Mining waste management in Spain. Recovery of critical raw materials: experience in Penouta mine

C.N. IGME, CSIC - Geological Survey of Spain
Mining Wastes and Environmental Geochemistry Research Group

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Convegno Scarti Minerari: da Rifiuto a Risorsa

Stava di Tesero, 7th October 2022

MINING LAW – 1973

Royal Decree 2994/1982, about the restoration of areas affected by the mining activity.

DIRECTIVE 2006/21/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC

↓

Royal Decree 975/2009, of June 12, on waste management from the extractive industries and protection and rehabilitation of the area affected by mining activities.

THE IGME- SPAIN COLLABORATED IN THE TRANSPOSITION

DIRECTIVE 2006/21/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 March 2006 on the management of waste from extractive industries:

Art. 20

"It is necessary for Member States to ensure that an inventory of closed, including abandoned, waste facilities located on their territory is drawn up in order to identify those which cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment. These inventories should provide a basis for an appropriate programme of measures.

It was necessary to carry out inventories. It was necessary to elaborate the technical criteria for the prioritization of the risk of mining waste facilities, and provide criteria on what can be considered serious or not serious."

CLOSED OR ABANDONED MINING WASTE FACILITIES

The IGME-SPAIN was entrusted to perform the national inventory and the methodology for risk assessment.

This works were carried out between 2010 and 2015. The inventory has been updated in 2019, 2020 and 2022.

Methodology published in the book "Simplified guide for closed/abandoned mining waste facilities risk assessment"

The methodology needed to be easy to apply, and serve to be applied in all the territory

http://www.mapama.gob.es/fr/calidad-y-evaluacion-ambiental/publicaciones/guiasimplificadaevaluacionriesgoseninglesversion2_tcm36-185046.pdf

POLLUTION RISK SCENARIOS

POLLUTION RISK SCENARIOS	Effects on the population	Effects on the natural environment	Effects on the socioeconomics
Generation of contaminating effluents with effect/impact to the surface waters (C1)	C1PO	C1NA	C1SE
Generation of contaminating effluents with effect/impact to underground water resources (C2)	C2PO	C2NA	C2SE
Mobilization of particulate material due to the action of the wind (C3)	C3PO	C3NA	C3SE
Emission of contaminating sediments due to erosion by water (C4)	C4PO	C4NA	C4SE
Direct contact arising from occasional access or from the development of activities (CD)	CD		

The probability of occurrence (hazard) and the severity of the consequences have been calculated for each scenario

FAILURE OF THE CONTAINMENT STRUCTURES RISK SCENARIOS

FAILURE OF THE CONTAINMENT STRUCTURES RISK SCENARIOS	Effects on the population	Effects on the natural environment	Effects on the socioeconomics
Failure or breach of the dyke or the external embankment of mining tailings impoundments (FPRE)	FPREPO	FPRENA	FPRESE
Failure or breach of the slope at dumps containing waste rock or low-grade ore (FESC)	FESCPO	FESCNA	FESCSE

The probability of occurrence (hazard) and the severity of the consequences have been calculated for each scenario

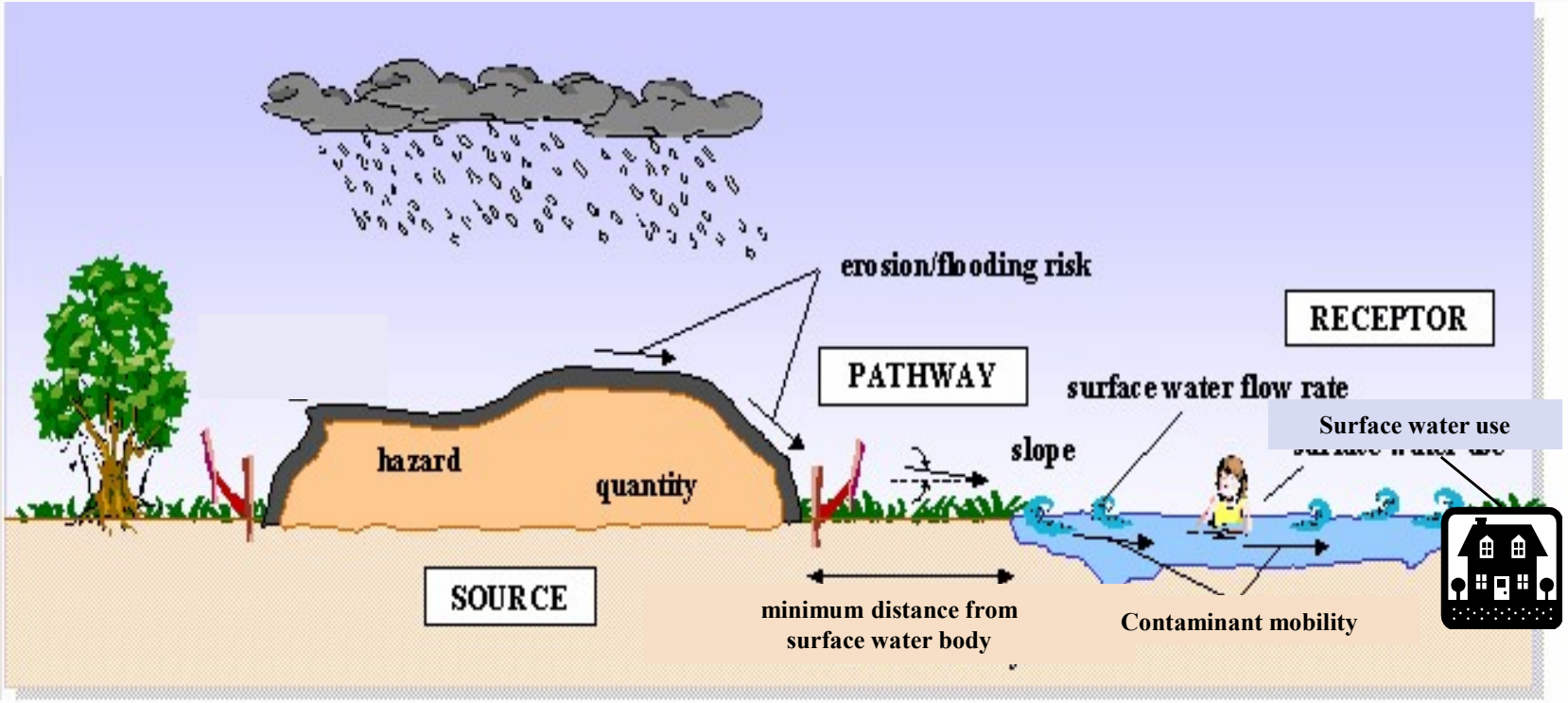
POLLUTION RISK SCENARIOS

Generation of contaminating effluents with effect/impact to the surface waters

C1

Scenario code

C1PO
C1NA
C1SE



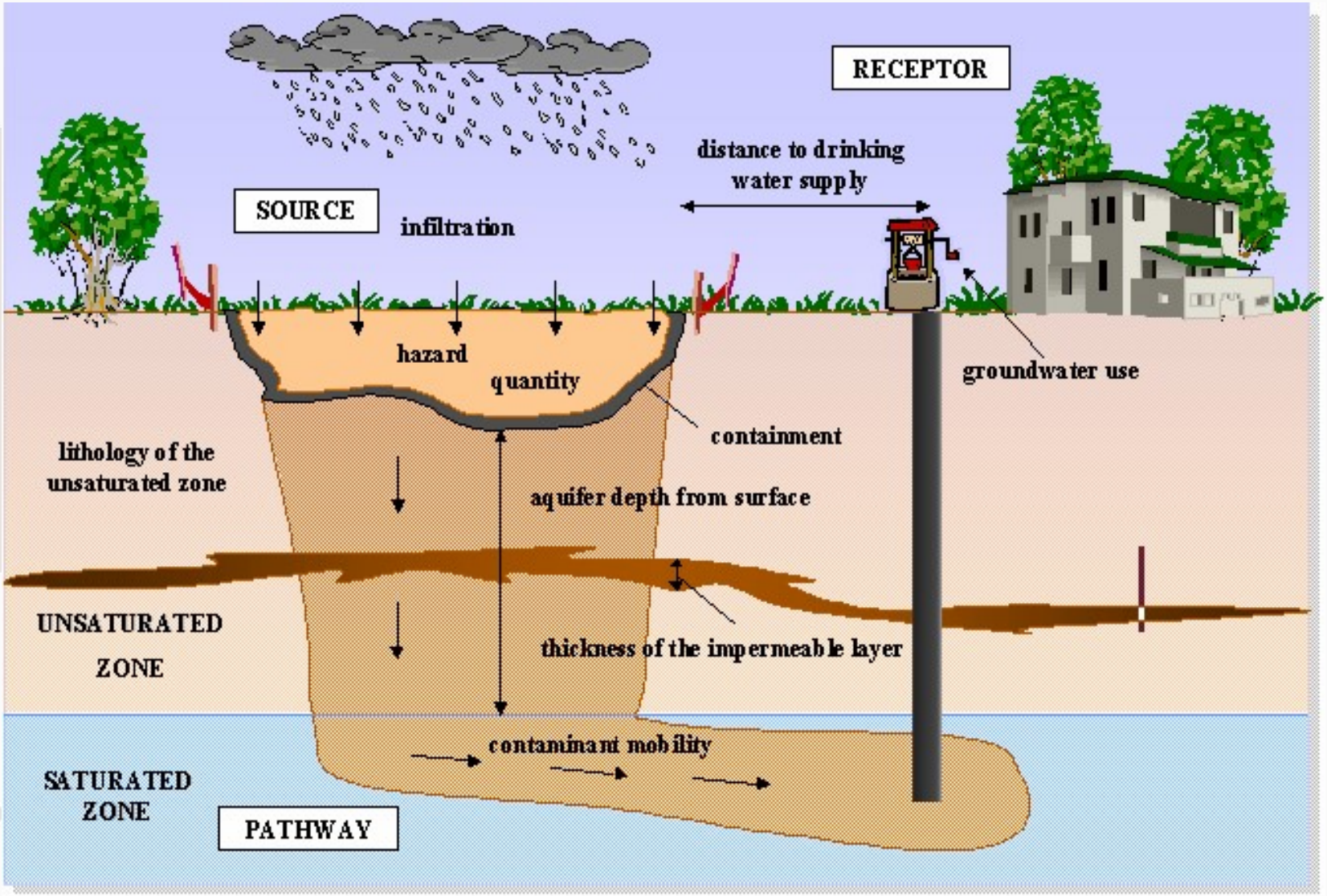
POLLUTION RISK SCENARIOS

Generation of contaminating effluents with effect/impact to underground waters

C2

Scenario Code

C2PO
C2NA
C2SE



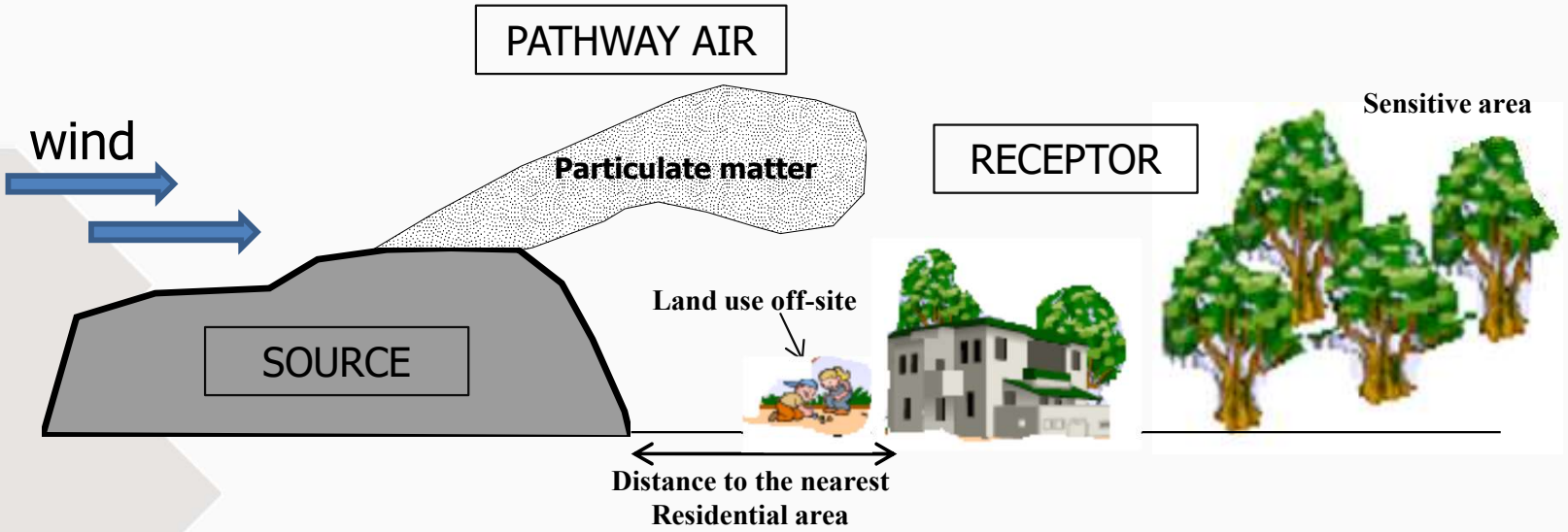
POLLUTION RISK SCENARIOS

Mobilization of particulate material due to the action of the wind

C3

Scenario code

C3PO
C3NA
C3SE



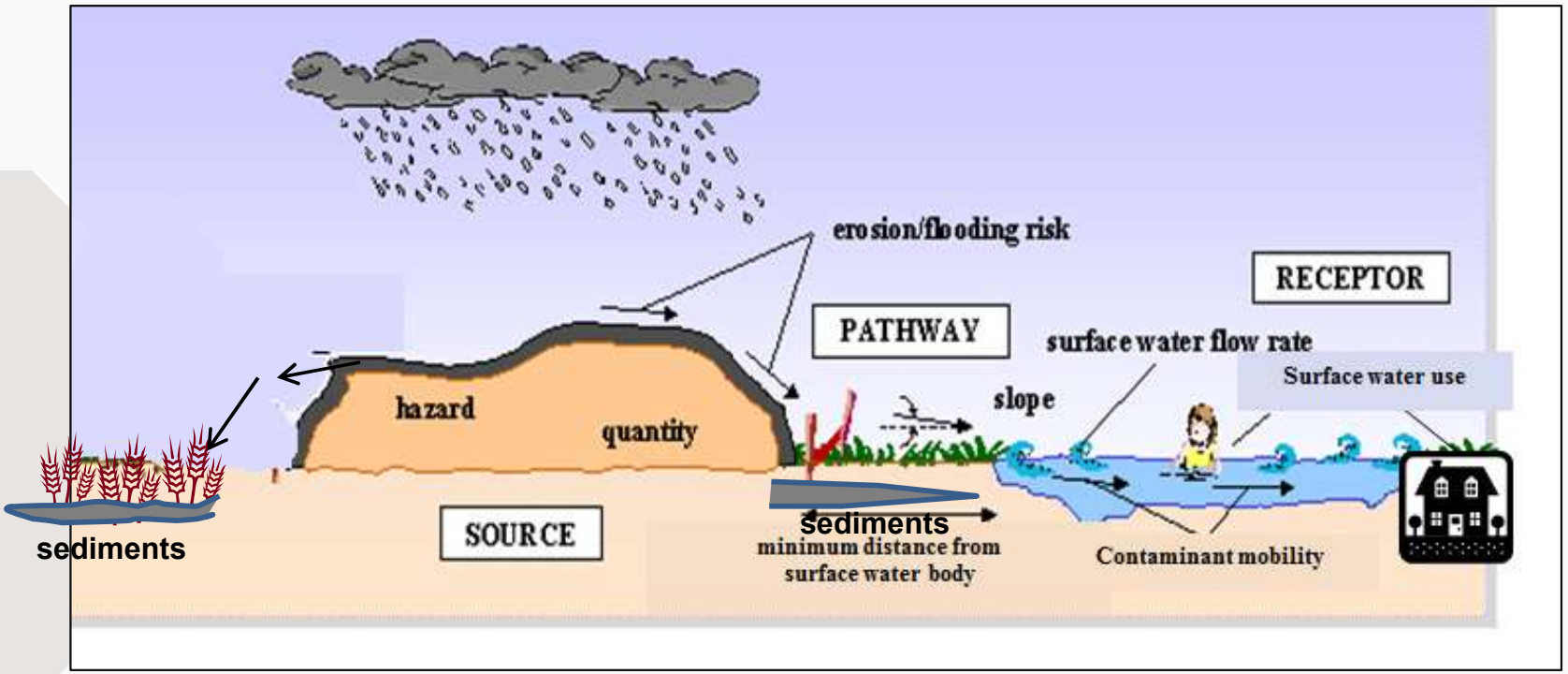
POLLUTION RISK SCENARIOS

Emission of contaminating sediments due to erosion by water

C4

Scenario code

C1PO
C1NA
C1SE



POLLUTION RISK SCENARIOS

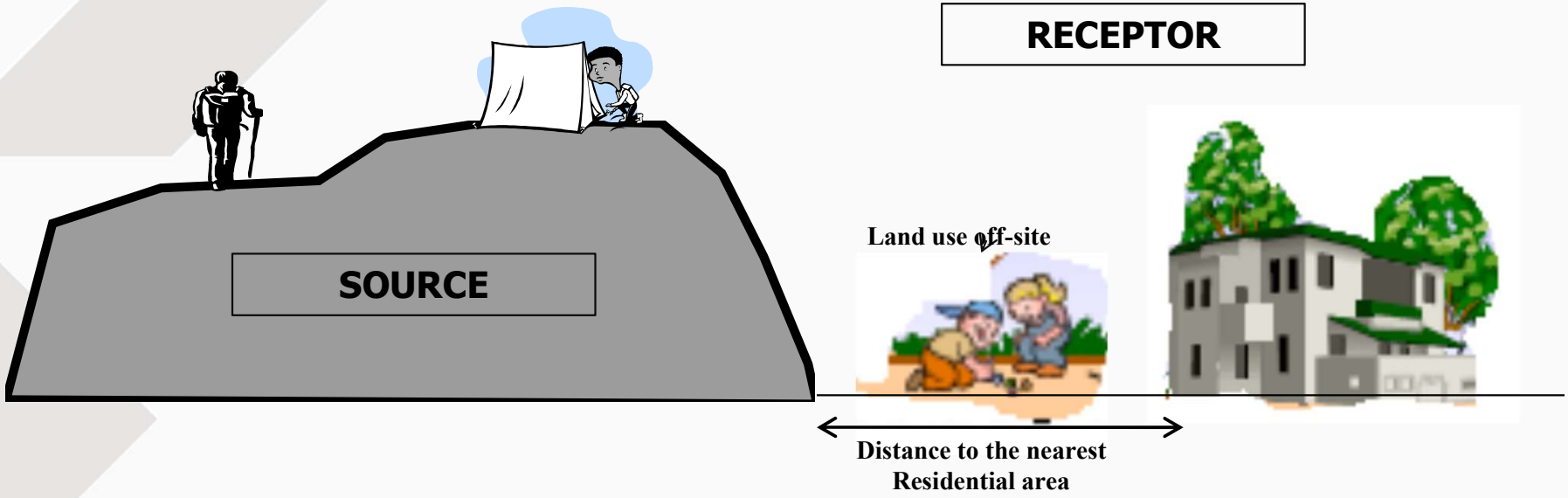
Direct contact arising from occasional access or from the development of activities

CD

Scenario code

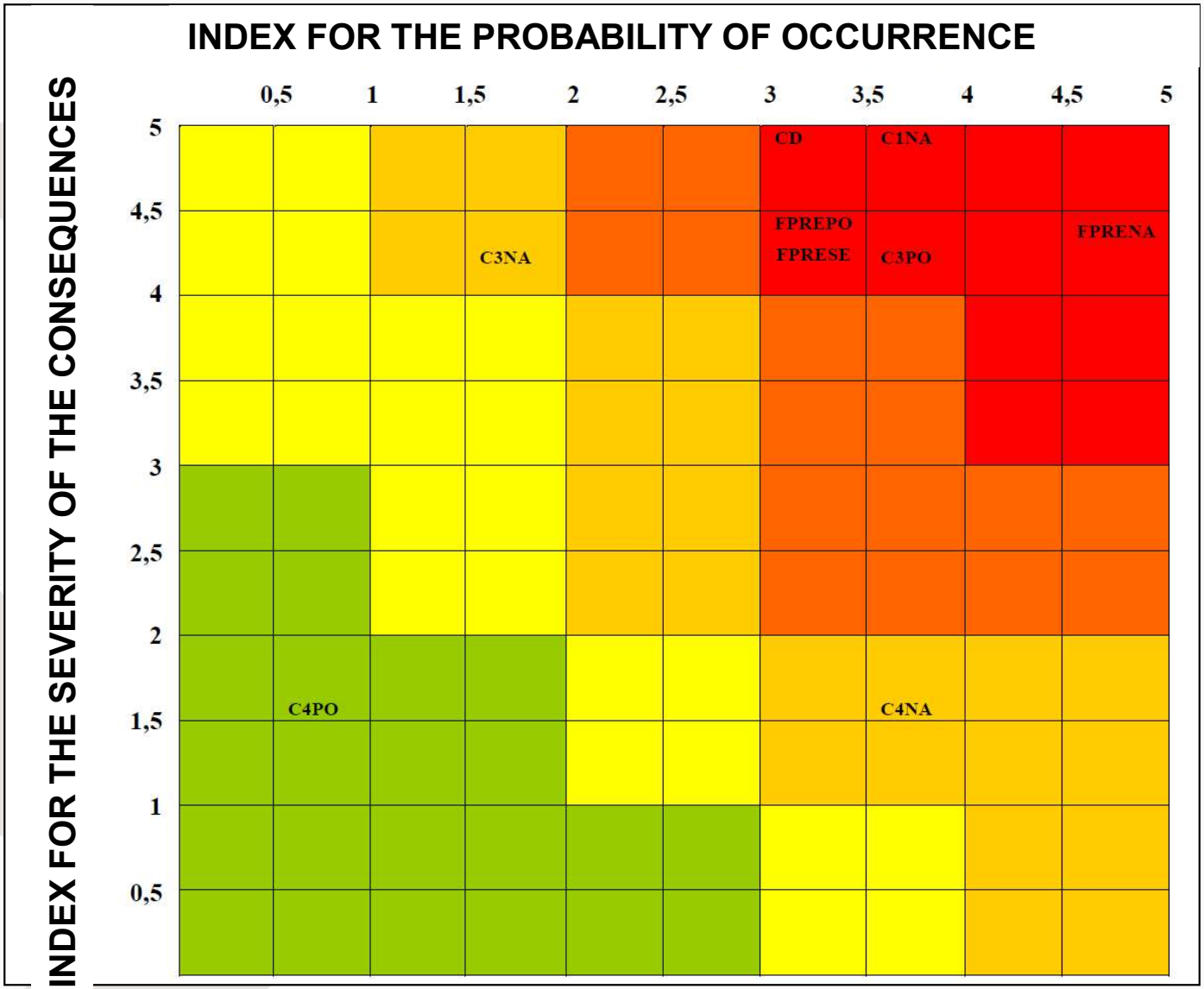
CDPO

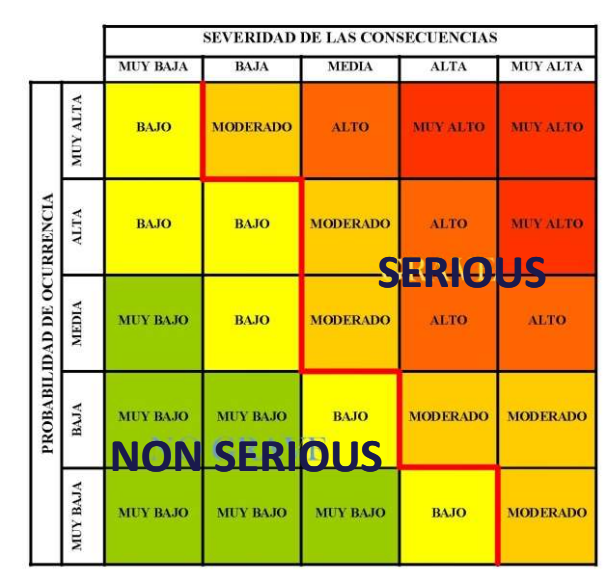
PATHWAY DIRECT CONTACT CONTAMINATED SOIL/WASTE



RISK MATRIX

Example of risk assessment





MAZARRÓN (MURCIA)

As a result: Spanish inventory of closed or abandoned mining waste facilities with risk in the medium or short term.

↓

109 mining waste facilities in 2022

A preliminary conclusion:

The fact of completing the inventory work without setting priorities for action (even in a simplistic way, or applying expert criteria) greatly reduces the practical usefulness of the inventories. It is necessary to characterize the sites and to establish priorities based on technical criteria.

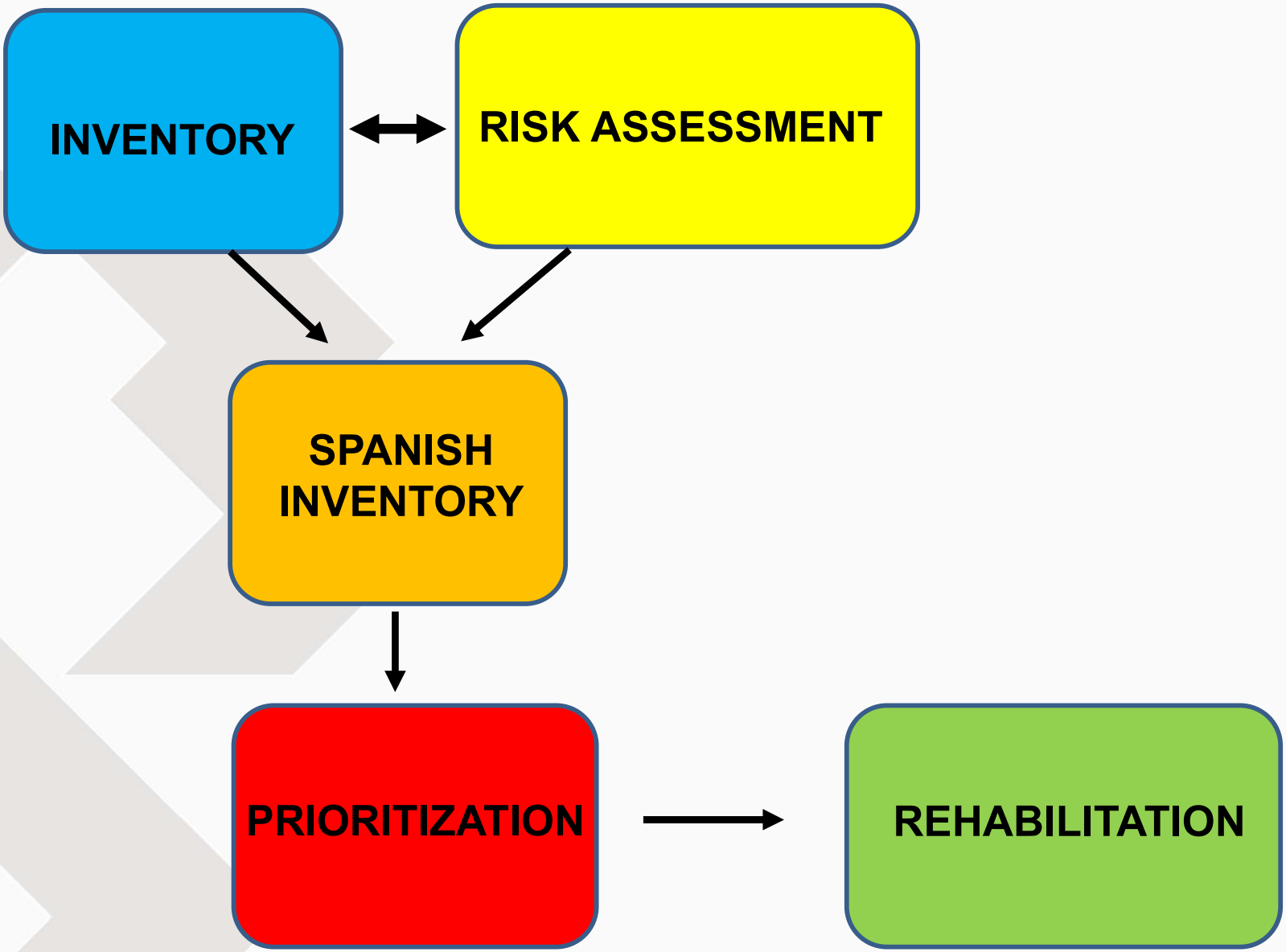
Methodology for prioritization on a risk assessment based approach

Inventario de instalaciones de residuos de industrias extractivas cerradas y abandonadas en España (Actualización marzo 2022)

(que tienen un impacto medioambiental grave o que pueden convertirse a medio o corto plazo en una amenaza grave para la salud de las personas o para el medio ambiente)

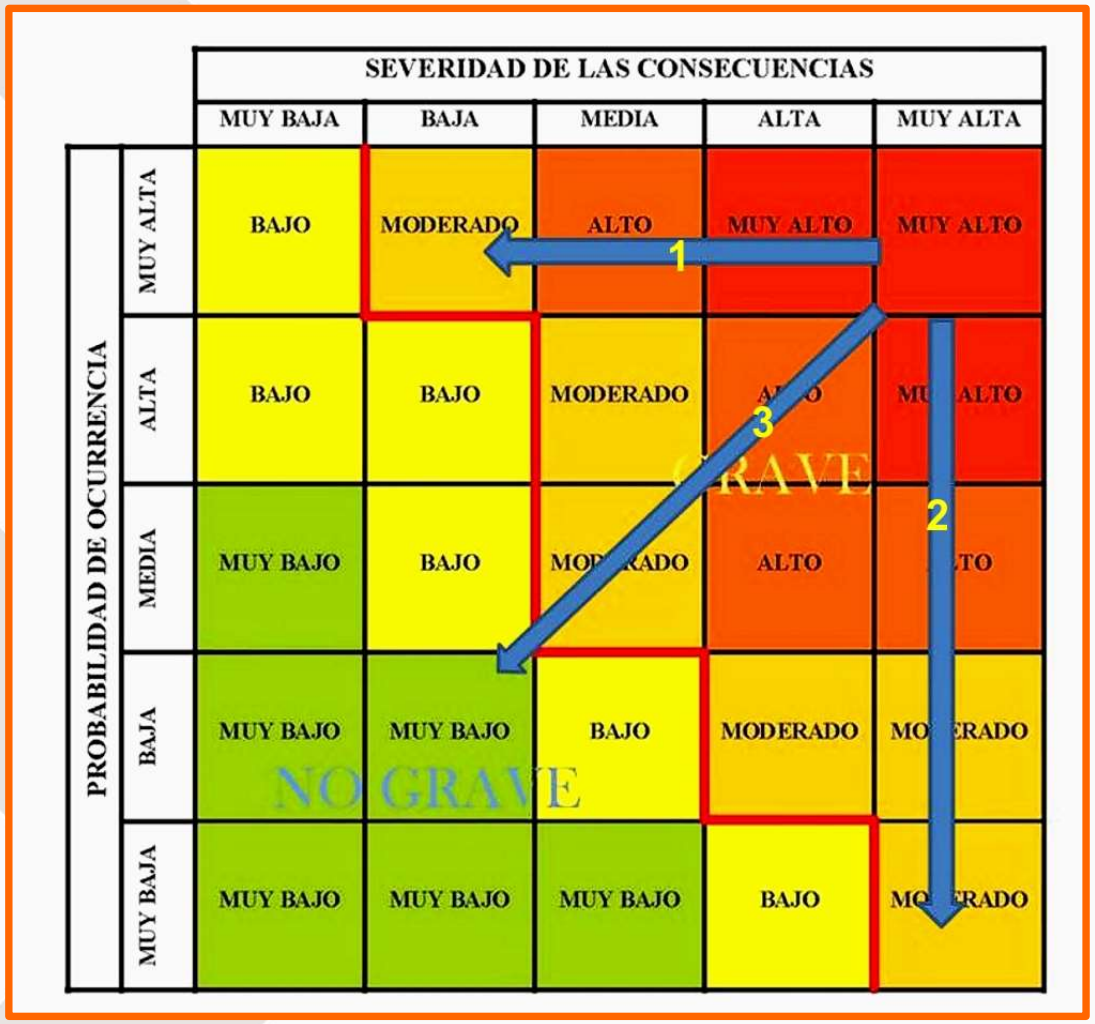
Código	C.C.A.A	Provincia	Municipio	Escombrera	Presa	Tipo de minería	Valor ordenación	Suma	Posición
978 I 3 026	Región de Murcia	Murcia	La Unión		X	Minería Metálica	42123	119,17	1
53 III 3 001	Principado de Asturias	Asturias	Lena	X		Minería Metálica	41412	103,32	2
977 II 4 029	Región de Murcia	Murcia	La Unión		X	Minería Metálica	42011	94,88	3
976 II 3 006	Región de Murcia	Murcia	Mazarrón		X	Minería Metálica	42021	93,58	4
938 IV 4 002	Andalucía	Huelva	Nerva		X	Minería Metálica	40211	78,75	5
34 III 4 007	Cantabria	Cantabria	Cartes		X	Minería Metálica	40003	61,75	6
34 III 4 003	Cantabria	Cantabria	Cartes		X	Minería Metálica	40000	61,4	7
977 II 4 041	Región de Murcia	Murcia	Cartagena		X	Minería Metálica	33321	116,3	8
976 II 3 004	Región de Murcia	Murcia	Mazarrón		X	Minería Metálica	34101	99,68	9
977 II 4 027	Región de Murcia	Murcia	La Unión		X	Minería Metálica	33151	98,8	10
977 II 4 043	Región de Murcia	Murcia	Cartagena		X	Minería Metálica	31323	84,39	11
978 I 3 022	Región de Murcia	Murcia	La Unión		X	Minería Metálica	31036	78,7	12
977 II 4 021	Región de Murcia	Murcia	La Unión		X	Minería Metálica	31130	76,66	13
938 IV 4 003	Andalucía	Huelva	Minas de Riotinto		X	Minería Metálica	30221	66,74	14
978 I 1 001	Región de Murcia	Murcia	Cartagena		X	Minería Metálica	31001	54,05	15
977 II 4 100	Región de Murcia	Murcia	La Unión	X		Minería Metálica	30112	53,46	16
34 III 4 002	Cantabria	Cantabria	Torrelavega		X	Minería Metálica	30010	52,9	17

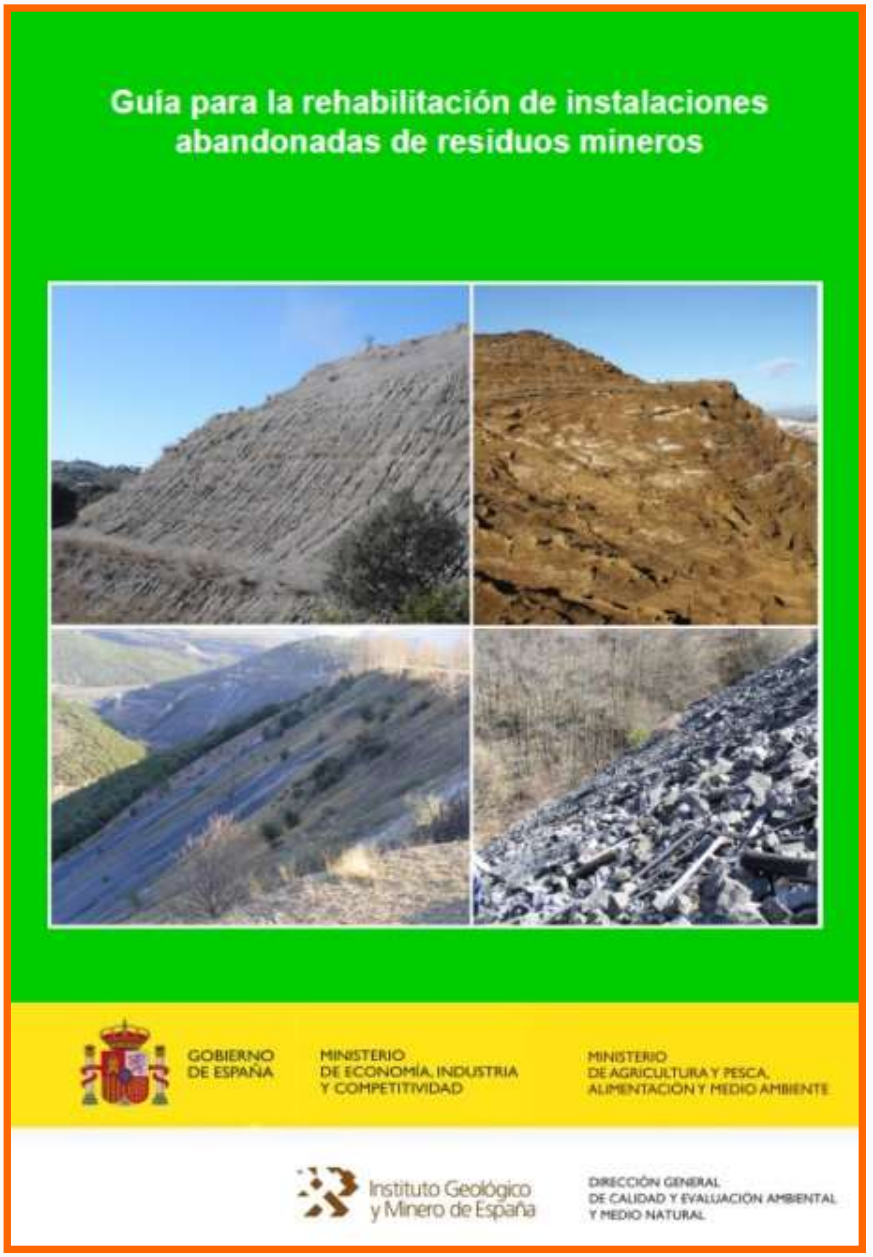
THE NEXT STEP: REHABILITATION



OTHER RELATED WORKS

Guide for the rehabilitation of abandoned mining waste facilities (on a risk based approach)





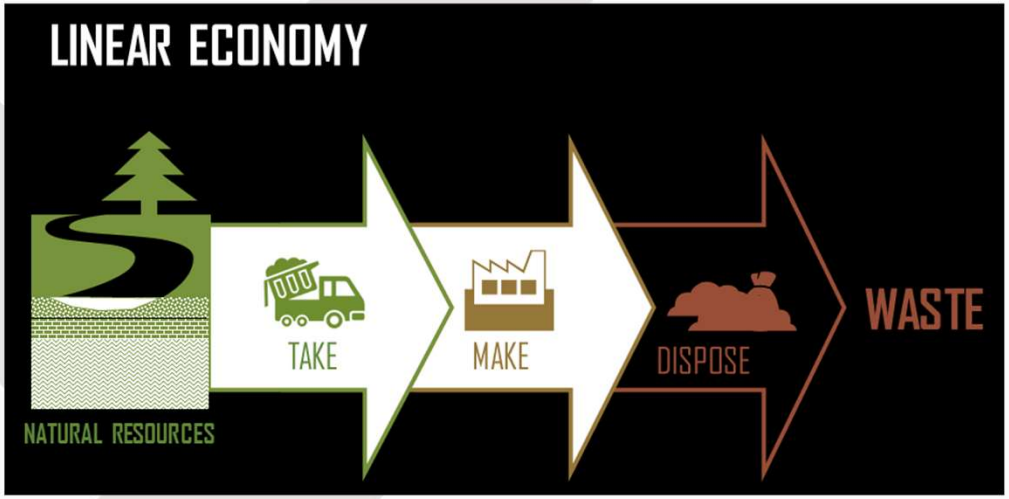
THE NEXT STEP: REHABILITATION

2018

WHAT ABOUT RECOVERY OF VALUABLE SUBSTANCES FROM MINING WASTE?

CIRCULAR ECONOMY – Closing the loop

Since the industrial revolution, our extractive industrial model have developed a 'take-make and dispose' pattern of growth — a linear model based on the assumption that resources are abundant, available, easy to source and cheap to dispose of. Moving towards a more circular economy is essential to deliver the resource efficiency agenda established under the Europe Strategy for smart, sustainable and inclusive growth. Circular economy systems keep the added value in products for as long as possible and eliminate waste. The circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimising negative impacts.



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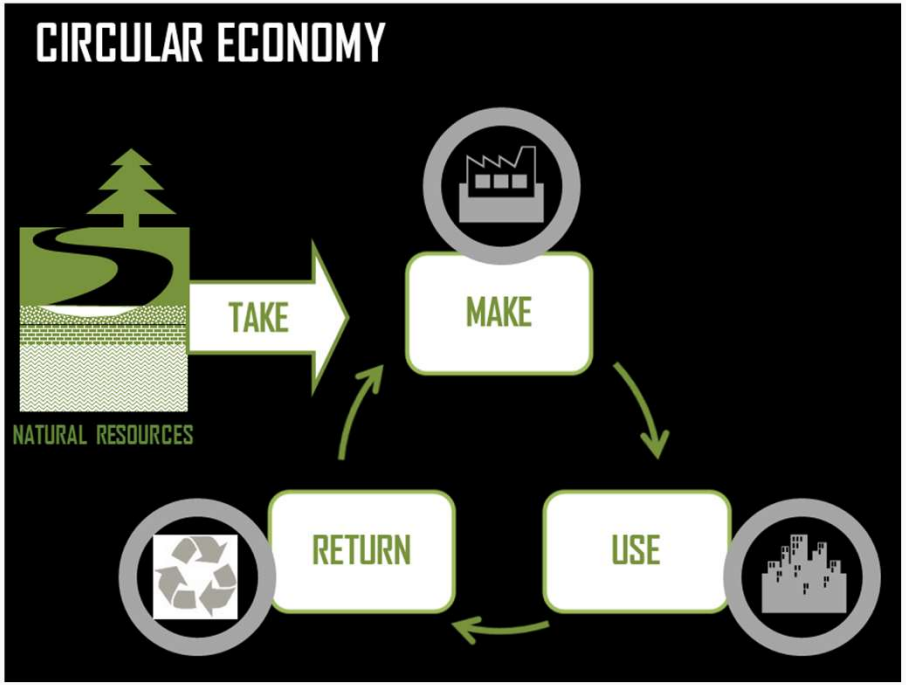


CIRCULAR ECONOMY IN THE FRAMEWORK OF SUSTAINABLE MINING

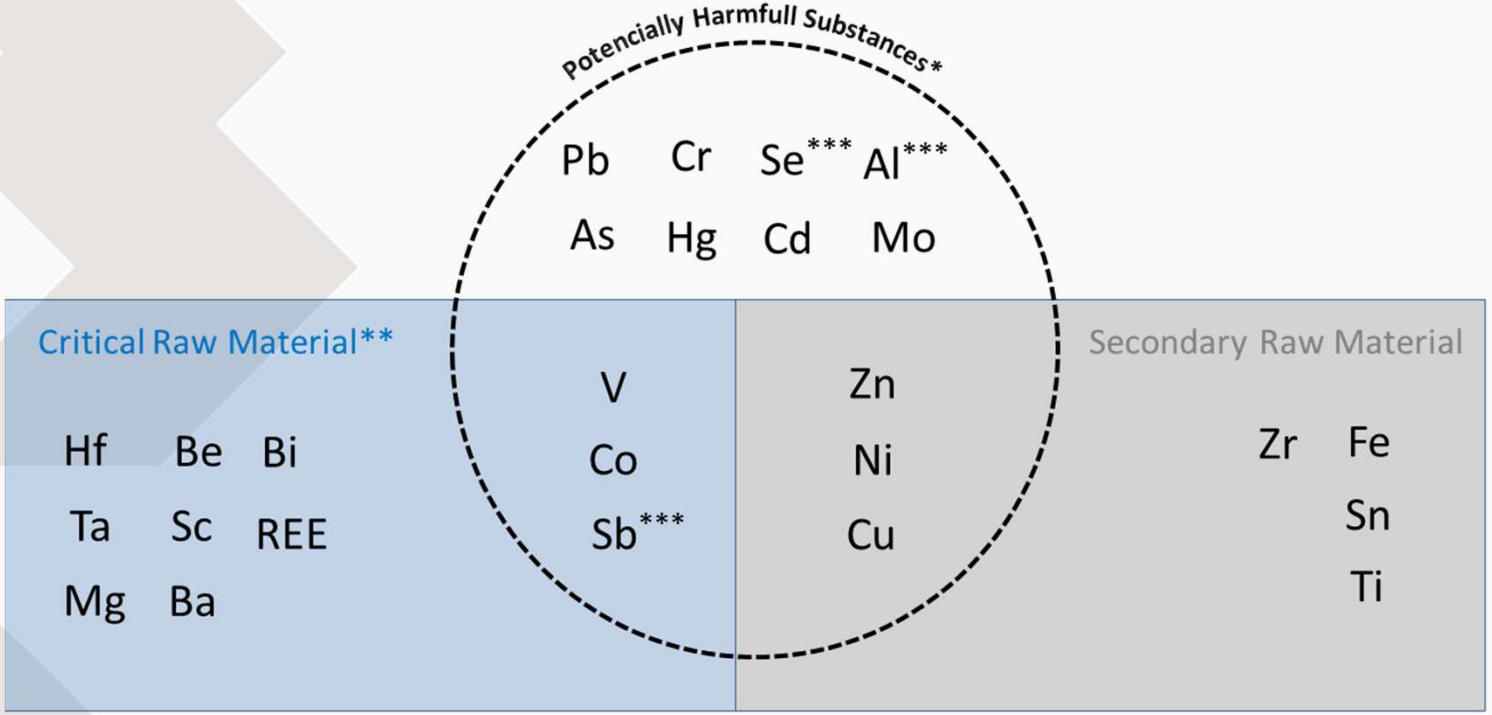
The implementation of the EU Strategy for Circular Economy necessarily goes through the **reprocessing of mining waste.**

Closed and abandoned mining waste facilities are a significant concern in Europe. For example, it is estimated that more than 14,000 closed and abandoned mining waste facilities exist in Spain.

Mining wastes often contain high concentrations of toxic elements, whose mobility and dispersion may pose an environmental hazard for soils, water, ecosystems and people.

Moreover, mining wastes can present interesting contents in Critical Raw Materials (CRM) and secondary raw materials. CRM have become essential for the industry sector, being necessary to produce a wide range of products and applications used in everyday life and modern technologies.

Reliable and unrestricted access to certain raw materials is a growing concern in the EU and around the world. They are highly important for the EU economy and the shortage of these materials poses a high risk. From the harmful substances that can be present in the mining wastes, V, Co and Sb, are also included in the 2017 list for critical raw materials for the EU. The recovery of other potentially harmful substances listed, although not being CRM, can be interesting as secondary raw materials (Cu, Zn, Ni). Other substances, also present in mining wastes but not listed as potentially harmful by the European Commission are catalogued as CRM or can be considered as secondary raw materials.



*2009/359/EC: Commission Decision of 30 April 2009 completing the definition of inert waste in implementation of Article 22(1)(f) of Directive 2006/21/EC of the European Parliament and the Council concerning the management of waste from extractive industries
**COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the 2017 list of Critical Raw Materials for the EU
***Added due to their probed toxicity

Regarding the compositional features of abandoned mining waste facilities inventoried in Spain, a high percentage of the test samples have shown contents of hazardous metals and metalloids above the limits set by the different territorial regulations of the Spanish regions. Although high concentrations of Cd, Cr and Sb have been found, the main environmental problems are clearly leaded by As and Pb in these facilities.

In addition, concentrations of Sb, Cd, Cr, V, Zn, Cu, and Ni (in some cases) are substantially above the geochemical background values considered.

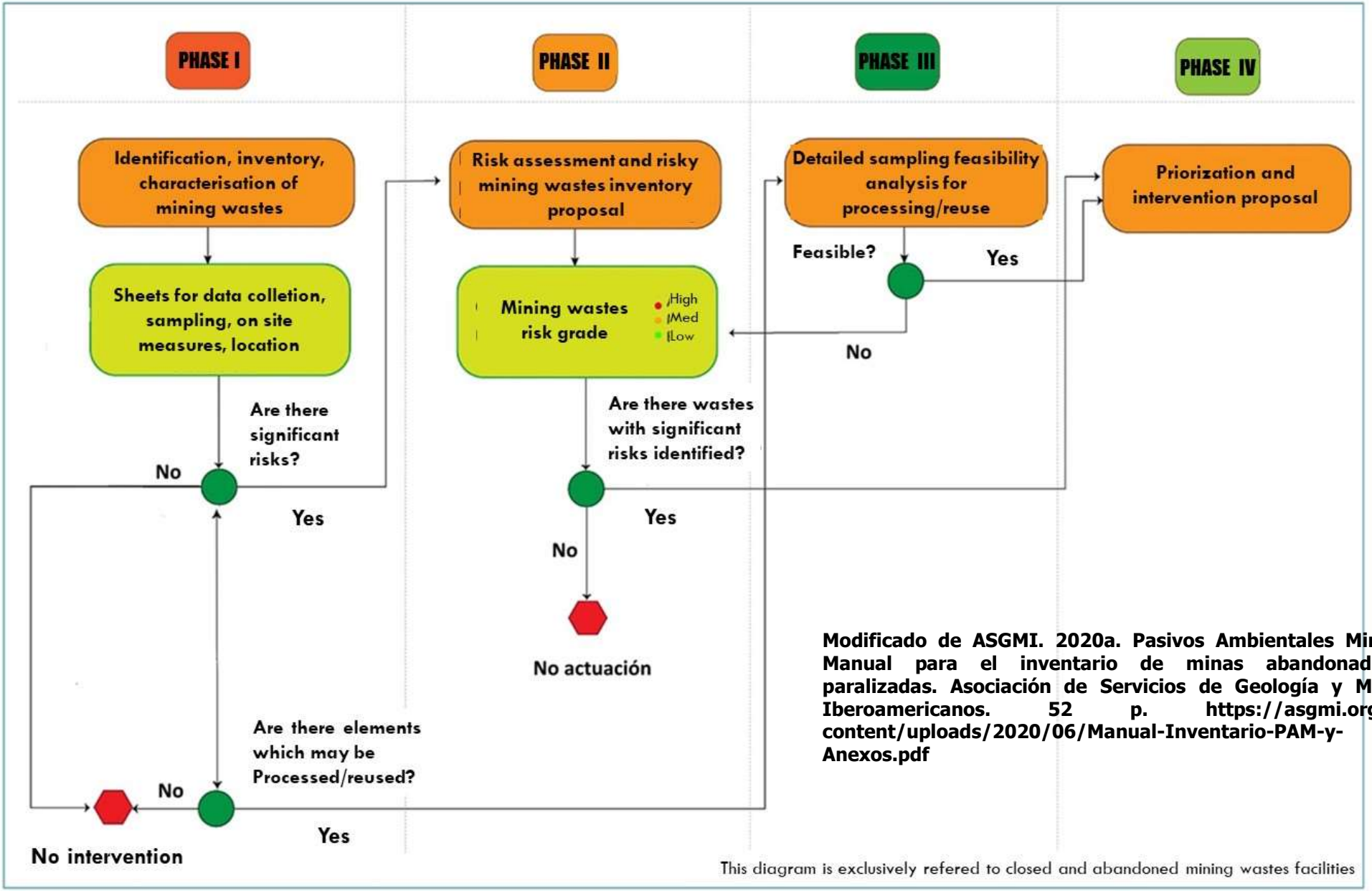
Furthermore, tailings dam samples showed a small particle size (below 2 mm). Thereby, it is relatively easy for the pollutants to get into the aqueous phase, as well as to be mobilized by the wind. This condition is adverse in terms of environmental risk. However, the fine granulometry and the potential of some metals to mobilize could be key aspects when recovery actions want to be implemented.

The removal of substances potentially harmful from the tailings dam is an important issue to solve in order to improve the environmental risk conditions of the facilities. In addition, the remaining materials may be a source of secondary raw materials (including CRM).

Thus, the reprocessing of mining waste provides a **triple benefit**:

- **Extraction of CRM and secondary raw materials from mining waste**
- **Removal of hazardous substances from the waste**
- **A new opportunity to manage properly the remaining waste**

THEORETICAL MANAGEMENT MODEL ABOUT PHASES OF ACTION RELATED TO ABANDONED MINING WASTE FACILITIES



Modificado de ASGMI. 2020a. Pasivos Ambientales Mineros. Manual para el inventario de minas abandonadas o paralizadas. Asociación de Servicios de Geología y Minería Iberoamericanos. 52 p. https://asgmi.org/wp-content/uploads/2020/06/Manual-Inventario-PAM-y-Anexos.pdf

LEGAL INSTRUMENT FOR THE RECOVERY OF VALUABLE SUBSTANCES FROM MINING WASTE IN SPAIN

MINING LAW – 1973

SECTION B PERMITS

59 Section B permits
- coal
- marble
- iron
- clays
- Nb-Ta

Exploitation permit focused on waste/secondary deposit

Strategic Minerals—Mina de Penouta. Available online: https://www.strategicminerals.com/en/our-job/penouta/

Penouta Mine

The only tantalum and niobium mine in production in Europe

The Sn-Ta-Nb Penouta Mine is located at the north-west of Spain

Penouta Mine initially began with the use of the tailings from the old exploitation within the framework of circular economy and environmental sustainability.
It is an European mine of strategic importance.

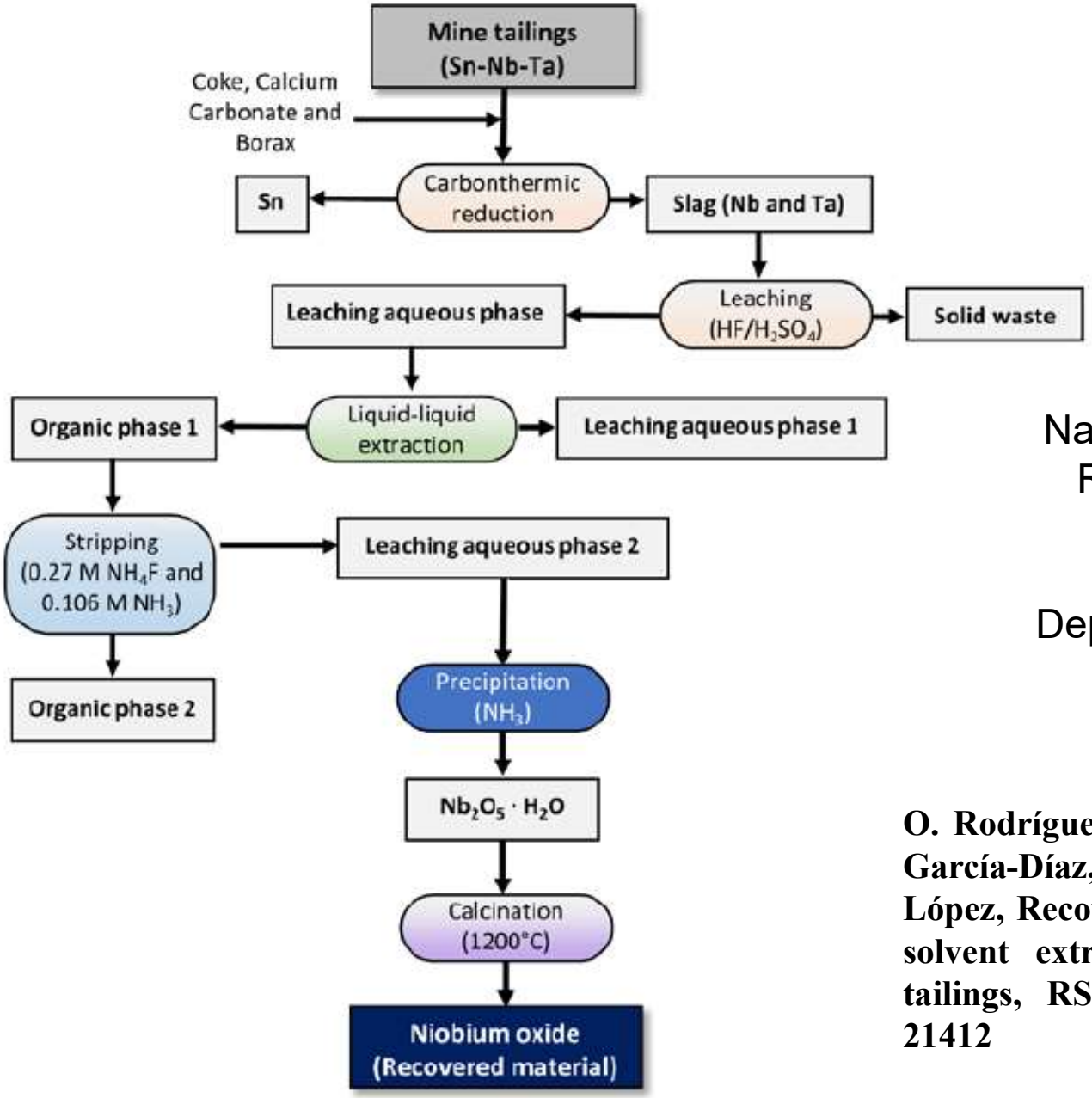
The Penouta project may be considered partly an active mine and partly an attempt of abandoned mine reactivation. Two mining permits have been conferred in this regard, according to the Spanish mining law: Section B (exploitation permit focused on waste/secondary deposit, which is currently under exploitation) and Section C (research project focused on primary mineralization).

PENOUTA MINE

During the mining activities developed in previous decades, large amounts of Sn- and Ta-bearing materials were deposited in the tailing ponds, due to deficient mineral processing. Due to economic and technological changes developed in recent years, exploitation of these sources seems to be potentially viable nowadays. Therefore, the permit for Section B "Penouta" is intended to reprocess those materials that were considered mining waste until now.

From a geological point of view, the deposit is composed of diverse rocks: leucogranite, aplite-pegmatite dikes, greisen and quartz veins, hosted by metamorphic rocks formed before the main Hercynian deformational phase: Mineralization of cassiterite, Nb and Ta oxides is disseminated throughout the alkaline granite.

A detailed estimation of resources has shown 4.82 million tons of wastes (secondary source) as an indicated source of Sn (av. 387 ppm) and Ta (av. 48 ppm), as well as 10.97 million tons of primary ore in an open-pit project with high contents of Sn (av. 461 ppm), Ta (av. 79 ppm) and Nb (av. 64 ppm). If developed, Penouta deposit could become the first own primary source of niobium and tantalum within the EU.

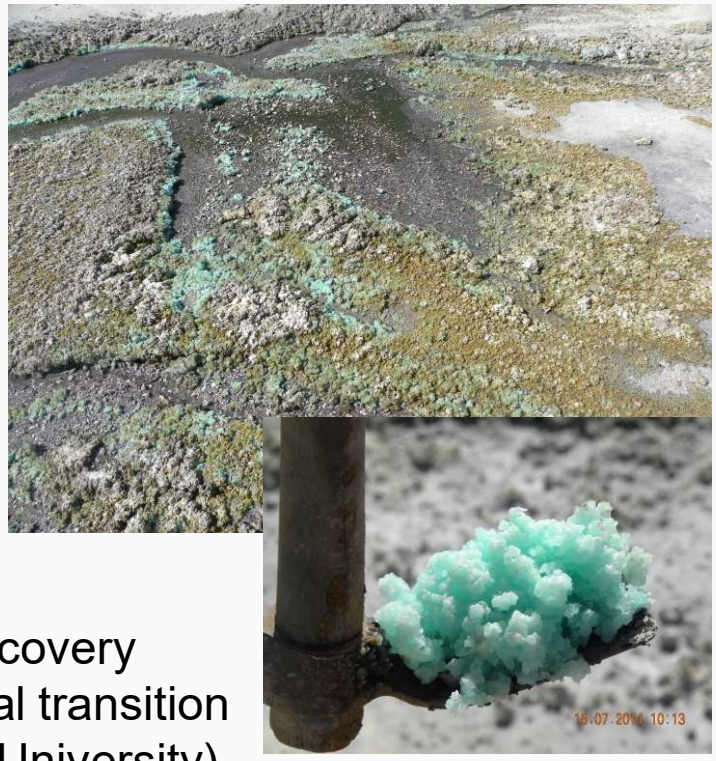


National Center for Metallurgical Research (CENIM), Spanish National Research Council (CSIC)
Department of Materials Physics, Complutense University of Madrid

O. Rodríguez, F.J. Alguacil, E.E. Baquero, I. García-Díaz, P. Fernández, B. Sotillo, F.A. López, Recovery of niobium and tantalum by solvent extraction from Sn–Ta–Nb mining tailings, RSC Advances, 10 (2020) 21406-21412

OTHER RESEARCH PROJECTS

The Geological Survey of Spain is currently developing two work lines linked to the reprocessing of mining wastes in the framework of Circular Economy:



- Recovery of metals from secondary sulphate salts formed in mining wastes (in cooperation with the Autonomous University of Madrid, UAM)

- Methods to extract CRM and secondary raw materials from mining wastes as well as removing hazardous substances and contaminants (in cooperation with the Higher Technical School of Mine Engineering of the Polytechnic University of Madrid, ETSI-Minas, UPM)

- Exergy and thermoeconomic assessment of the national recovery capacity of secondary resources essential for the ecological transition (RESET). Spanish R&D&I Programme. (Leader: Zaragoza University)

- START PROYECT (Sustainable Energy Harvesting Systems Based on Innovative Mine Waste Recycling). The aim is to transform mining wastes into materials for the storage of remaining heat ➔ TETRAHEDRITE

OTHER RESEARCH PROJECTS

- Assessment of the potential for REE and other metals (Nb, Ta, Sn) recovery from mining wastes in the Golpejas Mine and its ecological restoration (TI-RRES). 2023 – 2024. RECENTLY APPROVED.

- High-speed environmental monitoring of abandoned mining waste facilities and evaluation of their potential for recovery of raw materials by chemical mapping with drone-borne laser-induced plasma spectrometry (REMINLASER). PENDING FOR APPROVAL

- Contract with the Ministry for the Ecological Transition. 2022. Development of a national inventory of mining waste facilities containing CRM and secondary raw materials. Assessment of the potential for recovery. The base of this study is the knowledge acquired during the development of the Spanish inventory of closed or abandoned mining waste facilities all around Spain.

POTENTIAL FOR RECOVERY OF SECONDARY RAW MATERIALS FROM MINING WASTE IN SPAIN

Development of a national inventory of mining waste facilities containing CRM and secondary raw materials

Tabla 2. Concentración de elementos (ppm) en Instalaciones de Residuos Mineros de España (ICP)

Provincia	Cód. instalación de residuos	Volumen (m³)	Volumen (Mt) *	ELEMENTOS CRÍTICOS																			OTRAS MATERIAS PRIMAS DE IMPORTANCIA ECONÓMICA								
				ETR							Otros elementos críticos																				
				Ce	La	Nd	Sm	Sc	Y	Σ	Nb	Sr	Co	V	W	Ga	Hf	Sb	Ba	Be	Bi	Ta	As	Pb	Cu	Ag	Zn	Cd	Sn	Se	Tl	Th
Ciudad Real	809-II-1-001	270,000	0.46	ND	ND	ND	ND	ND	ND	—	ND	ND	6.41	71.30	ND	ND	ND	291.00	863.00	2.24	ND	ND	73.10	30,632.00	350.00	103.00	4,366.00	12.80	ND	5.69	5.03	60.05
	835-II-1-001	328,000	0.56	ND	ND	ND	ND	ND	ND	—	ND	ND	10.70	93.30	ND	ND	ND	32.70	778.00	2.12	ND	ND	62.10	3,648.00	147.00	13.10	1,786.00	9.42	ND	3.31	0.79	7.78
Córdoba	858-IV-3-004	320,000	0.54	ND	ND	ND	ND	ND	ND	—	ND	ND	21.60	79.90	ND	ND	ND	129.00	275.00	3.31	ND	ND	360.00	27,441.00	622.00	28.80	15,027.00	87.50	ND	15.30	0.79	6.41
	858-IV-3-002	70,000	0.12	ND	ND	ND	ND	ND	ND	—	ND	ND	26.60	109.00	ND	ND	ND	98.10	338.00	3.86	ND	ND	126.00	32,733.00	139.00	25.00	17,763.00	82.70	ND	4.01	0.60	7.90
	880-II-2-001	50,000	0.10	ND	ND	ND	ND	ND	ND	—	ND	ND	239.00	66.00	ND	ND	ND	129.00	346.00	2.57	ND	ND	919.00	6,861.00	2,465.00	43.90	396.00	2.13	ND	3.22	0.35	3.60
Jaén	905-II-1-012	360,000	0.61	ND	ND	ND	ND	ND	ND	—	ND	ND	5.25	16.40	ND	ND	ND	6,288.00	1,284.00	1.25	ND	ND	37.80	1,837.00	90.00	0.82	53.40	0.41	ND	2.15	0.56	5.02
Huelva	938-IV-4-002 Rojo	1,200,000	2.04	ND	ND	ND	ND	ND	ND	—	ND	ND	30.60	32.10	ND	ND	ND	1,795.00	1,349.00	0.50	ND	ND	24,366.00	20,086.00	2,986.00	205.00	1,930.00	12.60	ND	117.00	52.70	6.33
	938-IV-4-002 Gris			ND	ND	ND	ND	ND	ND	—	ND	ND	113.00	4.14	ND	ND	ND	621.00	623.00	<0.1	ND	ND	615.00	10,391.00	324.00	42.80	444.00	1.09	ND	59.20	21.70	2.72
	969-I-4-001	2,000,000	3.40	32.00	15.00	ND	ND	7.00	7.00	61.00	<10	48.00	17.00	76.00	<10	ND	ND	248.00	313.00	<1	124.00	ND	3,138.00	6,152.00	430.00	13.00	248.00	<2	ND	52.00	<20	ND
Murcia	976-II-3-007	180,000	0.31	ND	ND	ND	ND	ND	ND	—	ND	ND	4.70	35.40	ND	ND	ND	139.00	431.00	24.30	ND	ND	450.00	ND	45.40	10.70	4,524.00	3.09	ND	1.03	25.10	2,762.00
	977-II-4-100	1,500,000	2.55	ND	ND	ND	ND	ND	ND	—	ND	ND	12.30	75.20	ND	ND	ND	251.00	61.20	9.41	ND	ND	810.00	20,355.00	187.00	21.60	8,183.00	27.40	ND	2.17	0.49	2.47
	978-I-1-009	600,000	1.02	ND	ND	ND	ND	ND	ND	—	ND	ND	6.94	21.90	ND	ND	ND	122.00	57.80	18.00	ND	ND	651.00	5,931.00	60.70	7.82	5,501.00	18.60	ND	1.51	1.43	1.61
	978-I-3-026	750,000	1.28	ND	ND	ND	ND	ND	ND	—	ND	ND	6.46	52.30	ND	ND	ND	48.10	68.10	1.72	ND	ND	164.00	4,914.00	96.40	4.20	10,451.00	28.50	ND	1.71	1.13	4.63
	977-II-4-041	170,000	0.29	ND	ND	ND	ND	ND	ND	—	ND	ND	8.57	56.20	ND	ND	ND	80.80	164.00	5.29	ND	ND	521.00	ND	126.00	9.62	9,912.00	32.90	ND	2.84	2.76	7,577.00
	977-II-4-043	300,000	0.51	ND	ND	ND	ND	ND	ND	—	ND	ND	9.80	38.90	ND	ND	ND	59.60	161.00	2.76	ND	ND	214.00	ND	109.00	4.95	7,454.00	26.70	ND	3.18	2.32	4,063.00
Cantabria	34-III-4-001	3,200,000	5.44	ND	ND	ND	ND	ND	ND	—	ND	ND	14.10	5.46	ND	ND	ND	3.27	4.84	1.81	ND	ND	127.80	2,463.00	40.60	0.13	13,063.50	24.25	ND	1.00	0.70	0.28
	34-III-4-002	1,250,000	2.13	ND	ND	ND	ND	ND	ND	—	ND	ND	27.10	11.00	ND	ND	ND	5.12	14.00	2.83	ND	ND	345.00	3,920.00	172.00	0.12	10,064.00	24.40	ND	<1	1.17	0.55
	34-III-4-003	700,000	1.19	ND	ND	ND	ND	ND	ND	—	ND	ND	2.47	89.70	ND	ND	ND	3.92	243.00	12.60	ND	ND	74.10	3,044.00	15.00	0.24	7,660.00	10.90	ND	6.13	3.07	9.49
	34-III-4-006	2,125,000	3.61	ND	ND	ND	ND	ND	ND	—	ND	ND	8.98	86.20	ND	ND	ND	2.25	234.00	3.39	ND	ND	78.40	892.00	24.50	<0.1	3,471.00	9.67	ND	2.84	0.82	11.90

* γ = 1.7 t/m³ (Lodos); γ = 1.4 t/m³ (Carbón)

Some preliminary criteria:

Volume

Concentrations

Cut-off grade

Prize

→ **MAP OF POTENTIALITY**

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THANK YOU FOR YOUR ATTENTION