 1
The cemented paste sample soak in tap water

The water tubs containing the cemented paste specimens were subjected to semi-dynamic conditions, being agitated for eight hours per day using submersible pumps to ensure water circulation and contact with the immersed specimen. *Figure1* shows the soak method, and *Table 1* presents the dimensions and the ingredients of the used specimens. The water samples for both quality measurements, and the flotation tests were taken based on different soaking times in the days following the immersion of the cemented paste specimens in the water tubs. Water samples for quality measurements, and for the flotation tests and their sampling times are shown in *Table 2.*

3.2. Sample Preparation

The sample used in the flotation tests, as well in zeta-potential measurements was talc ore from Talc Processing Plant in Gemerska Poloma, which was dry ground to ≤315μm during Bond-tests.

Table 1

Cemented paste specimens dimensions and the ingredients

	Shotcrete (S)	Backfill (B)
Dimensions:		
Diameter (cm)	10 cm	10 cm
Length (cm)	10 cm	10 cm
Ingredients:		
Cement		
Flotation tailings		
Aggregates [>10 mm]		
Technological water		
Additive MG504		
Additive HCA		

Table 2

Quality measurement and flotation tests water samples and their sampling time

Soaked Water Sample (Designation)	Soaking Time (Days)
S.W1, B.W1	Day 1
S.W2, B.W2	Day 2
S.W3, B.W3	Day 3
S.W4, B.W4	Day 4
S.W5, B.W5	Day 8
S.W6, B.W6	Day 9
S.W7, B.W7	Day 10
S.W8, B.W8	Day 11
S.W9, B.W9	Day 14
S.W10, B.W10	Day 15
S.W11, B.W11	Day 16
S.W12, B.W12	Day 17

3.3. Flotation Procedure

A 310 g sample of talc was put into a self-aerated KHD Humboldt Wedag AG flotation machine with a volume of 1 L, and the rotor of the cell was lowered into the cell. The air intake valve was closed, and the cell was filled with water up to the 1 L mark. The rotor (rotation speed = 1900 min^{-1}) was started to agitate the solids for 2 minutes to achieve good conditioning of the pulp and to eliminate any possible air pockets. Afterwards, 4.65 ml of frother (Aerofroth 70, diluted to 1 g/L) was added and conditioned for 2 minutes. The flotation was started by opening the air, which was controlled through the air admission valve, and this was timed using the stopwatch. An additional frother of 4.65 ml was added twice to the rougher stage after 4 and 10 minutes from the start of the test. The froth was collected into the concentrate pan at 15-second intervals for a total of 20 minutes. *Figure 2* illustrates the flotation process flowsheet. After flotation, the concentrates and the tailings were put in the oven at 105 ºC.

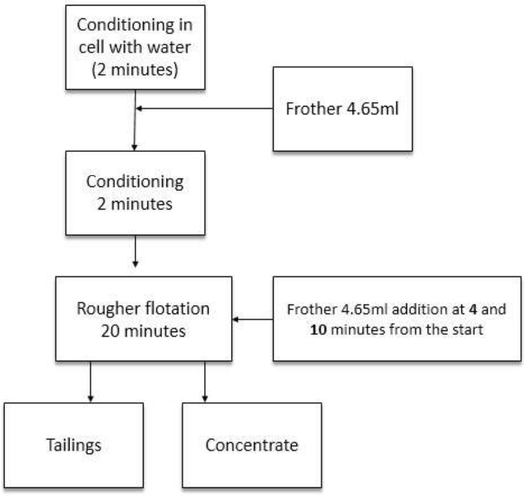


Figure 2
Flotation process flowsheet

3.4. Post Flotation Sample Preparation

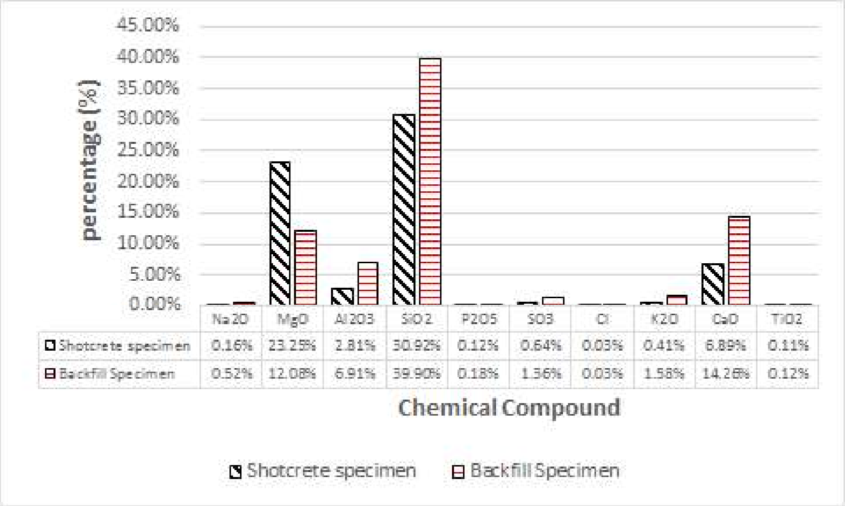
The dry samples were removed from the pans, taking special care to avoid loss and contamination of the fine material. The concentrates and tails were placed into small plastic bags. The bags were weighed for dry mass determination and marked for chemical analysis.

4. RESULTS AND DISCUSSION

The results from the chemical composition analysis of the used specimens (Shotcrete, Backfill) can be seen in *Figure 3*, and it reveals that silicon dioxide (SiO2) makes up the largest percentage of the composition (>30%) followed by magnesium oxide

(MgO) and calcium oxide (CaO) in both specimens. In addition to that, there were minor traces of sodium and potassium oxides.

Based on the results from the chemical composition analysis of the cemented paste specimens, it was assumed that the species migration from the immersed specimens towards the soak water would be to a great extent composed of the above-mentioned compounds. The dissolution of these compounds would contribute to an increase in the concentration of the following ions: Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}. Therefore, the water chemistry of the soaked water was analyzed to reveal the behavior of these specific ions.



	Na2O	MgO	Al2O3	SiO2	P2O5	SO3	Cl	K2O	CaO	TiO2
▨ Shotcrete specimen	0.16%	23.25%	2.81%	30.92%	0.12%	0.64%	0.03%	0.41%	6.89%	0.11%
⊟ Backfill Specimen	0.52%	12.08%	6.91%	39.90%	0.18%	1.36%	0.03%	1.58%	14.26%	0.12%

Figure 3

Chemical composition of Shotcrete and Backfill specimens

The test results from the chemical analysis of soak water in *Figure 4*, show that the concentration of calcium ions in the water samples *[Figure 4(a)]* has decreased sharply below that of tap water and continued to decline slightly as a function of soaking time. Magnesium ions *[Figure 4(b)]*, showed little to no change in concentration as the value didn't deviate from that of the tap water at 3.3 mg/L. The concentrations of Na^{+} and K^{+} [*Figure 4(c)* and *(d)*] varied erratically, but the common trend was that these ions were elevated moderately above the level in tap water. It can also be noticed from *Figure 4* that there is no significant difference in the behavior of the soak water from the shotcrete and the backfill specimens.

The initial assumption was that calcium and magnesium ion concentrations were expected to show an increasing trend as a function of soaking time, based on their high content in the immersed specimens. The actual results mentioned above disproved this claim, as the concentration of calcium was showing a decreasing trend as a function of sampling time, while the magnesium concentration showed no change in value. This may be due to favourable conditions for chemical reactions leading to the consumption of these ions in the water, most likely chemical reactions and bonding between CO_2 and Ca^{+2} species.

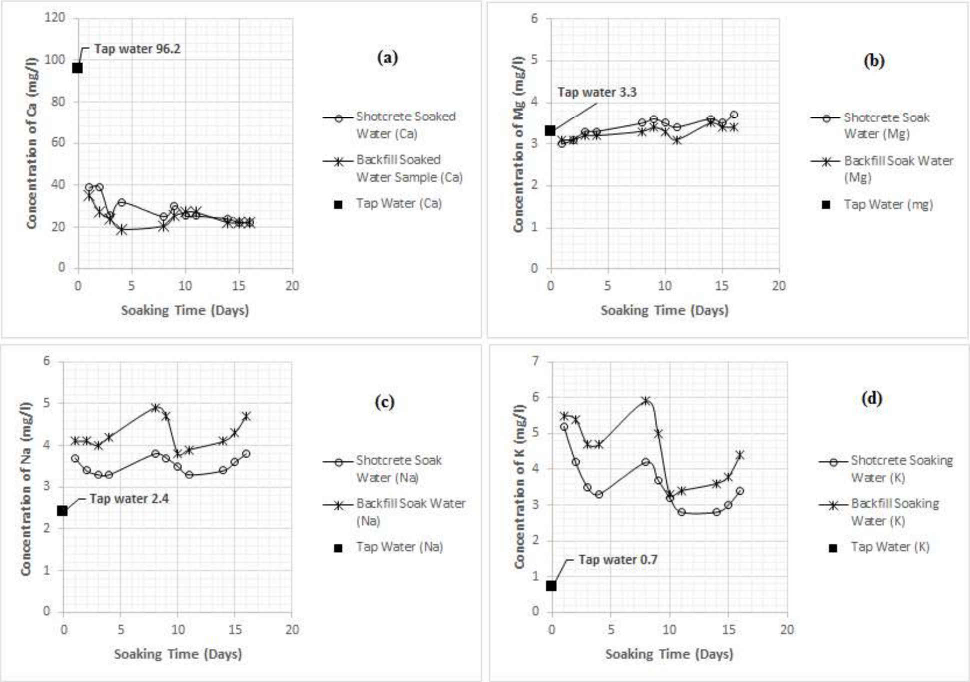


Figure 4

(a) *Concentration change of* Ca^{+2}; ***(b)*** *Concentration change of* Mg^{+2};
(c) *Concentration change of* Na^{+}; ***(d)*** *Concentration change of* K^{+}

Performing the rougher flotation stage for twenty minutes using the soak water from the two cemented paste specimens resulted in a complete recovery of the talc content in the feed. Therefore, the recovery values from the different flotation tests will not be used for further comparison of the soak waters' impact on talc flotation. The change in the concentrate grade as a function of the flotation mass pull is depicted in *Figure 5*.

Figure 5 shows that soaking water does have an adverse effect on flotation performance. From this, it is clear that the grade of the concentrate was decreasing with the increase of the concentrate yield. The grade of the concentrate was the highest (85%), corresponding to the lowest concentrate yield, with 50.92% obtained after using **B.W8** soak water. Furthermore, the highest concentrate yield (57.38%) using **S.W12** was associated with one of the lowest concentrate grades (74.10%). These results indicate that obtaining a higher concentrate yield had a negative effect on the final grade of the concentrate. Moreover, the soaking time does not appear to have a direct relationship with the yield obtained from the flotation test. However, a correlation of increasing grade with the increase in the soaking time of the cemented paste specimens was observed. Also, it can be noticed that using shotcrete soak water resulted in a higher concentrate yield when compared to using backfill soak water, which is reflected in their lower concentrate grade.

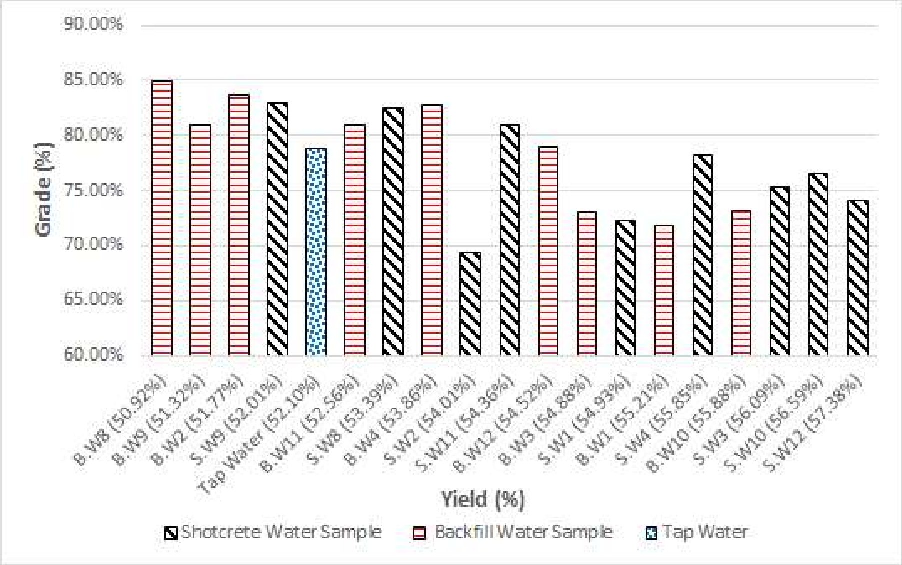


Figure 5

Flotation grade versus yield for different soak water

As initially expected, *Figure 6* shows that the pH of the soaking water has slightly increased over the pH of tap water, to be in the range of 7.8 to 8.15. The original assumption was that the pH increase would take place due to the increase in Ca^{+2} and Mg^{+2}, but based on the water analysis results, this assumption was proven to be invalid. This indicates that other species' migration and dissolution might be responsible for this increase in pH.

Figure 6 also shows that there is no link between the soaking time and pH, as the pH values, although higher than the original tap water, have changed randomly with different soaking times. Moreover, the shotcrete soaking water initially had higher pH values compared to that of the backfill, but as soaking time increased, this difference in pH values began to dissipate, and a less significant difference can be spotted.

In *Figure 7*, the talc flotation yield change as a function of pH is shown. In this plot, it can be seen the talc flotation yield increased with the increase of the pH value of the used process water. The increase was restricted to a pH value of 8.0, after which the talc flotation yield showed a decreasing trend.

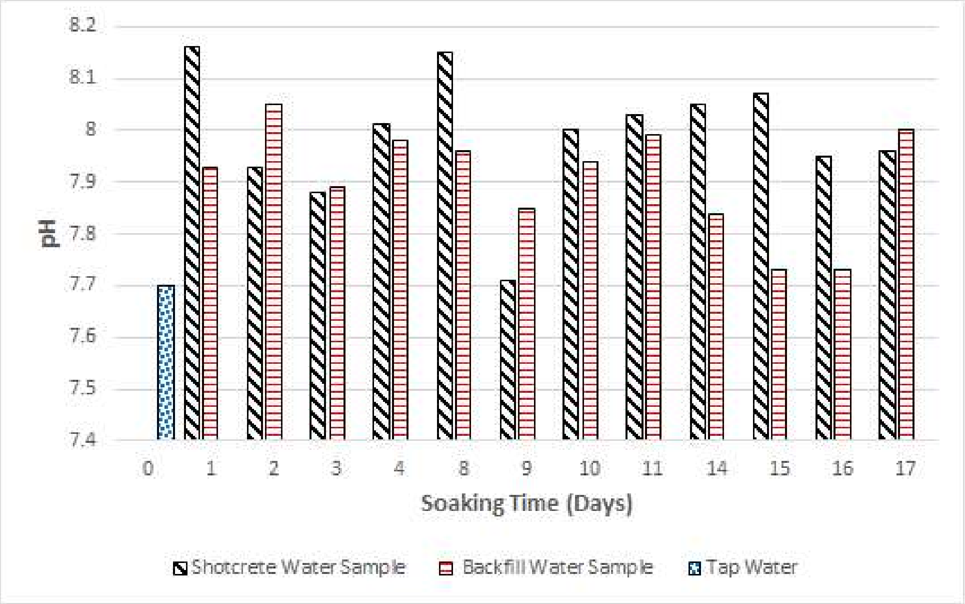


Figure 6
pH change with soaking time

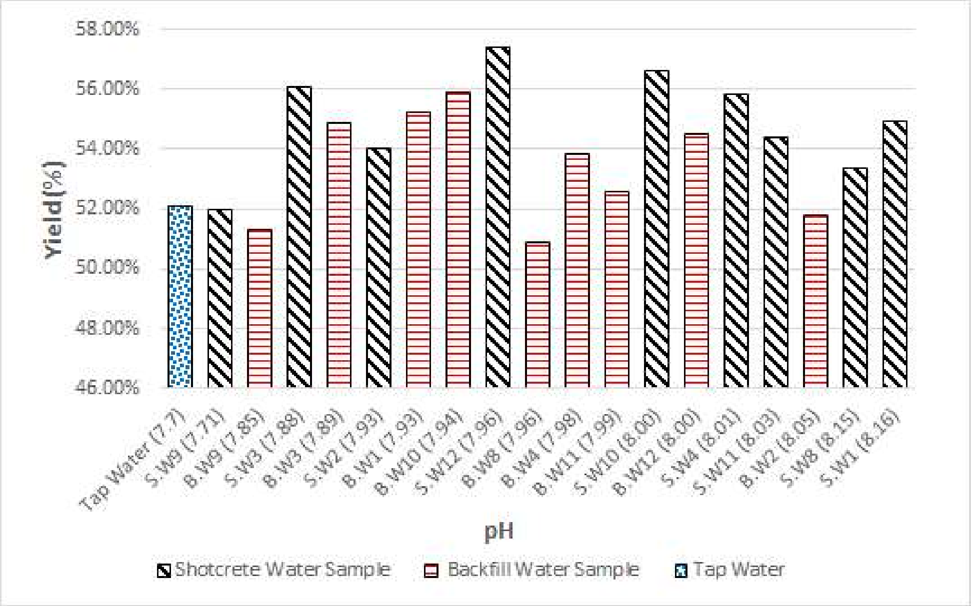


Figure 7
The plot of flotation yield versus pH

It can be seen from *Figure 7* that using shotcrete-soaked water generally results in a slightly higher talc flotation yield compared to using tap water or backfill soaked water. The yield while using shotcrete-soaked water showed a decreasing trend after pH of 7.96, and the yield using backfill soaked water declined after pH of 7.94. The highest flotation yield (57%) was achieved using shotcrete-soaked water after 17 days at a pH of 7.96, while the lowest (51%) was obtained by using the backfill soaked water sample after 11 days at a pH value of 7.96. These results are in agreement with [20], which, based on talc flotation tests, concluded that pH 8.0 was the optimum for talc's natural floatability.

The conductivity, as seen from *Figure 8*, is showing a gradual decrease as the soaking time progressed compared to the original conductivity value for the tap water (1208 µS). This trend in conductivity was completely unexpected since the original assumption was that the migration of species and their dissolution in water would result in higher conductivity values of the soaked water. These results indicate that the system has conditions favoring chemical reactions leading to the consumption of electrolytes in the soaked water. Finally, again, there was no significant difference in the behavior of shotcrete and backfill soaked water in terms of conductivity.

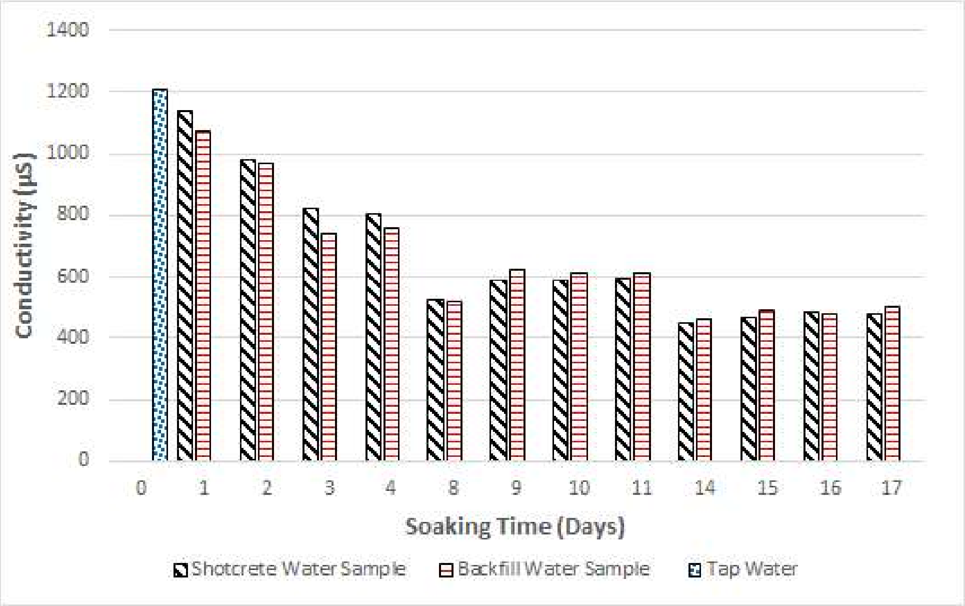


Figure 8
Conductivity change with soaking time

As observed in *Figure 9*, conductivity does influence talc flotation yield. The use of sample **S.W12**, with the lowest conductivity (477 µS) resulted in the highest flotation yield (57.38%).

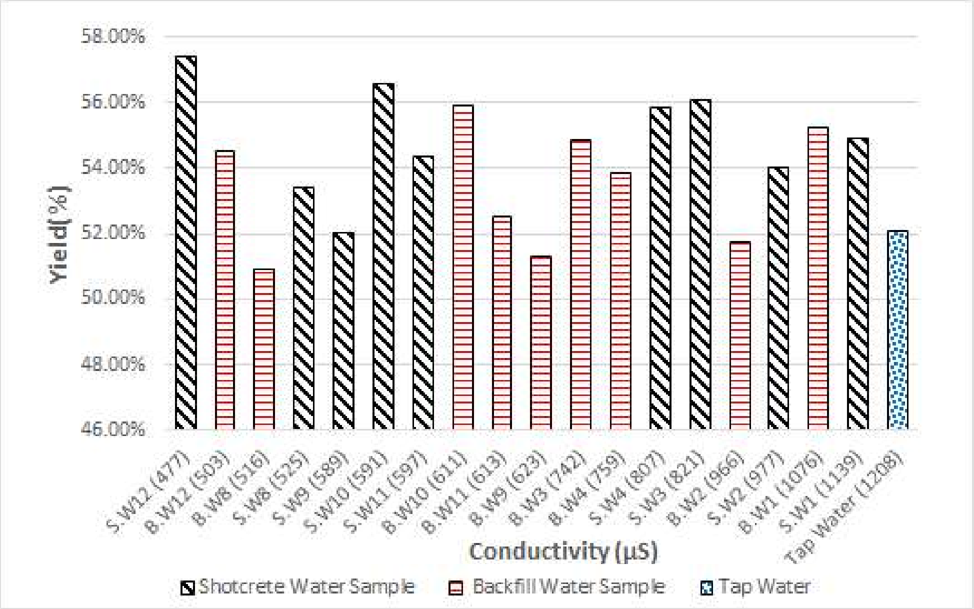


Figure 9

The plot of flotation yield versus conductivity

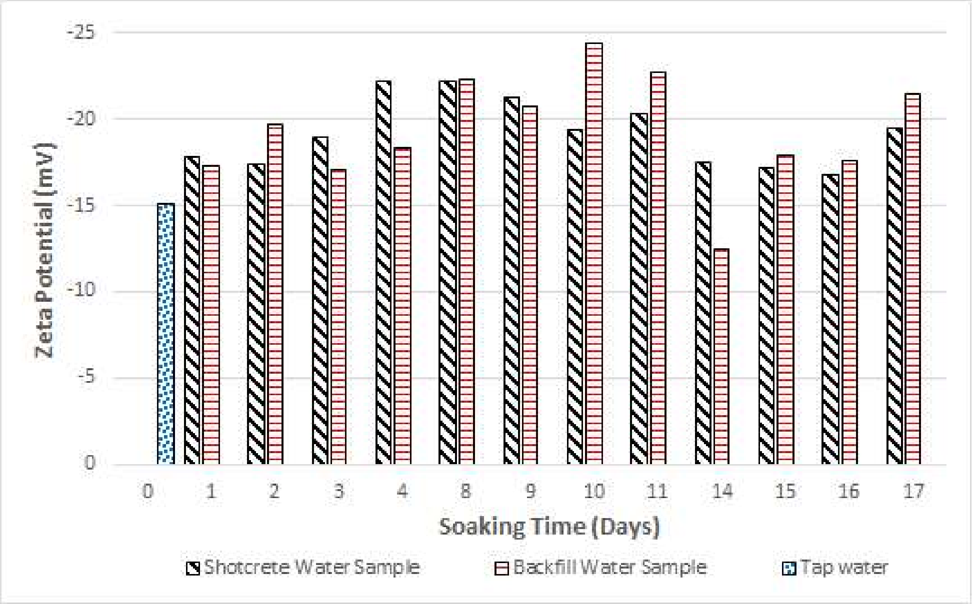


Figure 10

Zeta potential change with soaking time

Tap water with the highest

Tap water with the highest conductivity (1208 µS) produced one of the lowest flotation yield (52.1%) and according to [6] this can be attributed to the presence of high concentration of divalent cations such as Ca^{+2} (96.2 mg/l) which can decrease the natural floatability of talc resulting in a lower flotation yield.

The results from the zeta potential measurements revealed that there is indeed a migration of species from the cemented paste specimens towards the soaking water as the zeta potential values of talc have shown some changes as a function of soaking time. Although there is a lack of a certain trend in the zeta potential values of talc, as can be seen in *Figure 10*, it is observed that zeta potential values of talc increased slightly over the values obtained by using tap water, which indicates that there is some sort of species adsorbing onto the surface of talc particles. It can also be noticed that the behavior of talc zeta potential caused by shotcrete and backfill soaked water showed no significant difference.

From *Figure 11*, it can be seen the flotation yield has highly declined beyond the value of –19.5 mV, in particular with the backfill soaked water. However, this observation is not enough to generalize a legitimate link between zeta potential and talc flotation yield.

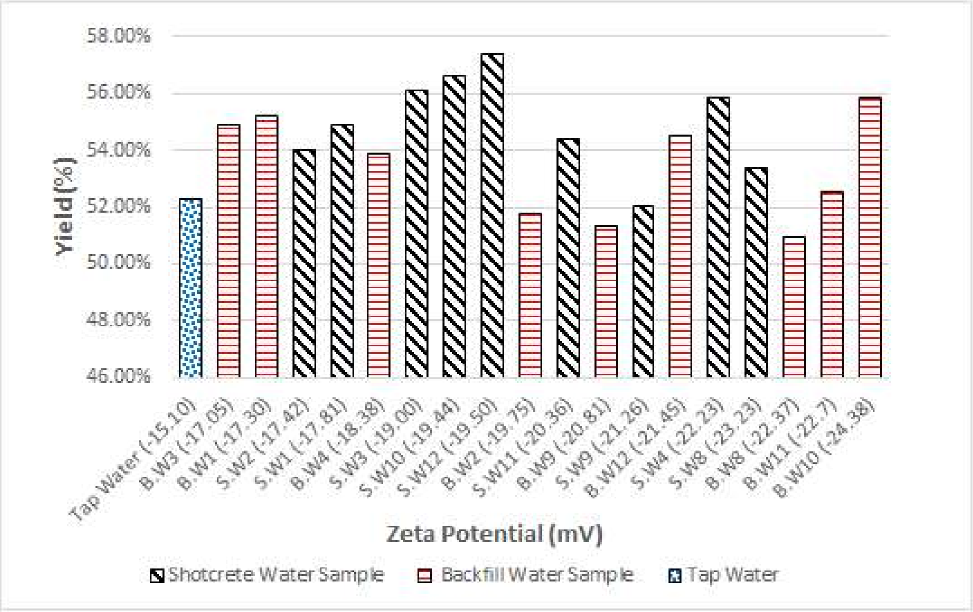


Figure 11

The plot of flotation yield versus talc zeta potential

5. CONCLUSIONS

Based upon laboratory analysis by measuring several water quality parameters (pH, conductivity, and zeta potential) for soaked water samples that resulted from the immersion of two cemented paste fillings at different soaking times, in addition to performing talc batch flotation tests using the soaked water samples, the following conclusions were drawn:

- The immersion of cemented paste fillings has proven to contribute to the migration of species towards the hosting water, and that was concluded based on changes taking place in the water chemistry of the soaked water, as well as due to the changes in the measured quality variables of pH and the conductivity of the soaked water along with the talc zeta potential.
- Although the initial assumption was that calcium and magnesium ion concentrations were expected to show an increase in the soaked water based on their high content in the used cemented paste filling specimens, the actual results disproved this assumption, as the concentration of calcium was showing a decreasing trend as a function of soaking time, potassium and sodium had minor increases, while the magnesium concentration showed no change in value.
- Shotcrete and the backfill specimens were different in composition as indicated in the preparation materials and chemical analysis, but both had similar effects on pH, conductance, and talc zeta potential.
- The results obtained in this study indicate that the soaking water has effect on flotation performance, in particular yield and grade, as a complete recovery was obtained from the 20-minute rougher flotation stage. Batch flotation results indicate that increased mass pull was associated with a lower concentrate grade. The mass pull was independent of the soaking time, while the grade showed some correlation with soaking time, since a better grade was achieved as more soaking time passed.
- Among the three measured variables, the conductance had a blatant tie with the flotation yield of talc since the yield decreased as the conductivity of the used soaked water increased, indicating that high conductivity had a negative effect on the flotation yield of talc mineral.

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REFERENCES

[1] Hefni, M., Ahmed, H., Omar, E., & Ali, M. (2021). The Potential Re-Use of Saudi Mine Tailings in Mine Backfill: A Path towards Sustainable Mining in Saudi Arabia. *Sustainability*, 13 (11), 6204. https://doi.org/10.3390/su13116204

[2] Jiao, H., Wu, A., Wang, H., Yang, S., Li, R., & Xiao, Y. (2011). The Influence of Cemented Paste Backfill on Groundwater Quality. *Procedia Earth and Planetary Science*, 2, 183–188, https://doi.org/10.1016/j.proeps.2011.09.030.

[3] Hamberg, R., Maurice, C., & Alakangas, L. (2017). Lowering the water saturation level in cemented paste backfill mixtures – Effect on the release of arsenic. *Minerals Engineering*, 112, 84–91. https://doi.org/10.1016/j.mineng.2017.05.005

[4] MEND. Mine Environment Neutral Drainage (2006). *Paste backfilling geochemistry- Environmental effects of leaching and weathering*. Available at http://www.mend- nedem.org.

[5] Schafer, William (2016). Geochemical Evaluation of Cemented Paste Tailings in a Flooded Underground Mine. In: Drebenstedt, C. & Paul, M.: *IMWA 2016 – Mining Meets Water – Conflicts and Solutions*. Freiberg/Germany (TU Bergakademie Freiberg), 714–724.

[6] Ann Bazar, J., Rahimi, M., Fathinia, S., Jafari, M., Chipakwe, V., & Chehreh Chelgani, S. (2021). Talc Flotation—An Overview. *Minerals*, 11 (7), 662. https://doi.org/10.3390/min11070662

[7] Muzenda, E. (2010). An investigation into the effect of water quality on flotation performance. *World Academy of Science, Engineering and Technology*. Retrieved 3 November 2021, from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.190.6757&rep=rep1&type=pdf.

[8] Slatter, K. A., Plin, T, N. D., Cole, M., De Vaux, D., Palm, N., Oostendorp, B. (2009). Water management in Anglo Platinum process operations: effects of water quality on process operations. *Int. Mine Water Conf.*, Pretoria, South Africa, 19th–23rd Oct. 2009, Proc. ISBN Number 978-0-9802623-5-3 46–55.

[9] Bradshaw, D., Oostendorp, B., & Harris, P. (2005). Development of methodologies to improve the assessment of reagent behavior in flotation with particular reference to collectors and depressants. *Minerals Engineering*, 18 (2), 239–246, https://doi.org/10.1016/j.mineng.2004.09.012.

[10] Khraisheh, M., Holland, C., Creany, C., Harris, P., & Parolis, L. (2005). Effect of molecular weight and concentration on the adsorption of CMC onto talc at different ionic strengths. *International Journal of Mineral Processing*, 75 (3–4), 197–206, https://doi.org/10.1016/j.minpro.2004.08.012.

[11] Yehia, A., & Al-Wakeel, M. (2000). Talc separation from talc-carbonate ore to be suitable for different industrial applications. *Minerals Engineering*, 13 (1), 111–116, https://doi.org/10.1016/s0892-6875(99)00154-5.

[12] Deng, M., Liu, Q., & Xu, Z. (2012). *Impact of Total Dissolved Solids in Process Water on the Surface Properties of Silica and Sphalerite Minerals*. Society for Minining, Metallurgy, and Exploration, 225–236.

[13] Reyes-Bozo, L., Higueras, P., Godoy-Faúndez, A., Sobarzo, F., Sáez-Navarrete, C., Vásquez-Bestagno, J., & Herrera-Urbina, R. (2014). Assessment of the floatability of chalcopyrite, molybdenite and pyrite using biosolids and their main components as collectors for greening the froth flotation of copper sulphide ores. *Minerals Engineering*, 64, 38–43. https://doi.org/10.1016/j.mineng.2014.04.004

[14] Liu, W., Moran, C., & Vink, S. (2013). A review of the effect of water quality on flotation. *Minerals Engineering*, 53, 91–100. https://doi.org/10.1016/j.mineng.2013.07.011

[15] Wang, B., & Peng, Y. (2014). The effect of saline water on mineral flotation – A critical review. *Minerals Engineering*, 66–68, 13–24. https://doi.org/10.1016/j.mineng.2014.04.017

[16] Corin, K., & Wiese, J. (2014). Investigating froth stability: A comparative study of ionic strength and frother dosage. *Minerals Engineering*, 66–68, 130–134, https://doi.org/10.1016/j.mineng.2014.03.001.

[17] Manono, M., Corin, K., & Wiese, J. (2018). Perspectives from literature on the influence of inorganic electrolytes present in plant water on flotation performance. *Physicochemical Problems of Mineral Processing*, 54 (4), 1191–1214, https://doi.org/10.5277/ppmp18157.

[18] Ata, S. (2012). Phenomena in the froth phase of flotation — A review. *International Journal of Mineral Processing*, 102–103, 1–12. https://doi.org/10.1016/j.minpro.2011.09.008

[19] Ikumapayi, F., Makitalo, M., Johansson, B., & Rao, K. (2012). Recycling of process water in sulphide flotation: Effect of calcium and sulphate ions on flotation of galena. *Minerals Engineering*, 39, 77–88. https://doi.org/10.1016/j.mineng.2012.07.016

[20] Boulos, T., Ibrahim, S., & Yehia, A. (2016). The Art of Talc Flotation for Different Industrial Applications. *Journal of Minerals and Materials Characterization and Engineering*, 04 (03), 218–227. https://doi.org/10.4236/jmmce.2016.43020.