Isoma Mining to Closure & Disposal Mine Site

Overview

CRM Ni

Location

Pre-Active & Disposal Site

VEs Map

Disposal Site VE

Mining to Closure

Disclaimer

Mining to Closure VE

Funded by the European Union

Erasmus+
Enriching lives, opening minds.

IMMERSE
Immersive Virtual Tours on Critical Minerals for Clean Energy Transition

TECHNICAL UNIVERSITY OF CRETE

NA
Nationale Agentur für Erasmus+ Hochschulzusammenarbeit

DAAD
Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Overview

General Information

LARCO is a temporary, under special corporate management regime, mining company. Until 2022, LARCO GMMSA mining company was recognized as one of the world's top 10 ferronickel producers and was a highly trusted brand.

The mining company was an entirely export industry and the unique ferronickel producer in Europe using domestic ore.

It operated continuously from 1966 until 2022. Most major stainless-steel manufacturers in Europe were successfully using LARCO granulated ferronickel in their facilities.

Specific Information

Surface mining in the mines of Euboea referred to an average nickel concentration of approximately 1,01 %, and an average annual production of 1.3 Mtonnes. 63.016.879 tonnes of FeNi have been extracted from 1969 to 2022. Removal of the waste material is estimated at 612.391.167 tonnes for the same time. The stripping ratio (waste/FeNi)equals 9,7/1 w/w, while the average FeNi concentration was approximately 1,017%.

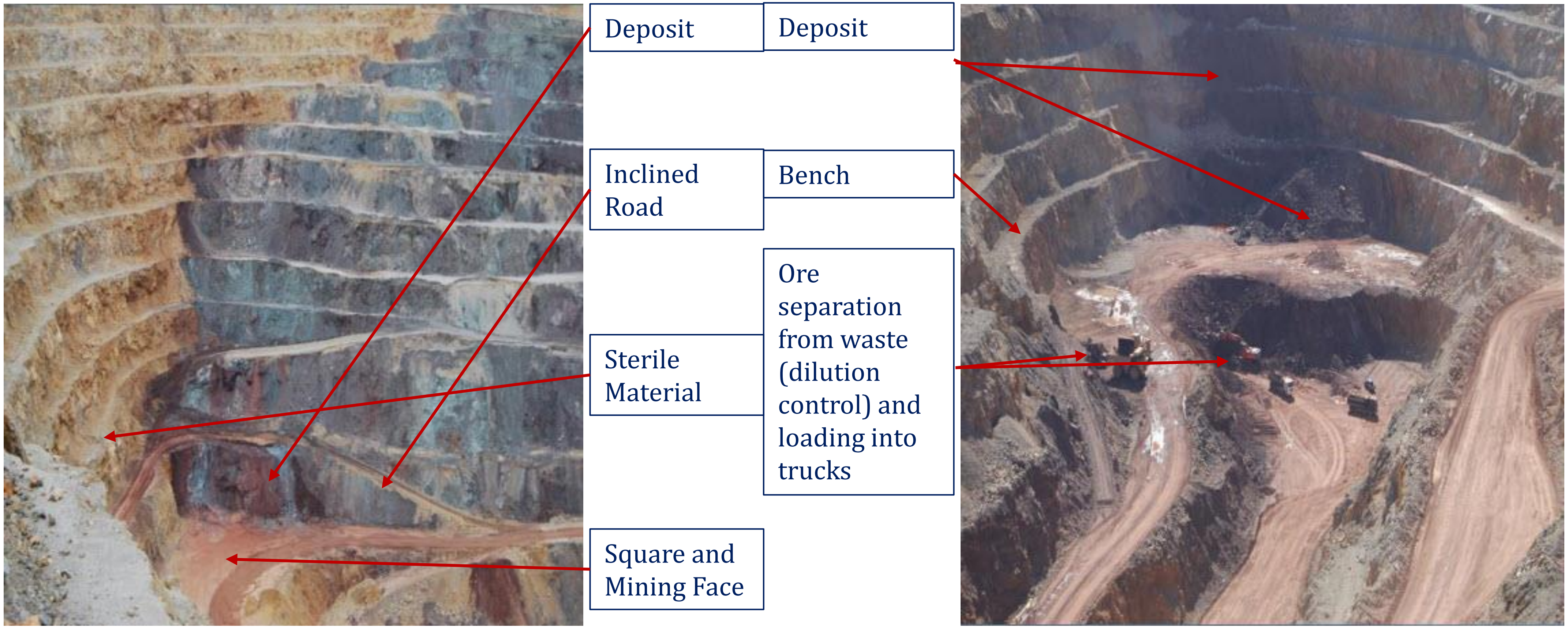
The 360 panoramas in the current VE refer to the disposal site of the extractive ferro-nickel sterile. Moreover, significant information regarding the structuring of the disposal site is provided, considering the mandatory legal obligations for the mining sector in terms of Sustainable Mining development.

Info from active sites | Mining Ore Information | LOM Flowchart

Info from Active Sites

Site	Production (Tonne/Year)		Land & Rehabilitation (m^2*1000/Year)	
	Laterite/FeNi	Waste/Slag	Land Occupation	Number of Plants
Euboea Mines	1.300.000	16.000.000	9.880	4.600
Agios Ioannis Mines	600.000	5.900.000	2.130	8.800
Kastoria Mines	400.000	6.000.000	1.300	15.900
Larymna Mines	17.500	1.650.000	-	-

Mining Ore Information



Flowchart of LOM (Life of Mine)

1st Exploration/ Geological Survey → 2nd Design the Mining Sites → 3rd Structure the Operation Area Earthworks/ Construction of the Road Network etc. → 4th Operation/ Mining Extraction → 5th Closure Environmental Management

(LOM) & Environmental Management

- The Life of Mine (LOM) includes five basic tasks that should be implemented.
- The first task focuses on the geological survey that evaluates a site area as suitable for exploitation.
- The second task refers to the optimization of mining engineering design, including a memorandum of activities that should be accomplished before the actual primary extraction.
- The third task refers to the implementation of design activities.
- The fourth task involves all the working activities and is crucial for the productivity of the mining site. The final task focuses on the optimization of the environmental management action plan depending on the physical conditions of each mining site.
- The environmental management system involves the actions of environmental rehabilitation, planting, creating pit lakes, earthworks, or alternative uses of the produced waste in terms of the Sustainable Mining respecting the 4Rs Policy and regulation of the Circular Economy.

It is essential to mention that closure activities have a significant impact on the brand name of a mining company while enhancing social approval, securing funding, and increasing political support for similar activities.

Pre-Active & Disposal Mine Site
Design and Construction Information

Design and Construction Plan at Isoma-Agia Triada pre-active/abandoned mine site

Before the mining activity of primary extraction at the Isoma-Agia Triada pre-active mine site, LARCO GMMSA mining company is responsible for the design and construction of the future exploited area. Ground soil must be well-compacted at a grade of over 95%. To permit the entrance of the required machinery equipment, such as bulldozers, excavators, and dumpers, for the primary extraction of the Ferro-nickel mining ore. The Design & Construction action plan includes:

1. Earthworks to smoothly slope the rambles, by structuring a road network that permitted entrance for the workers and machinery equipment.
2. Following the consultancy of the agronomists, geologists, and foresters, the mining company made a business decision to structure the whole area in a way that the rainwater could be easily removed from the main exploitation square.
3. After the design of the previously exploited area, the ground soil will be compacted at a grade of over 95%.
4. The exploited area will be structured in three separate slopes of a height of six meters.
5. After these steps, the primary extraction could start. Considering the stripping ratio of 9,7/1, 9,7 tonnes of sterile ore need to be removed to extract 1 tonne of Ferro-nickel mining ore that contains 0,1-1% Ni, and a low concentration of Co.
6. The sterile ore material is placed at a temporary disposal site.

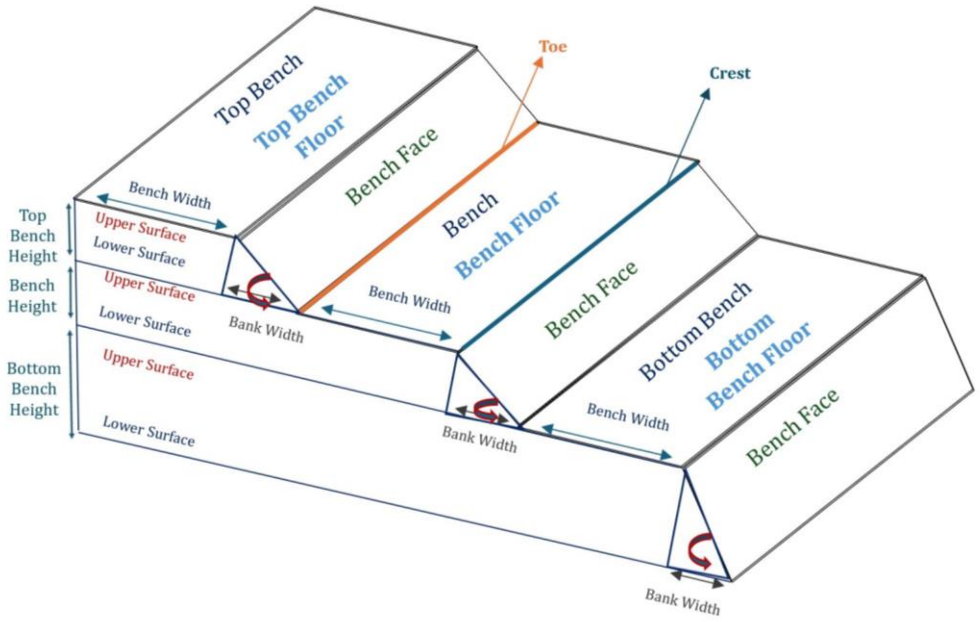
The consecutive environmental monitoring system will be maintained by the administration of the company.

Benching Terminology

Requirements of Construction Plan

Benching Characteristics & Terminology

A/A	Terminology	Definition
1	Bench	The uncovered horizontal part or block of the mineral, ore, or overburden is separated by its lower and upper surfaces and is called a bench.
2	Crest	It is the top part or point of a bench face (or bench).
3	Toe	It is the bottom part or point of a bench face (Bench).
4	Bench Height	It is the vertical distance between the uppermost surface (crest) and the lowermost surface (toe).
5	Bench Width	It is the uncovered horizontal distance between the toe & crest measured along the upper surface.
6	Bench Floor	It is the uncovered horizontal bottom surface of the bench.
7	Bentch Face	It is the uncovered sub-vertical surface of a bench.
8	Bench Slope Angle, symbolized with	It is an inclination of a bench face with the horizontal plane.
9	Bank Width	It is the horizontal projection of the slope face.
10	Angle of Repose	It is the maximum slope at which a pile of loose material will stand without sliding.



Required Geotechnical Characteristics to start the Nickel Primary Extraction

Geology in Surface Nickel Mine Sites-Euboea, Greece

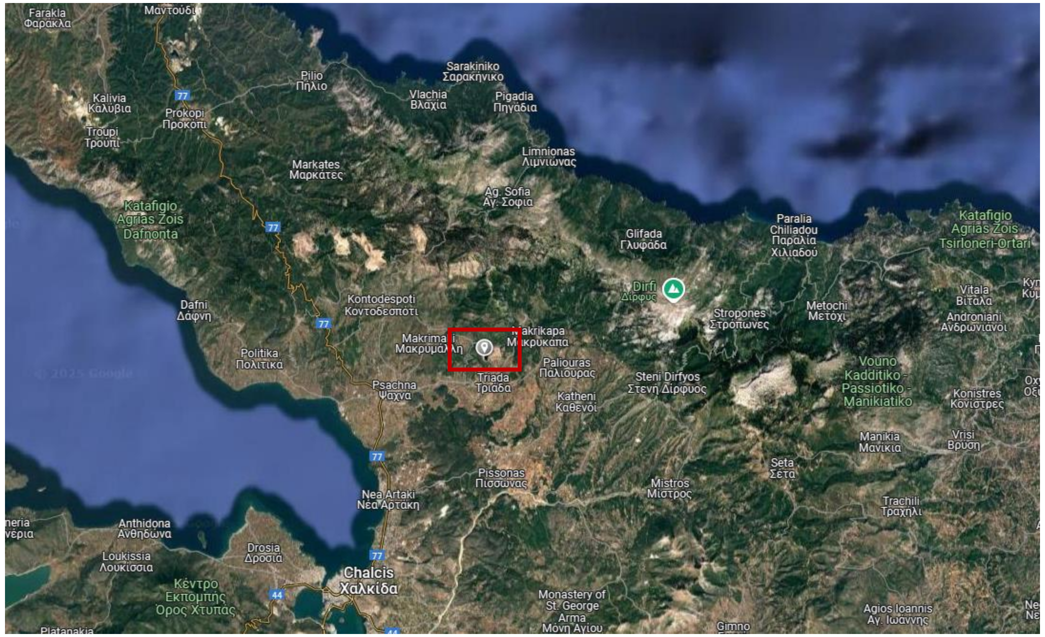
- The overburden profile varies significantly, comprising limonite, transition, and saprolite zones with thickness between **18–28 m** averaged across the pit.
- Slope design must account for alternating zones of hard (limonite) and weak (saprolite/clay-rich) materials—critical for stability.
- Waste-rock dumps in Central Euboea show a friction angle around 40°, indicative of laterite/limonite material
- In-situ slope materials at LARCO likely exhibit similar properties, potentially allowing bench face angles in the 60°–70° range in competent zones.

Bench Design Requirements

- Bench Face Angles: ~65°–70°, reflecting hard laterite and limonite layers.
- Bench Heights: Likely in the 10–15 m range, matching standard open-pit practice.
- Overall Slope Angle: ~35°–45°, tempering for weaker materials and hydrologic conditions
- Aim for a minimum Factor of Safety (FoS) ≥ 1.3 under static conditions; higher if dealing with perched water or seismic risks due to local tectonics.
- Limit-equilibrium or numerical modelling (FEM/FDM) is recommended given the complex stratigraphy

Parameter	Required Value / Range
Overburden thickness	18–28 m
Bench Face Angle	~60°–70°
Bench Height	~10–15 m
Overall Slope Angle	~35°–45°
Friction Angle (ϕ)	~40°
Pore Pressure Indicators	Perched water in clay/saprolite, dewatering needed
Safety Factor (FS)	≥ 1.3 static, consider ≥ 1.5 in hydric zones

Map of the Virtual Excursion



<u>LARCO GMMSA_Rehabilitated Area of Agia Triada mine site-Pit Lake</u>

Latitude_38°59’53” Longitude_23°71’06”

CRM-Ni

CRM	Supply Risk SR	Economic Importance EI	Criticality CR
Nickel (Ni)	0.5	5.7	2.85
Ranges for SR, EI, CR	0-5	0-9	0-45
Impact on SR, EI, CR (%) (Numerical Value of the CRM) ÷(Maximum Threshold)	$(SR)_{CRM}÷(SR)_{Max}$10%	$(EI)_{CRM}÷(EI)_{Max}$ 63.3%	$(CR)_{CRM}÷(CR)_{Max}$ 6.3%

Click to see the uses of Ni

Nickel is a metallic material that is applied in plenty of industrial applications. For instance, nickel is used as a structural material for battery production, in automotive manufacturing, for the construction of energy production units, in stainless steel production, in aerospace engineering, and rarely in the medical industry to produce pharmaceutical products. Despite its low supply risk grade, its economic importance is high. Therefore, according to the European Commission Ni belongs to the critical raw materials and not only a typical base metal.

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2873/725585**

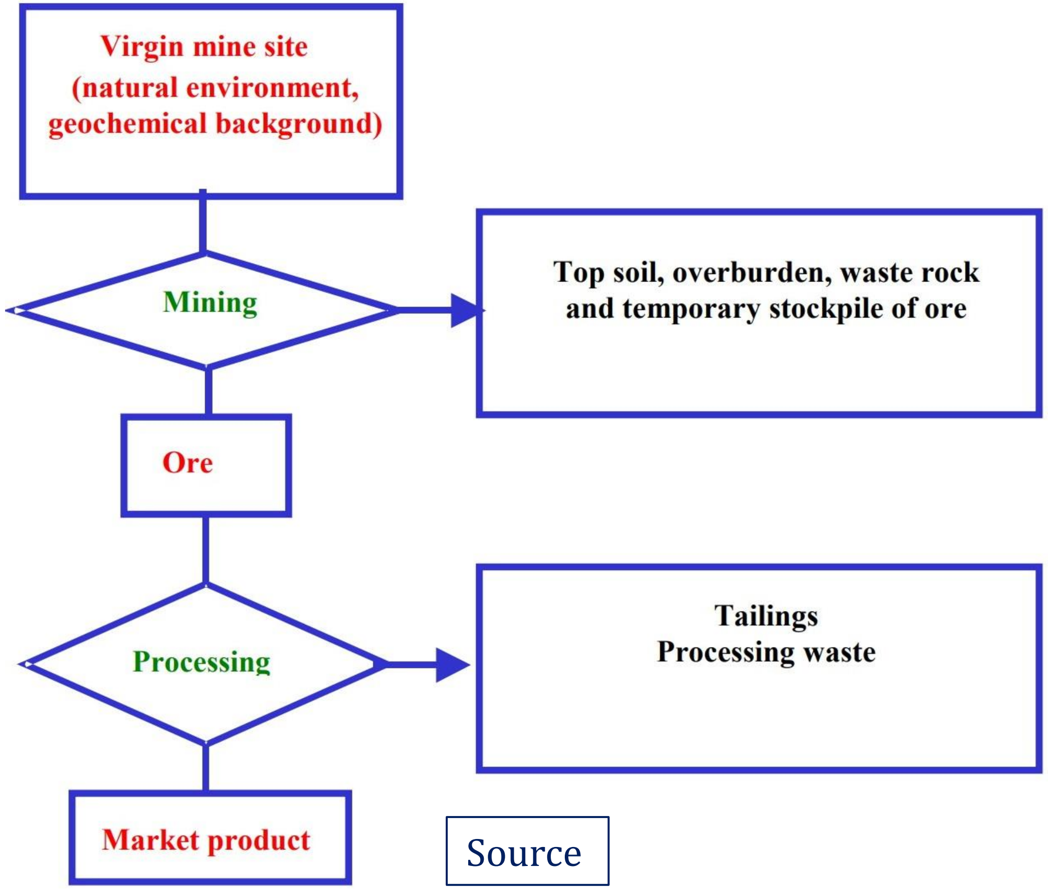
Criticality Matrix

Criticality Matrix		Supply Risk (SR)				
		1	2	3	4	5
(CR)=(EI)*(SR)						
Economic Importance (EI)	1	1	2 **(Ni=2.85)**	3	4	5
	2	2 **(Ni=2.85)**	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25
	6	6	12	18	24	30
	7	7	14	21	28	35
	8	8	16	24	32	40
	9	9	18	27	36	45

- The **Criticality Matrix** displays a quantitative assessment of the Criticality grade for each examined raw material, based on the information contained in the European Study on CRMs, as shown below on this slide.
- The **Supply Risk (SR)** and **Economic Importance (EI)** refer to variable parameters that depends on the entire resources of raw materials and their configured price values according to their demand, respectively. i.e. the SR of a raw material could fluctuate within a period. Therefore, depending on the global resources data and industrial needs, the corresponding Study for CRMs could be updated, including the existing SR and EI indices for raw materials.
- The **Criticality (CR)** is configured by the multiplication of EI and SR grades. The CR index shows the criticality grade of each examined raw material.

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2873/725585**

Sustainable Mining
Mining to Closure Flowchart



Source

- Sustainable Mining Engineering procedures, including the CRMs' exploitation (primary extraction, processing, geotechnical engineering, closure), must conform to the legal obligations that are declared in the Directives 2006/21/EC and 2008/98/EC.

- Complying with the environmental protection specs and the Green Deal, a mining company must **Reduce** the total volume of waste, **Recycle** and **Reuse** the beneficial material that primarily could be separated from the mining ore, and **Recover** beneficial ore that may be contained in the produced waste (tailings, sterile ore, etc).

- Usually, the mining tailings are characterized as Hazardous waste due to their acidic behavior after the metallurgical processing. On the other hand, the sterile mining ore that does not contain carbon, sulfuric, or other toxic chemical compounds and heavy metals is characterized as Non-Hazardous waste. In LARCO GMMSA mine sites, the sterile ore is Non-Hazardous waste material. So, a temporary disposal site of the newly extracted sterile material is an appropriate solution regarding the topsoil configuration.

Criteria for Constructing Final Disposal Site

Criteria for Constructing Final Disposal Site

Based on the legal obligations for the mining sector as declared in the corresponding Directives 2006/21/EC and 2008/98/EC the significant criteria for constructing the final disposal site are shown in the table below.

A/A	Criteria for Structuring the Final Disposal Site of the Sterile Waste Mining Ore	Explanation Click for further analysis
1	Environmental Risk Category of the extractive waste ore	Many sterile wastes contain compounds such as carbon or sulfides. That causes the acid mine drainage due to the consecutive rainfall. In that case, the sterile waste must not be freely disposed of.
2	Geotechnical soil characteristics	The geotechnical specifications of each local disposal site are evaluated , while the proposed environmental solution of free disposal should meet the geotechnical safety requirements for the structure. The optimal inclination and dimensions of the benching indirectly affect the safety factor of the project. Penetration strength tests, permeability control, and compaction tests are some of the most commonly useful tests to assess the project's stability.
3	Hydrological characteristics	Serious consequences to the free disposal site could occur due to the unpredictable conditions, especially in the case of heavy rainfalls. So, a tactical mode of the weather forecast should be monitored.
4	Natural conditions	Natural conditions, including the height, inclination of the topsoil, the steepness of the soil layers, etc. have a significant effect on the design of the road network to reach the final disposal site.
5	Machinery equipment specifications	The machinery equipment to be used is proportional to the geotechnical stability, hydrological characteristics, and natural conditions of the local area to be structured.
6	Cost of the Final Disposal Site configuration	All the parameters above should be economically assessed to detect the optimal plan regarding the construction of the final disposal site after the benching of primary extraction.

Structuring Final Disposal Site

Structuring Final Disposal Site

Configuration of the Final Disposal Site

The final disposal site, in case of non-hazardous mine waste production, is constructed by using:

1. Wheeling or Crawler Excavators to open the road that connects the active mining area with the final disposal site.
   *If the size of ground soil particles is coarse, both excavator types could be used. Otherwise, the excavator type is a Crawler Excavator for safety reasons, providing a homogeneous weight distribution to the ground, minimizing the collapse probability.

2. Bulldozers are to load the extracted sterile mining ore from the active mine sites into the trucks.

3. High-capacity trucks, known as dumpers, that transfer the sterile mining ore to the final disposal site.

4. Soil compactor to achieve a high level of compaction of the ramble network ground soil that leads from the active mine sites to the final disposal site.

Heavy Machinery Equipment

Heavy Machinery Equipment

Wheeled Excavator

Crawler Excavator

Bulldozer

Compactor

Dumper

Final Target & Sustainability

Final Target & Sustainability

SDGs (Sustainable Development Goals) and their impact on the Mining Sector

LARCO GMMSA mining company constructed a final disposal site after benching for the primary extraction of the Fe-Ni mining ore, considering that the produced solid mine waste is Non-Hazardous to the environment.

By the end of the primary Nickel extraction, the company constructed a final disposal site using the described machinery equipment. This sterile material is used in fertilizing and as a filler in conventional construction materials.

*It is essential to note that LARCO GMMSA frequently utilizes this sterile material in the event of a fire in the local area.

The Reuse of waste material aligns with the Green Deal and Circular Economy Principles. At the same time, any assistance provided by the company to the local community has a significant impact on the SDG of Social Approval, which enhances the continuity of mining activities.

Disclaimer

Co-funded by the European Union

The creation of these resources has been funded by the ERASMUS+ grant program of the European Union under grant no. 2023-1-DE01-KA220-HED-000165332.

The views and opinions expressed are solely those of the author(s) and do not necessarily reflect those of the European Union or the DAAD National Agency.

Neither the European Commission nor the project's national funding agency DAAD are responsible for the content or liable for any losses or damage resulting of the use of these resources.

Funded by the European Union

Erasmus+ Enriching lives, opening minds.

IMMERSE Immersive Virtual Tours on Critical Minerals for Clean Energy Transition

TECHNICAL UNIVERSITY OF CRETE

NA Nationale Agentur für Erasmus+ Hochschulzusammenarbeit | DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service