Wasted Critical Raw Materials. A polluted environmental scenario as potential source of economic interest elements in the Spanish part of the Iberian Pyrite Belt.

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Abstract

This paper explores the possibility of using the lixiviates generated by sulphide mining in the Iberian Pyrite Belt (IPB) as a source of economic interest elements, estimating the available metal reserves and discussing the economic gains that would result from the recovery of this potential source of Critical Raw Materials and other economic interest elements. For this purpose, 33 mining lixiviates have been evaluated. Results show annual contributions of more than 7000 t/yr of Mg, 4700 t/yr of Al, 3700 t/yr of Mn, 34 t/yr of

Co, 2.3 t/yr of Sb, around 24 t/yr of rare earth elements (REE), etc. Considering the market metal prices for 2019, the reserves contained in the evaluated lixiviates have a potential value of around 95 million USD, however, this value is largely underestimated. Making an estimate on the total area of abandoned solid waste in the IPB, this value would be increased to an annual total of more than 400 million dollars.

Keywords: Critical Raw Materials, Iberian Pyrite Belt, metal recovery, waste valorisation.

1. Introduction

Acid mine drainage (AMD) is one of the biggest environmental problems caused by mining of sulphide-rich mineral deposits. The main source of AMD is oxidation of sulphide mineral ores, which are exposed to the environment by intensive mining activities. In particular, among the metal sulphides, pyrite ore is one of the main responsible for generation of AMD due to its ease of oxidation when exposed to oxygen, water, and microorganisms (Kefeni, et al., 2017). Acid mine drainage contains high concentration of metals and metalloids, not only associated with metallic sulphides but also due to dissolution processes of the bedrocks by mine waters already acidic through which it flows.

The Iberian Pyrite Belt (IPB) is one of the most famous sulphide mining region in the world, containing original reserves of the order of 1700 Mt divided up in more than 50 massive sulphide deposits (Barriga and Carvalho, 1997). The mineralogical composition of these deposits is dominated by pyrite (FeS_2), with lesser amounts of sphalerite (ZnS), galena (PbS), chalcopyrite ($CuFeS_2$), arsenopyrite (FeAsS) and other sulphides containing accessory amounts of Cd, Ag, Au, Co, Ni, etc, including rare earth elements (REE).

Nowadays, there are more than 4800 ha occupied by waste dumps, open pits, tailing dams, and mining facilities, corresponding to 88 sulphide mines (Pérez-Ostalé et al., 2013). Most of them are inactive, surpassing the 200 million m^3 of abandoned waste (Sáinz et al., 2004). Waste dumps constitute the main source of contamination by AMD, when they are abandoned or improperly disposed (Loredo and Pendás, 2005), prior to current European environmental legislation. Mining waste dumps are potential sources of pollution, which after rainfall produce leachate discharges, loaded with AMD. The discharges generally occur in two phases: initial rapid leaching over a period of 1–7 days, followed by a variable period during which leaching decelerates (Sáinz et al., 2002).

The AMD discharges are responsible for the degradation of the Tinto and Odiel watersheds (Sánchez España et al., 2005; Sarmiento et al., 2009; Cánovas et al., 2010; Grande et al., 2010; Nieto et al., 2013) transporting a high load of elements to the Atlantic Ocean. Olías et al. (2006) estimated that the Odiel river alone transports high quantities of dissolved elements: 4557 t/yr of Al, 2612 t/yr of Zn, 1252 t/yr of Cu, 62 t/yr of Co, 12 t/yr of Pb and minor quantities of other elements.

Mining waste at the IPB amounts hundreds of square meters of surface area. Grande et al. (2014) estimated the affected area in the Iberian Pyrite Belt reaches a value of 4847 ha. Taking into account the average annual precipitation totals registered in the area, it means a high flow of acid leachate containing large quantities of metals and metalloids, some of them of great economic value. Among them, Critical Raw Materials (CRM) due which constitutes the high economic importance and at risk of supply for European countries (EC, 2017). Raw materials are crucial to global economy. They form a strong industrial base, for the production of a broad range of goods and applications used in everyday life and modern technologies. Reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. To address this challenge, the European Commission has created a list of critical raw materials (CRMs) for the EU, which is subject to a regular review and update. CRMs combine raw materials of high importance to the EU economy and of high risk associated with their supply. In 2020, the Commission published a revised methodology for establishing the EU list of 30 critical raw materials. Elements such as Be, Co, V, Sb, Sc, rare earth elements (REE) and others (e.g. Ga, Ge, Ta, W, etc.) are dissolved in these lixiviates in high concentrations. So, the presence of these elements and the large load of lixiviate generated could turn this waste into a potential commodity. The management of the lixiviates and the recovery of these elements could be both, an environmental and economic solution. However, the feasibility of recovery these elements relies mainly on the availability of appropriate technology.

This study examines the potential recovery of metals of economic interest contained in AMD lixiviates from SW Spain, estimating the available metal reserves and evaluating the economic gains that would result from their recovery.

2. Materials and methods

2.1. Sampling

Sampling was performed at 33 different tailing lixiviates from polymetallic sulphide mines throughout the whole Iberian Pyrite Belt in the Spanish zone (Figure 1).

Selection of the sampling points was focused on obtaining the different representative scenarios for the primary mineral paragenesis of the main mining exploitations from the IPB (Tornos F, 2006).

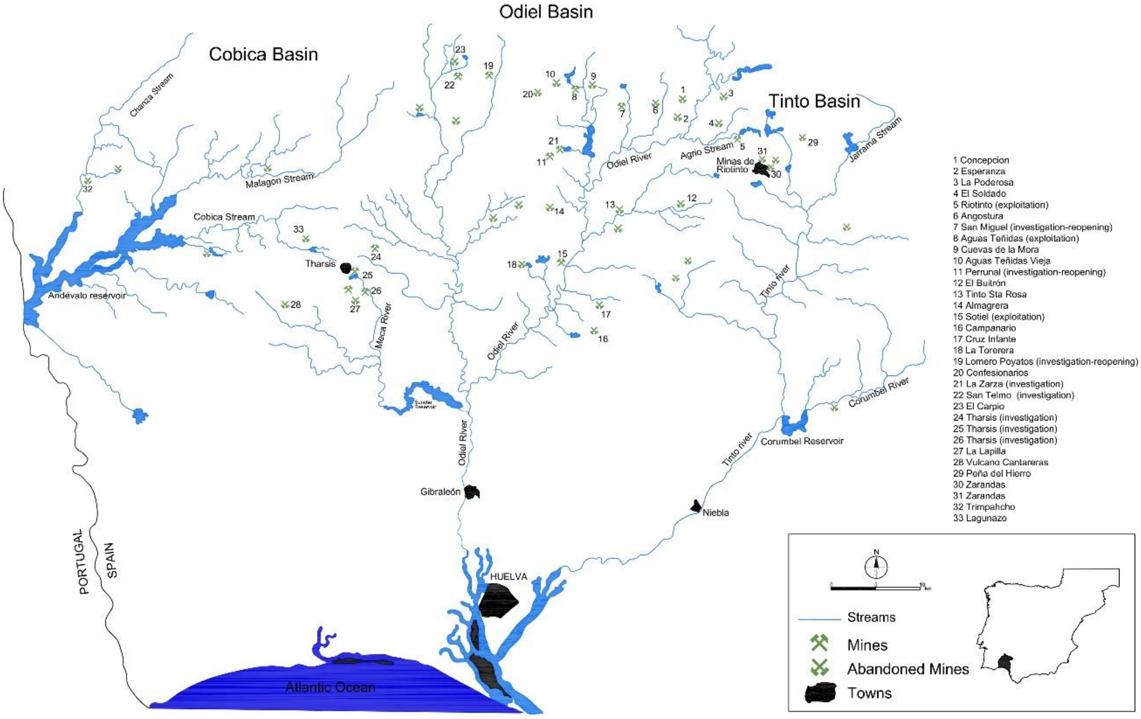

Figure 1. Studied Spanish part of the Iberian Pyrite Belt indicating sampled lixiviates

The data correspond to different samplings at different times of the year. In fact, the climatic seasonality considerably affects the mechanism of generation of AMD and the response of the river channel to the stimulus induced by the rain in the waste rock dump. Water samples were filtered immediately in the field through 0.22 µm Millipore filters fitted on Sartorius polycarbonate filter holders. Samples for cations and metal analysis were acidified in the field to pH < 2 with suprapur HNO_3 (2%) to avoid precipitation and then stored in the dark at 4 ºC in polyethylene bottles until analysis.

2.2. Analytical methods

Several physicochemical parameters were measured in the field. Temperature, pH, specific conductance, redox potential and total dissolved solids were measured using a multi-parametric portable device (CrisonMM40). The pH meter was calibrated using WTW standard solutions (pH 4.01 and pH 7.01),redox potential was checked using Hanna standard solutions (240 mV and 470 mV) and conductivity meter was calibrated with a KCl 0,001 M.

Concentration of trace metal analysis for the samples were performed with an Agilent Technologies 7700 Series inductively coupled plasma mass spectrometer (ICP-MS) and an Iris Intrepid Model atomic emission spectrometer (ICP-OES) at the Center for Research and Development of Agrifood Resources and Technologies (CIDERTA) from the University of Huelva.

Detection limits are defined by the equipment used:

0.5 mg/L for Zn, Fe, Al, Cu and Mn; less than 1 μg/L for As, Cd, Cr, Ge, Li, Ni, Pb, Rb, Ba, Co, Ga, Se and Sr; and less than 0.5 μg/L for the rest of the elements. The relative standard of deviations (RSDs) was less than 10% for all the analysed elements, indicating good repeatability of the procedures.

All the reagents used were analytical grade or of Suprapur quality (Merck, Darmstadt, Germany). Merck AA Certificate solutions were used in all experiments as standard solutions. Milli-Q water (Millipore, Bedford, MA, USA) was used in the preparation of reagents and dilutions.

3. Results and discussion

3.1. Abundance of base metals and economic interest elements

Figure 2A summarizes abundance of the main base elements (risk index between 4.8 and 6 by British Geological Survey, 2015) in the 33 lixiviate samples generated by the studied mining wastes in the IPB. As can be seen in Figure 2A, aluminium is the base element with the highest concentration in these lixiviates, with an average value of 612 mg/L. However, a high variability is observed with minimum and maximum values of 1.6 and 3100 mg/L, respectively. Zinc is the next most concentrated element, followed by Cu with average values of 153 and 54 mg/L, respectively and minimum and maximum ranged of 0.8-860 mg/L of Zn and 0.2-339 mg/L of Cu. Concentration up to 14 mg/L of Ni, 1.3 mg/L of Sn and 5.9 mg/L of Pb can be found associated to the sulphides oxidation (Sarmiento et al., 2009; 2018).

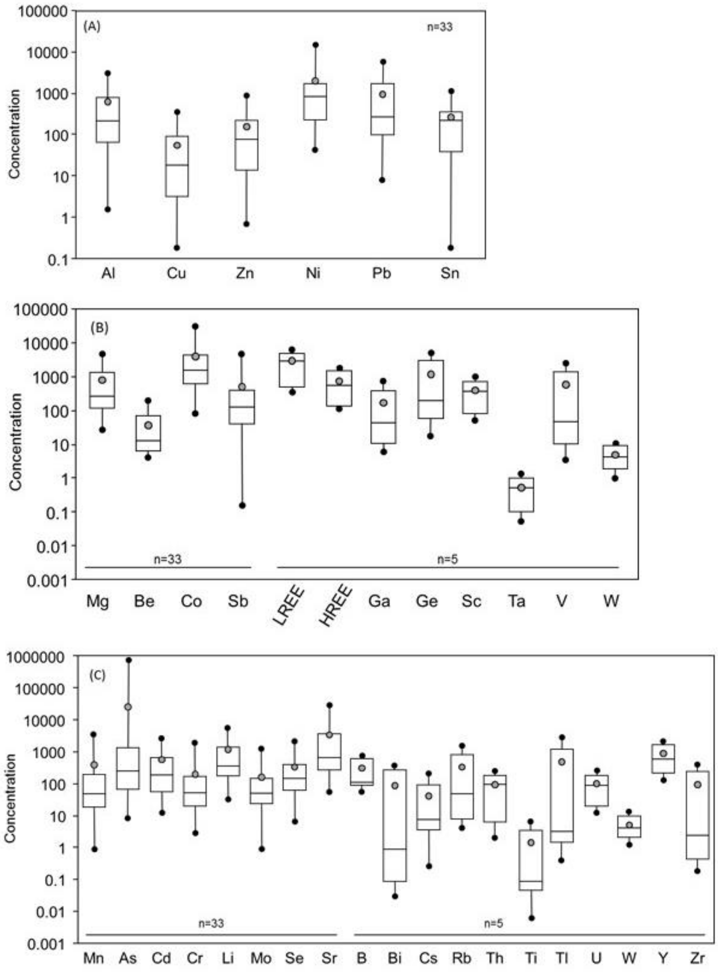

Figure 2. Boxplot with whiskers from minimum to maximum of (A) base elements in the studied lixiviates (data in mg/L except Ni, Pb and Sn in µg/L, the last on the graph). (B) some critical raw elements in the studied lixiviates (data in µg/L except Mg in mg/L (the first on the graph)). (C) other economic interest elements in the studied lixiviates (data in µg/L except Mn in mg/L (the first on the graph)); HREE, (Heavy REE), LREE (Light REE).

Figure 2B summarizes abundance of some of the CRMs, which were analysed in IPB lixiviates. Magnesium is the element with the highest concentration in these waters, with an average value of 780 mg/L and maximum value up to 4.2 g/L. Concentration up to 31 mg/L of Co, 4.8 mg/L of Sb, 5.3 mg/L of Ge, 2.6 mg/L of V and 7.2 mg/L of total rare earth elements (REE), being the concentration up to 5.7 mg/L of HREE and approximately for LREE 10 times up the values of HREE.

In reference to other economic interest elements included in the current supply risk list for chemical elements which are of economic value (British Geological Survey, 2015), Mn is the element with the highest concentration, with an average value of 366 mg/L and maximum value up to 3.3 g/L. Concentration up to 742 mg/L of As, 2.9 mg/L of Cd, 5.7 mg/L of Li, 1.4 mg/L of Rb, 2.3 mg/L of Tl and 26 mg/L of Sr can also be found (Figure 2C).

3.2. Metals revaluation assessment in the acid mine drainage

This chapter attempts to evaluate the money amount that would be annually involved if the economic interest elements dissolved in the lixiviates from IPB could be recovered with the appropriated technology. This assessment should be greatly underestimated, as only 33 of the hundreds of acid leachates flowing through the Iberian Pyrite Belt have been assessed.

For this purpose, the total surface area of each waste mining tailing where the lixiviate sampled originates has been calculated from the results of Grande (2016). Climatology of the area is an important factor to consider for calculating the flow rate of lixiviate originated in them. An assessment of 650 L/m^2 of the annual average rainfall was indicated by Grande et al. (2003) in the area.

Table 1 shows the total area (hectares) estimated in each sampled mining tailing, the total annual load of several economic interest elements, and annual dollars lost, both for each element and waste tailing studied. the price of metals has been obtained from several sources listed at the foot of the table 1.

			Al	Cu	Mg	Mn	Zn	As	Be	Cd	Co	Cr	Li	Mo	Ni	Pb	Sb	Sn	Sr	
	USD/kg*		2.20	6.17	5.18	0.007	2.76	2.10	660	2.6	37.48	11	13	26	14	2.20	8.60	18.96	0.08	
Lixiviated samples from mining tailings		ha	**Kg/year**																	**USD/year**
#1	Concepcion Mine	19.8	42983	9940	114440	82.7	38173	16.6	27662	92.8	15770	12.5	4431	82.1	423	32.6	-	883	4.43	255028
#2	Esperanza Mine	3.09	3026	558	11400	1.02	462	11.6	1375	1.92	272	4.22	390	28.0	26.0	3.20	-	155	0.89	17716
#3	Poderosa Mine	20.5	65847	97076	31103	10.7	19604	1270	20301	117	5418	24.4	2731	240	210	30.2	-	866	12.7	244862
#4	El Soldado Mine	1.4	31322	6945	98713	37.5	9636	10.5	14725	36.8	2550	16.1	3805	144	776	16.1	47.2	63.0	1.04	168844
#5	Riotinto Mine	117	3213197	492082	9787496	34706	744115	55.5	1513069	2717	225561	1512	442798	177	59064	10.4	2.31	2.14	585	16517150
#6	Angostura Mine	5.71	2228	705	7818	0.52	98.1	-	-	1.73	188	1.27	117	-0	25.1	0.96	-	27.4	0.19	11211
#7	San Miguel Mine	26.4	95946	2673	174754	66.9	4373	25.7	24723	10.3	3478	45.1	9210	145	359	40.1	-	769	8.31	316625
#8	Aguas Teñidas Mine	2.61	58.0	69.8	7185	4.45	5386	8.72	-	2.82	409	-	129	-	75.8	8.48	-	12.9	0.27	13351
#9	Cueva de la Mora Mine	29.5	46932	5219	344463	64.0	209856	113	64771	338	8298	15.6	10833	210	2884	101	94.6	99.0	4.33	694297
#10	Aguas Teñidas Vieja Mine	5.12	5856	3661	16153	4.50	8774	4.02	2922	25.8	100	15.6	1284	25	86.7	192	10.5	12.0	0.56	39127
#11	Zarza Mine	52.8	103585	37607	525086	457	27241	409	140138	86.7	21779	174	35650	699	7805	188	346	307	10.3	901567
#12	El Buitrón Mine	8.96	17957	17632	33961	13.8	11669	9.44	5160	27.8	3782	44.2	1613	121	272	37.9	47.8	53.9	1.60	92404
#13	Tinto Sta. Rosa Mine	13.2	14420	10170	61566	54.2	15944	386	9175	32.9	4080	13.8	3888	62.9	1253	46.1	34.5	390	7.12	121523
#14	Almagrera Mine	0.58	510	260	7840	7.04	1249	9.33	302	1.18	194	16.9	176	10.4	41.0	47.7	12.0	16.5	1.06	10694
#15	Sotiel Mine	132	35957	16749	335870	307	107924	33.1	-	107	9546	31.3	5422	-	2786	412	-	584	7.78	515739
#16	Campanario and Descamisada Mines	5.65	1564	279	10558	4.35	1171	5.38	-	1.99	158	1.25	484	11.6	74.6	9.66	5.42	-	0.49	14327
#17	Cruz Infante Mine	0.46	66.5	2.63	377	0.09	6.73	0.41	-	0.10	6.69	-	14.2	0.00	5.37	0.14	0.00	2.10	0.03	482
#18	Torerera Mine	7.14	6164	4241	50735	44.1	4859	9.09	3490	8.26	1908	12.6	1978	57.5	853	22.0	52.0	96.1	34.8	74565
#19	Lomero Poyatos Mine	10.3	8369	195	88781	8.63	2240	20.4	-	6.17	299	14.4	1166	54.0	55.9	51.3	-	379	126	101767
#20	Confesionario Mine	28.2	295009	3999	353897	63.9	1945	58.5	39463	175	22093	205	8381	995	612	162	449	738	7.44	728253
#21	Perrunal Mine	37.2	197421	29493	545419	321	35555	666	168886	176	13388	195	40752	972	4001	1151	485	548	6.31	1039437
#22	San Telmo Mine	74.2	695462	372881	2961941	669	423413	1312	512101	1015	54022	818	88152	2713	11845	2041	1096	2566	105	5132152
#23	El Carpio Mine	3.79	11041	425	31269	7.52	974	0.53	2940	2.72	618	12.4	877	24.9	138	2.19	-	110	11.0	48453
#24	Tharsis Mine	135	1755848	434390	12227130	2458	886761	7644	929451	2933	398051	2255	195726	9761	104228	1853	3911	16474	53.9	16978927
#25	Tharsis Mine	191	334935	302547	826263	274	27012	1062	79255	166	60457	989	43590	1484	9351	3771	540	7794	52.7	1699542
#26	Tharsis Mine	112	460016	109469	1256464	4963	152258	19.3	198868	304	65295	718	57685	-	10613	157	0.73	-	185	2317014
#27	La Lapilla Mine	10.6	300451	132285	1013152	359	158446	1047	113924	391	77263	680	29084	1217	13489	304	598	628	3.63	1843320
#28	Vulcano and Cantarera Mines	0.07	230	92.2	510	0.36	35.2	0.06	70.1	0.20	38.0	0.18	28.7	0.79	8.02	1.97	0.30	0.26	0.01	1016
#29	Peña Hierro Mine	29.3	1171412	106863	2250357	497	42492	4981	73893	1398	167755	1066	145635	9847	4113	1104	2932	4404	3.31	3988755
#30	Zarandas Mine	48.9	409187	55999	1854756	414	93704	147	126820	368	66084	439	37617	1533	4810	326	689	1039	18.3	2653949
#31	Zarandas Mine	12.6	68577	3771	568667	1188	24427	23.8	15156	15.4	13243	44.7	7369	2.19	635	1.42	0.08	-	35.3	703156
#32	Trimpancho Mine	1.72	74426	9052	236119	497	9224	19.5	30518	17.3	2031	107	8236	-	605	1.02	0.46	-	22.6	370876
#33	Lagunazo mine	31.7	1052707	417480	500829	5929	379859	310662	258263	1308	31848	3595	127503	3094	16155	1967	8201	445	154	3120000
	Total (USD/year)		10522709	2684811	36335072	53514	3448889	330042	4377422	11887	1275983	13078	1316756	33712	257677	14093	19554	39464	1465	

*Estimated price for: Mn from Manganese ore 46% Mn content; Be from compound 4% in Be; Li from carbonate of lithium price; Sr from celestite price.

Table 1. Estimated loads (expressed as kg/year) and valuation (USD/year) of basic and economic interest elements of lixiviates generated by several sulphide mining tailing wastes from the Iberian Pyrite Belt. Valuation estimated according to the metal prices for 2019 listed in USGS (2020).

Total annual contribution of 7014 t/year of Mg is obtained, which means more than 19 tons/day. Aluminium, Mn, Zn, Cu and As are the following in abundance, loading a total of 4780, 3730, 1250, 435 and 157 t/year, respectively. Taking into account the current price of these elements on the market (Table 1), it would mean an annual loss of almost 36 million dollars, only from the possible recovery of magnesium. In addition, almost 11 million dollars per year would come from Al, 4.4 million dollars from Be, 3.4 million dollars from Zn, 2.7 million dollars from Cu and 1.3 million dollars from both, Co and Li and 330, 258, 53 and 20 thousand dollars from As, Ni, Mn and Sb, respectively, inter alia. It is important to emphasize that Mg, Co and Sb are currently recognized as critical raw elements (EC, 2017).

The load of rare earth elements (REE) and other elements in these lixiviates is especially significant, which have a great economic impact due to their use in technological applications (Binnemans et al., 2013) and they are at the top of risk list for chemical elements which are of economic value (British Geological Survey, 2015). So, a total of 5.5 t/year of REE have been evaluated only from the five studied lixiviate samples, of which 4.2 t/year are LREE (Table 2). The recovery of REE and other elements would mean an annual profit of more than 35 million dollars originated in 275 ha sampled. Evaluating the REE content in the five studied tailing wastes, an approximation of the amount of REE in the 33 studied sites (total area of 1178.5 ha) can be performed, resulting a total of 23.6 t/year of REE.

Tables 1 and 2 can be given an idea of the most productive mining areas of these interest economic elements, not only because of the total surface area of the waste tailings but also the abundance of element contained in them. So, studied mining tailings from Riotinto and Tharsis mines are by far, the most potential sources of economic interest elements. Recovery of the studied elements in these mines would represent an annual profit of more than 15 million dollars each.

Lixiviated from mining tailings		#5	#26	#31	#32	#33	
	USD/kg*	**kg/year**					**USD/year**
La	2.00	2058	201	24.1	49.1	432	2764
Ce	2.00	3533	345	44.3	68.7	638	4629
Pr	119	150367	15964	1961	2874	31384	202550
Nd	105	86850	9283	1087	1536	16279	115035
Sm	4.22	1125	105	11.4	17.6	135	1394
Eu	73.9	4590	451	58.1	77.8	492	5669
Gd	54.4	20757	1845	226	325	2510	25663
Tb	1174	66425	5477	669	913	6303	79787
Dy	551	163476	12992	1642	2065	13983	194158
Ho	128	7112	571	72.0	85.1	618	8458
Er	60.6	8824	775	104	107	1101	10911
Yb	36.7	4346	318	36.6	46.0	165	4912
Lu	1410	24743	2012	253	280	2171	29459
B	0.38	30.4	27.6	1.93	2.42	45.2	108
Bi	7.55	1.35	-	0.02	0.12	511	512
Cs	63000	295172	12884	34625	7770	2210907	2561358
Ga	150	4674	775	191	206	19934	25780
Ge	920	101110	11995	31293	2824	1400088	1547310
Nd	105	86850	9283	1087	1536	16279	115035
Rb	87800	633508	378220	315798	104923	25241889	26674338
Sc	11951	585	185	35.3	22.6	154	982
Ta	162	305	19.4	5.82	3.57	-	334
Ti	9.20	0.92	0.09	0.10	0.05	19.7	20.9
Tl	7600	18007	2266	1682	745	3513427	3536127
U	201	34686	3358	235	291	3446	42016
V	26.2	1143	174	333	103	49241	50994
W	270	316	40.4	13.2	2.20	-	372
Y	3.00	10618	867	131	130	825	12571
Zr	21.6	36.3	3.35	1.06	1.64	1925	1967
Total USD/year		1731249	470437	391621	127005	32534902	

*Estimated prices from: oxides for rare earth elements, Ta from Ta_2O_5; V from V_2O_5

Table 2. Estimated loads (expressed as kg/year) and valuation (USD/year) of economic interest elements of lixiviates generated by several sulphide mining tailing wastes from the Iberian Pyrite Belt. Valuation estimated according to the metal prices reported by USGS (2019), Reuters (2019) and ISE (2019).

Considering the studied lixiviates from a total of 1178 ha. of mining tailings, large amounts of economic interest elements are wasted. The estimated annual profit from these elements recovery could be more than 95 million dollars, considering that this value is largely underestimated. Making an estimate on the total area in the IPB of abandoned solid waste calculated by Grande et al. (2014), this value would be increased to a total annual value of more than 390 million dollars.

4. Conclusions

In the Iberian Pyrite Belt (IPB) there are more than 4800 ha occupied by waste mining dumps, corresponding to 88 sulphide mines. Mining waste dumps are potential sources of pollution, which after rainfall produce lixiviate discharges, loaded with acid mining drainage (AMD). Critical Raw Materials, such as Mg, Be, Sb, Co, V, Sc, rare earth elements (REE) and others of economic interest (e.g. Mn, As, Cd, Cr, Li, etc.) are dissolved in these lixiviates in high concentrations. The presence of these elements and the large load of lixiviate generated could turn this waste into a potential commodity. This study examines the potential recovery of metals of economic interest contained in AMD lixiviates from SW Spain, estimating the available metal reserves and evaluating the economic gains that would result from their recovery. For this purpose, 33 mining lixiviates have been evaluated throughout the whole of the Spanish IPB. These lixiviates can be contained concentration up to 4.2 g/L of Mg, 31 mg/L of Co, 4.8 mg/L of Sb, 5.3 mg/L of Ge, 2.6 mg/L of V and 7.2 mg/L of total rare earth elements (REE), 3.3 g/L of Mn, 2.9 mg/L of Cd, 5.7 mg/L of Li, 1.4 mg/L of Rb, 2.3 mg/L of Tl, inter alia. Results show annual contributions of more than 7000 t/yr of Mg, 4700 t/yr of Al, 3700 t/yr of Mn, 34 t/yr of Co, 2.3 t/yr of Sb, around 24 t/yr of rare earth elements (REE), etc. Considering the current market metal prices, the recovery of these elements would mean an annual profit of almost 37 million dollars, only from the magnesium. In addition, almost 11 million dollars per year would come from Al, more than 4 million dollars from Be, almost 3.5 million dollars from Zn, 3 million dollars from Cu, 1.4 million dollars from Li and 330, 257 and 20 thousand dollars from As, Ni and Mn, respectively. Estimating from the five mines assessed alone, the recovery of Rb would amount to more than 26 million dollars per year. About 5 million dollars from SC, 3.5 million dollars from

Tl, 2.5 million dollars from Cs, etc. The reserves contained in the 33 evaluated lixiviates (total area 1178 ha of mining waste dumps) have a potential value of around 100 million dollars per year, considering that this value is largely underestimated. Making an estimate on the total area of abandoned mining waste dumps in the IPB (around 4800 ha), this value would be increased to an annual total of more than 400 million dollars.

A potential recovery of the pollutant loads in the Odiel river basin would cause, in addition to an economic benefit already described here, an unquestionable environmental benefit by improving the quality of the waters affected by AMD and thereby making them compatible for other uses such as agriculture, livestock, urban supply, etc. The role of each element dissolved in mine waters from an environmental perspective is not the same for all. Indeed, European regulations (European Council Directive 98/83/CE of 3 November 1998) dictate the maximum admissible concentrations for channels, rivers that are going to be dammed in supply dams, it is done according to the toxicity of each element; Let take Fe and As as an example; these two elements existent in sulfide ores are considered in different ways by the regulations, much more tolerant with Fe which is benefic for human intake, for example correcting anemia, compared to As which is especially undesirable due to its highly harmful nature (Grande (2011).

The technical processes involved in improving the quality of mine waters by eliminating toxic elements and recovering elements of economic interest is oriented to the concept of "Circular Mining" described by Grande et al. (2018). For these authors it still does not exist a global solution for all mining, having to apply different techniques depending on: mineral paragenesis, type of embedded rock, weather, toxicity of dissolved elements." Grande et al. (2018) suggest "The need for conservation and recovery of the affected water environment is evident as it is an increasingly valuable and scarce resource. It is clear here that the presence of "substances" of economic interest in the current socioeconomic context and under the protection of technologies must now be reoriented to make the recovery of the water environment in a sustainable manner compatible with positive financial results. We believe that the need to look for a solution to the AMD problem that is exportable to any affected scenario is a priority."

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