Emerging Low-Impact, Low-Visibility Extraction Methods in Mining

Deliverable D4.1

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This factsheet provides an overview of emerging technological trends in the mining industry focused on minimising environmental impact. It outlines reflections on key technological challenges and opportunities towards sustainable mining practices, particularly in environmentally sensitive and protected areas.

Global population growth, particularly in urban areas, industrialisation, and technological advances, contribute to highly increasing society's demand and dependency on minerals. However, finding new, easily exploitable high-grade ore deposits near the surface is becoming increasingly scarce and challenging.

Mining in Europe faces significant anti-mining movements, requiring convincing and demonstrated reduced environmental impact through three main approaches:

1. Overall mining optimisation
2. Emissions reduction
3. Minimising surface footprint

Mineral Exploration

- Advanced Geophysical Methods: Non-invasive exploration combining Unmanned Aerial Vehicles (UAVs) with innovative sensing technologies, such as Full Tensor Gradiometry (FTG) and 3D seismic imaging, allowing for detailed subsurface mapping without physical environment disturbance
- Enhanced Drilling Techniques: Core scanning technologies (XRF, XCT, and hyperspectral) and sonic drilling methods that reduce water consumption and generate less waste whilst providing high-resolution data on ore deposits
- Deeper Resource Detection: Integration of multiple geophysical methods through joint inversions and Machine-Learning algorithms to identify deep underground resources with minimal surface intrusion, enabling future underground mining with reduced environmental footprints.

Smart Mining Operations

- Real-time Monitoring: Integrated Remote Operating and Monitoring Centres (IROMCs) with autonomous sensing networks that continuously collect environmental and operational data for immediate response to potential issues, significantly enhancing health, safety, and environmental performance
- Autonomous Operations: Robotics and autonomous vehicle fleets controlled from centralised locations, reducing on-site personnel requirements, minimising transport needs, optimising haulage routes, and lowering both energy consumption and emissions
- AI & Data Analytics: Advanced big data management systems employing Artificial Intelligence tools for predictive maintenance, ore body knowledge optimisation, and real-time ore sorting, enabling precision mining that reduces waste generation and energy use.

Alternative Extraction Methods

- In Situ Recovery: A low-impact method that dissolves target metals in place using carefully selected lixiviants, then pumps the metal-rich solution to the surface for processing, eliminating the need for traditional excavation and dramatically reducing surface disturbance
- Brine Mining Technologies: Extraction of valuable elements from liquid sources using technologies such as nanofiltration, electrodialysis, and ion-exchange resins, providing alternatives to hard rock mining with lower energy consumption and potential for synergy with desalination efforts
- Bioleaching & Phytomining: Biological extraction using specialised microorganisms (bioleaching) or metal-accumulating plants (phytomining/agromining) to concentrate metals, requiring less energy than conventional methods and offering potential for site remediation combined with resource recovery.

Emissions & Waste Reduction

- Renewable Energy Integration: Implementation of solar arrays, wind turbines, and geothermal systems at mining sites, together with energy storage solutions and smart grids to manage fluctuating power demands, reducing carbon footprint and dependence on external fuel supply
- Electric & Hydrogen Vehicles: Replacement of fossil fuel-powered mining equipment with battery electric vehicles (BEVs) or hydrogen fuel cell alternatives, improving air quality (particularly in underground operations), reducing noise, and lowering greenhouse gas emissions
- Advanced Waste Management: Cemented paste backfilling using tailings materials, dust control technologies with biodegradable binders, and innovative passivation techniques against acid mine drainage, all working towards a circular economy approach with near-zero mine waste.

The successful implementation of these emerging technologies enables the identification and exploitation of mineral resources that align with fundamental environmental and societal requirements. This creates opportunities for responsible mining in areas previously considered too sensitive for potential mine operations, providing access to CRMs essential for green technologies while significantly reducing land disturbance, greenhouse gas emissions, water usage, and waste generation. These innovations also improve worker safety and community relations by minimising negative factors such as noise, dust, and visual impact of mining.

Finding an equilibrium between environmental preservation and economic imperatives remains a pivotal challenge for sustainable mining. This requires continuous technical innovation combined with heightened societal and environmental awareness. The sector's future likely points towards deep underground operations using highly automated systems, with digital twins providing complete operational oversight and predictive capabilities.

The development of new methods stems from the need to unlock viable exploitation of ore bodies with tailored technical solutions to enable the EU's achievement of policy targets, driven by the Green Deal and sustainable agendas. The optimal approach typically involves a customised combination of technologies for each site's unique geological, environmental, and social characteristics, rather than a 'one-size-fits-all' approach. Overall, comprehensive, real-time holistic monitoring systems will continue to play a critical role in ensuring these emerging technologies deliver their full potential for impact reduction.

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