Mineralogical characterization of the tailings deposits of La Prieta Mine in Parral Chihuahua, Mexico.

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ABSTRACT

A mineralogical characterization of the tailings deposits of La Prieta Mine was conducted. Samples of surface soil and soil profile were taken at 12 points distributed over an area of 80 hectares approximately. The analytes were As, Pb, Cd and Zn, as part of an assessment of potential damage to the health of the population and the environment; Ag, Cu and Fe, and Fluorite (CaF2) as part of a possible re-benefit of the tailings. It used Atomic Absorption techniques and X-ray Diffraction for the characterization of the samples collected. The concentrations of As, Pb and Zn range from 160.219 to 4141.806 ppm, 2063.222 to 17766.295 ppm and 2645.994 to 13004.36 ppm, respectively. Fluorite was detected in most of the sites in study, and Ag concentrations ranged from 7514 to 89914 ppm. The risk to people and the environment is evident when one considers that in the area are several strong winds events in the year and that the tailings are uncovered. This raises the risk of exposure by the dispersion of particulate matter containing heavy metals. Silver concentrations and the presence of fluorite open the possibility of a rework of the deposits and thus a reduction of environmental and health risk.

INTRODUCTION

In Mexico there have been various entities with a great development in the mining industry such as the city of Parral. The study of these activities and processes in general, which may represent a potentially damaging alteration of the environment, have gained importance in recent years due to the impact they cause to the health of humans and their environment, as reported by some authors in their investigations [1, 2, 3].

Mining is an economic activity that contributed, and contributes greatly to economic development in Mexico [4]. The mining industry is mostly metal, and is principally engaged in the production of copper, zinc, silver and lead [5].

The mining activity involves multiple sources of contamination. The primary process for treatment of metals and mining waste generation, known as tailings, represent two of the most important. The chemical composition of the tailings makes these waste toxic to living organisms, particularly the tailings cyanide in mining of precious metals [6].

With more than three centuries of history, mining in Parral has not only brought prosperity, in aspects of economic and urban development, but also an environmental issue that has been latent since the beginning of operation of one of the major mines in the area, La Prieta mine. With production of about 1500 tons of pure mineral daily, waste generated on the date cover an area of approximately 80 ha on whose soil lays waste from more than three centuries of operation.

The deficiency of ore beneficiation processes employed in the mid-seventeenth century, suggests the existence of significant amounts of silver and fluorite in the tailings; and, which represents an opportunity to add value to this material through the extraction of these minerals in a process of re-beneficiation of the tailings.

Past studies in the area show evidence of the concentrations of heavy metals present in topsoil of the urban area, which exceed the limits set by national and international organizations, and suggest that the tailings are a major source of issuance of the metals found in these studies [7].

The possible presence of commercially valuable minerals in the tailings, and the fact that they represent a potential risk of harm to the health of the population and its environment besides being one of the main emission sources of particulate matter with heavy metal content to the town and its surroundings, motivated a diagnostic study characterizing the tailings for Pb, Zn, As, Fe, Cu, Cr and Ag content using atomic absorption, and Fluorite (CaF_2) using f X-ray diffraction.

OVERVIEW

Experimental Methods

Characterization of the area under study

The tailings from the mine La Prieta, located in the city of Hidalgo del Parral, Chihuahua, covering an approximate area of 80 hectares that extends SSW-NNE direction, from the point located in -105.662537° longitude, latitude 26.937118° and up the point located in -105.656306° longitude, 25.954168° Latitude.

The approximate surface area of the tailings that was discovered, is approximately 64 hectares, whiles the floor area, covers an area of approximately 16 to 17 hectares.
The open-pit tailings have the potential to cause negative impacts on the surrounding population to deposits and in the growing areas toward the northeast of the city, and in whose direction, the prevailing winds flow.

Figure 1. Description of the area under study

Sampling Plan

A total of 33 samples from 12 sampling points located along the entire area incorporating the tailings, were collected, as shown in Figure 2.

Figure 2. Sampling points for the characterization of Mine Tailings of La Prieta Mine

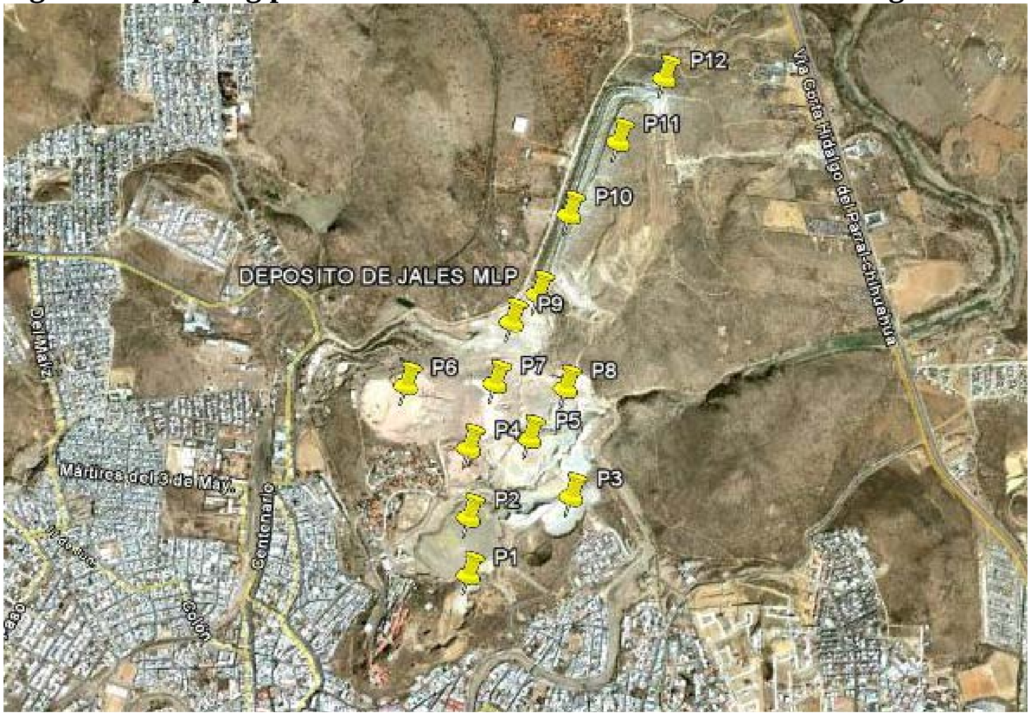

Table 1. Identification and Location of the Sampling Sites

ID*	LAT ^{o} N	LON ^{o} O	ELEV (m) usl
P1	26.9377	-105.6624	1732
P2	26.9396	-105.6624	1743
P3	26.9404	-105.6587	1743
P4	26.9418	-105.6624	1756
P5	26.9422	-105.6603	1743
P6	26.9438	-105.6648	1734
P7	26.9439	-105.6616	1738
P8	26.9438	-105.6590	1738
P9	26.9459	-105.6610	1757
P12	26.9540	-105.6557	1713

*Identifying sampling points

Table 1 shows the location and elevation of the monitoring sites, to which reference will be made in the results obtained.

Samples were collected from surface soil, and soil profile in the 0 to 30 centimeters and 30 to 60 centimeters, according to the guidelines established in the standard "NMX-AA-132-SCFI-2006".

Pre-treatment of the samples collected

Prior to analysis by atomic absorption and X-ray diffraction techniques, the samples were dried and screened to obtain the fine particle fraction (<75 microns, named silt), according to the provisions of ASTM C136.

Characterization of the samples collected

The concentration of the elements As, Pb, Cd, Cr, Zn, Ag, Fe and Cu was determined by atomic absorption Spectrophotometry, using the methods 3010, and 7000 B of the EPA on a equipment

Determining the presence of fluorite in the collected samples was performed using the technique of X-ray diffraction, with an X-ray diffractometer, Philips Xpert MPD 0-20.

Figure 4. Images of X-ray Diffractometer and sample preparation.

Results and Discussion

Chemical Analysis - Atomic Absorption Spectrophotometry

Based on NOM-147 SEMARNAT/SSA1-2004, which establishes the criteria for determining the concentrations of remediation of soils contaminated by heavy metals, and with reference to industrial land uses and residential, it was determined that concentrations of arsenic, cadmium and lead, exceed the parameters established by this rule.

The tables below show the comparison of the values of the concentrations obtained from samples of tailings, with baseline concentrations by type of land use of the standard NOM-147 SEMARNAT/SSA1-2004.

Table 2. Arsenic concentrations of Tailings and reference values by type of land use (NOM-147-SEMARNAT/SSA1-2004)

As	Top Soil (ppm)	Soil Profile 0 – 30 cm (ppm)	Soil Profile 30 – 60 cm (ppm)	MPL* Land Use Agricultural/Residential/Commercial (ppm)	LPM* Industrial Land Use (ppm)
P2	554.149	261.431	712.235	22	260
P3	4141.807	809.113	863.628		
P4	297.698	147.962	221.576		
P5	1384.737	799.601	812.973		
P6	1515.16	189.461	160.219		
P7	1019.63	527.161	364.283		
P8	2278.163	524.885	308.582		
P9	792.669	402.992	391.575		
P12	1932.387	624.391	1313.542		

*Maximum Permission Limit

Table 3. Cadmium concentrations of Tailings and reference values by type of land use (NOM-147-SEMARNAT/SSA1-2004)

Cd	Top Soil (ppm)	Soil Profile 0 – 30 cm (ppm)	Soil Profile 30 – 60 cm (ppm)	MPL* Land Use Agricultural/Residential/Commercial (ppm)	LPM* Industrial Land Use (ppm)
P2	17.313	61.989	104.224	37	450
P3	57.597	25.299	29.135		
P4	28.373	18.286	33.591		
P5	114.864	71.4	72.995		
P6	53.66	18.474	15.154		
P7	119.175	43.917	16.33		
P8	59.79	43.435	39.747		
P9	38.79	30.925	35.294		
P12	55.588	42.17	38.523		

*Maximum Permission Limit

Table 4. Cromium concentrations of Tailings and reference values by type of land use (NOM-147-SEMARNAT/SSA1-2004)

Cr	Top Soil (ppm)	Soil Profile 0 – 30 cm (ppm)	Soil Profile 30 – 60 cm (ppm)	MPL* Land Use Agricultural/Residential/Commercial (ppm)	LPM* Industrial Land Use (ppm)
P2	15.124	0	0	280	510
P3	0	0	0		
P4	13.69	0	0		
P5	0	0	0		
P6	0	0	0		
P7	0	0	0		
P8	0	0	0		
P9	12.333	0	0		
P12	0	0	0		

*Maximum Permission Limit

Table 5. Silver concentrations of Tailings and reference values by type of land use (NOM-147-SEMARNAT/SSA1-2004)

Ag	Top Soil (ppm)	Soil Profile 0 – 30 cm (ppm)	Soil Profile 30 – 60 cm (ppm)	MPL* Land Use Agricultural/Residential/Commercial (ppm)	LPM* Industrial Land Use (ppm)
P2	9.552	26.909	43.842	390	5100
P3	33.764	14.741	27.143		
P4	45.04	71.358	55.854		
P5	41.335	34.105	0		
P6	39.298	50.656	67.198		
P7	35.481	38.18	0		
P8	7.514	25.304	20.453		
P9	89.914	36.712	28.913		
P12	0	0	38.378		

*Maximum Permission Limit

Table 6. Lead concentrations of Tailings and reference values by type of land use (NOM-147-SEMARNAT/SSA1-2004)

Pb	Top Soil (ppm)	Soil Profile 0 – 30 cm (ppm)	Soil Profile 30 – 60 cm (ppm)	MPL* Land Use Agricultural/Residential/Commercial (ppm)	LPM* Industrial Land Use (ppm)
P2	1547.463	2911.5	6439.118	400	800
P3	8450.348	2792.629	3230.454		
P4	3975.992	2645.994	3269.528		
P5	12745.588	5342.042	6174.71		
P6	12883.573	3400.278	3024.725		
P7	8905.413	4096.736	2939.55		
P8	13004.356	5135.485	4782.974		
P9	10149.194	4317.138	4583.25		
P12	6764.735	3664.423	3282.168		

*Maximum Permission Limit

Metallographic Analysis – X-Ray Diffraction

The results obtained by X-ray diffraction confirm the presence of fluorite (CaF_2) in all samples under study.

Even when it was not possible to quantify the content of fluorite, it is important to note that this analysis confirms the hypothesis of the presence of said compound in the tailings, and to the qualitative results obtained are given across the board in every of the items discussed.

Results of points P6 in profile from 0 to 30 cm and P7 in topsoil, are added to confirmation this and for a better understanding of the interpretation of the XRD patterns as well as evidence of the presence of Fluorite in different points under study.

Figure 5. Diffractogram - P6 soil profile from 0 to 30 cm.

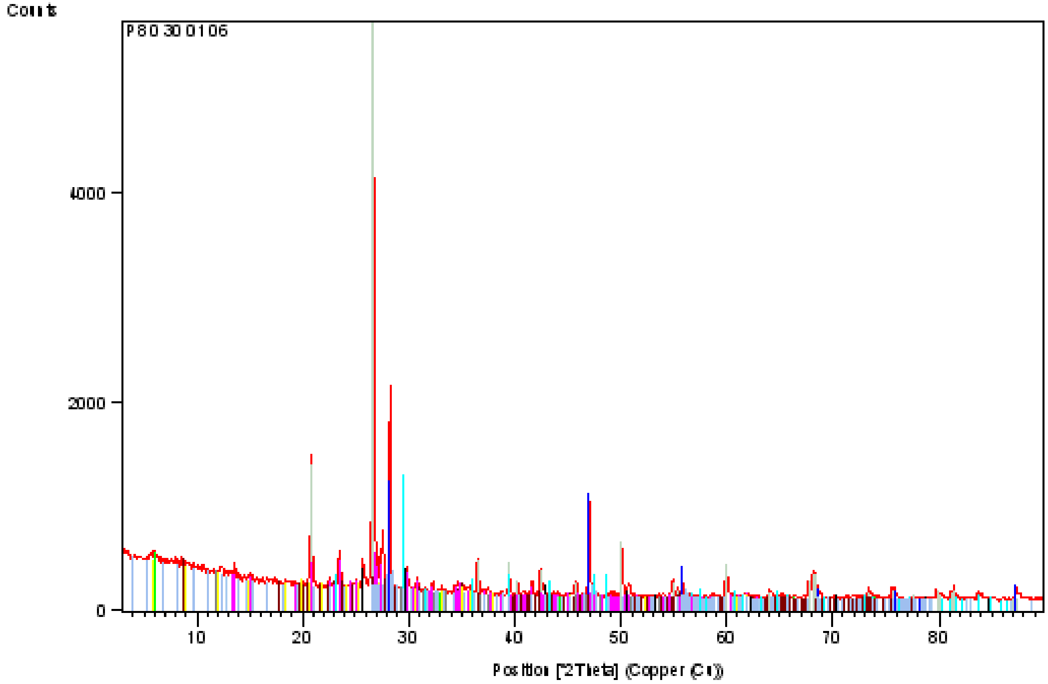

Table 7. Color code for identification of compounds in the diffractogram of P6, soil profile from 0 to 30 cm.

No.	Visible	Ref. Code	Compound N...	Chemical Formula	Score	Scale ...	SemiQua
1	☑	01-087-2096	á-Si O2	Si O2	82	0.986	-
2	☑	01-071-4796	Fluorite	Ca F2	54	0.188	-
3	☑	00-002-0017	Nontronite	Na0.33 Fe2 +3 (Si ,	10	0.025	-
4	☑	00-006-0047	Gypsum	Ca S O4 ·2 H2 O	Un...	0.116	-
5	☑	01-074-2428	Muscovite 2...	K Al3 Si3 O10 (...	Un...	0.348	-
6	☑	01-072-1937	Calcite	Ca C O3	3	0.253	-
7	☑	00-019-0931	Orthoclase	K Al Si3 O8	38	0.085	-
8	☑	00-046-1463	Tosudite	(K , Ca)0.8 Al6 (S	Un...	0.093	-
	☑	00-001-0880	Galena	Pb S	11	0.013	-
10	☑	01-089-2136	Zinc Sulfide	Zn S	15	0.127	-

Figure 6. Diffractogram – P7 Top Soil

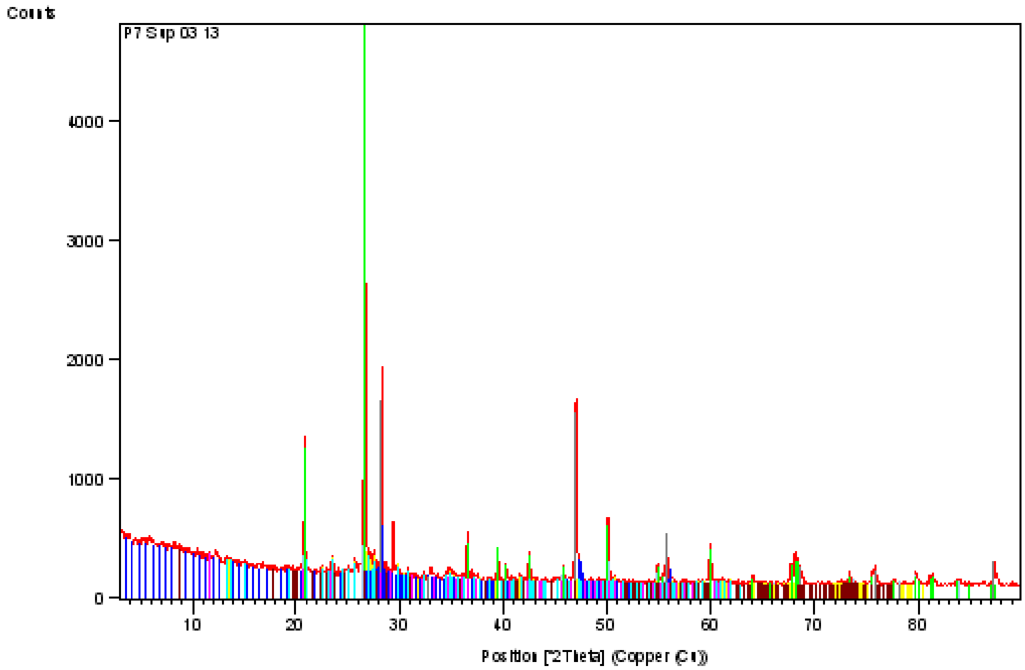

Table 8. Color code for identification of compounds in the diffractogram of P7 – Top Soil

No.	Visible	Ref. Code	Compound N...	Chemical Formula	Score	Scale ...	SemiQua
1	☑	01-071-0957	tetrapotassiu...	K4 Al4 Si12 O32	27	0.046	-
2	☑	01-089-2182	Zinc Sulfide	Zn S	31	0.171	-
3	☑	01-087-2096	á-Si O2	Si O2	81	1.010	-
4	☑	01-071-4796	Fluorite	Ca F2	60	0.191	-
5	☑	01-074-2428	Muscovite 2...	K Al3 Si3 O10 (...	Un...	0.435	-
6	☑	00-019-0931	Orthoclase	K Al Si3 O8	25	0.040	-
7	☑	00-006-0047	Gypsum	Ca S O4 ·2 H2 O	Un...	0.197	-

SUMMARY

The concentrations of Zn, As, and Pb are above the range set by the standard NOM-147-SEMARNAT/SSA1-2004, with values ranging from 147.96 to 2278.16 ppm of arsenic, 1547.46 to 13004.36 ppm of lead, and 2063.22 to 17766.3 ppm of zinc, which represents a risk to population health and the environment.

Cadmium concentrations in both surface soil samples as soil profile, beyond the limit of 37 ppm established for land use Agricultural / Residential / Commercial, with concentrations ranging from 15,154 to 119,175 ppm. This represents a potential risk to the health of the population located within a few meters from the tailings, as shown above in Figures 1 and 2.

The above results agree with those obtained in research conducted in other places where mine tailings were characterized, such as Santa Barbara-Chihuahua, Zimapán-Hidalgo and Taxco-Guerrero [8], places belonging to the North and South of the Republic respectively. Similar results are reported for districts Triunfo-San Antonio and Santa Rosalia, Baja California Sur, to the north-west of Mexico [9].

The results further indicate that for each of the sites that were detected high concentrations of heavy metals such as As, Pb and Zn, the composition of these elements associated with sulfur compounds is similar, presenting compounds such as, galena (PbS), and zinc sulphide (ZnS), among others.

Silver concentrations obtained by atomic absorption, do not exceed the limits established by the standard NOM-147-SEMARNAT/SSA1-2004, however, concentrations are considered to be reasonably high, for the purpose of reprocessing, compared with silver values obtained in some mining complexes as part of their normal production, approximately 80 g/ton.. Silver values found in tailings from La Prieta mine are up to 89 g/ton at P9, which is the point with the highest concentration. These values were obtained from the outer layers of the tailings. Based on the history of the deficiencies in the processes of beneficiation of minerals, in the early years of mine operation, it is presumed the existence of even higher concentrations of silver in the deeper layers of the tailings.

The presence of silver and fluorite, in tailings from La Prieta mine, open the possibility of adding value to the residue disposed in a place strengthening potential remediation, given the high concentrations of heavy metals such as As, Pb, Cd and Zn, should be remedied as soon as possible.

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KEYWORDS

Mineralogical characterization, heavy metals, tailings.