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DEVELOPING ALTERNATIVE INDUSTRIAL MATERIALS FROM MINING WASTE

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Abstract

The presence of mining waste (known as tailings or mining dumps) near residential zones has been a major health and environmental problem in the mining district of Hidalgo, Mexico, causing allergies and respiratory complications due to the strong winds that characterize the region. For this reason the development of industrial materials from mining waste is suggested in this paper. The stabilization of the tailings involved taking samples and determining their chemical composition and particle size. Afterwards, the alternative industrial materials were produced by using the tailings and heavy clay in order to give the composite a good green strength and plasticity during development, but above all to give it a compressive strength similar or higher than that of products derived from conventional processes.

Introduction

473 years of mining exploitation (mainly focused on gold and silver [1] in the state of Hidalgo have left a great amount of waste, such as mine drainage water, solid-transport water, mounds of abandoned, unprocessed minerals and mining waste, also known as tailings.

Regarding the latter, in the mining district of Pachuca-Real del Monte, there is a total of 108.1 million metric tons, covering approximately 1200 hectares [1,2,3] inside the urban sprawl of the municipalities of Pachuca de Soto and Omitlán de Juárez (Fig. 1). Due to the geography of this mining district, there are very strong wind currents, mainly between February and April, as well as in November (Fig. 2). This causes a considerable increase in respiratory diseases and eye complications of nearby inhabitants [1,2,3].

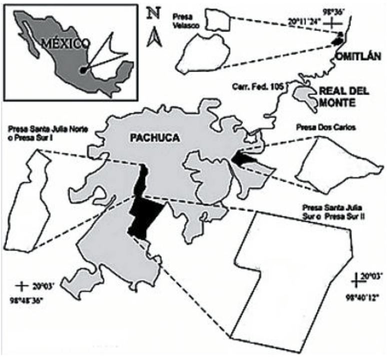

Fig. 1. Location of the tailings in the Pachuca-Real del Monte district.


Fig. 2. Tailings dust column caused by strong winds.

In this study we used the material of one of the oldest tailings in the mining district, which shows the use of different metallurgical processes, such as grinding-amalgamation (used for 353 years), grinding-cyanidation (used for 47 years), and grinding-flotation-cyanidation (used for 70 years). Undoubtedly, the oldest residues were found at the base; they bear witness from colonial times and the first years of an independent Mexico, to the arrival of the grinding-flotation-cyanidation technology, also known as "Tanques Pachuca". Inside the base of the tailings there is a higher concentration of gold and silver, as well as bigger particle size. This feature, when added to the use of heavy clays in order to conglomerate the tailings, helped to produce alternative industrial materials that contain similar or better properties than those of products derived from conventional processes.

Experimental procedure

Characterization of the Dos Carlos tailings was carried out by X-ray Diffraction and atomic absorption spectrophotometry (*AAS*) using a Philips X'PERT diffractometer and a *Perkin Elmer 2380* Atomic Absorption Spectrometer. Granulometric analysis was performed by using Tyler meshes with the following scales: 177, 149, 105, 74, 53 and 37 μm. 100g wet samples were sieved; the obtained fractions were dried at room temperature and then weighed.

For the production of the alternative materials, 13 ceramic composites were made by mixing the tailings material and heavy clays. In one case we used only the tailings material. The alternative materials were then produced by molding the ceramic composite in a roof tile mold. It was dried at room temperature and green sintering was finally applied.

Results and discussion

The results obtained by XRD, AAS and granulometric analysis from the Dos Carlos and Velasco tailings are presented as follows:

Regarding the Dos Carlos tailings, the diffractogram in figure 3 shows the presence of major mineral phases such as silica, orthoclase, albite, berlinite, potassium jarosite

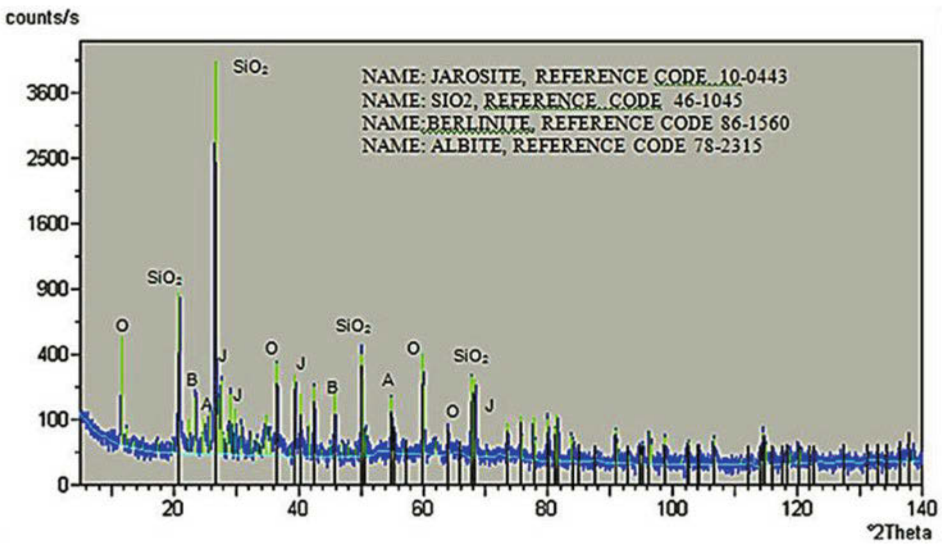

Figure 3. X Ray diffractogram of the Dos Carlos tailings, whose major mineral phases are silica (SiO_2), orthoclase (O), albite (A), berlinite (B) and jarosite (J).

The Dos Carlos tailings chemical characterization was carried out by taking a sample from each cardinal point. An average of the four points was obtained. The concentration amounts of each element in the tailings are shown in table I.

Table I. Characterization of the compounds contained in the Dos Carlos tailings.

Element/Compound	Concentration
SiO_2	70.43 %
Al_2O_3	7.32 %
K_2O	0.08 %
Na_2O	2.32 %
CaO	0.69 %
FeO	2.41 %
Fe_2O_3	2.80 %
MnO	0.73 %
MgO	0.54%
TiO_2	0.53 %
P_2O_5	0.12 %
Ag	55 ppm
Au	0.58 ppm
As	21.60 ppm
Ba	658.00 ppm
Be	1.00 ppm
Cd	5.92 ppm
Co	8.80 ppm
Cr	68.40 ppm
Cu	88.10 ppm
Mo	9.50 ppm
Ni	64.20 ppm

Pb	**420 ppm**
Sb	**0.55 ppm**
Sc	**7.00 ppm**
Sn	**4.86 ppm**
Sr	**106.40 ppm**
U	**0.76 ppm**
W	**5.85 ppm**
Zn	**900.00ppm**

Regarding the granulometric analysis, the distribution of retained weight was studied for the mesh sizes between 80 and 400 Tyler scale (177 µm and 37 µm respectively). Figure 4 shows the highest retained weight, which was found at mesh 100 (149 µm) and represents 19.18 % of all the analyzed material. Next there is a continuous decrease, which reaches its lowest peak at mesh 400 (37 µm), followed by another increase in retained weight at sizes smaller than 37 µm.

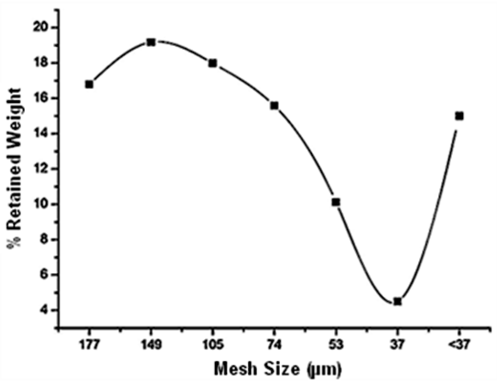

Fig. 4. Granulometric distribution. Dos Carlos tailings.

Later on, the ceramic composites were made from the previously stabilized tailings material (in the form of oxide or sulfide phases), and according to the granulometric analysis, the existing particle sizes and percentages were used. For the production of the alternative industrial materials, heavy clays were used as binding agents at a particle size of 200 mesh (74 µm) in order to give the materials similar properties to those of conventional processes.

Table II presents the composition of the different produced ceramic composites in weight percentage. In some cases two heavy clays were added, one of which has a higher plasticity. In the other cases only one heavy clay was added, except for the case where no extra materials were combined with the tailings.

Table II. Composition of the different ceramic composites used for the production of alternative industrial materials, weight percentage.

Ceramic composite	Tailings %	High plasticity clay %	Low plasticity clay%
1	66.67	26.67	6.67
2	63.00	31.00	6.00
3	63.00	31.00	6.00
4	60.00	34.00	6.00
5	60.00	40.00	---
6	60.00	40.00	---
7	60.00	40.00	---
8	55.00	45.00	---
9	50.15	49.85	---
10	45.30	54.70	---
11	40.45	59.55	---
12	35.60	64.40	---
13	100.00	---	---

Figure 5 shows the physical appearance of the mentioned composites; it can be affirmed that, at least regarding this aspect, different finishes and, above all, natural colors can be achieved. In the case of the last composite, a ceramic glaze finish was obtained without using enamels, ceramic fluxes or any other glaze-forming agent besides the own composition of the tailings.

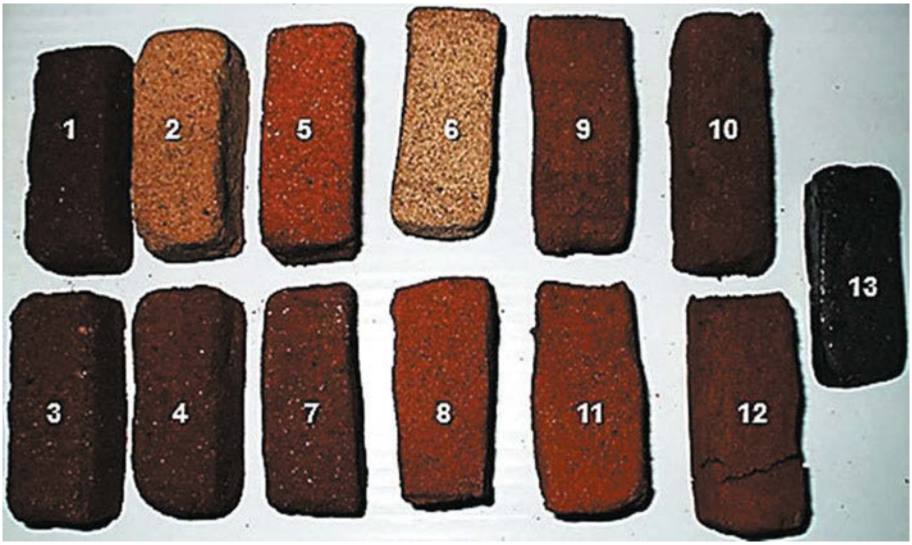

Fig. 5. Ceramic composite samples for the production of alternative industrial materials.

Finally, the alternative industrial material was produced by using the different ceramic composites. It is worth mentioning that samples 8 to 12 are the most suitable ceramic composites for the manufacture of roof tiles, and, as observed in Fig. 6, the alternative industrial material was left with a natural rustic style.

Fig. 6. Tile made from ceramic composite number 9.

Conclusions

1. According to their chemical and mineralogical characterization, the Dos Carlos tailings are made up of 70.43% silica. The other compounds contained in the tailings are 7.32 % Al_2O_3, 2.32% Na_2O, 0.08% K_2O and 0.69% CaO. These compounds, together with a part of the percentage of the silica, form the major mineral phases orthoclase, albite and berlinite, as well as the aluminosilicate minor mineral phase anorthoclase. It is also worth mentioning that the tailings contain 2.14 % FeO and 2.8 % Fe_2O_3, which are compounds that form the phases hematite and magnetite.

2. According to the granulometric analysis of the Dos Carlos tailings, the highest retained weight corresponds to mesh 100 (149 μm); therefore the material contained in the tailings is suitable for the production of alternative industrial material with the use of heavy clays as binding agents.

3. 13 ceramic composites were made from homogenized tailings (obtained from the Dos Carlos mining dumps) and heavy clays. 5 ceramic compounds were sintered in the shape of roof tiles. It can be noticed that these ceramic composites have natural colors and a better particle binding when adding heavy clays than when using only the tailings material.

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