Use of glass waste for the encapsulation of metals and metalloids present in mining waste

Guadarrama Guzmán Pedro [1], Fernández Villagómez Georgina [1] and María Teresa Alarcón Herrera [2]

1. *National and Autonomous University of Mexico, Faculty of Engineering, Coyoacán, México City*
2. *Research Center of Advanced Materials, Durango, Mexico*

Keywords: Heavy metals, Solidification, stabilization, Glass.
Presenting author email: pedrop1406@hotmail.com

Introduction

Mining is one of the main causes of heavy metal pollution, mainly due to the handling of contamination of its waste (tailings). The tailings are affected by weathering, which is why the metals present in these residues can be affected by different processes that can modify mobility, bioavailability as well as cause health problems due to their high toxicity (Ramos et al., 2012) (Medel et al., 2008). The recovery of tailings is contemplated in the United Nations Sustainable Development Goals (SDGs), mentioning that mining can contribute this type of waste to the construction of sustainable cities and communities (World Economic Forum, 2016). One way to valorize the tailings is through the solidification-stabilization technique, generally said technique is used Portland cement as a binder which has the disadvantage of being expensive as well as the greenhouse gas emissions associated with it are high. The replacement of cement by borosilicate glass has a positive effect since it modifies the mechanical properties (Bagheri et al., 2017). The objective of this research was to evaluate the use of borosilicate glass as a partial substitute for Portland cement in the solidification- stabilization technique.

Materials and methods

In this work we used tailings from an iron located in northern Mexico (figure 1), the tailings samples were characterized by the US-EPA 6200 method, x-ray fluorescence. For the application of the solidification-stabilization technique, broken laboratory material was used as glass (which was ground in a ball mill to a particle size of 0.149 mm), Portland cement and tailings in different proportions previously established (table 1) and based on a design of completely random effects experiments, the equation is seen in Figure 2.

Figure 1. Sampling point

Table 1. Mixtures in each treatment

Treatment	Proportions (g)		
	Tailings	Cement	Glass
1	1080	720	-
2	1260	540	-
3	1440	360	-
4	1080	360	360
5	1260	270	270
6	1440	180	180

$$y_{ij} = \mu + \tau_i + \varepsilon_{ij} \qquad i=1,\ldots,9 \quad j=1, 2, 3$$

y_{ij} = ijth observation

μ = Overall mean

τ_i = ith treatment effect

ε_{ij} = experimental error

The hypothesis are:

$$H_0; \tau_1 = \tau_2 = \ldots = \tau_t = 0$$

$$H_a; \tau_i \neq 0$$

For at least one i

Figure 2. Experimental desing

Once the hydrated tailings, glass and cement mixtures were placed in a mold to form bricks by extrusion, once the bricks were removed from the mold they were allowed to dry for a day and then taken to the curing process, which consisted of submerging them in water for 28 days (Figure 3). After curing, the bricks were allowed to dry for a week and subsequently taken to the leaching test using the method established in the NOM-141- SEMARNAT-2004 standard. The determinations of metals in the leachate were carried out by atomic absorption using a GBC Avanta device, for the case of antimony the determinations were made by the technique of inductively coupled plasma mass spectroscopy (ICPS-MS) with a 7500 ce device Aligent.

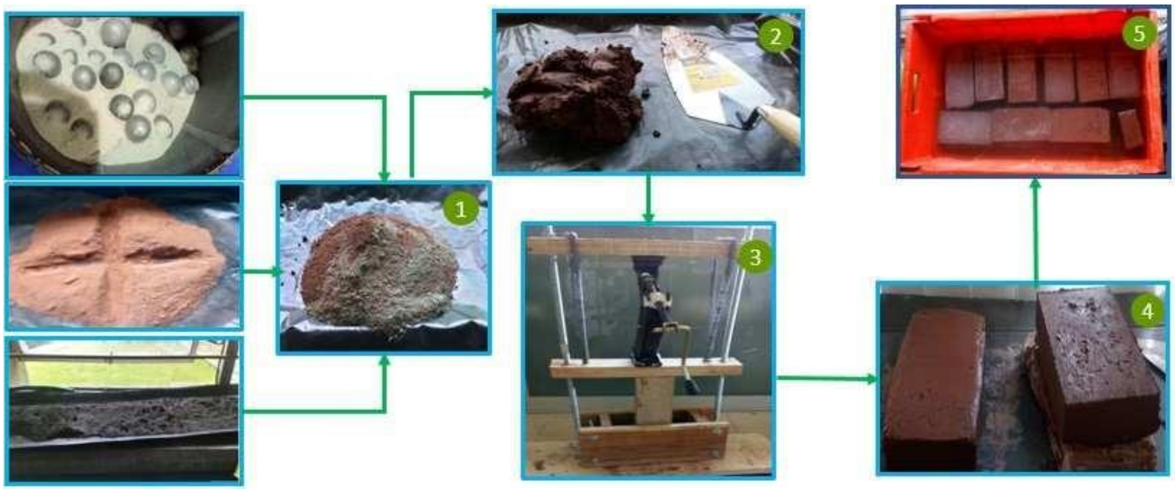

Figure 3. Solidification-Stabilization process

Results

The tailings characterization showed that two metals; chrome and antimony, exceed the maximum permissible limits (MPL) established in the norm NOM-157- SEMARNAT-2009, 100 mg / kg for chromium and 10.6 mg / kg for antimony. Due to the above, the leaching tests established in the NOM-141-SEMARNAT- 2004 standard were performed, finding that only the antimony exceeded the MPL (0.53 mg / L) with a value of 2.1 mg / L in the leachate, so that according to Mexican legislation, the tailings used are considered a hazardous waste.

The solidification stabilization technique showed that the bricks made of tailings-cement, tailings-cement-ground glass exceeded the minimum resistance value established in Mexican regulations, 30 kgf / cm2 (Figure 4), the treatments with tailings, cement and volcanic ash were below of the mentioned value. The replacement of cement with ground glass did not affect the compressive strength of the bricks, on the other hand, the replacement of cement with volcanic ash affects by decreasing the compressive strength.

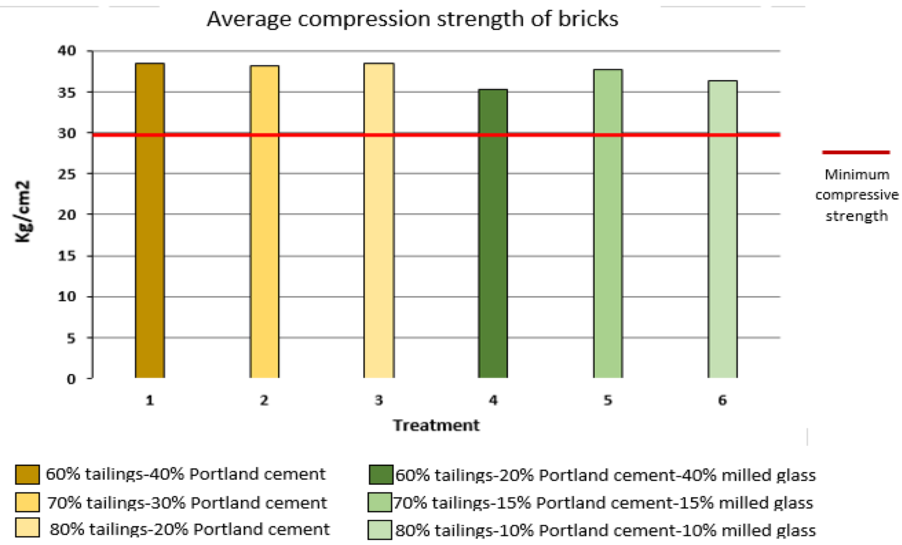

Figure 4. Average compression strength

Anova

Response: Compression

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Treatment	1	3.253	3.253	2.5315	0.1868
Residuals	4	5.140	1.285		

With $\alpha = 5\%$, the anova shows that there is no significant difference between treatments.

In figure 5 the using cement and milled glass reduces the concentration of Sb in the leachate from 2.4 mg / L to approximately 0.5 mg / L. The treatments 1, 2, 4 and 6 are below the maximum allowed limit, while treatments 3 and 5 exceed this value.

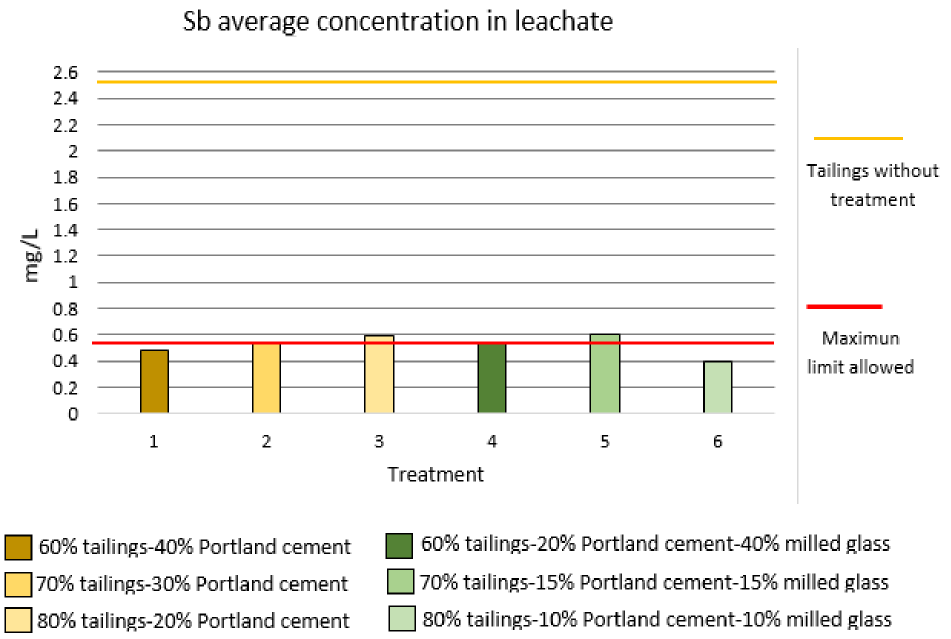

Figure 5. Sb average concentration

Anova

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Response: concentration
          Df    Sum Sq   Mean Sq F value Pr(>F)
Treatment  1 0.0012943 0.0012943  0.1785 0.6944
Residuals  4 0.0290069 0.0072517
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With α = 5%, the anova shows that there is no significant difference between treatments.

Conclusion

According to the objective, it is concluded that the use of borosilicate glass was evaluated as a partial substitute for Portland cement in the stabilization solidification technique, finding that this type of material can replace cement in the treatment of mining tailings and reuse them. both wastes (tailings and glass from broken material)

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