The Second International Conference on Mining Engineering and Metallurgical Technology

The influence of cemented paste backfill on groundwater quality

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Abstract

This little literature studies the influence of cemented paste backfill (CPB) on ground water in diggings based on quality comparison between tailings slurry, thickener overflow, indoor soak sample, and seepage of underground paste. Firstly, determine the proportion of injurious ingredient filled underground. Secondly, investigate the amount of hazardous material which are leached from paste during the long time soaking. At last, the detection is made on underground seepage water, and also sample's quality is judged by multi-object decision. The result shows, 16.74% ~ 79.83% of injurious material in the tailings slurry has been filled into the underground, however, the soak and seepage water turned out to be level I and II when synthetically evaluated by five indexes, which shows the CPB would not pollute the underground water, and it is safe, also feasible to adopt CPB in mining industry.

1. Introduction

The five basic types of reagents used in froth flotation recovery include collectors, frothers, depressants, activators and modifiers. Reagents dosed in small quantities are not consumed, retained in the process or discharged with the tailings. Seepage from tailings may lead to surface water and groundwater contamination. It may be more economical to hold water for longer periods of time to allow natural degradation of reagents rather than promoting rapid degradation through dosing [1].

Cemented paste backfill is an economic and safe storage method that respects current environmental regulations with advantages to environment as following. Firstly, the tailings are stored underground and

thus prevent surface disturbance. This is more environmentally friendly as areas of land don't have to be used for a surface tailings storage area. Secondly, due to the colloidal water-retention capabilities of paste, very little free water is available for generation of a leachate, thereby reducing potential impacts on receiving waters and biological receptors [2]. At last, co-disposal of other waste materials with paste is made feasible by the paste production technology. In particular, "encapsulation" of acid generating waste in appropriately designed paste may provide significant benefits in terms of environmental control [3].

The mine uses floatation technique to carry out the mineral processing, and waste is unclassified tailings slurry, with a concentration of 18% to 30%, where there are lots of residual beneficiation reagents and metal ions (Pb, Zn, Cu, Cb) [4]. Then, tailings slurry is pumped into deep cone thickener for dewatering. Residual reagents together with tailings form paste, and pumped down to underground [5].

It is still uncertain whether it would pollute the underground water, or it would be a threat to the water use of the local people, and enterprise if paste with residual beneficiation reagents and metal ions are filled into the underground areas. Through sampling tests, indoor experiments and water quality analysis, this paper studies on the effect of paste filling on the underground water quality.

2. The portion of reagents pumped underground

The reagents content in the tailings slurry and and overflow of Deep-Cone Thickener (DCT) have been tested, the dosage reduction in tailings water is translated underground voids. The results show in Table 1.

As shown in the Table 1, the contents of Pb have exceeded the Standard, while the other metal's contents are all lower than the Standard. The number of each index in the overflow is toboggan, where 16.74% to 79.83% of injurant are separated into cemented paste tailings filling underground.

Table 1. Test results of tailings water and overflow

Sample	pH	Pb	Zn	C	Cd	SS
		(mg/L)				
Tailings water	8.86	3.922	1.704	0.031	0.024	55.25
DCT Overflow	7.01	0.791	0.640	0.024	0.014	46.00
Filled Rate (%)	—	79.8	62.4	22.6	41.7	16.7
Discharge Standard (GB8978-1996)	6-9	1.0	5.0	1.0	0.1	300

3. Indoor test on the quality of paste soak water

3.1. The CPB sample

The principle is that the contents of sample must the same to the underground CPB. The ratio of CPB is 6:2:1 (tailings: water-quenched slag: cements), consistency is 2.07g/cm3. Finally, the dimension of CPB sample is 70.7 mm*70.7 mm*70.7 mm. The contents of sample are shows in Table 2 [6].

3.2. Soak

The 5 paste samples are soaked in distilled water for different days (8d, 30d, 45d, 60d and 75d), and then detect the ions in the soaking water. The soak method shows in Fig. 1.

Table 2. The main compositions of paste sample.

Component	Chemical composition (%)			
	S	CaO	MgO	SiO$_2$
Tailings	2.02	38.62	6.63	6.17
Water quenching slag	0.21	15.26	3.98	33.14

Fig. 1. The paste sample soak in distilled water.

3.3. Analysis on test results

The test results shows in Fig. 2, it can be found that the quantity of partial ions in the water sample has changed erratically, such as arsenic, barium and so on. Then, we analyze the mechanism and the reasons of these changes.
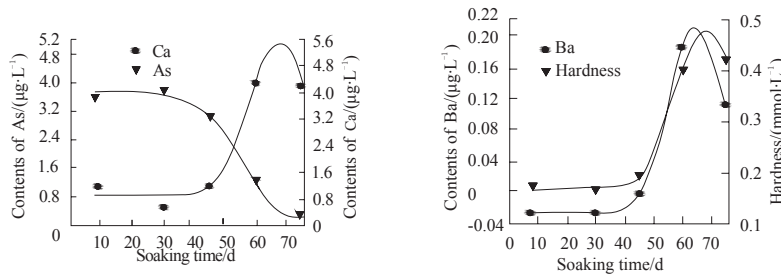

Fig. 2. (a)The content changes of As and Ca; (b) The content changes of Ba and hardness

There are mass of arsenic & sulphur contained in the ore body and wall rock. The long time soaking diffuse the the arsenic and other deleterious metal ions used to adsorb on the tailings. The concentration gradient causes the transference of these ions, also the reductive circumstance and low pH is propitious for the transfer [7]. The Fig. 2(a) shows that, the content of arsenic has increased slightly after 8~30 days' soak, however, as time goes by, the ions adsorb on the paste sample again, which cause the sudden decrease of arsenic ion. Therefore, the curve of arsenic ion shows a trend of first slight increase, then sharp decrease, so do selenium and other metal ions.

As shown in Table 2, there are plenty of calcium, magnesium, iron and other oxide in the paste, so the water becomes alkalescent. As shown in Fig. 2(a), the content of ions has increased, and the total hardness shares the same situation. The value of hardness presents the quantity of calcium, barium ions in the water, and neutral circumstance won't affect the water in tailings filling [8]. The quantity of chloride ion increases with soaking time , and there is a sudden increase after 45 days which shows the chemical composition in the paste begins to hydrolyze and diffuse, therefore, the quantity of chloride and total

hardness increase. After 60 days' soaking, the quantity of chloride ion decreases, which explains that the concentration of water sample increases with that of all kinds of ions, as shown in Figure 2(b).

To conclude, with the longer of soaking time, every target ions content in the water sample has decreased differently. It can drop the concentration of heavy metal ions, so does the total hardness, and sulphate breaks down, the water quality has improved.

3.4. Evaluation on the soaking water quality

The 5 of 21 indexes tested is used to be analyzed, while the others cannot be scaled, or the value is much lower than the National Standard, which can be ignored. Based on the method published by Cao [9] and the National Underground Water Standard GB/T 14848-93[10].

Five indexes are chosen to evaluate the water quality, they are arsenic, selenium, fluoride, cyanide and barium, 3 samples are used to classified and contrasted. According to the ideal point method, we set every standard c_j [c_{j1}, c_{j2}, c_{j3}] in the pollution classification standard of the underground water quality as the desired value, then calculate the distance between each detected value d_i [d_{i1}, d_{i2}, d_{i3}, d_{i4}, d_{i5}] and ideal point, and estimate their level and quality. Five values of the underground water are equal-weighted, namely $\lambda_1 = \lambda_2 = \cdots \lambda_5 = \frac{1}{5}$, set $\lambda = 1$ and $p = 2$ for convenience, then formula turns to:

$$L_2(x) = \left\{ \sum_{i=1}^{m} \left[f_i(x) - f_i^* \right]^2 \right\}^{\frac{1}{2}} \tag{1}$$

In the formula (1), $L_2(x)$ is the Euclidean distance in three-dimensional space, presenting the distance between vector $F(x)$ and vector F^* in Euclidean space. The water quality belongs to the level where the distance is the shortest. It can be calculated as below based on formula (2):

$$L_{ij} = \left\{ L\left[d_i(As) - c_j(As) \right]^2 + \left[d_i(Se) - c_j(Se) \right]^2 + \cdots + \left[d_i(Be) - c_j(Be) \right]^2 \right\}^{\frac{1}{2}} \tag{2}$$

In the formula (2), L_{ij} is overall distance between each water sample to I, II, III level, d_i (As...Be) is detected value of arsenic, selenium, fluorid, cyanide, barium in the water sample, c_j (As...Be) is desired value of arsenic, selenium, fluorid, cyanide, barium in the water samples. Then, we choose the minimal value in the three samples, namely $L=\min \{L_{i1}, L_{i2}, L_{i3}\}$ [7]. The results are shown in Table 3.

Table 3. Water quality level of paste water sample

Paste sample	L_{i1}	L_{i2}	L_{i3}	Min distance	Level
8 d	0.910	0.914	1.34	0.910	I
30 d	0.902	0.915	1.01	0.902	I
45 d	0.870	0.873	1.312	0.870	I
60 d	0.882	0.861	1.214	0.861	II
75 d	0.874	0.862	1.198	0.862	II

As shown in Table 3, the water quality tested is at level I and II, and the paste filling won't cause pollution on the underground water.

4. Indoor test on the quality of paste soak water

After solidification in the goaf, the paste becomes permanent filling body. Under the effect of seepage, partial toxic substance and heavy metal ions have been taken down to the underground water-course,

causing certain long-range pollution. Through test and evaluation on the underground water quality, whether it can cause pollution onto the underground water or not can be determined.

4.1. Sampling locate

The locate of sample 1st is the roof of 72th hole in level 1451m, sample 2nd is at the roof of 98th hole in 1451m, and sample 3rd is near the 110th hole in 1261 level roadway. The depth of sample 3rd is deeper than the other two by 190 m. And the volume of each sample is 500 ml.

4.2. Test results

21 targets ions were tested, as shows in Table 4.

Table 4. Test results of underground paste seepage sample

Sample	Arsenic	Selenium	Silver	Total Mercury	Total Hardness	Total Chrome	Sexavalent Chrome
1#	3.73	4.39	<0.004	0.044	6.03	<0.01	<0.004
2#	2.57	3.57	<0.004	<0.015	2.02	<0.01	<0.004
3#	0.089	<0.09	<0.004	<0.015	2.05	<0.01	<0.004
Sample	Fluorid	Cyanide	Cadmium	Beryllium	Barium	Zinc	Copper
1#	0.110	0.047	<0.001	0.001	0.033	0.049	<0.01
2#	0.091	0.003	<0.001	<0.0003	0.105	<0.006	<0.01
3#	0.26	0.010	<0.001	0.001	0.047	0.026	<0.01
Sample	Nickel	Kalium	Natrium	Mmagnesium	Calcium	Lead	Sulfate
1#	0.02	1.55	24.5	18.0	4.03	0.01	646
2#	0.02	0.538	0.328	12.4	4.12	<0.01	20.9
3#	<0.01	3.46	3.99	11.2	5.11	<0.01	89.1

Remark: Total Hardness, mol/L, Total Mercury, μg/L, others, mg/L

4.3. Analysis of partial test results

The mining area and its wall rock are rich in arsenic and sulphur. As can be seen in Table 5, with the depth increases, the quality of arsenic, selenium and other heavy metal ions is increasing too. The total hardness also increases with mining depth, which is mainly because of the increase of the chloride, especially the total hardness increases with the concentration of magnesium ion. Fluoride decreases while depth increases, which is caused by the increasing of pH, and the water turns to alkalescence. Besides, the concentration of fluoride is affected by the concentration of Ca^{2+} and SO_4^{2-} and the modality of their complex ions. By the test results of calcium and sulphate, The concentration of fluoride has a positive relationship with that of Ca^{2+}, while a negative relationship with that of SO_4^{2-}, and it is also affected by the surface rain dilution. However, most fluoride can dissolve in acidic water, so there is a obvious degressive trend of fluoride with the increasing of mining depth. The others have no result which is simply because of the value is below the limit of the instrument, and would not cause pollution.

As shown in Table 5, the quantity of the seepage sample is all at level I or level II, so it won't pollute the underground water.

Table 5. Sample quality standard classify

Water sample	L_{i1}	L_{i2}	L_{i3}	Min distance(L)	Level
1#	0.891	0.895	1.315	0.891	I (C_1)
2#	0.914	0.911	1.277	0.911	II (C_2)
3#	0.740	0.742	1.210	0.740	I (C_1)

5. Conclusion

1) 16.74% to 79.83% injurious ions in the tailings slurry have been filled into the underground voids.

2) The results of indoor test and in-situ monitoring show that it won't cause pollution to the underground water quality after paste filling, and it is doable to use paste filling. Though the quantity of arsenic and other heavy metal ions rises and falls, it is far below the national stand value, and it won't cause bad effect.

3) The quality of water leaching from paste is good, which is level I or level II. These water can be directly used for living and industry.

4) The underground water won't be polluted by cemented paste backfill, which shows it is feasible to adopt CPB into mining.

Acknowledgements

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