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Sustainable iron recovery and management strategies for the tailings of the Mohammad Abad copper flotation plant, Iran

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ABSTRACT

The tailings from mining and mineral processing have dangerous environmental effects and the reprocessing of these tailings is considered a newly emerging solution. The representative sample of the tailing dams of Mohammad Abad copper flotation plant (Markazi Province, Iran) containing 18.95% Fe_2O_3 was investigated for the identification and initial feasibility studies for the recovery of iron-containing minerals. Characterization studies showed that basanite, calcite, specularite, and quartz minerals were the important minerals found in the tailing dam. In the beneficiation experiments of iron minerals, the gravity beneficiation experiment did not have a good yield, but with magnetic separation with an intensity of 6000 Gauss, the grade of Fe_2O_3 increased up to 50.06%. Performing the reverse flotation test of calcium-containing minerals in the tailings of the magnetic separation experiment decreased the CaO grade from 23.98% to 17.07% and SO_3 from 14.08% to 11.52%. The results of the feasibility tests showed that it is possible to produce iron concentrate and it is not possible to completely remove calcium and sulfur by flotation method, but the tailing of the magnetic separation (final tailing) contained 28.02% SiO_2, 9.51% Fe_2O_3, 7.12% Al_2O_3, 23.98% CaO, and 14.08% SO_3 and has the potential to be used in the cement industry.

Keywords: *Tailing dam, Copper flotation plant, Characterization, Iron recovery, Cement industry feed.*

1. Introduction

Most of the elements used in industrial applications are produced through mining and mineral processing techniques. The mining industry accounts for 6.9% of global gross domestic product (GDP) [1]. However, the increasing global demand for natural resources poses a serious threat to future resource availability [2] and the mining industry generates a huge volume of tailings (approximately 7 billion tons annually) as a consequence [3]. Recent estimates show that by 2025, the total amount of solid tailings could reach 19 billion tons [4, 5]. In Chile, there are 744 tailings dams, with 66 dams holding more than 5 million tons and 28 dams containing over 50 million tons of tailings [6]. Geochemical data reveal that at least 21 of these tailing dams have the economic potential to be reprocessed to recycle several valuable metals, including copper, molybdenum, silver, iron, cobalt, zinc, and lead [7]. Given the large environmental footprint of mining operations and the ongoing pollution concerns, effective tailings management has become crucial for the sustainability of mineral processing plants. One solution to this issue is the recovery and reprocessing of these tailings, which can help mitigate environmental damage while also offering economic benefits.

The rising prices of metals have increased the importance of reprocessing these tailings, which offer an alternative source of valuable materials [8]. There are several methods currently being explored for utilizing iron-containing tailings, including the recovery of metals such as iron, cobalt, nickel, and copper [9], the direct production of building materials (e.g., clinker cement, ceramics, and glass), and even their use as soil modifiers or magnetic fertilizers. Iron recovery is typically the first and simplest step in these processes [10, 11].

The recovery of iron from low-grade ores and tailings has been widely studied, with methods, such as flotation [12], reverse anionic quartz flotation [13], and magnetic separation [14] being commonly used. Among these, magnetic separation has proven to be the most economical and effective method. In addition to these methods, reprocessing tailings from flotation plants has included technologies, such as gravity separation, high-intensity magnetic separation, and flotation [15-18]. Recently, a method based on the thermal conversion of iron oxides and hydroxides to magnetite, followed by magnetic separation, has been proposed as an effective method for recovering iron from tailings [19]. Li et al. (2010) demonstrated that thermal reduction followed by magnetic separation can recover iron from iron ore tailings, resulting in a magnetic concentrate with a grade of 61.3% and a recovery of 88.2% [20].

In some cases, tailings from iron recovery processes can also be considered a potential source of materials for cement production. The main components of Portland cement include CaO (61-67%), SiO_2 (19-23%), Al_2O_3 (2.5-6%), and Fe_2O_3 (0-6%), all of which are critical in the chemical reactions during clinker production [21]. CaO is especially important for the formation of calcium silicate compounds that increase the strength of the final product [22]. Gypsum is commonly found in the copper processing tailings. Gartner (2004) indicated that $CaCO_3$ and calcium sulfates (gypsum or anhydrite) can be used to produce Portland cement clinker, with the active component being Ca_3SiO_5 (C_3S) [23]:

$$3CaCO_3 + SiO_2 \rightarrow Ca_3SiO_5 + 3CO_2 \tag{1}$$

$$3CaSO_4 + SiO_2 + H_2O \rightarrow Ca_3SiO_5 + 3H_2SO_4 \tag{2}$$

SiO_2 and Al_2O_3 also contribute to other clinker phases and affect the

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setting time of cement. Iron oxide (Fe_2O_3) influences both the color and the formation of other mineral phases. The required amounts of these compounds are specified in standards such as ASTM C150 [21] and EN 197-1 [24]. However, securing a consistent and high-quality supply of these compounds can be challenging in some regions, making it necessary to explore alternative materials. One alternative is the tailings from copper processing plants, which contain significant amounts of CaO, SiO_2, Al_2O_3, and Fe_2O_3, potentially offering a secondary source of these essential components.

Mohammad Abad copper plant (Markazi Province, Iran) has four tailings dams to store the tailings from the flotation plant. Currently, tailings dams 1 and 2 are filled, and the plant's tailings are being transferred to dam 3. This research focused on analyzing the chemical composition and different phases of tailings from dams 1 and 2, and the possibility of recovering iron-containing minerals using gravity and magnetic methods to produce a salable iron concentrate. Additionally, flotation was used to process the tailings with the goal of removing Ca and SO_3 for use in building materials. The research tries to present an integrated process where iron concentrate is recovered from copper processing plant tailings and the remaining materials (the final tailings) are repurposed into useful construction materials or cement components. This not only reduces environmental impact but also adds economic value by utilizing waste products. It contributes to the growing field of sustainable mining and resource recovery.

2. Materials and methods

2.1. Sample collection and preparation

Tailings dams 1, 2, and 3 of Mohammadabad flotation plant are shown in Figure 1. Nine samples from tailing dam 1 and 10 samples from tailing dam 2 (total of 19 samples with an approximate weight of 515 kg) were prepared using standard sampling methods and the use of a hand auger. All samples were first dried at 105°C for 24 hours and then weighed. In the next step, each sample was divided into four parts and a quarter of each sample was mixed to prepare the overall representative sample.

Figure 1. A view of the Mohammad Abad flotation plant and tailings dams 1 to 3 (June 2023_Google Earth).

2.2. Sieving analysis of the samples

All the samples were wet screened using 38, 75, and 125 µm sieves. Results showed that d80 of samples of tailings dams 1 and 2 were about 25 to 175 µm and the size of largest particles in the tailing dams were estimated to be 250 µm. Moreover, d_{80} of the overall representative sample was 104 µm. It should be noted that in the places that are close to the tailing transfer pipes (the pulp entry points to the tailing dam), the particles are coarser and d_{80} of the samples is also larger. In other words, the tailing flow has been able to carry smaller particles to the end parts of the tailing dam.

2.3. Characterization of the samples

Main oxides in all the samples were analyzed using the alkaline fusion method (the AF01 method of Zarazma Company using lithium metaborate salt). Minor and rare elements analysis were performed by the ICP-MS method (Zarazma Company). X-ray diffraction (XRD) analysis (Zarazma company with a nickel filament, Cu Ka copper target with a voltage of 40 kV and 30 mA) was used to characterize the phases in the representative sample. Determining the relationship between different phases in the sample as well as studying the degree of freedom of valuable minerals was carried out using microscopic studies (thin and polished sections).

2.4. Concentration experiments

After the characterization of the samples, concentration experiments, including magnetic separation and flotation were conducted to produce a marketable iron concentrate. Subsequently, magnetic separation tailings were analyzed for possible production of construction materials. These tests involved recovering iron-containing minerals through gravity and magnetic methods, along with preliminary flotation tests aimed at removing calcium and sulfur.

Gravity concentration experiments were carried out using the laboratory spiral equipment to separate iron-containing minerals from other minerals of the sample. The spiral used in the gravity concentration test is made of polyurethane, has five turns, and has a capacity of 2.5 to 3 tons per hour. The entire setup (including the box below) has a height of 5 meters.

Given the presence of iron minerals in the sample, concentration of the feed sample was tested using wet magnetic separation equipment. The tests were conducted with a magnetic field intensity of 6000 Gauss and a solid percentage of 25%. Box Mag Rapid variable intensity lab equipment (AL/4253/1 model, England) was used for the tests in the magnetic field intensity of 6000 Gauss.

Reverse flotation experiments were conducted to remove sulfur-containing minerals using a Denver model flotation machine. Initially, a specified volume of water was added to the cell and the rotor was started. Then, 400 g of the feed was gradually introduced into the cell, and the initial pH (without reagents) was measured. Sulfuric acid was added to adjust the pH to the range of 6 to 6.5. The collector preparation was carried out at an alkaline pH with water heated to 60°C to ensure complete dissolution in the aqueous medium. Flu YS20 as a fatty acid (carboxylate) group collector produced by Isfahan Copolymer Company was added. The initial froth, collected and labeled as C1, was followed by the addition of a drop of MIBC frother, after which the C2 froth was collected. The concentrates and tailings were then dried and prepared for analysis using the alkaline fusion method with lithium metaborate (Zarazma Company, Iran).

3. Results and Discussion

3.1. Characterization Studies

3.1.1. Elements and Compounds in the Tailings Dams and Their Distribution

A comprehensive overview of the chemical composition of samples taken from two tailings dams, as well as the detailed ICP-MS analysis of representative samples is presented in Tables 1 to 3, respectively. This information is important for the characterization of the tailings and planning material recovery methods.

After analyzing the sieve results and the main elements in all collected samples, it was observed that areas with coarser particle sizes (higher d80) had higher percentages of Fe_2O_3 and SO_3. This indicates that non-ferrous minerals containing Al_2O_3, Na_2O, and SiO_2 are more likely to be transported by the tailings flow and accumulate at the end of the tailings dam. Therefore, the particle size, particle shape, mineral composition, and especially mineral density significantly affect the deposition and distribution of particles. Additionally, samples from tailings dam 2 contained more iron than those from tailings dam 1.

The results of the ICP analysis in Table 3 showed that except for iron, the amounts of other elements in the tailings dam samples were very low and their reprocessing was not economically feasible.

Table 1. Minimum and maximum concentrations of the main elements in the tailing dam 1 (TD1) and tailing dam 2 (TD2).

Component	TD1	TD2	Component	TD1	TD2
CaO	21.9-26.4	20.1-24.3	MgO	0.20-0.51	0.45-0.68
Fe_2O_3	17.39-28.2	12.55-17.30	BaO	0.05-0.13	0-0.17
SiO_2	15.83-23.15	22.57-27.96	TiO_2	0.15-0.24	0.23-0.39
SO_3	13.8-20.8	12.5-18.80	MnO	0-0.05	0.05-0.08
Al_2O_3	3.5-5.96	5.62-8.38	Cu	0.11-0.22	0-0.25
K_2O	0.34-1.55	0.95-1.47	LOI	7.53-15.1	10.5-14.20
Na_2O	0.75-1.08	0.56-1.02			

Table 2. The grade of the main oxides of representative samples of tailings dams 1 and 2 in different size fractions.

Component	Head	MDRS4	MDRS3	MDRS2	MDRS1
		-38 µm	-75 +38 µm	-125 + 75 µm	+125µm
		58.14%	12.67%	12.94%	16.25%
SiO_2	28.43	25.58	25.03	24.50	29.01
Al_2O_3	6.10	6.99	4.87	5.01	6.69
BaO	0.03	0.08	0.10	0.08	0.06
CaO	28.66	20.36	21.49	24.88	24.81
Fe_2O_3	19.84	17.81	26.35	18.50	12.07
K_2O	1.11	1.44	0.77	0.78	1.04
MgO	0.48	0.53	0.39	0.42	0.56
MnO	0.05	0.05	0.08	0.08	0.09
Na_2O	0.85	0.86	0.91	0.92	1.19
P_2O_5	0.08	0.07	0.06	0.06	0.09
SO_3	16.83	15.47	7.99	11.28	7.55
TiO_2	0.29	0.32	0.30	0.27	0.36
LOI	-	10.35	11.45	12.99	16.23
Cu	0.13	0.09	0.16	0.23	0.26

Table 3. The elemental analysis (using the ICP-MS method) of the representative sample prepared from both tailing dam 1 and tailings dam 2.

Element	Concentration (ppm)	Element	Concentration(ppm)	Element	Concentration(ppm)	Element	Concentration(ppm)
Ag	0.8	Eu	0.65	Sb	5.20	U	3.3
As	11.8	Gd	1.96	Sc	6.70	V	72
Ba	235	Hf	0.52	Se	0.97	W	45.9
Be	0.7	La	8	Sm	2.28	Y	14.7
Bi	0.7	Li	31	Sn	13.80	Yb	2.1
Cd	0.2	Lu	0.18	Sr	405	Zn	54
Ce	16	Mo	34	Ta	0.49	Zr	37
Co	190	Nb	2.3	Tb	0.35		
Cr	31	Nd	7.2	Te	0.57		
Cs	3.5	Ni	13	Th	2.43		
Dy	2.54	Pr	1.32	Tl	0.30		
Er	1.35	Rb	22	Tm	0.16		

3.1.2. Mineralogical and degree of liberation studies

Thin and polished sections prepared from the representative sample were examined using a polarizing microscope across four size fractions: +125 µm, -125+75 µm, -75+38 µm, and -38 µm. Analysis of the thin sections revealed that the sample contains crystal fragments of opaque minerals, quartz, calcite, goethite, plagioclase, alkali feldspar, amphibole, chlorite, and clay minerals. Specularite, goethite, hematite, magnetite, chalcopyrite, covellite, and bornite were identified in the polished sections as indicated in Figure 2. In Figure 2 (a to d), quartz and calcite were observed to comprise the predominant volume of minerals in the thin sections. The presence of amphibole, depicted in a dark brown color, appeared to undergo transition into more stable minerals. Chlorite exhibited a characteristic green color. Plagioclase minerals manifested as elongated to square crystals across Figure 2 (a to d). Notably, calcite, accompanied by small rock fragments containing clay minerals, exhibited pronounced staining with iron oxide in Figure 2 (d). Additionally, Figure 2 (a) revealed that alkali feldspar frequently underwent alteration into sericite. Examination of the polished sections revealed that goethite exhibited a larger volume compared to other opaque minerals, appearing scattered throughout most of the sample (Figure 2 (e and h)). Traces of hematite were scarce, with evidence of alteration to goethite according to Figure 2 (f, g, and h). In certain regions of the sample, magnetite exhibited either transformation into hematite, characterized by a martite texture, or transition into secondary minerals, such as goethite (Figure 2 (h)). Additionally, specularite needles and sheets had been identified in selected sections (Figure 2 (f and g)). Notably, chalcopyrite was less than pyrite with observed occurrences often undergoing conversion to covellite and bornite. Covellite was discernible as bluish streaks within chalcopyrite, while bornite manifested as reddish-brown plates found along the margins or within the grains of chalcopyrite (Figure 2 (h)). The findings from the section studies revealed that approximately 80% of iron-bearing minerals, including specularite, hematite, goethite, and magnetite were liberated in size fractions smaller than 75 µm (Figure 3). In order to produce a concentrate with an iron content greater than 60%, it was necessary that the largest particles be ground to sizes smaller than 75 microns.

3.1.3. XRD Analysis

The XRD method was employed for *the characterization of* various mineral phases and evaluated *the relative quantity* of each phase within the representative sample. As *indicated* in Table 4, the results of the XRD analysis revealed that the predominant minerals in the sample included bassanite, calcite, specularite, quartz, muscovite-illite, albite, orthoclase, chlorite, and kaolinite.

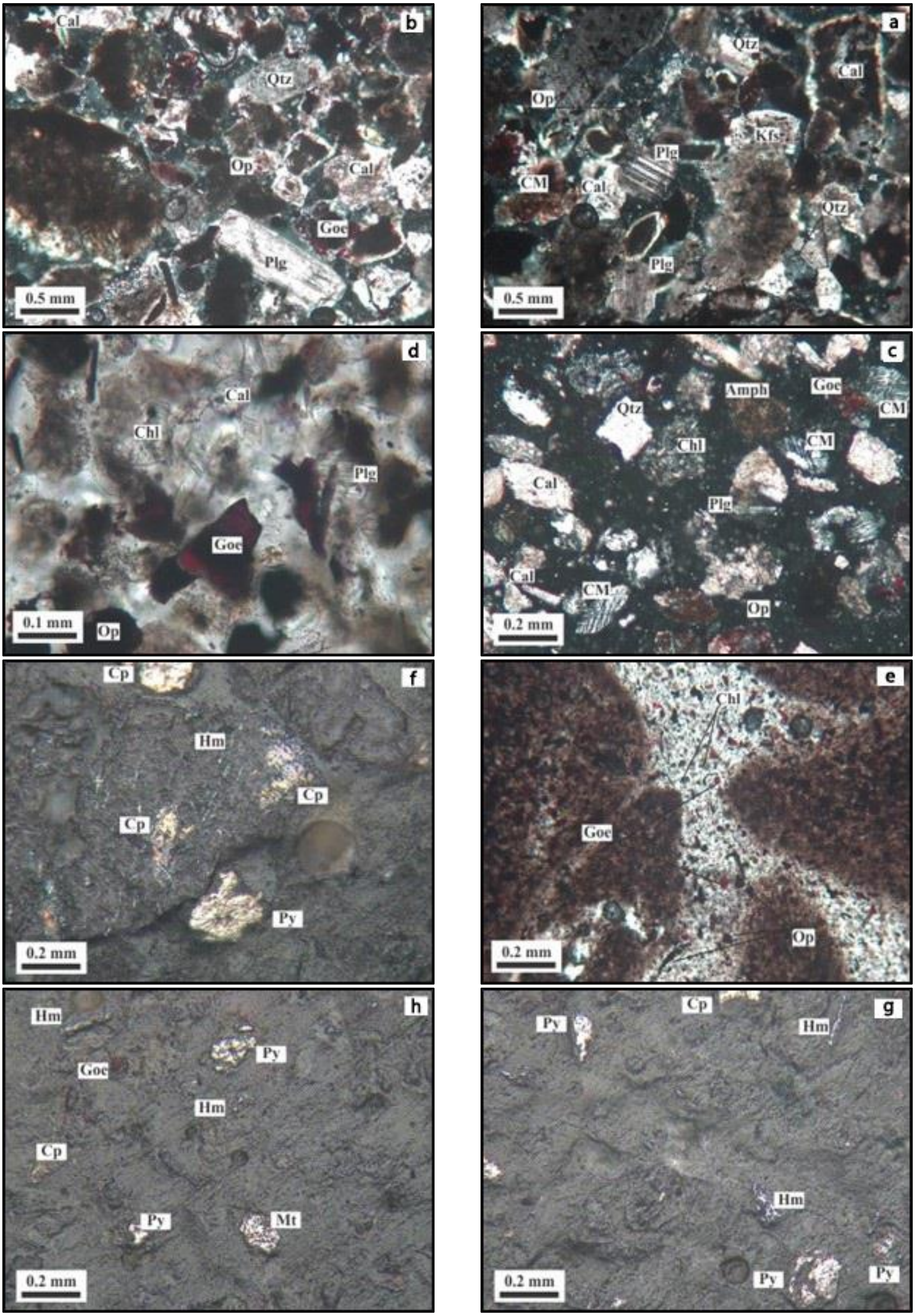

Figure 2. The microscopic images of thin and polished sections derived from various size fractions of the representative sample (a to d and e to h related to thin and polished sections, respectively).

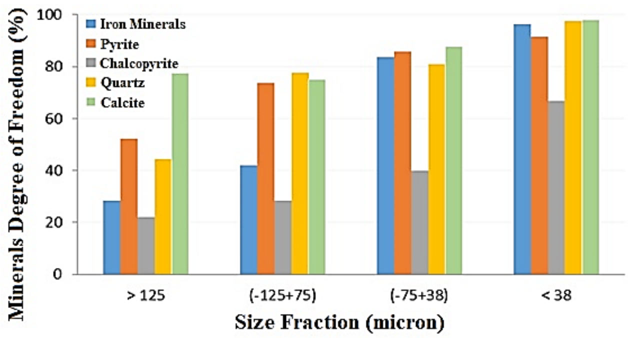

Figure 3. Changes in the degree of freedom of the main mineral of the tailings dam in different size fractions.

Table 4. The type and abundance of minerals in the representative sample.

No.	Mineral	Percent	S. G. (g/cm³)
1	Bassanite ($CaSO_4$. $0.5H_2O$)	27	2.69
2	Calcite ($CaCO_3$)	17	2.71
3	Specularite (Fe_2O_3)	15	5.26
4	Quartz (SiO_2)	14	2.65
5	Muscovite-Illite($KAl_2Si_3AlO_{10}(OH)_2$)	8	2.77
6	Albite ($NaAlSi_3O_8$)	7	2.60
7	Orthoclase ($KAlSi_3O_8$)	4	2.55
8	Chlorite $(Mg,Fe)_6(Si, Al)_4O_{10}(OH)_8$	3	2.6-3.3
9	Kaolinite ($Al_2Si_2O_5(OH)_4$)	3	2.68
Total		98	——

3.2. Concentration Experiments

3.2.1. Gravity Separation

Table 4 illustrates the minerals identified in the representative sample from the tailings dam along with their corresponding specific gravities. Specularite was the most valuable mineral within the sample with a specific gravity of 5.26 g/cm³, whereas gangue minerals exhibited specific gravities ranging from 2.55 to 3.3 g/cm³. For this reason, gravity concentration utilizing the laboratory spiral equipment was used and the results are shown in Figure 4 .

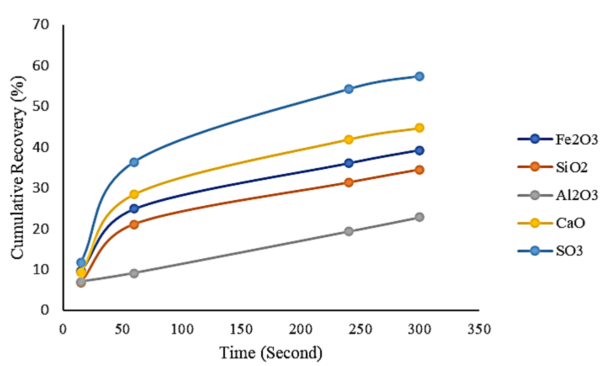

Figure 4. The results of the gravity concentration experiments using the spiral equipment.

According to Figure 4, the results of the gravity concentration experiments using the spiral method indicated an inability to effectively separate iron minerals from other minerals of the sample. This inadequate separation of iron in the concentrate could be attributed to the fine nature of the iron mineral particles. In fact, according to the elemental analysis of different size fractions (Table 2), approximately 54.65% of the sample is finer than 38 micron with Fe2O3 grade of 17.81%.

3.2.2. Magnetic Separation

Based on the results of semi-quantitative XRD analysis (Table 4) and microscopic studies (Figure 2), the iron-bearing minerals were mainly in the form of specularite. The sample also contained small amounts of goethite, pyrite, and chalcopyrite. Specularite had a magnetization of 3.7 x 10−6 m3/kg, which was stronger than hematite (2.16-0.6 x 10−6 m3/kg) but much weaker than magnetite (625-1156 x 10−6 m3/kg) [25, 26]. Consequently, a high magnetic field intensity (6000 Gauss) was used to increase the efficiency of high-intensity magnetic separation.

The composition of the concentrate obtained from the magnetic separation experiment at a field intensity of 6000 Gauss is shown in Table 5. The grade of Fe_2O_3 in the concentrate increased from 18.95% to 50.06% with an iron recovery of 58.7% (Figure 5). Based on these results, this method is recommended for iron beneficiation. However, considering the particle size used in the test, optimizing both the particle size and magnetic field intensity could further enhance iron recovery. Additionally, the weight recovery of the magnetic concentrate was approximately 21%.

Table 5. The change of grade of the main components of the sample as a result of the magnetic separation at a field intensity of 6000 Gauss.

Code	W, %	Fe_2O_3	SiO_2	Al_2O_3	CaO	SO_3
Feed	100	19.84	28.43	6.1	28.66	16.83
MD-M1	21.26	50.06	15.62	3.97	11.76	9.57
MD-NM1	78.74	9.51	28.02	7.12	23.98	14.08

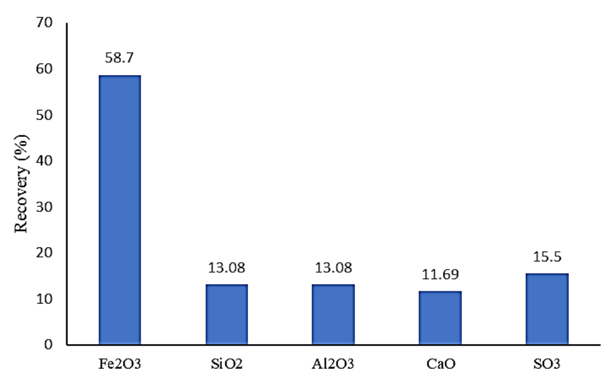

Figure 5. The recovery of iron and other important elements in the concentrate of the magnetic separation experiment at a field intensity of 6000 Gauss.

3.2.3. Froth Flotation

According to Table 5, the tailings from the magnetic separation process still contained significant amounts of sulfur, which exceeded the limits set by standards for building materials production (general brick and ceramic). Given the presence of calcium in the mineral containing calcium and sulfur (i.e., gypsum with the chemical formula $CaSO_4.2H_2O$), fatty acid anionic collectors could be utilized in the flotation of this mineral, as described in Eq. (3). Under these conditions and in accordance with reaction (4), the anion-metal salt formed on the surface of calcium-containing minerals was $(RCOO)_2Ca$.

$$RCOOH=RCOO^{-}+H^{+} \quad (3)$$

$$RCOO^{-}+Ca^{2+}=(RCOO)_2Ca \quad (4)$$

The results of the flotation test conducted on the tailings from the magnetic separation process revealed that 53.32% of CaO and 46.34% of SO_3 from the feed were transferred into the concentrate through fatty acid flotation (Figure 6). This process reduced the CaO grade from 23.98% to 17.07% and the SO_3 grade from 14.08% to 11.52%. Therefore, considering that the acceptable limit for sulfur is typically around 0.5% (Table 7), it can be concluded that the flotation method was not effective in adequately removing sulfur.

Table 6. The conditions and results of the gypsum flotation test.

Code	W% ,	Fe_2O_3	SiO_2	Al_2O_3	CaO	SO_3
MD-F1-C1	15.04	3.71	10.22	4.38	38.65	21.88
MD-F1-C2	19.38	7.77	14.19	4.97	35.98	16.69
MD-F1-T	65.58	11.35	36.19	8.38	17.07	11.52
Feed	100	9.51	28.02	7.12	23.98	14.08

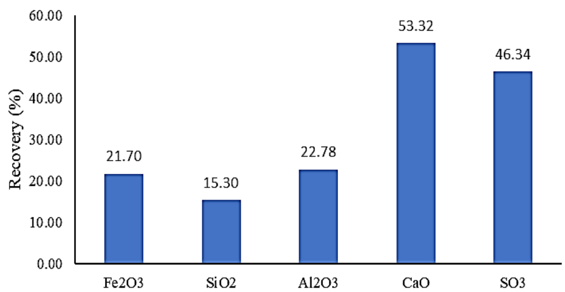

Figure 6. The recovery of iron and other components in the concentrate obtained from the flotation on the tailings of the magnetic separation experiment.

In a similar study, Chaoli et al. (2010) examined a sample containing quartz (47.39%), hematite (24.82%), calcium oxide (8.85%), aluminum oxide (7.42%), magnesium oxide (0.085%), sodium oxide (0.32%), and potassium oxide (0.7%). Their aim was to recover iron from the sample and utilize the reprocessed iron tailings. In their research, the grade of the magnetic concentrate reached 61.3%, with a recovery rate of 88.2%. Ultimately, the reprocessed tailings were used as a raw material (constituting 30% of the cement composition) in the preparation of ordinary Portland cement [20]. Liu et al. (2009) studied Bayer red mud containing quartz (20.98%), hematite (27.93%), aluminum oxide (22%), calcium oxide (6.23%), magnesium oxide (1.32%), titanium oxide (2.3%), sodium oxide (10.5%), potassium oxide (0.04%), and SO_4 ion (0.6%). They aimed to recover iron and produce building materials from the aluminosilicate tailings. In their research, the iron recovery rate was81.40%, and the compressive strength of the fired brick samples reached 24.10 MPa at 13% hydrated lime content [27].

3.3. Analysis of the composition of the final tailing

The results of the magnetic separation and flotation feasibility experiments showed that the magnetic separation method is efficient for producing iron concentrate. It should be emphasized that optimization is needed to increase the grade and recovery of iron in the magnetic separation process.

To explore the feasibility of producing building materials from the remaining tailings, the chemical characteristics of a standard soil sample used for building materials and the characteristics of the reprocessed tailings are compared in Table 7. However, the flotation method on the tailings of the magnetic separation experiment was not successful in removing sulfur and it is not a good option as a feed material for the production of general brick and ceramic (Table 7).

By comparing the chemical composition of the reprocessed tailings with the standard requirements for raw construction materials, it was found that the sample currently did not meet the necessary conditions for construction material production due to excessive amounts of iron and sulfur. The mineralogical results indicated that gypsum, the main mineral containing calcium and sulfur, was not completely removed by the flotation method.

In cement production, the primary components typically include calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). Sulfur trioxide (SO_3) content is also considered, but excessive amounts can be detrimental to cement quality. CaO is an important component for cement production as it is a primary ingredient in the formation of cement clinker. CaO content of the tailing was 23.98% which is lower than the typical range used in the Portland cement industry. SiO_2 content of the final tailing was 28.02% which is also within the acceptable range. Al_2O_3 and Fe_2O_3 components are considered as fluxes and can influence the properties of the cement. The tailing Al_2O_3 content of 7.12% and Fe_2O_3 content of 9.51% were within acceptable ranges. The final tailing SO_3 content of 14.08% seemed quite high and excessive amounts could lead to adverse effects on cement properties. As discussed in the mineralogical studies section, the SO_3 content was in the form of gypsum. Gypsum is often added to control the setting time of cement and acts as a retarder. The presence of 14.08% gypsum in the final tailing indicated that it was already present in the tailing and could potentially contribute to the cement production process. In the past, the amount of SO_3 in clinker was less than 1%. But this amount is expected to increase in the future, because gypsum is recently used to produce cement [28]. It is generally accepted that replacing a part of limestone with gypsum in the production stage of cement clinker improves the properties, such as setting time and strength of Portland cement [29].

In connection with the production of SO_2 gas in the kiln, sulfur comes from two sources, one is the kiln feed and the other is the kiln fuel. Sulfur in the fuel can be oxidized to form SO_X products but can easily be removed by lime. The sulfur in the kiln feed may be in the form of elemental sulfur, organic sulfur, sulfides, or sulfates. If the sulfur is in the form of sulfate, it usually does not convert into SO2 and often leaves the kiln environment together with the clinker [30].

Considering that the amount of CaO differs greatly from the Portland cement standard, it is possible to simultaneously increase the amount of CaO and decrease the amount of SO_3 by adding sufficient amounts of limestone to the final tailings sample. Overall, based on the provided chemical composition, the tailing appeared to have potential for use in cement production. It is advisable to conduct laboratory tests and trials to confirm its suitability for use in cement manufacturing.

Table 7. Standard chemical specifications for the preparation of various construction products in comparison with the chemical analysis of the reprocessing tailing sample.

Components	Fe_2O_3	Al_2O_3	SiO_2	CaO	BaO	K_2O	MgO	MnO	Na_2O	P_2O_5	SO_3	TiO_2	LOI
Unit	%	%	%	%	%	%	%	%	%	%	%	%	%
Process Tailing	11.35	8.38	28.02	17.07	0.08	1.26	0.53	0.07	1.01	0.05	11.52	0.33	10.64
General Brick Standard	3-12	9-21	40-60	Max:17	-	-	Max:4	-	-	-	Max:0.5	-	-
ASTM Portland Cement Standard	0-6	2.5-6	19-23	61-67	-	-	Max:5	-	-	-	Max:2.5	-	-
Alumosilicate Standard	0.4-5	29-39	40-54	0-4.4	-	-	0-6.3	-	-	-	-	-	-
Ceramic Standard Clay	7.15	17.85	52.69	11.29	-	4.23	4.24	0.0502	0.394	0.195	0.57	0.868	-

4. Conclusion

Examining the distribution of samples in tailings dams No. 1 and 2 of the Mohammadabad Flotation plant located in Dilijan (Markazi province, Iran) showed that the location of the samples and the particle size had a direct effect on their chemical composition. The gravity separation experiment did not yield good results, but the magnetic separation process at an intensity of 6000 Gauss increased the Fe_2O_3 grade from 18.95% to 50.06%, with potential for further improvement through optimization of effective parameters. Applying reverse flotation to the tailings from the magnetic separation experiment reduced the CaO grade to 17.07% and the SO_3 grade to 11.52%.

Ultimately, the composition of iron reprocessing tailings was compared with the standard requirements for materials used in construction. According to these standards, the tailings did not meet the necessary quality to be used as a raw material for construction materials, such as general brick and ceramic. However, it is possible to simultaneously increase the amount of CaO and decrease the amount of SO_3 by adding sufficient amounts of limestone to the final tailings sample.

Optimization of the magnetic separation process and the addition of different amounts of limestone to magnetic beneficiation tailings are significant points that should be accomplished in future studies on the tailings dam of Mohammad Abad flotation plant and similar tailings dams. In this way, the final tailing can be used as a feed material in the cement industry.

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