G20

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COMPENDIUM OF BEST PRACTICES: RESTORATION OF MINING AFFECTED AREAS

JULY 2023

PRESIDENCY DOCUMENT

COMPENDIUM OF BEST PRACTICES:

RESTORATION OF MINING AFFECTED AREAS

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The information included in this report is based on voluntary submissions from the G20 members.

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CHAPTER 2 : MINING SCENARIOS IN G20 COUNTRIES

LIST OF ACRONYMS

AANDC	:	Aboriginal Affairs and Northern Development Canada
ABP	:	Aravalli Biodiversity Park
AMAK	:	Al-Masane Al-Kobra Mining Company
AMC	:	Americas Mining Corporation
AMD	:	Acid Mine Drainage
AMF	:	Arbuscular Mycorrhizal Fungi
AML	:	Abandoned Mine Land
AMLER	:	Abandoned Mine Land Economic Revitalization
AMLT	:	Abandoned Mine Lands Team
ANRE	:	Agency for Natural Resources and Energy
APEC	:	Asia-Pacific Economic Cooperation
ARD	:	Acid Rock Drainage
ASAOC	:	Administrative Settlement Agreement and Order on Constent
ASX	:	Australian Stock Exchange
BALCO	:	Bharat Aluminum Company
Balitek-KSDA	:	Balai PenelitianKonservasiSumber Daya Alam
BBergG	:	Birmingham Botanical Gardens & Glasshouses
BCCL	:	Bharat Coking Coal Limited
BGS	:	British Geological Survey
BHP	:	Broken Hill Proprietary Company Limited
BHUVISAMVAD	:	Basic Holistic Understanding Visible Interaction Synergy Accelerate innovation Modernisation Vibrant Achieve excellence Develop skilled resource
BKMP	:	Badan KoordinasiPenanaman Modal
BLMCL	:	Barmer Lignite Mining Company Limited
BLM	:	Bureau of Land Management - USA
BLZ	:	Belize
BMF	:	Bundesministerium der Finanzen
BMWK	:	Bundesministerium für Wirtschaft und Klimaschutz
BPPT	:	Badan Pengkajian Dan PenerapanTeknologi
BRGM	:	Bureau de RecherchesGéologiques et Minières
BMUV	:	Bundesministerium für Umwelt, Naturschutz, nukleareSicherheit und Verbraucherschutz

CAMPA	:	Compensatory Afforestation Fund Management and Planning Authority
CAMIMEX	:	Cámara Minera de México
CBD	:	Convention on Biological Diversity
CCO	:	Coal Controller Organization
CEF	:	Continuous Ecological Function
CEO	:	Chief Executive Officer
CEMDE	:	Centre for Environmental Management of Degraded Ecosystems
CERCLA	:	Comprehensive Environmental Response Compensation and Liability Act
CESMAT	:	Centre d'Etudes Superieuresdes Marées Premieres
CESSEM	:	Center of Advanced Studies for Safety and Environmental Concerns in Mining
CH4	:	Methane
CIAT	:	Capacity Improvement & Advancement for Tomorrow
CIL	:	Coal India Limited
CIRAN	:	Commune in the Indre-et-Loire department in central France
CMPDI	:	Central Mine Planning and Design Institute
COFEMIN	:	Consejo Federal de Minería, Argentina
CONAGUA	:	Comisión Nacional del Agua
COO	:	Chief Operating Officer
CoP	:	Conference of the Parties
Corp	:	Corporation
CPRP	:	Civil Penalty Reclamation Program
CRM	:	Critical Raw Material
CSRM	:	Centre for Social Responsibility in Mining
CSIR	:	Council of Scientific & Industrial Research
CSN	:	CompanhiaSiderúrgica Nacional
CSOs	:	Civil Society Organizations
CUSTF	:	Change of Use on Forest Land
DDA	:	Delhi Development Authority
DEFRA	:	Department of Environment, Food and Rural Affairs
DfE	:	Department for the Economy
DGDM	:	General Directorate of Mining Development
DGM	:	General Directorate of Mines
DGMC	:	Directorate General of Mineral and Coal
DGMS	:	Directorate General of Mines Safety
DGPR	:	Direction générale de la prévention des risques
DMF	:	District Mineral Foundation
Eco-DRR	:	Ecosystem-based disaster risk reduction
EIA	:	Environmental Impact Assessment

EITI	:	Extractive Industries Transparency Initiative
ELTI	:	Environmental Leadership and Training Institute
EMIL	:	Essel Mining and Industries Limited
ENVISAT	:	Environmental Satellite
EPA	:	Environmental Protection Agency
ERA	:	Energy Resources of Australia Ltd.
ERS	:	European Remote-Sensing
ESG	:	Environmental, Social, and Governance
ESERM	:	Environment Safety and Exploitation of Mineral Resources
EU	:	European Union
EV	:	Electric Vehicle
FAO	:	Food and Agricultural Organization
FEB RAS	:	Far Eastern Branch of the Russian Academy of Sciences
FEDIEX	:	Fédération de l'industrie extractive en Belgique, Belgium
FFH	:	Fauna Flora Habitat
FICEMIN	:	Forum Internacional de Capacitacion y Educacion Minera
FIGNR	:	Federal Institute for Geosciences and Natural Resources
FIFOMI	:	Fideicomiso de Fomento Minero
FRI	:	Forest Research Institute Dehradun
FYM	:	Farm Yard Manure
G20	:	Group of Twenty
GARD	:	Global Acid Rock Drainage
GBF	:	Global Biodiversity Framework
GDP	:	Gross Domestic Product
GDR	:	German Democratic Republic (Deutsche Demokratische Republik)
GHG	:	Green House Gases
GIS	:	Geographic Information System
GISOS	:	Group Information Security Officer
GLI	:	Global Land Initiative
GmbH	:	Gesellschaft mitbeschränkter Haftung (Company with limited liability)
GMC	:	Global Marine Commodities
GMDC	:	Gujarat Mineral Development Corporation Limited
GRI	:	Global Reporting Initiative
GSITI	:	Geological Survey of India Training Institute
ha	:	Hectare
HCL	:	Hindustan Copper Limited
IBM	:	Indian Bureau of Mines
ICFRE	:	Indian Council of Forestry Research & Education

ICMM	:	International Council on Mining & Metals
IFC	:	International Finance Corporation
IGF	:	Intergovernmental Forum
IIED	:	International Institute for Environment and Development
IIEST	:	Indian Institute of Engineering Science and Technology
IIT-ISM	:	Indian Institute of Technology-Indian School of Mines
Implats	:	Impala Platinum Holdings
INAP	:	International Network for Acid Prevention
INERIS	:	Institut national de l'environnementindustriel et des risques
InSAR	:	Interferometric Synthetic Aperture Radar
INTRAW	:	International Raw Materials Observatory
IRMA	:	Initiative for Responsible Mining Assurance
ISPRA	:	Istituto Superiore per la Protezione e la Ricerca Ambientale
IWRM	:	Integrated Water Resources Management
JATAM	:	Jaringan Advokasi Tambang
JOGMEC	:	Japan Organization for Metals and Energy Security
KEI	:	Korea Environment Institute
KIOCL	:	Kudremukh Iron Ore Company Limited
KML	:	Korean Metals Exploration Limited
KOICA	:	Korea International Cooperation Agency
KOMIR	:	Korea Mine Rehabilitation and Mineral Resources Corporation
KSDA	:	Konservasi Sumder Daya Alam
KSMCL	:	Karnataka State Minerals Corporation Limited
KWT	:	Kuwait
LDN	:	Land Degradation Neutrality
LEESU	:	Laboratoire Eau Environnement et Systèmes Urbains
LGEEPA	:	Ley General del Equilibrio Ecológico y la Protección al Ambiente
LIDAR	:	Light Detection and Ranging
LMBV	:	Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft
MAB	:	Man and the Biosphere Programme
MAC	:	Mining Association of Canada
MAPEG	:	The General Directorate of Mining and Petroleum Affairs
MCDR	:	Mineral Conservation and Development Rules
MCRP	:	Mine Closure and Reclamation Plan
MEMR	:	Ministry of Energy and Mineral Resources
MET	:	Mining Environmental and Social Impact Assessment Tool
METI	:	Ministry of Economy, Trade, and Industry
MIRECO	:	Mine Reclamation Corporation

MISE	:	Industrial and Systems Engineering
MMDR	:	Mines and Minerals Development and Regulation
MMSD	:	Mining, Minerals and Sustainable Development Project
MMSS	:	Mining and Metals Sector Supplement
MOE	:	Ministry of Environment
MOEFCC	:	Ministry of Environment, Forest and Climate Change
MOIL	:	Manganese Ore India Ltd.
MOTIE	:	Ministry of Trade, Industry, and Energy
MPLs	:	Mineral Prospecting Licenses
MSc	:	Master of Science
MSRS	:	Mine Site Restoration Standards
MSWC	:	Municipal solid waste compost
Mt.	:	Metric
MVLWB	:	Mackenzie Valley Land and Water Board
NALCO	:	National Aluminium Company Limited
NCL	:	Northern Coalfields Limited
NEERI	:	National Environmental Engineering Research Institute
NEPA	:	National Environmental Policy Act
NGO	:	Non-Governmental Organization
NIDLP	:	National Industrial Development and Logistics Program
NLC	:	Neyveli Lignite Corporation
NMA	:	National Mining Association
NMDC	:	National Mineral Development Corporation
NMT	:	National Mining Team
NOAMI	:	National Orphaned and Abandoned Mines Initiative
NPS	:	National Park Service
NRD	:	Nucleo di Ricercasulla Desertificazione (Desertification Research Centre)
OBD	:	Over Burden Dump
OGP	:	Obvious Geological Potential
OMDC	:	Odisha Mining Corporation Limited
ONF	:	Office National des Forêts
ONFI	:	International French Forest Service
OSH	:	Occupational Safety and Health
OSM	:	Office of Surface Mining
OSMRE	:	Office of Surface Mining Reclamation and Enforcement
PbS	:	Phosphate buffered saline

PC	:	Piacenza in the Italian region
PGMs	:	Platinum Group Metals
PGPR	:	Plant Growth-Promoting Rhizobacteria
pH	:	Potential of Hydrogen
PhD	:	Doctor of Philosophy
PMKKKY	:	Pradhan Mantri KhanijKshetra Kalyan Yojana
PNPE	:	Parc Natureldes Plaines de l'Escaut
POCP	:	Photochemical Ozone Creation Potential
PPP	:	Public-Private Partnership
PROFEPA	:	Procuraduría Federal de Protección al Ambiente
PS	:	Plastic support system
PTEs	:	Potentially Toxic Elements
pXRF	:	Portable X-ray fluorescence
R&R	:	Reclamation and Rehabilitation
RCRA	:	Resource Conservation and Recovery Act
RE	:	Reggio Emilia region
RFRI	:	Rain Forest Research Institute
RISG	:	Italian Geological Surveys Network
R&R	:	Reclamation and Rehabilitation
RRC	:	Restoration Resource Center
RSMML	:	Rajasthan State Mines and Minerals Limited
RWTH	:	Rheinisch-Westfaelische Technische Hochschule
SA	:	Société Anonyme (Public Limited Company)
SAC	:	Special Area of Conservation
SAIL	:	Steel Authority of India
SAR	:	Synthetic Aperture Radar
Sb	:	Antimony
SDGs	:	Sustainable Development Goals
SECA	:	Soil Environment Conservation Act
SEMARNAT	:	Secretaría del Medio Ambiente y Recursos Naturales
SER	:	Society for Ecological Restoration
SGM	:	Servicio Geológico Mexicano
SIA	:	Social Impact Assessment
SLE	:	Republic of Sierra Leone
SLM	:	Sustainable Land Management
SMCRA	:	Surface Mining Control and Reclamation Act
SMP	:	Saudi Mining Polytechnic
SPOT	:	Satellite Pour l'Observation de la Terre

SPA	:	Special Protection Area
SRK	:	Steffen, Robertson and Kirsten
SRT	:	Significant Risk Transfer
StuBA	:	Steering and Budget Committee for Lignite Reclamation
TCFD	:	Task Force on Climate-related Financial Disclosures
TLAC	:	Tribal Lands Assistance Center
TNFD	:	Task Force on Nature-Related Financial Disclosure
TSM	:	Towards Sustainable Mining
TSS	:	Total Suspended Solids
TVTC	:	Technical and Vocational Training Corporation
UAC	:	Community Assemblies Union
UAV	:	Unmanned Aerial Vehicle
UCIL	:	Uranium Corporation of India Ltd
UK	:	United Kingdom
UN	:	United Nations
UNCCD	:	United Nations Convention to Combat Desertification
UNEP	:	United Nations Environment Program
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UNFCCC	:	United Nations Framework Convention on Climate Change
UNIS	:	UniversitàdegliStudi di Sassari
UNKRA	:	United Nations Korean Reconstruction Agency
UNMIG	:	Ufficio Nazionale Minerario per glildrocarburi e la Geotermia
UNSDGs	:	United Nations Sustainable Development Goals
USACE	:	United States Army Corps of Engineers
USAMIN	:	Use of Abandoned Mines
USD	:	United States Dollar
USFS	:	United States Forest Service
USGS	:	United States Geological Survey
VNIMI	:	Research Institute of Mining Geomechanics & Mine Surveying
WFD	:	Water Framework Directive
WP	:	Wood and Pozzolana support system
WOCAT	:	World Overview of Conservation Approaches and Technologies
WWF	:	World Wildlife Fund
YMAD	:	YacimientosMineros de Aguas de Dionisio

I

INTRODUCTION

1.1 LAND DEGRADATION, G20 AND MINING

Humans have long depended on the land and the resources it provides to meet their basic needs and support their families. At the same time, population growth, unsustainable consumption of natural resources, intensive agricultural practices, damaging extractive or mining technologies, and climate change are pushing the planet to its limits, causing land degradation on a vast scale[1]. Increasing misuse and demand for resources are rapidly intensifying desertification and land degradation globally – an issue of growing importance for all people and at all scales. Environmental shifts induced through stressors (i.e., climate change) and dissolution of ecosystem stability are further decreasing the ability of the land to respond resiliently to natural or anthropogenic pressures.

Over 60 percent of the Earth's land surface is managed, and approximately 60 percent of managed land is under agricultural land use[2]. Estimates of the extent of land degradation vary. Still, about one-third of the world's arable land is thought to have been affected by degradation and desertification to date, indicating that it is widespread, on the rise, and occurring in all land cover types and agro-ecologies, especially so in drylands. Land degradation jeopardise ecosystem services globally, including agricultural products, clean air, fresh water, disturbance regulation, climate regulation, recreational opportunities, and fertile soils[3]. In addition to that, biodiversity is also declining at significant rates: the Living Planet Index reports an average decline of 68 percent in mammals, birds, amphibians, reptiles, and fish between 1970 and 2016[4]; which is mainly attributable to land use changes such as the conversion of grasslands, savannas, forests, and wetlands for agriculture and extractive industries[1].

To address these issues, the restoration and conservation of ecosystems have become crucial components of sustainable development programs globally. The Bonn Challenge Declaration, Land Degradation Neutrality Targets of UNCCD, and the United Nations Declaration of 2021–30 as the 'Decade of Ecosystem Restoration' have placed ecological restoration at the forefront of the world's biodiversity and climate change agendas. Although protected areas have significantly expanded – from 10 to 15 percent terrestrially and 3 to 7 percent in marine areas[4], but still the rate is insufficient to arrest or combat land degradation.

The UN Decade on Ecosystem Restoration identifies the following barriers to meeting global restoration objectives:

- Limited awareness globally on the negative effects of ecosystem degradation on human wellbeing and livelihoods, the cost of degradation, and societal benefits that can accrue with investments in ecosystem restoration.
- Lack of significant public and private sector investment in long-term ecosystem restoration initiatives.

[1] thegef.org/sites/default/files/publications/UNDP%20Listening%20to%20our%20land.pdf

[2] Ellis, E.C., Goldewijk, K.K., Siebert, S., Lightman, D., & Ramankut ty, N. (2010). Anthropogenic transformation of the biomes, 1700 to 2000. Global Ecology and Biogeography, 19(5): 589–606.

[3] United Nations Environment Programme (UNEP). (2012). Inclusive Wealth Report 2012. Measuring progress toward sustainability. Cambridge, U.K.: Cambridge University Press.

[4] https://livingplanet.panda.org/en-IN/

- The relative scarcity of legislation, policies, regulations, tax incentives and subsidies that incentivize a shift in investments towards large scale restoration and production systems and value chains.
- The limited technical knowledge and capacity of stakeholders in designing and implementing large-scale restoration initiatives
- The limited investment into long-term research, including social as well as natural sciences, that focuses on innovation to improve restoration protocols through time.

Acknowledging these challenges and barriers, several global commitments have been made aligning to the three Rio Conventions, i.e., UNFCCC, CBD and UNCCD. Countries have strengthened their national policies and programmes in relevant sectors to meet their Land Degradation Neutrality (LDN) targets.

Restoration of the terrestrial ecosystem can contribute substantially to carbon sequestration and biodiversity conservation. In most terrestrial ecosystems, vegetation and soils store more carbon than agricultural, forestry, or grassland systems. Biodiversity offsetting mitigates the negative impacts of development (for instance, urban growth, mining, and agricultural expansion) by setting aside areas for restoring or maintaining biodiversity elsewhere. Biodiversity offsets compensate for carbon storage in biomass and soils by creating new habitats on public or private lands. Therefore it is unsurprising that the international community has pledged to restore over one billion hectares of degraded land by 2030. Many countries have independently commenced major restoration activities like, Indonesia has committed to restoring 600,000 hectares of mangroves, South Africa aims to create 3.6 million hectares of forest, and China intends to achieve 30 percent forest coverage by 2050. India has committed to restoring 26 million hectares of degraded land by 2030.

In addition, the recently agreed Kunming-Montreal Global Biodiversity Framework (GBF) also illustrates the need for land restoration and ecological connectivity. Target 2 under the GBF emphasises onbringing at least 20 percent of degraded freshwater, marine and terrestrial ecosystems under restoration, ensuring connectivity and focusing on priority ecosystems.

Land Degradation and the G20

Since 2015, the G20 summits have placed a significant emphasis on discussing critical global issues, with an emphasis on environmental sustainability and land degradation neutrality in particular. Climate change, resource efficiency, air and water pollution, marine plastic debris, biodiversity loss, sustainable consumption, urban environmental quality, and energy transitions have been addressed in these discussions. The G20 has sought to utilize scientific innovations to promote sustainable growth while addressing pressing environmental issues.

The G20 Global Initiative for '*Reducing Land Degradation and Enhancing Conservation of Terrestrial Habitats*' was launched in Riyadh, Saudi Arabia, in November 2020 with a shared ambition to achieve a 50 percent reduction of degraded land by 2040.

The G20 Global Initiative brings to the table at least three new elements namely, (i) It incentivizes the global community to tackle climate change, biodiversity losses and land degradation together. (ii) it demands that while we think globally, we pursue inclusive solutions at the regional and national levels alongside indigenous and local communities, with their traditional knowledge at the heart of the action. (iii) it demands the engagement of public and private actors.

Building on the G20 voluntary commitments and the Kunming Montreal Global Biodiversity Framework, the Indian Presidency aims to define an action-oriented framework towards achieving these commitments and aims to:

1. Enable achievement of G20 voluntary commitment to reduce land degradation by 50% by 2040, Land Degradation Neutrality by 2030 and relevant commitments under the Kunming Montreal Global Biodiversity Framework by defining a common baseline and measuring progress via clear indicators and globally aligned standards to ensure transparency and accountability.
2. Drive inclusive, decisive and action-oriented initiatives on restoring landscape and calls for voluntary commitments from all signatories to bring 100% of identified priority landscapes (forest fire-impacted areas, mining-affected areas etc.) based on each country's geographical landscape and circumstances under effective restoration by 2030 and complete ecological restoration by 2040.

Box 1: Global Commitments for the priority landscapes

The global commitments for the priority landscapes identified by India, could be as follows;

- Enable effective transfer and co-development of technology and knowledge sharing with developing and least developed countries.
- Substantially and progressively increase the level of financial resources from all sources in a practical, timely and easily accessible manner towards landscape restoration.
- Create a collaborative model of best practice sharing among G20 and other countries – to enable the creation of a framework of action based on agro-climatic conditions/ timezone.

Mining and Land Degradation

Global Scenario

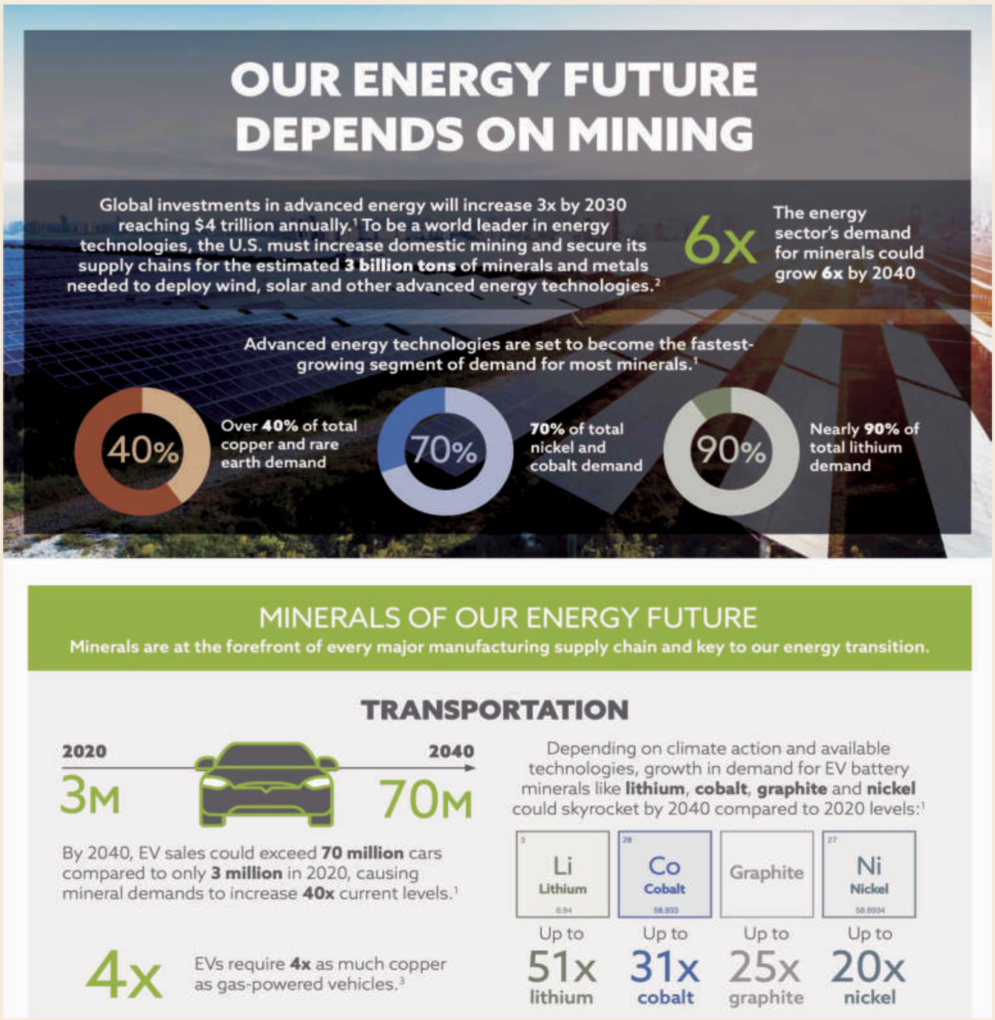
Mineral resources are the backbone of our economy, and mining contributes significantly to the development of many countries. The modern world can't function without mining, as minerals are essential for agriculture, energy, construction, transport and communication sectors.

In response to societal demands for energy minerals (e.g., coal, uranium), metals (e.g., iron, copper, zinc), construction minerals (e.g., natural stone, aggregates, sand, gravel, gypsum), and industrial minerals (e.g., borates, carbonates, kaolin) mining is expanding globally[4]. Since the 1970's, the extraction of metals has grown by more than 75 percent, non-metallic industrial minerals by 53 percent, and building materials by 106 percent[5].

[4] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions

[5] Cherlet, M.; Hutchinson, C.; Reynolds, J., Hill, J.; Sommer, S.; von Maltitz G. World Atlas of Desertification:Rethinking Land Degradation and Sustainable Land Management. (Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., von Maltitz G, ed.). Luxembourg: Joint Research Centre, Publication Office of the European Union; 2018. https://wad.jrc.ec.europa.eu/download.

Box 2: Minerals for our energy future[6]



Maus et al. (2022)[7] mapped 101,583 km^2 under mining land use, while Cherlet (2018)[5] estimates place the global land area affected by mining and quarrying between 300,000 to 800,000 km^2. Global mineral production has grown exponentially, from 9.6 billion metric tonnes in 1985 to 11.3 billion metric tonnes in 2000 and 17.2 billion in 2020[8]. However, the mining areas are not uniformly distributed across countries (Figure 1 & Table 1). According to the Maus et al. (2022), 52% of the mapped mining area is concentrated in just six countries: Russia, China, Australia, the United States, Indonesia, and Brazil. Another nine countries account for 27% of the total mining area, while the remaining 130 countries contribute only 21percent[8]. G20 Countries account for 70% of the total mining area, which amounts to 70,734 km^2 (Figure 2).[7]

[6] https://mineralsmakelife.org/resources/our-energy-future-depends-on-mining/

[7] Maus V, Giljum S, da Silva DM, et al. An update on global mining land use. Sci data. 2022;9(1):433

[8] Reichl, C., Schatz M. World Mining Data 2022. Fedral Ministry of Agriculture, Regions and Tourism, Stubenring 1, 1010 Vienna. 2022. https://www.world-mining-data.info/wmd/downloads/PDF/WMD2022.pdf.

Figure 1: Area under mining in different countries.

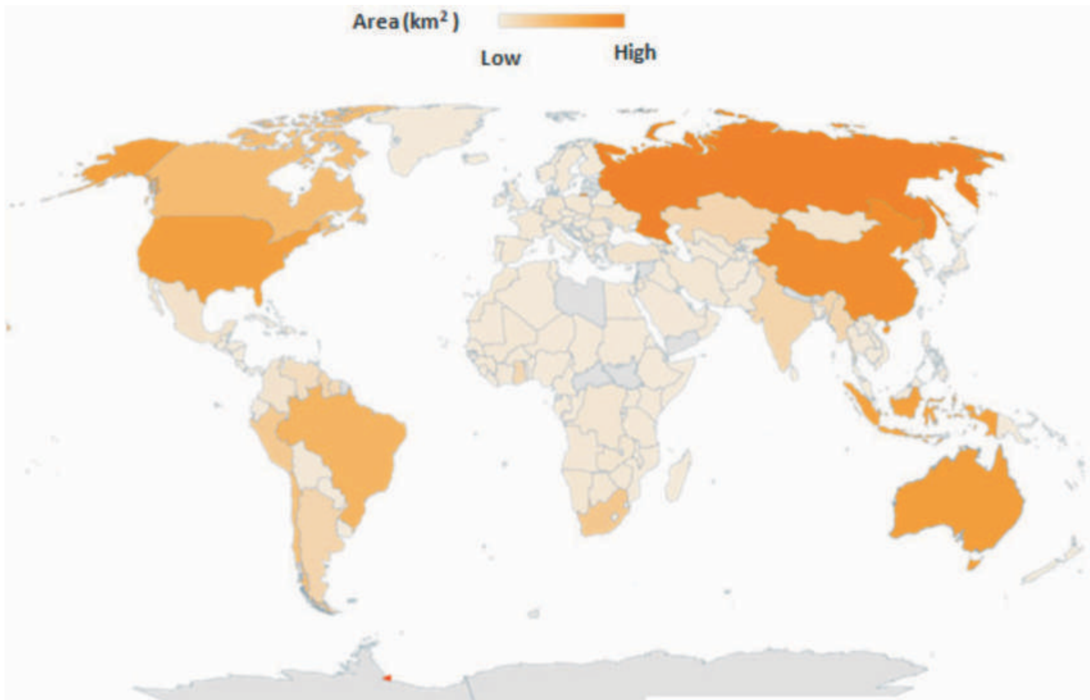
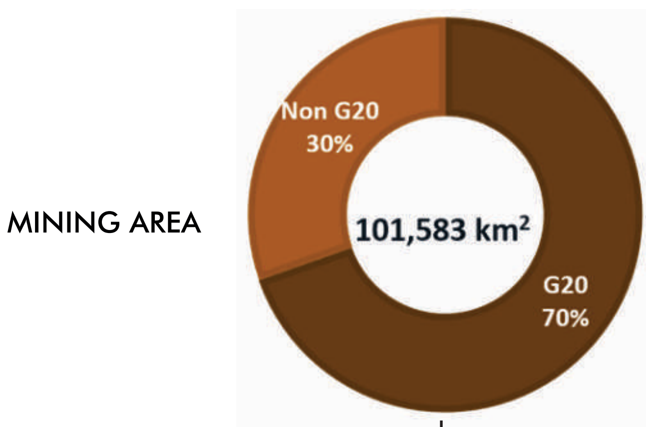


Figure 2: Percentage contribution of G20 countries to the global area under mining



Russia	11.59%	European Union	1.88%
China	10.20%	Mexico	0.92%
Australia	8.35%	Turkey	0.76%
United States of America	8.06%	Germany	0.54%
Indonesia	7.90%	France	0.20%
Brazil	5.82%	Great Britain	0.17%
Canada	5.01%	Saudi Arabia	0.11%
South Africa	3.54%	South Korea	0.04%
Argentina	2.27%	Italy	0.02%
India	2.26%	Japan	0.01%

% of total mining area of the world

Table 1: Area under mining in different countries[7].

Country Code	Country	Area (km^2)
AFG	Afghanistan	6.79
ALB	Albania	17.2
DZA	Algeria	42.77
AGO	Angola	294.51
ARG	Argentina	2301
ARM	Armenia	43.4
ABW	Aruba	0.36
AUS	Australia	8482.63
AUT	Austria	14.94
AZE	Azerbaijan	24.59
BGD	Bangladesh	1.27
BLR	Belarus	24.69
BEL	Belgium	1.91
BEN	Benin	0.11
BOL	Bolivia	286.77
BIH	Bosnia and Herzegovina	29.06
BWA	Botswana	315.2
BRA	Brazil	5915.79
BGR	Bulgaria	226.15
BFA	Burkina Faso	112.51
BDI	Burundi	0.08
KHM	Cambodia	4.6
CMR	Cameroon	4.41
CAN	Canada	5087.56
TCD	Chad	0.2
CHL	Chile	4562.65
CHN	China	10364.57
COL	Colombia	772.43
CRI	Costa Rica	1.36
CIV	Côte d'Ivoire (Ivory Coast)	107.3
CUB	Cuba	118.32
CYP	Cyprus	16.27
CZE	Czech Republic	165.88
COG	Democratic Republic of the Congo	426.22
DMA	Dominican Republic	31.18
ECU	Ecuador	71.02
EGY	Egypt	72.75
SLV	El Salvador	0.59
ERI	Eritrea	10.63
SWZ	Eswatini	0.33
ETH	Ethiopia	16.3
FJI	Fiji	3.53
FIN	Finland	143.9
FRA	France	199.46
GAB	Gabon	51.84
GEO	Georgia	14.6
DEU	Germany	550.87
GHA	Ghana	1882.81
GRC	Greece	216.26
GRL	Greenland	0.36
GTM	Guatemala	10.6
GIN	Guinea	231.34
GNB	Guinea-Bissau	0.06
GUY	Guyana	2388.75
HTI	Haiti	3.36
HND	Honduras	9.66
HUN	Hungary	71.39
ISL	Iceland	0.05
IND	India	2293.41
IDN	Indonesia	8020.15
IRN	Iran	363.08
IRQ	Iraq	8.85
IRL	Ireland	25.81
ISR	Israel	55.26
ITA	Italy	23.3
JAM	Jamaica	25.62
JPN	Japan	13.22
JOR	Jordan	263.89
KAZ	Kazakhstan	2082.59
KEN	Kenya	23.52
KGZ	Kyrgyzstan	126.61
LAO	Laos	56.49
LSO	Lesotho	12.2
LBR	Liberia	15.13

Country Code	Country	Area (km^2)
LUX	Luxembourg	1.42
MDG	Madagascar	44.47
MWI	Malawi	5.00
MYS	Malaysia	112.12
MLI	Mali	194.94
MRT	Mauritania	114.89
MEX	Mexico	932.22
MNG	Mongolia	782.92
MNE	Montenegro	10.87
MAR	Morocco	369.73
MOZ	Mozambique	123.42
MMR	Myanmar	2140.09
NAM	Namibia	494.68
NLD	Netherlands	1.42
NCL	New Caledonia	251.66
NZL	New Zealand	118.08
NIC	Nicaragua	16.98
NER	Niger	127.52
NGA	Nigeria	24.65
PRK	North Korea	24.52
MKD	North Macedonia	53.57
NOR	Norway	35.88
OMN	Oman	201.53
PAK	Pakistan	22.8
PAN	Panama	15.57
PNG	Papua New Guinea	77.3
PRY	Paraguay	3.52
PER	Peru	3539.54
PHL	Philippines	302.68
POL	Poland	331.66
PRT	Portugal	39.94
COG	Republic of the Congo	10.37
ROU	Romania	176.98
RWA	Rwanda	1.64
SAU	Saudi Arabia	111.4
SEN	Senegal	58.96

Country Code	Country	Area (km^2)
SRB	Serbia	149.67
SLE	Sierra Leone	88.51
SVK	Slovakia	19.43
SVN	Slovenia	1.75
SLB	Solomon Islands	5.93
SOM	Somalia	0.7
ZAF	South Africa	3594.62
KOR	Republic of Korea	39.11
ESP	Spain	292.44
LKA	Sri Lanka	10.12
SDN	Sudan	50.95
SUR	Suriname	1972.02
SJM	Svalbard and Jan Mayen	1.03
SWE	Sweden	159.29
CHE	Switzerland	0.55
TJK	Tajikistan	34.23
TJK	Tanzania	146.6
THA	Thailand	168.98
RUS	The Russian Federation	11770.93
TGO	Togo	5.43
TUN	Tunisia	75.48
TUR	Türkiye	769.49
TKM	Turkmenistan	13.07
UGA	Uganda	3.14
UKR	Ukraine	877.1
ARE	United Arab Emirates	4.21
UK	United Kingdom	168.91
USA	United States of America	8188.54
URY	Uruguay	13.45
UZB	Uzbekistan	468.39
VEN	Venezuela	1401.4
VNM	Vietnam	263.31
ESH	Western Sahara	62.91
ZMB	Zambia	480.05
ZWE	Zimbabwe	242.48

Mining and the Environment

Mining has been regarded as one of the most widespread and invasive land use causing land degradation, and the environmental costs of mining are substantial[9]. Open-cast mining and underground mining are two prevalent methods of mining. Open-cast mining requires the removal of topsoil and overburden to access the mineral deposits, whereas underground mining involves excavating tunnels and shafts. As the mineral-rich locations with high-grade mineral deposits get exhausted, the low-quality ores are now being mined. This requires removing and disposing of much more overburdened material and waste rock, resulting in a global transition from confined mine shafts that follow specific ore veins or enhanced deposits to large-scale open-pit mines. Tailings-mixtures of crushed rock and processing fluids from mills, washeries, or concentrators-minerals, mineral fuels, and other potentially dangerous contaminants-are produced in large quantities by such extraction methods[10].

It is essential to note that mining is a temporary land use, as mineral resources are finite, and the eventual closure of the mining operation is inevitable. Mining companies prioritize restoring the landscapes affected by their activities to leave a positive legacy. This benefits the local community, ecosystem and the reputation of the mining company. However, if the restoration is not planned carefully, this abandoned mine may pose serious environmental and health risks (Fig 3). There are three types of mining residue problems.

1. Mine spoils from metal and coal mining- Spoils (often piled up on the ground) are a mix of chemically inert and reactive materials.
2. Tailings, usually fine-grain deposits rich in sulfide minerals, generate acid mine drainage and are more environmentally harmful than spoils.
3. Metal and metalloid-rich acidic discharge fluids.

Abandoned mines pose substantial concerns, but their global influence is unknown. Another issue in the mining sector is artisanal or small-scale subsistence mining, which is more often illegal and unregulated. It causes much disruption and pollution. For instance, the unregulated use of cyanide and mercury in gold extraction pollutes soils, surface- and groundwater and exposes mine employees and nearby residents to serious health risks[11] as artisanal mining is the biggest mercury polluter.[12]

Emissions from the Mining Sector

The mining sector is also one of the major emitters of greenhouse gases (GHG). It produces fossil energy resources that also significantly contribute to global CO_2 emissions the global metals and mining business accounts for about 8% of the worldwide carbon footprint[13]. The preliminary estimate of GHG emissions linked with primary mineral and metal production in 2018 (excluding energy carriers like Coal, Uranium) comes to $3.6x10^{12}$ kg of

[9] Cherlet, M.; Hutchinson, C.; Reynolds, J., Hill, J.; Sommer, S.; von Maltitz G. World Atlas of Desertification:Rethinking Land Degradation and Sustainable Land Management. (Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., von Maltitz G, ed.). Luxembourg: Joint Research Centre, Publication Office of the European Union; 2018. https://wad.jrc.ec.europa.eu/download.

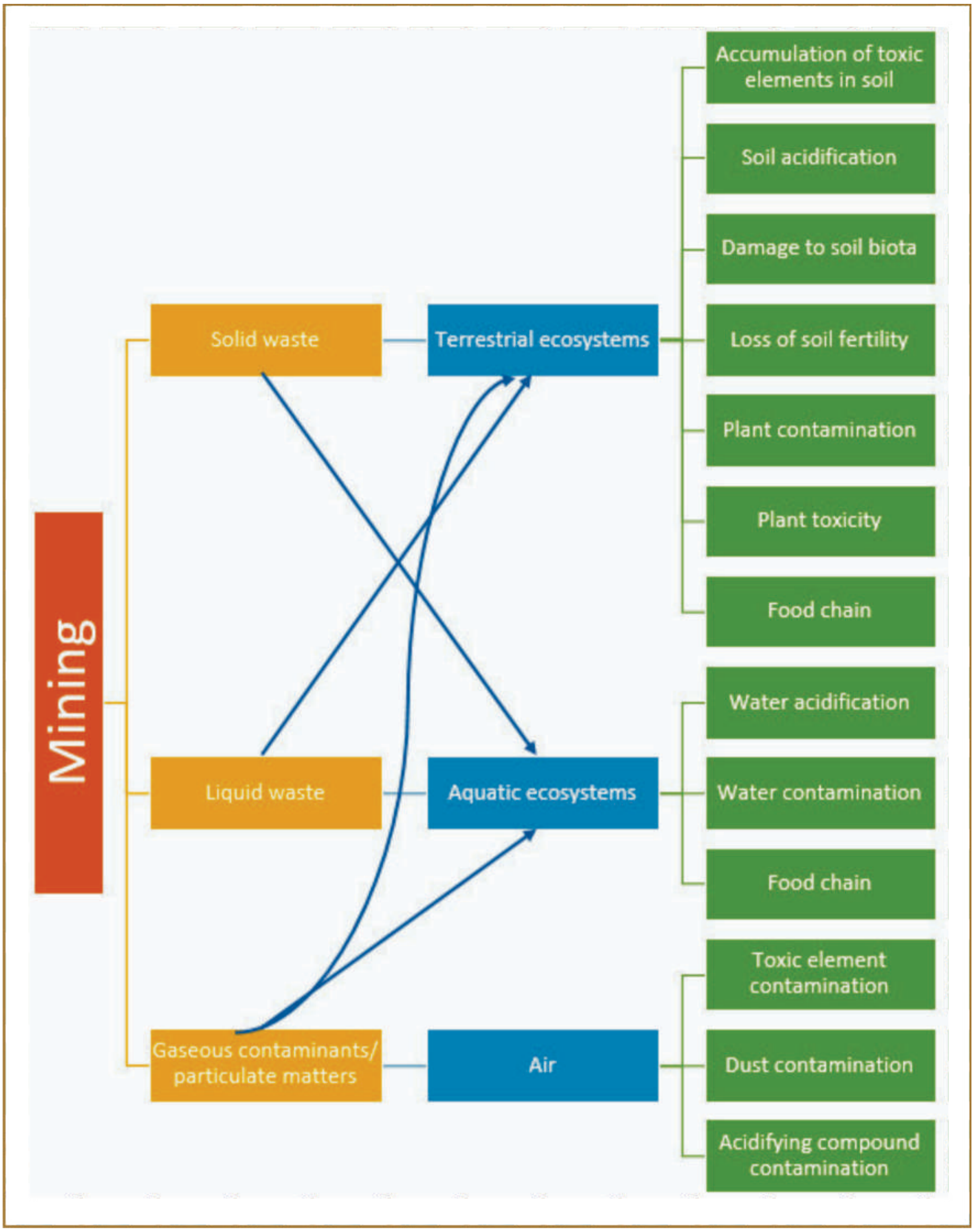
[10] Giurco D, Prior TD, Mudd GM, Mason LM, Behrisch JC. Peak Minerals in Australia: A Review of Changing Impacts and Benefits. Institute for Sustainable Futures, UTS & Department of Civil Engineering …; 2010.

[11] UNCCD. The Global Land Outlook First Edition Bonn, Germany; 2017

[12] Casso-Hartmann,L. Rojas-Lamos, P, McCourt, K. Velez-Torres, I. Barba-Ho, L.E. Bolanos, B.W. Montes, C.L. Mosquera, J. Vanegas, D. Water Pollution and Environmental Policy in Artisanal Gold Mining frontiers: The case of La Toma, Colombia, Science of total Environment; 2022.

[13] Cox B, Innis S, Kunz NC, Steen J. The mining industry as a net beneficiary of a global tax on carbon emissions. Commun Earth Environ. 2022;3(1):17.

Figure 3: Environmental pollution due to metal mining and processing[12]



CO_2, equal to 10% of total global energy-related greenhouse gas emissions in 2018[14] (Figure 4).

The magnitude of GHG emissions associated with individual mining and mineral processing operations is highly variable. GHG emissions can also arise from the decomposition of carbonate minerals and calcite during weathering and neutralising of waste rock and tailing materials, as well as tailings during acid leaching and metallurgical processing, which are rarely quantified[14].

[14] Azadi M, Northey SA, Ali SH, Edraki M. Transparency on greenhouse gas emissions from mining to enable climate change mitigation. Nat Geosci. 2020;13(2):100-104.

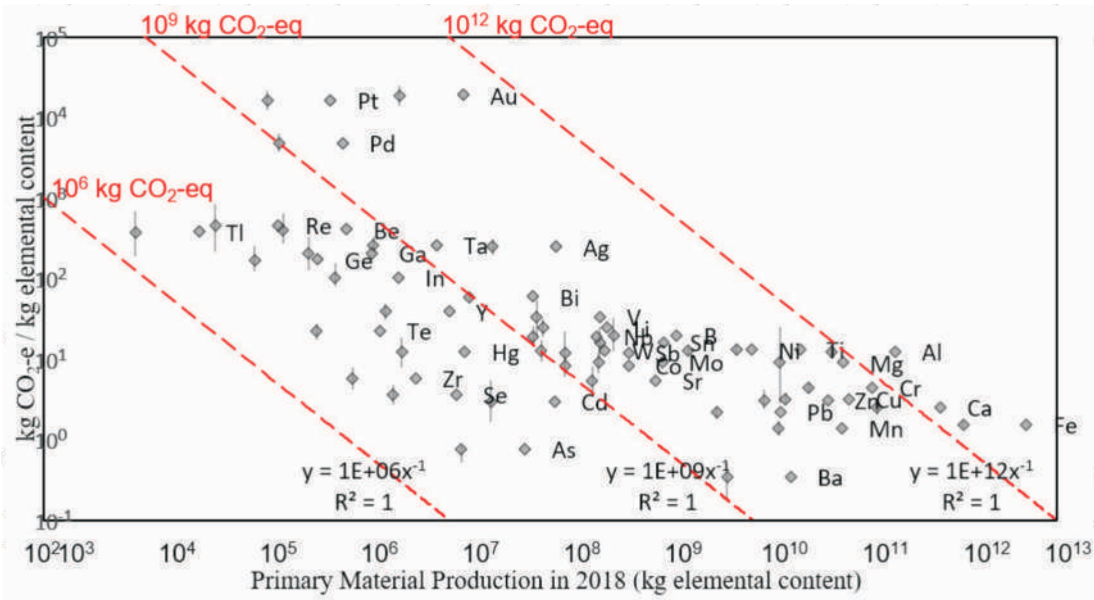


Figure 4: GHG emissions associated with primary mineral and metal production in 2018 (kg elemental content) Excludes energy carriers and minerals aggregates.[14]

Mining and Biodiversity

Mining has a wide range of impacts on biodiversity at different spatial scales, including site, landscape, regional, and global scales (Figure. 5)[15]. The mining site-level consequences result from habitat loss and degradation caused by mine expansion. Mining activities directly impact biodiversity at the landscape and regional scales, chemical and physical waste discharge affects ecosystems over great distances. Chemical

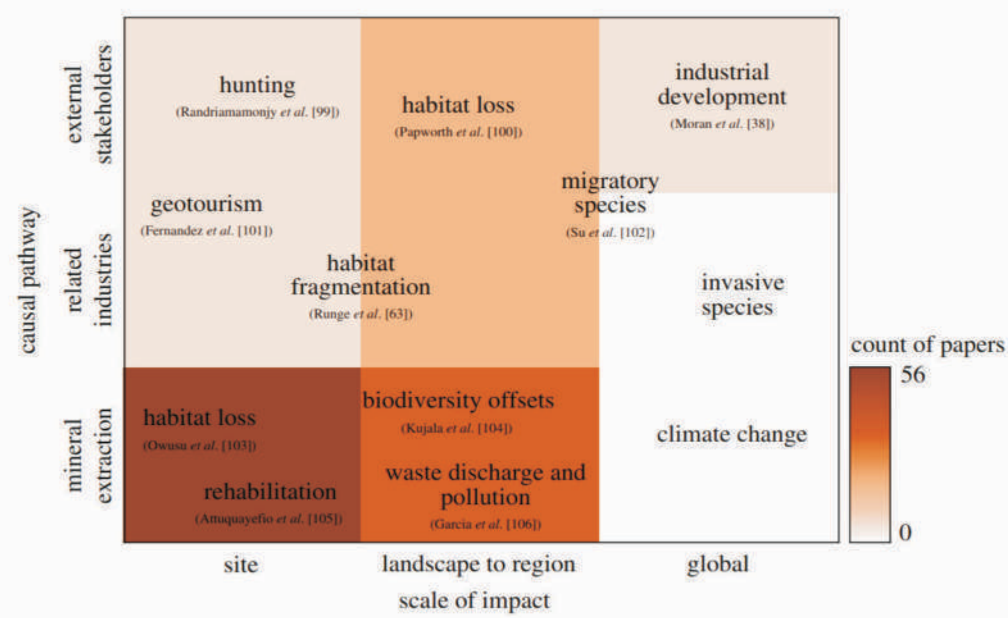


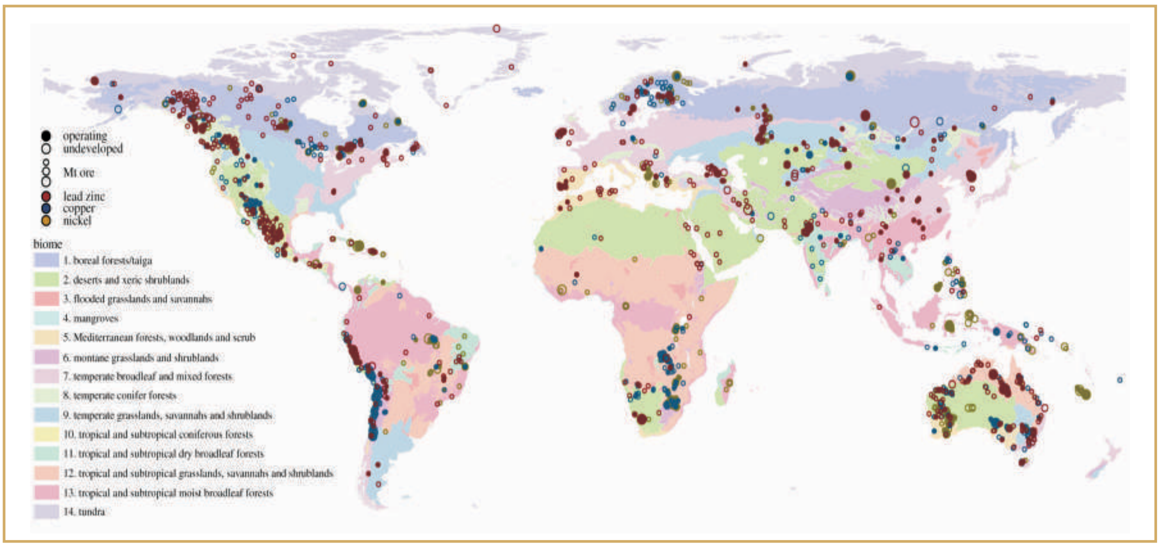
Figure 5: Impacts of mining on biodiversity at different scales and stages[20]

[15] Jacobi CM, do Carmo FF, Vincent RC, Stehmann JR. 2007Plant communities on ironstone outcrops: a diverse and endangered Brazilian ecosystem. Biodivers. Conserv. 16, 2185-2200. (doi:10.1007/s10531-007-9156-8)

emissions, such as mercury or cyanide used to extract gold and acids released from oxidized minerals, negatively impact biodiversity[16]. Indirect impacts also occur when mining attracts human populations or exacerbates pre-existing threats, such as over-exploitation, invasive species, and habitat loss[17]. Mining activities emit carbon, contributing to anthropogenic climate change and negatively affecting biodiversity[18]. Mineral supply chains have extensive but often hidden impacts on biodiversity. Global trade and supply chains may also have extensive ecological footprints[19], but the consequences for biodiversity remain largely unknown.

Threats to biodiversity vary based on the biome in which the mining takes place (Figure 6) as well as the method used for mining and the minerals extracted, with subsurface alluvial gold extraction affecting riparian and downstream ecosystems[21], while high-value thermal coal mining often threatens prime agricultural land[22]. Stone, sand, and gravel mining move large amounts of earth. Metal ore extraction and processing using various reagents produce harmful chemical emissions[23]. Additionally, the scale of mining operations plays a role in their potential impact on biodiversity.

Figure 6: Distribution of mines among terrestrial biomes[18]



[16] Malm O. 1998Gold mining as a source of mercury exposure in the Brazilian Amazon. Environ. Res. 77, 73-78. (doi:10.1006/enrs.1998.3828)

[17] Sonter LJ, Herrera D, Barrett DJ, Galford GL, Moran CJ, Soares BS. 2017Mining drives extensive deforestation in the Brazilian Amazon. Nat. Commun. 8, 1013. (doi:10.1038/s41467-017-00557-w)

[18] Fischedick MJet al.. 2014Climate change: industry. In Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change (eds Edenhofer Oet al.). Cambridge, UK: Cambridge University Press

[19] Moran D, Petersone M, Verones F. 2016On the suitability of input output analysis for calculating product-specific biodiversity footprints. Ecol. Indic. 60, 192-201. (doi:10.1016/j.ecolind.2015.06.015)

[20] Sonter, L. J., Ali, S. H., & Watson, J. E. M. (2018). Mining and biodiversity: key issues and research needs in conservation science. Proceedings of the Royal Society B: Biological Sciences, 285(1892), 20181926. doi:10.1098/rspb.2018.1926

[21] Asner GP, Llactayo W, Tupayachi R, Luna ER. 2013Elevated rates of gold mining in the Amazon revealed through high-resolution monitoring. Proc. Natl Acad. Sci. USA 110, 18 454-18 459. (doi:10.1073/pnas.1318271110)

[22] Lechner AM, Baumgartl T, Matthew P, Glenn V. 2016The impact of underground longwall mining on prime agricultural land: a review and research agenda. Land Degrad. Dev. 27, 1650-1663. (doi:10.1002/ldr.2303)

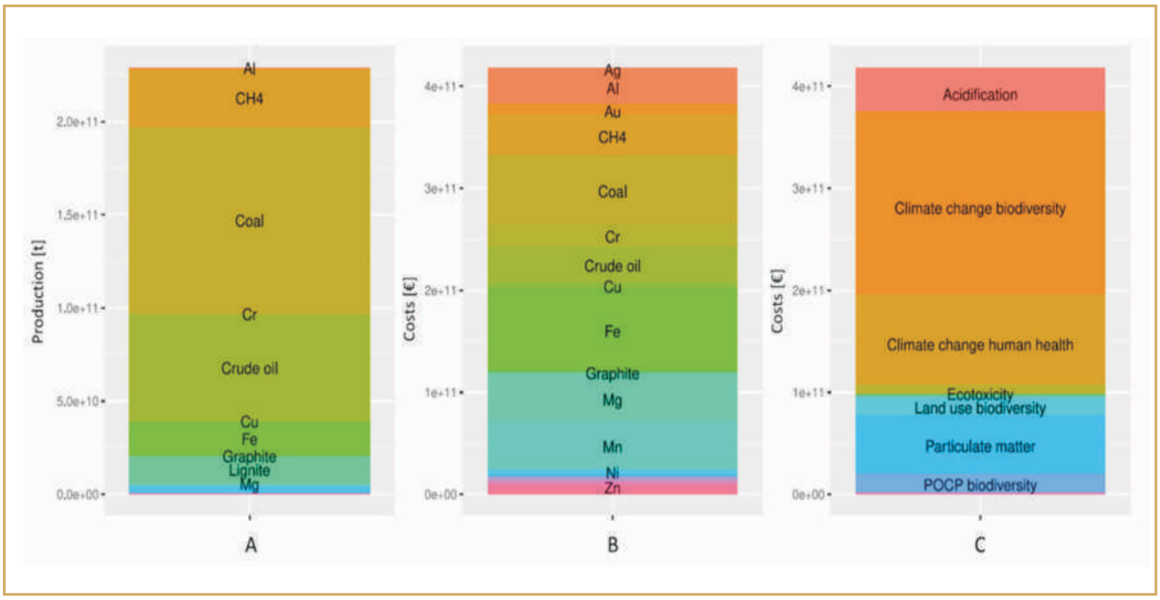
[23] Bridge G. 2004Contested terrain: mining and the environment. Annu. Rev. Environ. Resour. 29, 205-259. (doi:10.1146/annurev.energy.28.011503.163434)

Natural and protected regions experience the highest degradation from mining, while mining activity in the tropical moist forest ecosystem has doubled since 2000[24]. Over 79% of the worldwide metal ore extraction in 2019 originated from five to six of most species-rich biomes, and 90% of extraction sites correspond to below-average relative water availability[25]. The direct impacts of mining on forests can be significant at a local level, but they are probably less important at a global scale. The indirect impacts of mining on forests are significant at both the local and global scales. Environmental impacts on forest biodiversity also have significant social impacts on forest-dependent communities.

A cost-benefit Economic Analysis of Mining

The total environmental cost of the mining of fossil fuels, metal ores and mineral resources amounts to as much as €0.4 to 5 trillion every year, which can be attributed to the emission of GHGs, particulate matter and acidification (particularly for coal and steel sectors), biodiversity loss and its impact on human health[26]. Of the total environmental cost of mining, the cost share impact of climate change is 64% of the total cost (43% for impact on ecosystems and 21% are damages to human health), followed by the impact of particulate matter (14% of the total cost) and terrestrial acidification impact (Figure 7) (10% of the total cost)[26].

Figure 7: Mass share of materials (left, A), cost share of materials (middle, B), share of impacts (right, C) prices in euro, low estimate[26]



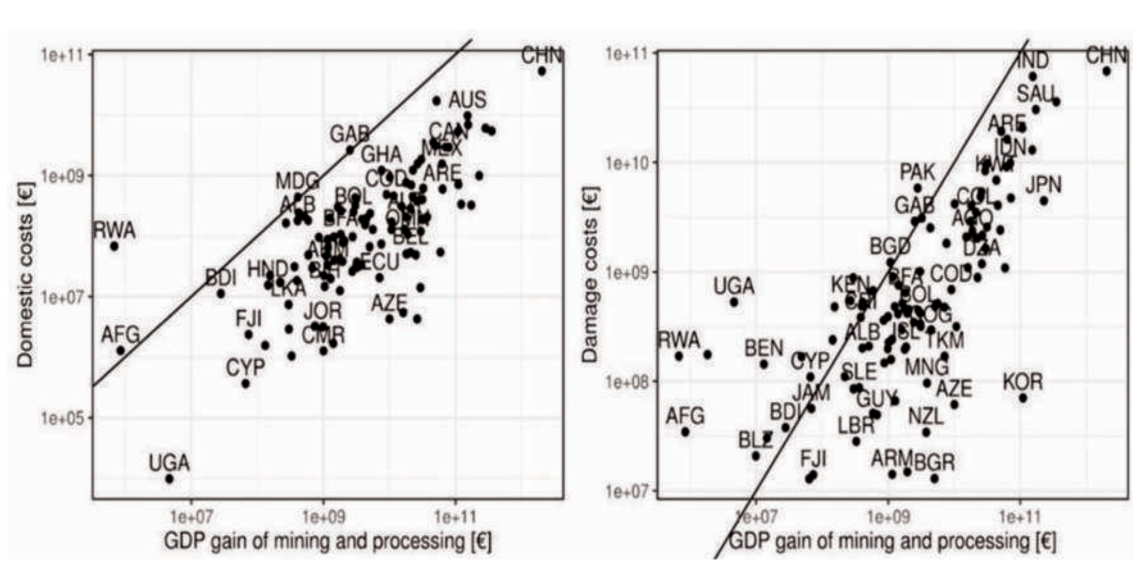
Mining economically benefits for most countries when domestic costs are considered without climatic effects. The nations with the largest environmental costs – China, Brazil, India and Russia – all have higher benefits than costs associated with their mining activities. When climate change damages are included in the high "global" estimate, 20 countries' GDP losses exceed mining gains. If climate change costs are added to domestic costs, more countries have a negative cost-to-benefit ratio (their overall environmental costs exceed their GDP contribution for mining and processing)[26].

[24] Sonter LJ, Herrera D, Barrett DJ, Galford GL, Moran CJ, Soares-Filho BS. Mining drives extensive deforestation in the Brazilian Amazon. Nat Commun. 2017;8(1):1013.

[25] Luckeneder S, Giljum S, Schaffartzik A, Maus V, Tost M. Surge in global metal mining threatens vulnerable ecosystems. Glob Environ Chang. 2021;69:102303.

[26] Arendt R, Bach V, Finkbeiner M. The global environmental costs of mining and processing abiotic raw materials and their geographic distribution. J Clean Prod. 2022;361:132232.

Figure 8: GDP gain vs domestic costs (left), GDP gain vs damage costs (right), low estimate, double logarithmic scale[26].



The countries involved in the processing of minerals (e.g., the Steel Industry In Germany and Japan) and oil-producing countries (for example Algeria, Azerbaijan, and Nigeria etc.) gain the most economic benefits as they largely externalize the environmental cost of upstream and downstream processes (Figure 8).

As on May 2023, BHP, Rio-Tinto and Glencore were the world three leading mining companies based on the mine capitalisation. These companies have headquaters in Australia, United Kingdom and Switerland respectively,[27] however their operations are spread throughout the world.

Mining Restoration and International Obligations

The UN Conference on Sustainable Development (June 2012, Rio de Janeiro)[28] recognized that mining is vital, especially for least-developed countries, and advised addressing its environmental impacts[29]. Several United Nations conventions have adopted goals specifically focused on restoration (CBD 2011; UN 2012; UNCCD 2013, GBF 2022, GLI 2020). The UN Environment Program (UNEP) and the Food and Agricultural Organization (FAO) have declared 2021–2030 the "UN Decade on Ecosystem Restoration" to safeguard and restore ecosystems worldwide for people and the environment. In September 2015, the 2030 Sustainable Development Agenda was adopted, focusing worldwide on land for SDG 1, 5, 11, 14, 15, and other land-related SDG goals. Land restoration and ecological connectedness are also stressed in the post-2020 GBF. Goal 2 of the post-2020 GBF emphasizes restoring at least 20% of degraded freshwater, marine, and terrestrial ecosystems, connectivity, and prioritizing ecosystems.

Given the international agendas requiring more minerals but less biodiversity loss, mining firms, policymakers, and conservation organizations must start talking. Traditional, site based conservation measures will not

[27] https://mining.com/top-50-biggest-mining-companies/

[28] Leggett JA, Carter NT. Rio+ 20: The United Nations Conference on Sustainable Development, June 2012. In: Library of Congress, Congressional Research Service Washington, DC; 2012.

[29] Mudd GM. The sustainability of mining in Australia: key production trends and their environmental implications. Dep Civ Eng Monash Univ Miner Policy Institute, Melb. 2007.

prevent biodiversity loss against a rising mining footprint, but long-term strategic evaluation and planning can enhance the outcomes.[20]

Mining must be considered from a broader environmental perspective[30], especially when the anthropogenic impact on biodiversity is considered. For ecosystems to stay healthy, proactive actions like limiting road expansion[31], reducing the impact on biodiversity through legal controls and strategies for sustainably using resources[32] and ensuring the ecorestoration of mines through forestry and agriculture interventions after mine closure[33].

Box 3: Definition of Common Terms Related to Restorative Processes[34]

Ecological Restoration: Process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration differs from other types of restorative activities in that it aims to assist in recovering the ecosystem to the trajectory it would be on if degradation had not occurred, accounting for environmental change.

Ecosystem Restoration: Process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choice.

Reclamation: A broad term used to describe multiple post-mining activities but often relates to the process of reconverting disturbed land to its former or other productive uses. In some areas, it may be synonymous with or a subset of rehabilitation, whereas in others, it is more closely related to and may include ecological restoration.

Rehabilitation: Management actions that aim to reinstate a level of ecosystem productivity or functioning on degraded sites, where the goal is renewed and ongoing provision of ecosystem services rather than the recovery of a specified target native ecosystem.

Remediation: Management actions that aim to remove degradation (e.g., detoxify areas with contaminants or excess nutrients from soil and water) to achieve safe, stable, and nonpolluting landscapes. It is a pre-requisite for ecological restoration, reclamation or rehabilitation following mining.

Repurposing: The process of identifying a new use for a mine site, either in whole or in part, that takes advantage of site characteristics to provide an economic or social activity post-closure, or other post-closure land use (e.g., light industry, recreation, solar or wind farms).

Revegetation: A process of establishment of plants and vegetative cover on sites (including terrestrial, freshwater, and marine areas) that may or may not involve local or native species

Significance of Ecosystem Restoration in the Mining-Affected Area

Restoring mining-affected areas through ecological restoration has the potential to positively impact the environment by providing a variety of ecosystem services. (Figure 9) These services include enhanced water

[30] Maxwell SL, Fuller RA, Brooks TM, Watson JEM. Biodiversity: The ravages of guns, nets and bulldozers. Nature. 2016;536(7615):143-145.

[31] Laurance WF, Clements GR, Sloan S, et al. A global strategy for road building. Nature. 2014;513(7517):229-232.

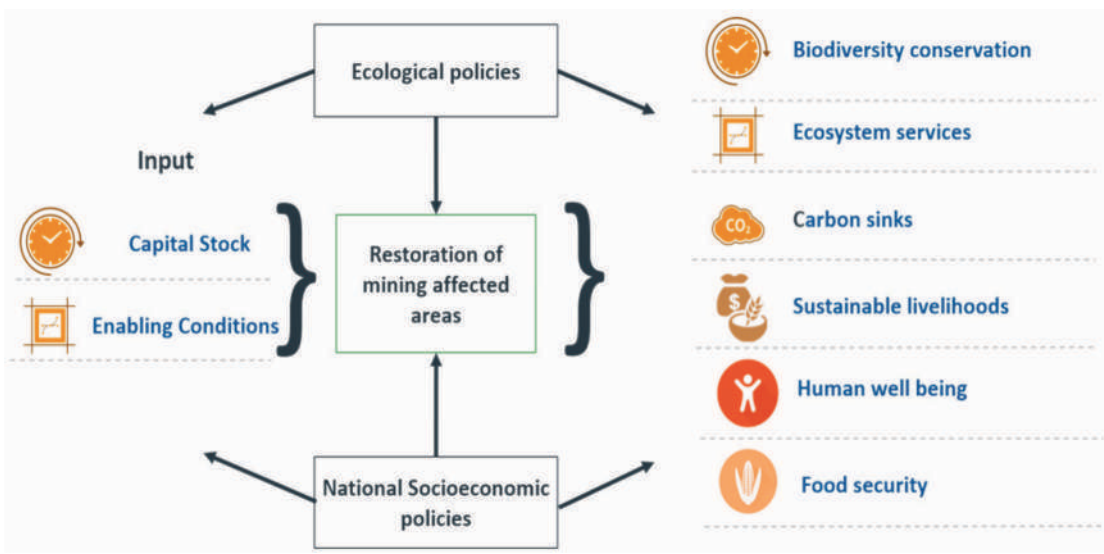
[32] Redford KH. The empty forest. Bioscience. 1992;42(6):412-422.

[33] Watson JEM, Evans T, Venter O, et al. The exceptional value of intact forest ecosystems. Nat Ecol Evol. 2018;2(4):599-610.

[34] Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, C. R., Tashe, N., Jasper, D., Silveira, F. A. O., Carrick, P. J., Hägglund, T., Carlsén, S., & Dixon, K. International principles and standards for the ecological restoration and recovery of mine sites. Restor Ecol. 2022;(30(S2)). doi:https://doi.org/10.1111/REC.13771

quality, soil conservation, carbon sequestration[35], biodiversity preservation[36], and recreational opportunities[37]. Restoration efforts prioritize delivering biodiversity-related services, such as habitat, support, and regulation, resulting in a more stable and resilient ecosystem[38]. Additionally, restoring mining-affected areas can significantly benefit food security and sustainable agriculture by promoting agroforestry systems that enhance soil fertility, increase crop diversity, and provide additional sources of income[39]. Traditional and indigenous knowledge in agriculture and land management can also be promoted through restoration efforts planned and implemented with the involvement of local communities and relevant stakeholders. Restoration can increase the abundance and distribution of endangered species[40] and contribute to the recovery of critical ecosystem functions such as pollination, nutrient cycling, and water filtration. The restored areas and their biodiversity benefits also offer opportunities for ecotourism and traditional resource use, benefiting the local community[41].

Figure 9: Significance of restoration of mining-affected areas



[35] Lamb D. Undertaking large-scale forest restoration to generate ecosystem services. Restor Ecol. 2018;26(4):657-666.

[36] Wang, Y.; Lu, X.; Ren H. Bird community and vegetation restoration in coal mining subsidence areas in China. Ecological Engineering. Ecol Eng. 2017;(103):10-17.

[37] Miao Z, Marrs R. Ecological restoration and land reclamation in open-cast mines in Shanxi Province, China. J Environ Manage. 2000;59(3):205-215.

[38] Chen, X., Chen, G., Yang, X., Wang, Y.,; Chen Y. Assessing the potential for ecological restoration of mining areas using ecosystem service value transfer: A case study in China. Sustainability. 2016;(8(10)):1082.

[39] Vlassenroot K, Ntububa S, Raeymaekers T. Food security responses to the protracted crisis context of the Democratic Republic of the Congo. Univ Ghent. 2007

[40] Hapsari KA, Biagioni S, Jennerjahn TC, et al. Resilience of a peatland in Central Sumatra, Indonesia to past anthropogenic disturbance: Improving conservation and restoration designs using palaeoecology. J Ecol. 2018;106(6):2473-2490.

[41] Chen, X., Chen, G., Yang, X., Wang, Y.,; Chen Y. Assessing the potential for ecological restoration of mining areas using ecosystem service value transfer: A case study in China. Sustainability. 2016;(8(10)):1082.

Furthermore, restoring mining-affected areas can significantly contribute to climate change mitigation and adaptation through carbon sequestration, reducing greenhouse gas emissions, and improving soil conditions[42]. By restoring vegetation cover in mined-out areas, soil erosion can be reduced, infiltration rates can increase, and groundwater recharge can improve, maintaining the quality of surface water and groundwater resources[43,44] . Ecological restoration of mines in mining-affected areas can help increase community resilience to climate change by providing tangible benefits, such as fuel, fodder, food, non-timber forest products, and other essential ecosystem services.

In addition, the recently agreed Kunming-Montreal Global Biodiversity Framework (GBF) also stresses the need for land restoration and ecological connectivity. Target 2 under the GBF emphasises onbringing at least 20 percent of degraded freshwater, marine and terrestrial ecosystems under restoration, ensuring connectivity and focusing on priority ecosystems.

[42] Amichev BY, Burger JA, Rodrigue JA. Carbon sequestration by forests and soils on mined land in the Midwestern and Appalachian coalfields of the US. For Ecol Manage. 2008;256(11):1949-1959.

[43] Vivian-Smith G, Handel SN. Freshwater wetland restoration of an abandoned sand mine: seed bank recruitment dynamics and plant colonization. Wetlands. 1996;16:185-196.

[44] Miao Z, Marrs R. Ecological restoration and land reclamation in open-cast mines in Shanxi Province, China. J Environ Manage. 2000;59(3):205-215.

1.2 STANDARDS, PRINCIPLES AND FRAMEWORKS FOR ECOLOGICAL RESTORATION OF MINES

The new global standards[45] for the ecological restoration of mines were launched at CBD, CoP15 (2022) and provide a framework for ensuring mining restoration is long-lasting and has economic and social justice benefits[46]. Eight fundamental principles underpin the standards, and together these present a method to define, guide and measure outcomes of ecological restoration practices in the mining landscape (Figure 10).

Figure 10: Eight principles underpinning restoration of ecosystems after mining

The mining process often alters the substrates to such a degree that the difference between pre-mining and post-mining biodiversity is often negative. This difference between these two is termed the "recovery gap". The hierarchy decision flow chart (Figure 11) provides guidance in reducing this gap and achieving no net loss of environmental and biodiversity values.

The goal of ecological restoration[47,48] is to increase ecosystem services and biodiversity. Ecosystem services related to the physical properties of the soil, such as checking erosion, filtering water, and improving the macro

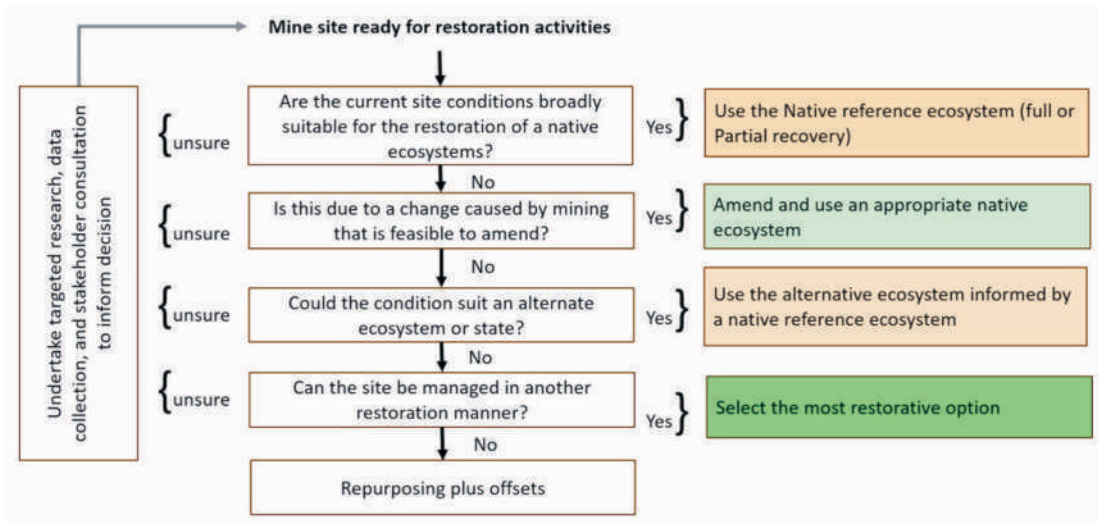
[45] Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, C. R., Tashe, N., Jasper, D., Silveira, F. A. O., Carrick, P. J., Hägglund, T., Carlsén, S., & Dixon, K. International principles and standards for the ecological restoration and recovery of mine sites. Restor Ecol. 2022;(30(S2)). doi:https://doi.org/10.1111/REC.13771

[46] Urzedo D, Pedrini S, Hearps C, Dixon K, van Leeuwen S. Indigenous environmental justice through coproduction of mining restoration supply chains in Australia. Restor Ecol. 2022;30:e13748.

[47] Whisenant S. Repairing damaged wildlands. 1999;1.

[48] Farber S, Costanza R, Childers DL, et al. Linking ecology and economics for ecosystem management. Bioscience. 2006;56(2):121-133.

Figure 11: Hierarchy decision flow chart[49]



and microclimate, are often prioritised when undertaking ecological restoration at post-mining sites[50]. This supports the establishment of native vegetation, improving the productivity of sites, the sequestration of carbon, and the aesthetic value of the entire landscape.

Over time various national and international agencies have provided Mining Standards, Guidelines and Resources (enlisted in Table 2). The many restoration principles provide the guidance for restoration of the mining landscapes to the highest level of recovery possible as per site conditions and societal choice. At the same time, the regulatory documents address the environment and social context of the mining[51]. Environmental and Social Governance performance has become the key performance indicator for metal and mining industries[52], and the performance of the mine companies in these acts as key drivers for financial investors[53]. Most mining companies have adopted the TCFD (Task Force on Climate-related Financial Disclosures), TNFD (Task force on Nature-Related Financial Disclosure), Equator Principles, and Principles for Responsible

[49] Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, C. R., Tashe, N., Jasper, D., Silveira, F. A. O., Carrick, P. J., Hägglund, T., Carlsén, S., & Dixon, K. International principles and standards for the ecological restoration and recovery of mine sites. Restor Ecol. 2022;(30(S2)). doi:https://doi.org/10.1111/REC.13771

[50] K, Tolvanen A. How can we restore biodiversity and ecosystem services in mining and industrial sites? Environ Sci Pollut Res. 2016;23:13587-13590.

[51] Mitchell P. Top 10 Business Risks and Opportunities for Mining and Metals in 2022 EY—Global. 2021.

[52] Young R, Manero A, Miller B, et al. A framework for developing mine-site completion criteria in Western Australia. 2019.

[53] Eccles RG, Klimenko S. The investor revolution. Harv Bus Rev. 2019;97(3):106-116.

Banking[54]. These standards also necessitate the mining companies to align their business strategy for achieving Sustainable Development Goals and the Paris Climate Agreement.

Table 2: Mining Standards, Guidelines and resources[55]

Agency	Mining Standards, Guidelines, and Resources
The Society for Ecological Restoration	International principles and standards for the ecological restoration and recovery of mine sites.
Asia-Pacific Economic Cooperation (APEC)	Mine Closure: Checklist for Governments. 2018.
Extractive Industries Transparency Initiative (EITI)	The EITI Standard 2019: The Global Standard for the Good Governance of Oil, Gas and Mineral Resources. 2019.
Global Reporting Initiative (GRI), RG & MMSS	Sustainability Reporting Guidelines & Mining and Metals Sector Supplement. 2010.
Global Tailings Review	Global Tailings Standard: Draft for Public Consultation. 2019.
Initiative for Responsible Mining Assurance (IRMA)	IRMA Standard for Responsible Mining IRMA-STD-001. 2018.
Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF)	IGF Mining Policy Framework: Mining and Sustainable Development.
Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF)	Guidance for Governments: Improving Frameworks for Environmental and Social Impact Assessment and Management (First Draft). 2019.
Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF)	State of Sustainability Initiatives Review: Standards and the Extractive Economy. 2018.
International Council on Mining & Metals (ICMM)	Integrated Mine Closure – Good Practice Guide. 2019.
International Council on Mining & Metals (ICMM)	Mining Principles. 2020.
International Cyanide Management Institute	International Cyanide Management Code. 2018.
International Finance Corporation (IFC)	Environmental, Health and Safety Guidelines for Mining. 2007.

[54] United Nations Environment Programme. UNEP Finance Initiative (2019) Principles for responsible banking. https://www.unepfi.org/wordpress/wp-content/uploads/2019/07/PrinciplesOverview_Infographic.pdf.

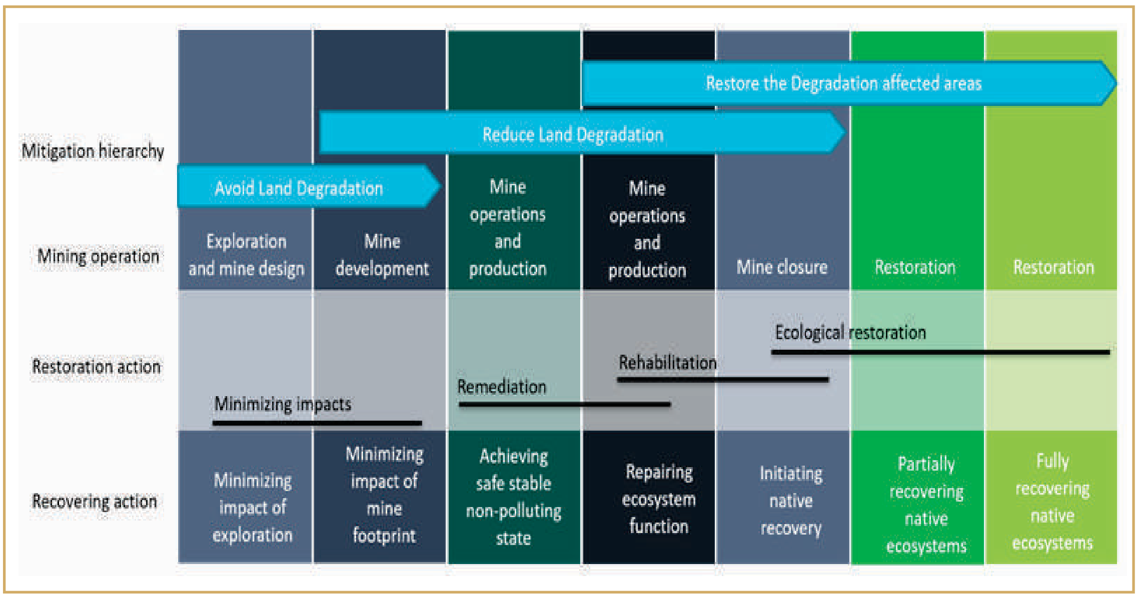
[55] Boubacar, B., Lori, H.K., Narine, T., Mcmahon, Raymond, G.J., Maria, F.R., Gayane, M., Qing W., Mine Closure : A Toolbox for Governments (English). Washington, D.C. : World Bank Group. 2021 http://documents.worldbank.org/curated/en/278831617774355047/Mine-Closure-A-Toolbox-for-Governments

Agency	Mining Standards, Guidelines, and Resources
International Finance Corporation (IFC)	Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets. 2007.
International Network for Acid Prevention (INAP)	Global Acid Rock Drainage (GARD) Guide. 2014.
International Institute for Environment and Development (IIED)	Breaking New Ground: The Report of the Mining, Minerals and Sustainable Development Project (MMSD). 2002.
The Mining Association of Canada (MAC)	Tailings Guide Version 3.1. 2019.
The Mining Association of Canada (MAC)	Towards Sustainable Mining: 2019 Highlights (TSM). 2019.
MVLWB/AANDC	Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories. 2013.
National Orphaned/Abandoned Mines Initiative (NOAMI)	The Policy Framework in Canada for Mine Closure and Management of Long-Term Liabilities: A Guidance Document. 2010.
United Nations Development Programme (UNDP)	Extracting Good Practices. 2018.
United Nations Development Programme (UNDP)	Managing Mining for Sustainable Development, a Source-book. 2018.
World Bank Multi-Stakeholder Initiative	Towards Sustainable Decommissioning and Closure of Oil Fields and Mines: A Toolkit to Assist Government Agencies Version 3.0. 2010.
World Bank Group	The Extractive Industries Sector : Essentials for Economists, Public Finance Professionals, and Policy Makers. 2015.
World Bank Group	Mine Closure a Toolbox for Governments 2021.
World Economic Forum	Voluntary Responsible Mining Initiatives: A Review. 2015.
World Gold Council	Responsible Gold Mining Principles. 2019.

Young et al., (2022)[49] recently developed the framework for delivering socially and environmentally responsible ecological restoration after mining (Mine Site Restoration Standards - MSRS). This borrows from international standards concepts and tools such as the Eight Principles of Ecological Restoration[56], Five Star System[57], and the Social Benefits and Ecological Recovery Wheels[58], all tailored to meet the recovery and restoration challenges of mine sites. These criteria are meant to inspire and strive for higher and better results in post-mining landscapes by directing and encouraging the highest possible level of restoration that supports the global mission to protect and restore nature. The system also draws on leading guidance documents such as International Finance Corporation[59,60]. The MSRS establishes best practices for planning and carrying out ecological restoration projects following the SER (Society for Ecological Restoration) code of ethics[61].

These Standards align with the United Nations Decade on Ecosystem Restoration, the United Nations Sustainable Development Goals, the Mitigation Hierarchy, and international best practices for ecological restoration (Figure 12). They are founded on the International Principles and Standards for the Practice of Ecological Restoration and incorporate essential concepts customised to the unique challenges of global mining. The Standards are underpinned by eight guiding principles that provide a framework for making evidence-based, resilient, and acceptable restoration choices for mining companies, communities, and stakeholders[62].

Figure 12: Mining operations viz-a-viz, land degradation mitigation and restoration[49].



[56] Gann GD, McDonald T, Walder B, et al. International principles and standards for the practice of ecological restoration. Restor Ecol. 2019;27(S1):S1-S46.

[57] McDonald T, Gann GD, Jonson J, Dixon KW. International standards for the practice of ecological restoration– including principles and key concepts.(Society for Ecological Restoration: Washington, DC, USA.). Soil-Tec, Inc,© Marcel Huijser, Bethanie Walder. 2016.

[58] Hall MM, Wehi PM, Whaanga H, Walker ET, Koia JH, Wallace KJ. Promoting social and environmental justice to support Indigenous partnerships in urban ecosystem restoration. Restor Ecol. 2021;29(1):e13305

[59] Baker SH. Why the IFC's Free, Prior, and Informed Consent policy does not matter (yet) to indigenous communities affected by development projects. Wis Int'l LJ. 2012;30:668.

[60] ICMM. Integrated Mine Closure—Good Practice Guide. 2019

[61] SER. Code of Ethics. 2021. https://www.ser.org/page/CodeofEthics.

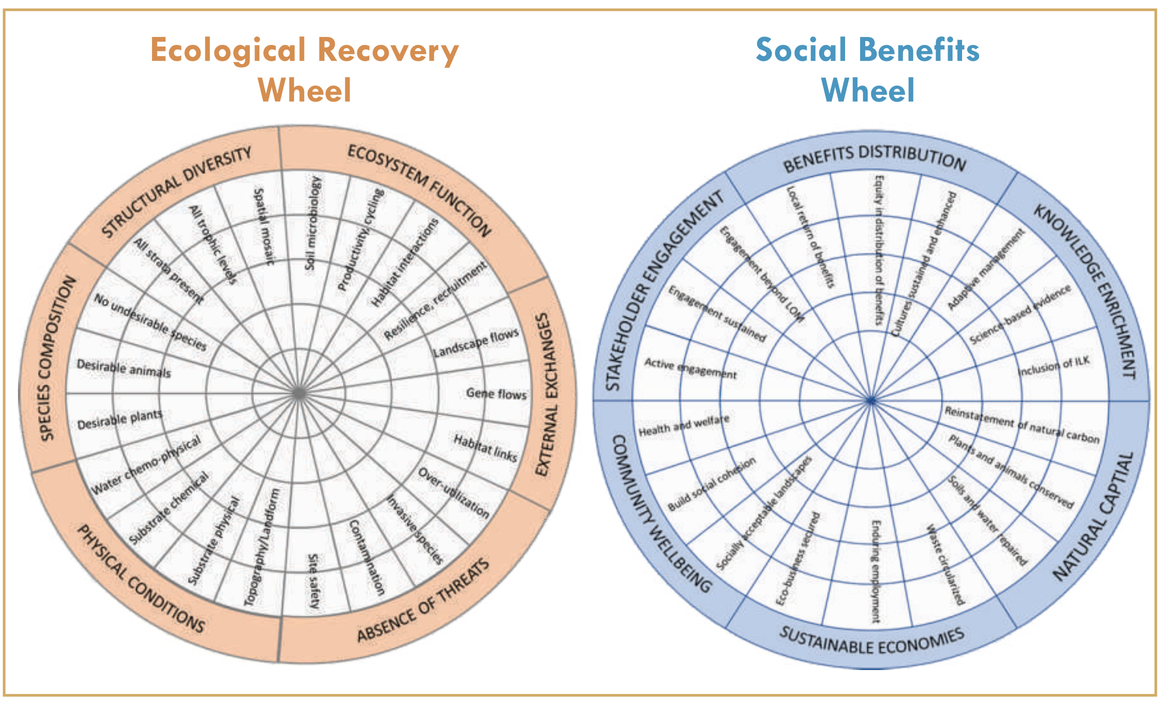
[62] Gann GD, McDonald T, Walder B, et al. International principles and standards for thepractice of ecological restoration. Restor Ecol. 2019;27(S1):S1-S46.

In regions where the restoration to the native reference ecosystem is not possible, mine sites are repurposed. The regulatory requirement, site nature, stakeholder's demand, and health and safety issues determine the repurposing of the mined-out area. Repurposing can aid in a transition towards a sustainable decarbonizing solution[63]. According to Bainton & Holcombe (2018)[64], collaborative mine closure processes that consider an alternative land-use and ecological restoration may include repurposing mining infrastructure and landscape, reskilling and redeploying labor, establishing alternative economic opportunities, and strengthening local livelihoods and food security. They show that best practice post-mining land use is varied, context-specific, and suited to distinct social and cultural sensitivities.

Core to the Standards is the Environmental and Social Benefits Recovery Wheels which provide an effective visual tool for assessing the progress of a mine rehabilitation program toward ecological restoration (Figure 13). Each of the six key attributes provides a unifying framework for evaluating mine rehabilitation while acknowledging that a mine may have unique considerations that require the sub-attributes ('spokes') to be customized according to the particular project or stakeholder aspirations.

Progressive use of the Wheels can be used to assess the performance of the mining operation against ecological impact from the commencement of mining to completion of mining restoration and mine closure. Regular performance assessment against the restoration trajectory during the project will identify departures from the planned course, allowing adaptive program management and reducing the risk of time and cost blowouts late in the mine life.

Figure 13: Social benefit wheel and Ecological recovery wheel [49]



[63] McCauley D, Heffron R. Just transition: Integrating climate, energy and environmental justice. Energy Policy. 2018;119:1-7.

[64] Bainton N, Holcombe S. A critical review of the social aspects of mine closure. Resour Policy. 2018;59:468-478.

1.3 RESTORATION OF MINING IMPACTED AREAS – CHALLENGES AND OPPORTUNITIES

Restoring the Structure and Functionality of the Ecosystem

Mining is an invasive process and may trigger irreversible changes in the site's geomorphology. Removal of vegetation, surface sediments, blasting, overburden dumps, and increasing slopes increase the vulnerability of landscape failure, erosion, floods, and subsidence. Mining leads to changes in many natural factors, which determines the vegetation of the ecosystem. Restoration of the ecosystem to its original state is a challenging task due to the complexity of the ecosystem and incomplete knowledge of the interaction of abiotic and biotic components of the ecosystem at different hierarchical levels[65]. Due to social, economical and practical constraints, the restored areas are typically relatively small, which makes them vulnerable to unpredictable cataclysmic events. Also, the changing climate adds to the unpredictability of the ecosystem.

Ecosystems are dynamic in space and time; therefore, it is crucial to account for spatial and temporal aggregation of various restoration measures within the landscapes to maintain viable habitat networks and species population over the long term; mine restoration plan should aim to avoid any harm to these habitat networks. When the habitat network is destroyed by landscape alteration, mine restoration should strive to define essential habitat categories and focus on establishing those habitat links.

Mining-affected ecosystems also take generations to become self-sustaining. A crucial ecological restoration issue is measuring and assessing naturally functioning restored ecosystems[66]. Most restoration studies document vegetation diversity[67], soil and water quality. These variables may not be enough to determine the resilience of the ecosystem. A thorough monitoring method should be created and used to measure the structure and processes of the ecosystem should be developed, to assess the achievement of restoration goals and understand the ecological processes in restored mined-out areas.

Conflicting Interests and Restoration Objectives

Restoration of mining-affected areas may also face conflicts between short-term goals and the long-term aims of other restoration actions. While restoration efforts are directed toward halting the decline of biodiversity in these areas, there is also a need to address the impact of mining activities on the climate. This often requires measures that maximise carbon storage and reduce greenhouse gas emissions. However, such actions may conflict with efforts to restore biodiversity, as they may prioritise intensive land management that promotes carbon fixation but ignores other ecological values. Additionally, there may be pressure to use wood-based energy and extract dead wood from cleared and harvested areas, further reducing habitat availability and

[65] Burton PJ, Macdonald SE. The restorative imperative: challenges, objectives and approaches to restoring naturalness in forests. 2011.

[66] Shorohova E, Kuuluvainen T, Kangur A, Jõgiste K. Natural stand structures, disturbance regimes and successional dynamics in the Eurasian boreal forests: a review with special reference to Russian studies. Ann For Sci. 2009;66(2):1-20.

[67] Asr ET, Kakaie R, Ataei M, Mohammadi MRT. A review of studies on sustainable development in mining life cycle. J Clean Prod. 2019;229:213-231.

biodiversity. In such cases, restoration efforts may need to compensate for habitat loss by implementing additional measures, leading to higher costs and potentially irrational treatments[68,69]. Therefore, a comprehensive evaluation of the rationale, cost-efficiency, and ecological impacts of different restoration actions is necessary to avoid conflicts and ensure effective restoration of mining-affected areas.

Social Challenges

The restoration of mining-affected areas also faces social challenges. While ecology determines the overall objective of ecological restoration, social constraints can make it challenging to choose optimal environmental restoration due to the varied interests of the landowners/stakeholders or conflicting land use[70]. Finding an intact land area to meet restoration objectives becomes a challenge in densely populated areas with fragmented land ownership. Also, the restored areas in such land use remain isolated and have no connectivity with the natural ecosystem. Such fragmented ecosystems are low in biodiversity. Additionally, conflicts over resource use in such areas may trigger unsustainable resource exploitation and degradation of the restored land. Any disputes over land ownership can prevent restoration measures at the landscape level.

To address these challenges, it is crucial to provide employment opportunities and other resources to the local community that may depend on mining activities. There is also a need to create awareness and change in public perception of the importance of restoring mining-affected areas. New methods are constantly being developed to integrate societal needs and conservation targets in restoring mining-affected areas[71].

Technology for Restoration

Mining is a technology-intensive industry; technical expertise is required during exploration, mining, transportation, processing, pit closure, and governance[72]. Innovative technology, equipment, facilities and restorative engineering design facilitate Environment and Socially responsible mining[73]. Ecological restoration

[68] Rabinowitsch-Jokinen R, Vanha-Majamaa I. Immediate effects of logging, mounding and removal of logging residues and stumps on coarse woody debris in managed boreal Norway spruce stands. 2010

[69] Rabinowitsch-Jokinen R, Laaka-Lindberg S, Vanha-Majamaa I. Immediate effects of logging, mounding, and removal of logging residues on epixylic species in managed boreal Norway Spruce stands in southern Finland. J Sustain For. 2012;31(3):205-229.

[70] Knight AT, Sarkar S, Smith RJ, Strange N, Wilson KA. Engage the hodgepodge: management factors are essential when prioritizing areas for restoration and conservation action. Divers Distrib. 2011;17(6):1234-1238

[71] Group WB. World Bank Group (2021) Mine closure: a toolbox for governments. 2021. https://openknowledge.worldbank.org/handle/10986/35504?locale-attribute=en.

[72] KPMG. Mining in Argentina: Current situation, potential, and opportunity. 2016.

[73] Chen Z, Yang Y, Zhou L, et al. Ecological restoration in mining areas in the context of the Belt and Road initiative: Capability and challenges. Environ Impact Assess Rev. 2022;95:106767.

in mining-affected areas is complex, with various factors governing the success of restoration[74] technology is not advanced. The Post-Mining Institute of Germany provides training to the personnel with the multidisciplinary skill to deal with complex ecological problems for the restoration of mines[75]. However, there is insufficient technological research and development and a lack of knowledge of restoration practices. Capacity building, knowledge sharing and training for ecorestoration will help scale up ecorestoration practices.

Financial

The mining sector provides a potentially vast, largely untapped opportunity for engaging the mining companies in socially and environmentally responsible operations compatible with Sustainable Land Management and Land Degradation Neutrality. Many independent cases of successful Ecorestoration of Mining Affected areas are built on the inherent principles of Sustainable Land and Ecosystem Management. There is the potential of upscaling these practices, with enabling statutory framework, financing arrangement and involvement of diverse stakeholders. Currently, the restoration by the mining companies is undertaken mainly for compliance with a legally binding regulatory framework and sometimes for convenience.

Without a politically practicable, legally binding global agreement forcing compliance with the international UN target, market forces offer a valuable solution to generate the necessary transformational change at the appropriate level and scale. In this regard, public policies and announcements, such as the voluntary SDG targets, can play an instrumental role in sending a signal to market operators, the effectiveness of which will ultimately depend on the public commitments that follow.

With provisions for the business case for SLM/LDN, the mining companies can be further encouraged to undertake restoration activities. Such an enabling context may result from both public and private sector policies and strategies and would not necessarily need to depend on centralized governance structures or institutions. Market-driven solutions such as industry standards for sustainable land management, land stewardship certifications, and innovative financial solutions to mobilise adequate capital could provide the right incentives to trigger the necessary response[76].

Governance

Ecological restoration in mining sites involves multiple stakeholders, trade-offs, and conflicts. However, environmental protection issues arise due to inadequate regulatory standards, insufficient proactive and Initiative efforts, and minimal public participation. There is a need for enabling policies, promoting effective governance, institutional involvement, multi-sector and actor involvement, general private partnership and coordination among stakeholder groups for advancing ecological restoration.

Government agencies and mining companies are responsible for ecological restoration in most countries under the principle, "those who cause the damage pay for the repair"[77]. While the governance provides a regulatory

[74] Aung TS, Fischer TB, Shengji L. Evaluating environmental impact assessment (EIA) in the countries along the belt and road initiatives: System effectiveness and the compatibility with the Chinese EIA. Environ Impact Assess Rev. 2020;81:106361.

[75] Kretschmann J. Done for Good: Challenges of Post-Mining. Deutsches Bergbau-Museum; 2016.

[76] Quatrini S, Barkemeyer R, Stringer L. Involving the mining sector in achieving land degradation neutrality. Solutions. 2016;7(5):55-63.

[77] Chen Z, Yang Y, Zhou L, et al. Ecological restoration in mining areas in the context of the Belt and Road initiative: Capability and challenges. Environ Impact Assess Rev. 2022;95:106767.

framework, mining companies prioritise short-term economic growth and may not take responsibility for environmental conservation. Local communities may not have much input. International standards recognise the participation of government agencies, mining companies and local communities to address the social and ecological challenges and Ecological restoration in mining-affected areas. For effective restoration of the ecosystem to the highest level of restoration attainable, stakeholders must be identified, and their interest in their concerns, aspirations and requirements should be addressed[78].

[78] Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, Hallett JG, Eisenberg C, Guariguata MR, Liu J, Hua F, Echeverría C, Gonzales E, Shaw N, Decleer K DK. International principles and standards for the practice of ecological restoration (Second edition). Restor Ecol. 2019;(Restor. Ecol.):S1–S46.toward sustainability. Cambridge, U.K.: Cambridge University Press.

II

MINING SCENARIOS IN G20 COUNTRIES

2.1 G20 COUNTRY PROFILES - MINING

1 Argentina

Key Mining Sectors

Mining tradition in Argentina spans over a century and has played an important role in the country's development[79]. The first milestone in Argentina's mining sector was the enactment of the Mining Promotion Law in 1813. Argentina has recognized copper, gold, silver, and lithium mining potential. The growing global demand for minerals, especially lithium and silicon, can also place the country's mining sector at the global forefront[80].

In 2019 (pre-pandemic), mining exports accounted for USD 3.2 billion with a 3.5 per cent growth per year. Yet the country holds resources to expand production and achieve exports valued at over USD 11 billion annually[81]. Although there is a high level of activity in the mining sector and a sizable number of projects in the pipeline, most of the nation's natural resources are yet unexplored.

Key Mining Areas

Argentina has significant potential for mineral exploration, due to a diverse range of geological phenomena[82]. However, the exploration of key minerals in the country remains unexplored, with only 25% of the total geographic area having undergone detailed exploration.

[79] KPMG. Mining in Argentina: Current situation, potential, and opportunity. 2016.

[80] Walter M, Wagner L. Mining struggles in Argentina. The keys of a successful story of mobilisation. Extr Ind Soc. 2021; 8(4): 100940.

[81] UNRP. Global resources outlook. 2019: natural resources for the future we want. 2019. https://www.resourcepanel.org/reports/global-resources-outlook.

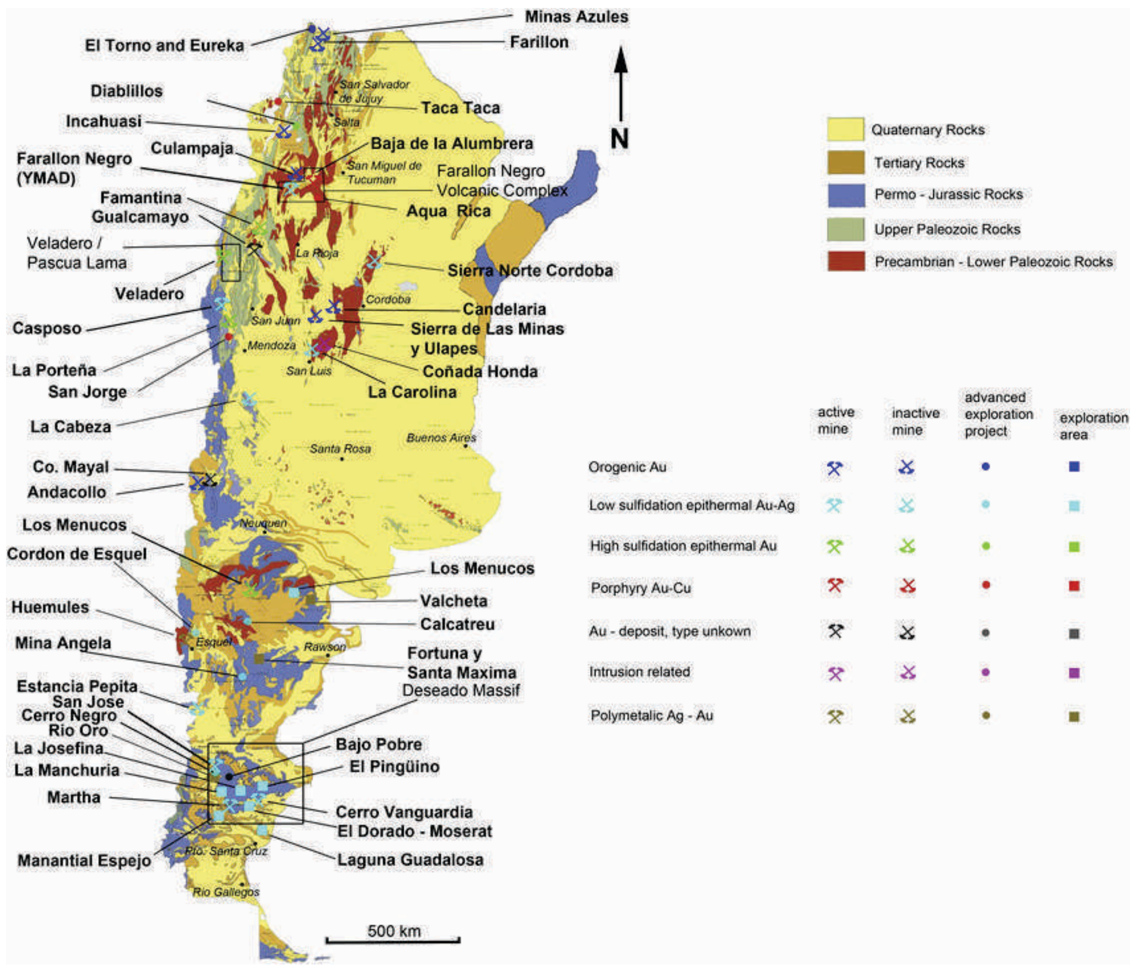
[82] Siboldi , A., Fanelli, A., O'Farrell E. Mining in Argentina: Overview | practical law. 2020.

II

Northwest Argentina, encompassing Jujuy, Salta, Catamarca, La Rioja, and Tucuman provinces, is a mineral-rich region known for the lithium triangle that extends to Chile and Bolivia. In contrast, central-west Argentina, comprising San Juan, San Luis, Mendoza, and Neuquen provinces, has mountainous Cordilleran regions hosting numerous gold mines[83]. Lastly, Central-West Argentina comprises Reio Negro, Chubut, and Santa Cruz provinces including the Deseado Massif volcanic plateau, which hosts high-grade precious metal mines. Figure 14 depicts elaborate mining areas throughout Argentina, specifying active, inactive, and exploration areas[82]. The main mining areas in Argentina that are currently in the exploration stage per province are:

1. San Juan province: Veladero (operated by Minera Argentina Gold SA); Gualcamayo (operated by Minas Argentinas SA), and Casposo (operated by Troy Resources Argentina Ltd).

Figure 14: Key mining areas in Argentina



[83] Group NM. Focus on Argentina mining: An investors guide. 2016. https://issuu.com/bigmininglp/docs/focus_on_argentina/28.

2. Santa Cruz province: San José-Huevos Verdes (operated by Minera Santa Cruz SA); Manantial Espejo (operated by Panamerican Silver), and Cerro Vanguardia (operated by Anglo Gold Ashanti and Fomicruz).
3. Catamarca province: Bajo la Alumbrera (operated by Minera Alumbrera YMAD UTE).
4. In the province of Jujuy: Pirquitas (operated by Silver Standard).

Key Mining Companies

The Veladero Mine in San Juan, one of the largest mines in Argentina produced 728.77 thousand ounces of silver in 2021. These mines are operated and owned by Shandong Gold Group Co Ltd and Barrick Gold Corp, which will continue to run through 2031. The Gualcamayo Mine in San Juan, produces mostly gold (61.49 thousand ounces) and is the second-largest mine. The mine is owned by Mineros SA, which will continue to run through 2024. The Lindero Project located in Salta, was the third-largest mine. Fortuna Silver Mines Inc owns the project which is due to operate until 2033.

Major Environmental Concerns Linked to Mining

Land Degradation

Desertification in Argentina is due to soil erosion or land degradation[84], Around 40% of the country's lands are affected by degradation processes[85]. Open-pit mining, because of its huge magnitude is one of the major contributor of land degradation in Argentina.

Biodiversity Loss, Including Invasive

Argentina's forests once covered more than 100 million hectares; today, they only cover less than 20 million hectares, with half of them experiencing an accelerated pace of deterioration. Apart from farming and other man-made activities, infrastructural work for mining has also directly impacted on deforestation and biodiversity loss. Endangered animals, such as Jaguar, in Argentina North Provinces are threatened by projects like the construction of a pipeline for natural gas transportation from eastern Salta to northern Chile's copper mines. Mining and agricultural encroachment threaten the Sierra de Famatina mountain range, which harbours rare and endangered species[86].

Chemical Contamination

Disputes regarding mining activities in Argentina have usually been around major environmental impacts and risks. In 2015 and 2017, hazardous concentrations of mercury and other pollutants were found in the river system near a mine located at a high elevation in northwest Argentina[87]. It was later reported that over the seven years of the Veladero mine that was under operation in the region had at least five hazardous spills. Similarly, near the San Antonio salt marsh in Patagonia, there are mining waste deposits that date back forty

[84] Xie H, Zhang Y, Wu Z, Lv T. A bibliometric analysis on land degradation: Current status, development, and future directions. Land. 2020;9(1):28.

[85] Serafini P. The Argentinian fight against "mega mining." Conversat. 2022. https://theconversation.com/the-argentinian-fight-against-mega-mining-95672.

[86] Rozzi R, Quilodrán CS, Botero-Delgadillo E, et al. The Subantarctic Rayadito (Aphrastura subantarctica), a new bird species on the southernmost islands of the Americas. Sci Rep. 2022;12(1):13957.

[87] Moran RE. Veladero Mine Lixiviant Spill, Argentina: Replies to Federal Judge Casanello Regarding His Questions and Related Comments. 2016

years and were produced by the metallurgical extraction of heavy metals. Additionally, studies revealed that the San Antonio salt marsh's heavy metal pollutants from mines abandoned four decades ago continue to be a source of metal pollution[88].

Legislative Provisions for Mine Restoration and Rehabilitation

Argentina's mining legislation currently lacks specific provisions for mine rehabilitation following closure[89]. The existing regulations only mention the possibility of incorporating post-closure oversight in the Environmental Impact Assessment. Furthermore, unless the environmental damage is deemed significant, there are no explicit requirements for remediation during mine closure. The inclusion of post-closure supervision guidelines in the EIA is not mandatory.

According to the General Environmental Law of 1994, individuals engaged in activities that could harm the environment must obtain insurance to fund restoration activities and contribute to an environmental restoration fund if opportunities[90].

Environmental protection in Argentina follows a shared jurisdiction between federal and provincial authorities, with provincial governments having the power to establish supplementary environmental criteria. The majority of environmental legislation is enacted at the provincial level. The Province of Mendoza has the most comprehensive restrictions. The Minister is in charge of the environment, and the law calls for an EIA process that produces a formal for specific projects. Public hearings are another provision made by the legislation for the evaluation procedure. The Federal Mining Code and provincial requirements apply to uranium production sites, including Córdoba and other provinces, with substantially comparable legislation.

Key Institutions involved in Mine Restoration and Rehabilitation

- **Federal Mining Council (COFEMIN):** Responsible for designing, executing, and monitoring national mining policies[91]. It promotes consensus between the nation and provinces in mining policy and ensures compliance through monitoring and evaluation.
- **National Atomic Energy Commission:** Implements the "Argentina Mining Environmental Restoration Project" funded by the World Bank. The commission is in charge of nuclear energy research and development, promoting the peaceful use of atomic energy in Argentina.

Financing Arrangements for Mine Restoration and Rehabilitation

On July 31, 2008, the World Bank approved a US$30 million loan to support an environmental program intended to help the National Atomic Energy Commission, Argentina comply with its legal obligations to permanently remediate closed uranium mines and milling facilities in accordance with generally accepted standards for the safe disposal and handling of hazardous materials[92]. The closed Malargüe, Mendoza, uranium processing site would remedy with financial support from the Mining Environmental Restoration

[88] Idaszkin YL, del Pilar Álvarez M, Carol E. Geochemical processes controlling the distribution and concentration of metals in soils from a Patagonian (Argentina) salt marsh affected by mining residues. Sci Total Environ. 2017;596:230-235.

[89] Achen EN. Impact of new environmental and safety regulations in Argentina. 2001

[90] Nonna S. The Argentine Constitution and Its Relationship with Environmental Standards.

[91] FICCI. Argentina: Country of Great Mining opportunity. 2021. https://ficci.in/international/54526/Add_docs/Mining-Opportunity-in-Argentina.pdf.

[92] Group WB. World Bank Group (2021) Mine closure: a toolbox for governments. 2021. https://openknowledge.worldbank.org/handle/10986/35504?locale-attribute=en.

Program, and up to seven additional sites will receive technical support for planning and engineering design. The project had a grace period of 5 years and a maturity period of 30 years. The fund entailed remediation and safe disposal of 710,000 tons of tailings and soils. The project aims to enhance mine restoration efforts and strengthen institutions by providing technical assistance in the design and study of mine rehabilitation practices aligned with international standards.

Role of the Private Sector in Restoration

- **SRK Consulting:** Canada-based firm is actively researching, monitoring, and evaluating mine rehabilitation techniques and provides recommendations for restoration of silver, lead, and zinc mine in Jujuy province, including revegetation, tailings relocation, and a prioritization plan aligned with the budget and management expectations[93].

Community Involvement and Engagement

- **Community Assemblies Union (UAC):** The UAC was founded by local assemblies to address mining and environmental issues[94]. It aims to include indigenous and minority groups, collaborating with other environmental organizations and foundations to shape campaigns against mining and land exploitation[95].

Academic and Research Institutions Involved

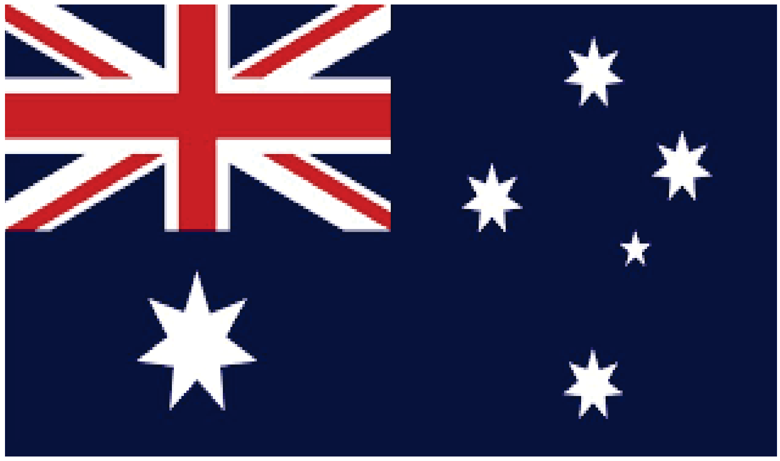
- **Intergovernmental Forum on Mining, Minerals, Minerals and Sustainable Development:** Provides a guide to financial assurance for mine closure in Argentina, promoting best practices and establishing of applicable financial assurance within the mine's life cycle.
- **Agreste Foundation:** Accredited organization promoting environmental education and conducting specific studies to rehabilitate of areas affected by desertification. It also manages a centre for sustainable development research and prevention of natural disasters.
- **College of Agricultural Engineering of Santiago del Estero:** Coordinates technical and scientific use of natural resources in agricultural and livestock production. Establishes networks with provincial, national, and international institutions to develop sustainable land management processes.

[93] Macdonald C. The role of participation in sustainable community development programmes in the extractive industries. Extr Ind. 2017;591.

[94] Unión de Asambleas Ciudadanas (UAC). Construyendo caminos colectivos en defensa de nuestros territorios. 2018. https://asambleasciudadanas.org.ar/wp-content/uploads/2018/04/CuadernilloUACAbril2018.pdf.

[95] Walter M, Wagner L. Mining struggles in Argentina. The keys of a successful story of mobilisation. Extr Ind Soc. 2021;8(4):100940

2 Australia



Key Mining Sectors

In 2020, Australia ranked first in the global production of bauxite, iron ore, rutile and lithium. It was the second-largest producer of gold, lead, uranium, zinc and zircon; the third-largest producer of cobalt, diamond, ilmenite and manganese ore. Overall Australia is fifth top producer of 20 important commodities[96].

Key Mining Areas

Every state of Australia is involved in mining, including the Northern Territory and Christmas Island. The only exception is the Australian Capital Territory, which solely operates quarries. Figure15 depicts the geographical spread of the major mines by commodity type and mine status. It is worth noting that the precious metals gold and silver and iron ore are mainly mined in Western Australia, whereas coal mines are primarily found on the east coast in Queensland and New South Wales.

In addition, the recently agreed Kunming-Montreal Global Biodiversity Framework (GBF) also stresses the need for land restoration and ecological connectivity. Target 2 under the GBF emphasises onbringing at least 20 percent of degraded freshwater, marine and terrestrial ecosystems under restoration, ensuring connectivity and focusing on priority ecosystems.

Key Mining Companies

BHP: Operations in Australia are based in Queensland, Western Australia, New South Wales and South Australia, where iron ore, copper, coal and nickel are produced.

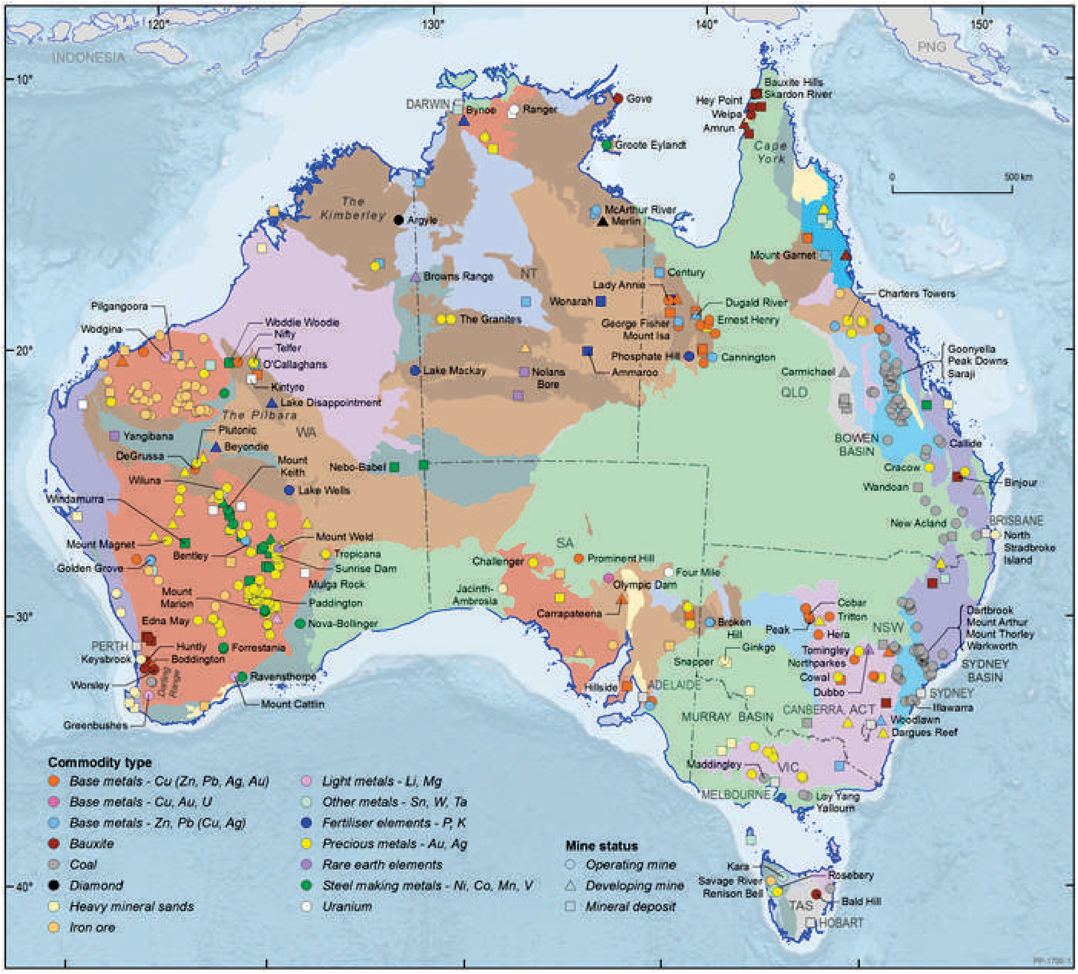
Rio Tinto: Operate at 18 sites across Western Australia, the Northern Territory, Queensland, New South Wales and Tasmania, where iron ore, bauxite, seaborne salt, diamond and uranium are produced[97].

Fortescue: Fortescue was founded in 2003 and is the third-biggest mining company in Australia, based in West Australia. It is specialized in the mining of iron ore.

[96] Government Australian. Australian mineral facts. https://www.ga.gov.au/education/classroom-resources/minerals-energy/australian-mineral-facts.

[97] RioTinto. RioTinto. Annual Report 2021, Melbourne. 2022.

Figure 15: Major Mines and Mineral Deposits in Australia[96]



Major Environmental Concerns linked to Mining

Land Degradation

Before 1970s, the mining industry didn't pay much attention to environmentally managing abandoned mines, leading to chronic environmental problems[98]. According to the European Commission (2019), only 24% of mining-affected land in Australia was subject to preliminary remediation in 2003. Therefore the 'rehabilitation gap' was significant and potentially highly toxic. As of 2014 there were 50,000 abandoned mines left in Australia, classified as degraded land[99].

Biodiversity, Including Invasive

According to the Leading Practice Sustainable Development Program for the Mining Industry by the Australian Government[100], the Australian mining industry continues to negatively impact biodiversity, even though the

[98] Hilson G. An overview of land use conflicts in mining communities. Land use policy. 2002;19(1):65-73

[99] Unger CJ, Lechner AM, Kenway J, Glenn V, Walton A. A jurisdictional maturity model for risk management, accountability and continual improvement of abandoned mine remediation programs. Resour Policy. 2015;43:1-10. Government Australian. Australian mineral facts. https://www.ga.gov.au/education/classroom-resources/minerals-energy/australian-mineral-facts.

[100] Zhou JW, Zhou AG, van Zyl D, Tang ZH, Bu JW. Mine closure in China–problems, strategies and forecasts. In: Mine Closure 2011: Proceedings of the Sixth International Conference on Mine Closure. Australian Centre for Geomechanics; 2011:501-509

industry standards and regulations have improved in the past decades. Key impacts include: (i) Clearance of native habitat, (ii) degradation of terrestrial habitat (iii) degradation/pollution of aquatic habitat (iv) abstraction and contamination of freshwater

Chemical Contamination

Coal mining can release chemicals into the environment, which are potentially toxic to aquatic and terrestrial organisms. They could also affect water quality, which in turn would have negative impacts on human health. The mobilization of naturally occurring underground chemicals can also be a consequence of coal mining, as they are brought up to the surface on mine discharge water. A national assessment of chemicals associated with coal seam gas extraction in Australia is being conducted, led by the Department of the Environment and Energy in collaboration with the National Industrial Chemicals Notification and Assessment Scheme, the Commonwealth Scientific and the Industrial Research Organisation. It is set to develop a better understanding of the environmental risks arising from chemicals used in drilling and hydraulic fracturing.

Legislative Provisions for Mine Restoration and Rehabilitation

The Minerals Council of Australia[101] has issued a Land Stewardship Policy which states that mining must minimise disturbance and prioritise rehabilitation for sustainable land use. The legislative provisions for mine restoration and rehabilitation are managed by individual state territories in Australia. The following paragraphs outline some legislative provisions for mine restoration and rehabilitation of the individual states.

New South Wales: The rehabilitation of mines is stipulated in part 11, division 5 of the Mining Act 1992, which is dedicated to rehabilitation and environmental management plans. The rehabilitation activities are regulated by the New South Wales Resources Regulator, against the mining lease conditions (issued under the Mining Act 1992), to ensure the attainment of the restoration commitments outlined in the development consent.

Queensland: While the Mineral Resources Act 1989 contains divisions on rehabilitation activities, the Environmental Protection Act 1994 comprises legislation on final rehabilitation reports, auditors and costs. The Queensland Government is also the first state to appoint a mine rehabilitation commissioner year 2021.

South Australia: The south Australian legislative provisions on rehabilitation are regulated by the Mining Act 1971, including legislation on rehabilitation funds and operating approval for environment protection and rehabilitation.

Tasmania: The Mineral Resources Development Act 1995 includes legislation on Rehabilitation Trust funds and contracts on the rehabilitation of mining lands under part 10 division 2.

Victoria: The Mineral Resources (Sustainable Development) Act 1990 determines rehabilitation plans, liability assessments and bonds, and establishing a rehabilitation authority and regional rehabilitation strategies.

Western Australia: In Western Australia the Mining Act 1978 defines mine closure plans in regard to the rehabilitation of the land. The Mining Regulations 1981 further specify that the cost of rehabilitation activities can be used to calculate of expenditure on the mining tenement. The Offshore Minerals Act 2003 attends to rehabilitation activities regarding areas in coastal waters.

[101] Ogden L, Heynen N, Oslender U, West P, Kassam K-A, Robbins P. Global assemblages, resilience, and Earth Stewardship in the Anthropocene. Front Ecol Environ. 2013;11(7):341-347

Key Institutions involved in Mine Restoration and Rehabilitation

Besides mining companies, the respective state governments play a crucial role, in approving rehabilitaion strategies and closure plans before operations begin. The companies collaborate with authorities, regularly updating the estimates of the requirements for rehabilitation[102]. Companies specialising in environmental management also contribute significantly, working closely with local ranger departments to restore landscapes to their natural state with thriving flora and fauna. Other important stakeholders include state environmental departments, environmental NGOs, and indigenous and other local communities.

Financing Arrangements for Mine Restoration and Rehabilitation

New South Wales: The mining companies are required to provide a security deposit to the Department of Planning and Environment, to ensure full coverage of rehabilitation costs. The deposit amount is determined based on the mine rehabilitation and closure plan. In 2016 the total value of security deposits was $2.2 billion for around 450 mines.

Queensland: The Financial Provisioning Scheme, introduced in 2019, reduces the states financial risk by requiring mining companies to provide surety for estimated rehabilitation costs. Companies undergo an annual assessment to determine contributions to the scheme's Financial Provisioning Fund. The Scheme's funds provide financial support for rehabilitating abandoned mines and further research on the rehabilitation of mines[103].

South Australia: In South Australia, the Extractive Areas Rehabilitation Fund intervenes when mine operators cannot meet their rehabilitation obligations. It is funded through royalties, with a bond being set by the Minister on a case-by-case basis.

Tasmania: Mining leases are granted upon the provision of a security deposit by the applicants, covering rehabilitation costs. The Rehabilitation Trust Fund, funded by a portion of the increased royalties of the mining industry, is used to repair and rehabilitate abandoned mining lands[104].

Victoria: Financial capability assessment under the Mineral Resources (Sustainable Development) Act 1990, determine financing arrangements for mine rehabilitation. As required by the Mineral Resources Act 1990, there is also an operational policy on rehabilitation bonds by Earth Resources Regulations, a branch of the Department of Jobs, Precincts and Regions. Mine operators must provide financial security, equivalent to the estimated rehabilitation cost[105].

Western Australia: The Mining Rehabilitation Funds require contributions from mining companies whose rehabilitation liability estimates are higher than $50,000. Disturbance

[102] Unger CJ, Everingham J-A, Bond CJ. Transition or transformation: shifting priorities and stakeholders in Australian mined land rehabilitation and closure. Australas J Environ Manag. 2020;27(1):84-113

[103] Queensland Government. Financial Provisioning Scheme. 2022. https://www.treasury.qld.gov.au/resource/financial-provisioning-scheme/.

[104] Tasmanian Government. Rehabilitation Trust Fund. https://www.mrt.tas.gov.au/land_and_resource_management/Rehabilitation_Trust_Fund.

[105] Government Victoria State. Rehabilitation bonds - minerals exploration, mines and quarries. 2022. https://earthresources.vic.gov.au/legislation-and-regulations/guidelines-and-codes-of-practice/rehabilitation-bond

data reporting is mandatory for all companies. The funds supports rehabilitation when obligations are not met.

Role of the Private Sector in Restoration

Major mining companies like BHP, Rio Tinto, and Fortescue, and privately owned companies like Hancock Prospecting, contribute to restoration efforts. Private sector involvement extends to investment, with companies like Taurus Funds funding rehabilitation projects. Environmental management specialists, such as Trace Ecology, restore natural terrains. Law firms provide strategic advice and guidance on rehabilitation plans and mineral sector deals[106].

Community Involvement and Engagement

In 2016 the Australian Government launched the Leading Practice Sustainable Development Program for the Mining Industry on Community Engagement and Development. Community involvement in rehabilitation begins during land access negotiations, with considerations for cultural heritage and community well-being. Around five years before the closure of a mining site, a closure planning committee is to be established, which should partly consist of persons from the community. The committee, envisions the post-closure sustainability of the restored area. Inclusivity and valuing local knowledge are emphasized, and traditional ecological knowledge is increasingly integrated into rehabilitation work[107].

Academic and Research Institutions Involved

Australian Universities host various centres and research streams focused on mine rehabilitation, for example, the Centre of Mined Land Rehabilitation at the University of Queensland, Future Regions Research Centre with a research stream called 'Stable Landforms and Mine Rehabilitation' of the Federation University and the Western Australian Biodiversity Science Institute hosts a program dealing with mine rehabilitation and closure. Academic and research institutions are highly involved in improving the procedures, and policies in the field of rehabilitation[108].

Capacity Building

- The University of Queensland offers a course on 'Managing Post-Mining Landscapes: Land Rehabilitation in the Mining Industry' for undergraduate students.
- The Federation University offers a course termed 'Landscape Restoration and Mine Site Rehabilitation' as a postgraduate course.
- The Australian Research Council's Industrial Transformation Training Centre for Mine Site Restoration provides multi-disciplinary training to professionals, focusing on research areas such as restoration genetics, seed technology, rare species management, restoration ecophysiology, restoration trajectory, and mining industry policy extension.

[106] Allens. Mining. 2022. https://www.allens.com.au/sectors-services/sectors/mining/

[107] Australian G. State of the Air Report:Community Summary 1991-2001. www.environment.gov.au.

[108] Campbell R, Carter L. Mind the gaps: unused capacity and unfunded rehabilitation in Upper Hunter coal mines. 2021

Figure 16: Pit rehabilitation site of Australia– Ranger Uranium Mine (Ranger) is located approximately 250 km east of Darwin in the Northern Territory of Australia, surrounded by the World Heritage listed Kakadu National Park

3 Brazil

Key Mining Sectors

Brazil's mining sector is dominated by Iron ore accounting for 68 % of the total mining activity in the country. Gold and copper follows with 11 % and 7 %[109] respectively. Brazil holds the second largest iron reserves globally, comprising 19.6% of the total global Iron ore reserves, while gold reserve account for 3.4% of the international gold reserves. In 2020, mineral production generated a gross value of $43.7 billion, making mining a significant contributor to Brazil's economy[110].

Key Mining Areas

Brazil's most important mining areas are located in the states of Manai Gerais, Pará, Bahia and Goiás. The Carajás in Pará and Iron Quadrangle in Minas Gerais are the largest mining areas. The area is surrounded by rainforest[111]. The Iron Quadrangle is located in the southern part of Minas Gerais. It includes the Paleoproterozoic banded iron formation of the Quadrilátero Ferrífero, classified as an IUGS geological heritage site[112].

Key Mining Companies

Vale: Vale operates multiple mines in Brazil, extraction iron ore, nickel, manganese, ferroalloys, and copper. The mining sites of Vale are located in Minas Gerais, Pará, Rio de Janeiro, Maranhao and Espirito Santo.

Anglo American: Anglo-American operates at four mining sites in Brazil located in Barro Alto, Codemin, Minas-Rio and Niquelandia in Brazil.

Companhia Siderúrgica Nacional (CSN) Mineração: CSN Mineracao ranks as Brazil's second largest iron ore producer.

[109] Euclydes FM, Macedo A dos S, Macedo SV, Valadares JL. Capacidades estatais e mineração: uma análise da agência nacional de regulação. Rev Adm Pública. 2022;56:163-175

[110] OECD. Organization for Economic Cooperation and Development: Regulatory Governance in the Mining Sector in Brazil. 2022.

[111] Souza-Filho PWM, de Souza EB, Júnior ROS, et al. Four decades of land-cover, land-use and hydroclimatology changes in the Itacaiúnas River watershed, southeastern Amazon. J Environ Manage. 2016;167:175-184.

[112] IUGS. International Union of Geological Sciences, 2022. The first 100 IUGS Geological Heritage Sites. 2022

Major Environmental Concerns Linked to Mining

Land Degradation

Mining has led to massive deforestation in Brazil in recent decades. From 2005 to 2015 alone, more than 11 000 km^2 were deforested, accounting for 9% of the total deforestation activity during this period. Deforestation extends up to 70 km beyond the mining lease boundaries[113], resulting in land degradation[114], including soil erosion due to the absence of tree roots[115].

Biodiversity Loss

The demand for minerals puts pressure on protected areas for mining in Brazil[116], leading to deforestation and land degradation and thereby threatening biodiversity and essential ecosystem services[117]. The amazon rainforest, the worlds largest continuous rainforest, is particularly at risk[118].

Chemical Contaminations

Abandoned mines in Brazil contribute to soil and surface water pollution, as indicated by a recent study on environmental degradation associated with mining and urbanisation[119]. There are also studies showing that the Amazon forest is heavily polluted with mercury due to artisanal gold mining[120].

Legislative Provisions for Mine Restoration and Rehabilitation

Brazilian Constitution: The Constitution states that all minerals on Brazilian soil, i.e. on land and off the coast, belong to the Brazilian state. Landowners must obtain a licence from National Mining Authority to explore and mine the minerals.

National Environmental Act (Law 9985, July 18th, 2000): The act establishes standards for rehabilitating ecosystems and biodiversity. The goal is to restore a mining area as closely as possible to its original sate in terms of ecosystem and wildlife populations[121].

Law No.14.066/2020: This Law prohibits using upstream tailings ponds, and introduces new safety measures, contributing to safer and more sustainable mining rehabilitation.

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[113] Sonter LJ, Herrera D, Barrett DJ, Galford GL, Moran CJ, Soares-Filho BS. Mining drives extensive deforestation in the Brazilian Amazon. Nat Commun. 2017;8(1):1013

[114] Beuchle R, Achard F, Bourgoin C, Vancutsem C, Eva H, Follador M. Deforestation and Forest degradation in the Amazon. Luxemb Eur Union https//doi org/102760/61682. 202

[115] Dregne HE. Land degradation in the drylands. Arid L Res Manag. 2002;16(2):99-132

[116] Siqueira-Gay J, Metzger JP, Sánchez LE, Sonter LJ. Strategic planning to mitigate mining impacts on protected areas in the Brazilian Amazon. Nat Sustain. 2022;5(10):853-860

[117] Qin Y, Xiao X, Wigneron J-P, et al. Carbon loss from forest degradation exceeds that from deforestation in the Brazilian Amazon. Nat Clim Chang. 2021;11(5):442-448.

[118] Gillespie TW. Policy, drought and fires combine to affect biodiversity in the Amazon basin. 2021

[119] Zuquette L V, Pejon OJ, Dantas-Ferreira M, Palma JB. Environmental degradation related to mining, urbanization and pollutant sources: Poços de Caldas, Brazil. Bull Eng Geol Environ. 2009;68(3):317-329

[120] Gerson JR, Szponar N, Zambrano AA, et al. Amazon forests capture high levels of atmospheric mercury pollution from artisanal gold mining. Nat Commun. 2022;13(1):559

[121] Gastauer M, Souza Filho PWM, Ramos SJ, et al. Mine land rehabilitation in Brazil: Goals and techniques in the context of legal requirements. Ambio. 2019;48(1):74-88

Key Institutions involved in Mine Restoration and Rehabilitation

National Mining Agency: The National Mining Agency is the regulatory body for the mining sector in Brazil, linked to the Ministry of mines and Energy. It grants mining rights and ensures that mine rehabilitation is properly integrated into the mine closure plan.

Brazilian Institute of Environment and Natural Resources: The Brazilian Institute of Environment and Natural Resources is part of the Ministry of Environment. The activities of the institute involve carrying out actions on national environmental policy and the authorisation of natural resource use and environmental controls.

Brazilian Mining Association: The Brazilian Mining Association is a non-profit organisation with 130 members from the Brazilian mining sector. It promotes innovation, technological development, and sustainability. The association has published a guide for socially, environmentally, and economically sustainable mine closure planning[122].

Financing Arrangements for Mine Restoration and Rehabilitation

The closure and remediation costs estimation is a part of the closure plan, which includes activities during the operational, closure and post-closure phases. These involve conducting surveys, monitoring programmes, landscaping, infrastructure removal and disposal of critical materials after closure. In Brazil, most companies set up a fund to cover the costs of the rehabilitation process. There are different rules to follow for different jurisdictions, but in general it is recommended to set up the fund for all foreseeable costs included in the decommissioning plan and, in addition, to include a certain percentage to cover unforeseeable costs. The provision for the fund usually increases at the beginning of the mine development and remains constant during the active operating period.

Role of the Private Sector in Mine Restoration

Major mining companies like Vale, Anglo American, CSN, and privately owned companies like Priscu and Associates Consulting Engineers, contribute to restoration efforts. The company has completed a mine site rehabilitation project where they have developed closure strategies using a risk-based approach. Vale and other companies viz. Itaú Unibanco, Marfrig, Rabobank, Santander and Suzanne, have created a new company Biomas that aims to contribute to sustainable development through the restoration, protection and conservation of Brazilian biomes. The company's specific goal is to restore 4 million hectares of land within 20 years.

Community involvement and engagement in Mine Restoration

The Brazilian Mining Association's Guide to Mine Closure Planning includes a chapter on community and stakeholder involvement. Engaging the local community begins during the feasibility stage, considering factors like project location, size and stakeholders profiles. Regular updates and consultations foster a collaborative environment, taking community concerns into account.

Academic and Research Institutions Involved in Mine Restoration

- Federal University of Rio de Janeiro: Offers a Bachelor's degree program in Conservation and Restoration,

[122] Sánchez LE, Silva-Sánchez SS, Neri AC. Guide for mine closure planning. Inst Bras Mineração Bras Brazil. 2014

- Centre for International Forestry Research and World Agroforestry: Conducts research on forests and restoration of forest landscapes in Brazil since 2004,
- Technological Institute Vale: The institute is a private non-profit institution promoting science, technology, and innovation in mining to drive sustainable development and socio-environmental changes.

Capacity Building

Environmental Leadership & Training Initiative: Offers free webinar courses on forest and landscape restoration in Brazil as part of the Forest and Landscape Restoration in Practice series.

Instituto de Pesquisas ecológicas: Provides short courses that combine biodiversity conservation projects with education for sustainability, helping professionals put knowledge into practice and connect with researchers.

4 Canada

Key Mining Sectors

Canada's leading minerals by value of production are gold (25%), coal (14%), and iron ore concentrates (12%). Other minerals mined include potash, copper, nickel, sand and gravel, platinum group, and diamonds. In 2020, Canada ranked fifth in gold production globally, with a production value of $12.3 billion and 182 tonnes of gold produced. It is the fourth-largest exporter of metallurgical coal, with Alberta and British Columbia contributing 83% of the country's coal production. Canada is the seventh-largest iron ore producer, with an output of 57.5 million tonnes in 2021, primarily mined in Quebec, Newfoundland, Labrador, and Nunavut[123].

Key Mining Areas

Minerals are produced in every single Canadian province and territory. The value of total Canadian mineral production in 2021 amounted to $55.5 billion. The largest provincial and territorial contributions came from British Columbia ($12.8 billion), Quebec ($11.9 billion) and Ontario ($11.1 billion). In 2021, British Columbia's mining focused on copper, gold and silver. The mining industry in Quebec was centered on gold, iron ore concentrates and silver, while the Ontario mining industry mainly produced cobalt, copper, gold, nickel, silver and platinum gold.

Key Mining Companies

Nutrien: Nutrien produces potash, nitrogen and phosphate with total sales of 27 million tonnes annually. The company operates six potash plants and six nitrogen plants in Canada. The company's headquarters are located in the city of Saskatoon, Canada[124].

Barrick: Barrick produces gold and copper in 18 countries. The company's main gold production site in Canada is in Hemlo, Ontario, where over 21 million ounces of gold have been produced in past 30 years. For 2022, a production of 170,000 ounces of gold is forecasted[125].

[123] Government of Canada. Government of Canada, 2022. Gold facts. 2022. https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts.

[124] https://www.nutrien.com/

[125] https://www.barrick.com/

Newmont: Newmont is a leading gold producer that also produces copper, silver, zinc and lead in North America, South America, Australia and Africa. Canadian gold production sites are in Timmins and Opapamiskan Lake, Ontario, and Eeyou Istchee/James Bay, northern Quebec[126].

Major Environmental Concerns Linked to Mining

Land Degradation

Considering all the material taken out of the ground during mining in an average mine in Canada, approximately 42 % is discarded as waste rock, leaving only 58 % for processing. Out of this remaining amount, 96% becomes slag or toxic tailing, resulting in only 2% being processed into valuable resources. Over the years of production, millions of tonnes of hazardous waste are generated, posing the risk of acid mine drainage and heavy metal pollution[127].

Biodiversity Inclusive Invasive

A technical subcommittee's report on mining impacts on biodiversity in British Columbia highlighted several significant concerns, including surface and subsurface soil degradation, water and soil pollution, atmospheric pollution, and erosion caused by waste rock disposal. The pollution from abandoned mines continues to affect biodiversity, gravel pits, for example, which occur on mining sites, can be the reason for the invasion of noxious weeds, as they are very effective breeding sites due to their location near travel corridors[128].

Chemical Contaminations

Mining various minerals can release highly toxic compounds such as mercury, arsenic, lead, manganese or dioxins these toxins settle in plumes from the release site. The vegetation at that site absorbs the toxins, which eventually move further up the food chain.

Legislative Provisions for Mine Restoration and Rehabilitation

Canadian Environmental Assessment Act: The Canadian Environmental Assessment Act outlines the procedures for conducting environmental assessments during mine rehabilitation. These assessments aim to promote sustainable development, prevent environmental degradation, and ensure the consideration of environmental factors in planning and decision-making processes.

Canadian Impact Assessment Act: The Canadian Impact Assessment Act evaluates the social, environmental, economic, and health impacts of mining projects. It also assesses the impact on indigenous peoples. The Act aims to foster sustainability, establish assessment processes and timelines, and enhance collaboration and coordination[129].

Minerals and Metals Policy of the Government of Canada: The Minerals and Metals Policy, developed through consultations with stakeholders, encompasses legislation for sustainable mining and mine site rehabilitation for future generations. It involves federal ministries, aboriginal communities, provincial mining ministries, environmental groups, and the mining industry[130].

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[126] https://www.newmont.com/

[127] Lalonde L. Curation: Representation in the Reclamation of Sudbury, Ontario Landscapes. 2014

[128] Gayton D. Major Impacts to Biodiversity in British Columbia (Excluding Climate Change). Biodiversity BC; 2007

[129] Regulator AE. & Canadian Environmental Assessment Agency.(2019). Rep Jt Rev Panel Teck Resour Ltd Front Oil Sands Mine Proj.

[130] Government of Canada, 2017. Policy. 2017. https://www.nrcan.gc.ca/our-natural-resources/policy.

Key Institutions involved in Mine Restoration and Rehabilitation

Impact Assessment Agency of Canada: Reporting to the Minister of Environment and Climate Change, the Impact Assessment Agency conducts environmental, social, economic, and health impact assessments. It leads the assessment process for major federal projects, facilitates consultation with Indigenous peoples, and promotes public participation.

Natural Resources Canada: Natural Resources Canada supports scientific innovation and the natural resources sector. Their work includes the minerals and mining sector, highlighted by publications like the Canadian Minerals and Metals Plan that address mine rehabilitation and restoration measures.

National Orphaned and Abandoned Mined Initiative

The National Orphaned and Abandoned Mine Initiative (NOAMI) operates the NOAMI Inventory, a web portal with information on inactive mineral sites across Canadian jurisdictions. NOAMI's advisory committee reports to the Minister of Mines through the Intergovernmental Working Group on the Mineral Industry, analyzing issues and providing recommendations.

Financing Arrangements for Mine Restoration and Rehabilitation

Closure costs are estimated while preparing a mining project's closure and reclamation plan, and it is refined over its lifecycle. Financial assurance approaches vary among provinces/territories in Canada. In Ontario, available instruments include cash, bank guarantees, insurance guarantees, corporate guarantees, and environmental funds, while Quebec offers cash, bank guarantees, and environmental funds. Government involvement in financing mine rehabilitation like direct funding, using mining revenue, imposing levies on mineral production, cost-sharing arrangements, and government-industrypartnerships[131].

Role of the Private Sector in Mine Restoration

The following section presents, three stakeholders from the private sector active in mine restoration.

Canadian Land Reclamation Association: The Canadian Land Reclamation Association is a non-profit organization that promotes corporate participation in mine rehabilitation. It provides a platform for sharing ideas and essential information about reclamation projects. The association is governed by an elected board of directors representing various regions of the country.

Stantec: Stantec is a global private company with expertise in ecosystem restoration. With 26,000 employees, it offers technical consultancy services for projects of any scale. Stantec is also a partner of the United Nations for the Decade for Ecosystem Restoration, emphasizing the importance of thriving ecosystems in improving lives and combating climate change.

Nuna: Nuna is a Canadian company specializing in heavy construction, earthworks, and mining. It is predominantly Inuit-owned and operates in the Canadian Northern Territories, Ontario, and Saskatchewan. Nuna's management team and operations personnel have experience in mine reclamation and rehabilitation.

[131] Cowan WR, Mackasey WO. Rehabilitating abandoned mines in Canada: a toolkit of funding options. Prep Natl Orphaned/Abandoned Mines Initiat Cowan Miner Ltd, Sudbury, Ontario, Canada. 2006

Community Involvement and Engagement in Mine Restoration

The Canadian Environmental Assessment Agency facilitates public participation, including various interest groups such as Aboriginal communities, community organizations, educational institutions, residents, and small business owners. The agency collaborates with federal ministries to engage the public, provide opportunities for commenting on study reports, and offer funding for participation through the Participant Funding Program, primarily linked to environmental assessment projects. The program has regular funding for the public, non-profit organizations, and Aboriginal groups, and an aboriginal funding framework specifically supporting Aboriginal and public consultation.

Academic and Research Institutions Involved in Mine Restoration

- **Canadian Institute of Mining, Metallurgy and Petroleum:** With over 10,000 members, the Canadian Institute of Mining, Metallurgy and Petroleum is a leading industry technical resource for everything related to minerals. The Institute aims to improve awareness of the minerals industry and believes that working with various stakeholders such as expert committees, technical societies and students, will shape a sustainable future for mineral resources.
- **Aquatic Systems Professional and Industrial training for the Restoration Economy:** The Aquatic Systems Professional and Industrial training for the Restoration Economy is an initiative funded by the Natural Science and Engineering Research Council of Canada and is a collaborative graduate research and training programme. The programme aims to provide training on a practical and theoretical basis in aquatic systems restoration projects, enhance the skills required in the environmental rehabilitation sector and create networking opportunities.
- **Mining Association of Canada:** Since 1935, the Mining Association of Canada has worked with governments on mining sector policy and public education. It sees its role as contributing to the sustainable development of Canada's mining sector. Its goal is to create an industry that provides prosperity and opportunity for every Canadian.

Capacity Building

- The University of Victoria offers a continuing studies course on mining reclamation. The course consists of site visits and lectures on policy, environmental impact assessment, mine waste, site closure and reclamation ecology.
- Laurentian University offers a modular in-person course on environmental remediation aimed at professionals and students. Participants will learn about strategies for restoring terrestrial and aquatic ecosystems impacted by mining. The interconnectedness of ecosystems and the impacts of mining play a central role.

5
China

Key Mining Sectors

By 2019, 173 minerals had been discovered in China, including energy materials, metals, non-metallic minerals and gases. The top three sectors were iron ore with production of 840 million tonnes in 2019: crude steel, with a production of 1 billion tonnes and gold production of 500.4 tonnes that same year[132].

Key Mining Areas

The People's Republic of China covers an area of 9.6 million square kilometers. The highest density of mines is found in the east and southeast of the country. The three largest mines (Green Mine, Northern Shaanxi Mine and Daliuta-Huojitu Mine) are all located in Sichuan and Shaanxi, provinces in central China[133].

Key Mining Companies

- **China Shenhua:** China Shenhua Energy Company focuses on its core business, coal mining, but has seven business units, including electricity, coal, new energy, coal chemicals, railways, port handling and shipping[134].
- **China Coal Energy:** China Coal Energy Company Limited focuses on modern coal mining operations by using washing and blending technology. The company has interconnected coal transportation channels and coal ports, which creates favourable conditions for the company[135].
- **Zijin Mining:** Zijin Mining is a multinational mining group engaged in the production of copper, gold, zinc and lithium, as well as research in technology and engineering. Its mining projects span 15 different Chinese provincial regions[136].

[132] Ministry of Natural Resources. Ministry of Natural Resources, 2020. China Mineral Resources, Beijing. Geol Publ House. 2020

[133] Globaldata. China: Five Largest Mines in 2021. 2022. https://www.globaldata.com/data-insights/mining/china--five-largest-mines-in-2090634

[134] http://www.csec.com/

[135] https://en.chinacoalenergy.com/

[136] https://www.zijinmining.com/

Major Environmental Concerns Linked to Mining

Land Degradation and Biodiversity Loss

Human activities in mining areas increase soil erosion and lead to soil degradation. A study investigating the driving factors of soil degradation in mining areas in China found that these factors mainly involve ecological degradation, pollution and natural erosion. Soil degradation can therefore be divided into these three categories[137]. Another study found that underground coal mining in China alters soil ecology, leading to soil degradation, loss of surface water and nutrients[138].

Biodiversity Loss

Industrial mineral extraction requires the expansion of land areas, leading to habitat loss and biodiversity reduction[139]. The transformation of the landscape through mineral exploration and extraction in China is a major threat and contributing to biodiversity loss. A study by Kang et al. (2014)[140] at the Yimin open-pit coal mine found that local biodiversity responded with a time lag to changes in construction patterns in 1975, 1990, 2000 and 2010.

Chemical Contaminations

In China, mining causes pollution that leads to the destruction of water bodies, soils, the atmosphere and vegetation[141]. In particular, pollution from metals from mining and metal smelting is a significant problem. Pollution from the Dexing mine, the largest open pit mine in Asia, has had a devastating impact on local communities. The village of Dai, located 20 kilometers downstream from the mine, suffers extreme pollution from mining. Studies have found high levels of cadmium, chromium, copper, lead and zinc in the hair of residents[142].

Legislative Provisions for Mine Restoration and Rehabilitation

- **Mineral Resources Law:** The Mineral Resources Act defines the basic rules for mining and stipulates that mineral resources belong to the state, regardless of who owns the land rights. It also states that anyone who wants to mine must apply and register after receiving permission. Accordingly, the Department of Geology and Mineral Resources under the State Council is responsible for registering the exploration of mineral resources.
- **Provisions on the Protection of the Geologic Environment of Mines:** The Provisions on the Protection of the Geological Environment of Mines were issued by the Ministry of Land and Resources in 2009. It builds on the Mineral Resources Act and specifies that to apply for a mining licence, the applicant must prepare

[137] Li H, Shen W, Si W, Yan Q. Investigation of driving factors of land degradation in mine areas in China: concept, types and approaches. J Ecol Rural Environ. 2015;31(4):445-451

[138] Ma K, Zhang Y, Ruan M, Guo J, Chai T. Land subsidence in a coal mining area reduced soil fertility and led to soil degradation in arid and semi-arid regions. Int J Environ Res Public Health. 2019;16(20):3929

[139] Lu Y, Yang Y, Sun B, et al. Spatial variation in biodiversity loss across China under multiple environmental stressors. Sci Adv. 2020;6(47):eabd0952

[140] Kang S, Zhang Q, Niu J, et al. Effect of mining landscape history on local species diversity: a case study of the Yimin open-pit coal mine in Inner Mongolia. Biodivers Sci. 2014;22(2):117-128

[141] Wang Y, Wu X, He S, Niu R. Eco-environmental assessment model of the mining area in Gongyi, China. Sci Rep. 2021;11(1):17549

[142] Lin W, Wu K, Lao Z, et al. Assessment of trace metal contamination and ecological risk in the forest ecosystem of dexing mining area in northeast Jiangxi Province, China. Ecotoxicol Environ Saf. 2019;167:76-82

a geological environment restoration plan that includes specific measures, a budget estimate and a commitment to deposit a security for the restoration measures[143].

- **Regulation on Environmental Impact Assessment of Planning:** The Regulation on Environmental Impact Assessment of Planning was issued by the State Council in 2009. State Council ministries and local governments and their relevant departments must conduct an environmental impact assessment when planning matters such as land use, construction or natural resource development[144].

Key Institutions Involved in Mine Restoration and Rehabilitation

- **Ministry of Natural Resources:** The Ministry of Natural Resources is a ministerial-level sub-department responsible for implementing guidelines and agreements on natural resources. It coordinates the restoration of mined land through national-level restoration plans, major projects, and compensation systems for environmental protection.
- **Ministry of Ecology and Environment:** The Ministry of Ecology and Environment aims to enhance environmental quality in China. It collaborates with other government agencies to develop environmental policies, regulations, and standards. The ministry investigates cases of environmental pollution and actively participates in environmental restoration and compensation measures.
- **Technical Innovation Center for Mine Geological Environment Restoration Engineering:** This centre, approved by the Ministry of Natural Resources, focuses on mine area restoration research. Managed by the Department of Natural Resources in Guangxi, it collaborates with institutions such as the Institute of Karst Geology and conducts research on restoration topics[145].
- **Chinese Research Academy of Environmental Sciences:** Established under the Ministry of Ecology and Environment, the academy plays a vital role in advancing environmental science and technology. It addresses significant environmental challenges, promotes international cooperation on global issues, and provides technological support, integration, and demonstration in environmental protection[146].
- **Nanjing Institute of Environmental Science:** Founded in 1978, this public research institution conducts forward-looking research in ecological conservation, soil pollution prevention, and control. Its research spans various areas, including biodiversity conservation, pollution prevention, and environmental engineering. The institute also offers extensive technical consulting services in ecological and environmental planning, certification, safety assessment, and contaminated site remediation[147].

Financing Arrangements for Mine Restoration and Rehabilitation

In 1998, China implemented a bond system in Zhejiang province to facilitate mine rehabilitation. This system was subsequently adopted by all provinces, autonomous regions, and municipalities under the central government by 2013. While three national policies promote the mine rehabilitation system, each province has its own regulations and implementation measures. Currently, there is no national authority overseeing bond or reclamation standards, districts or provinces handle the calculation, collection, and release of deposits. Cash

[143] Ministry of Land and Resources. Provisions on the Protection of the Geologic Environment of Mines. 2009

[144] State Council. Regulation on Environmental Impact Assessment of Planning. 2009. http://en.pkulaw.cn/display.aspx?cgid=120685&lib=law

[145] Center MGERETI. Mine Geological Environment Restoration Engineering Technology Innovation Center. 2022

[146] http://www.craes.cn/en/

[147] https://www.nies.org/ywz/about_us/brief_introduction/

bonds deposited in designated bank accounts are managed by the Finance Department, Ministry of Lands and Resources, and mining companies. Each province employs its own calculation methods, considering factors such as mineral type, mine area, sales revenue percentage, and mineral production. Zhejiang province also applies, a scaling coefficient based on mining disruption depth. Typically, deposits are released after the completion of reclamation work if the permit duration is less than three years. For permits exceeding three years, release occurs after each reclamation phase is finished[148].

Role of the Private Sector in Mine Restoration

- **SGS Group:** Companies like SGS Group support mining companies in managing their environmental impact and conducting impact assessments to minimize environmental harm and enhance operational efficiency. They identify potential issues, such as pollution and contamination, early in planning to facilitate effective remediation measures.
- **SRK Consulting:** SRK Consulting operates offices in Beijing, Hong Kong, and Nanchang, offering a range of consulting services related to mining. Their expertise spans mine closure and rehabilitation, contaminated site assessment, stakeholder consultation, public involvement, and environmental and social management planning.
- **China Coal Company:** China Coal Company exemplifies private-sector mining companies actively engaged in mine site rehabilitation. In 2006, the company invested $51.5 million in ecological restoration, with $32.9 million allocated to the endangered Pingshuo mining area in Shanxi Province. By the end of the year, approximately 30,000 hectares of mined land were rehabilitated, featuring the cultivation of 6 million plants and 1,000 hectares of herbs. The rehabilitation rate reached 41.6%, significantly improving the ecological environment of the mining area[149].

Community Involvement and Engagement in Mine Restoration

There is no legislation for community participation or engagement in China. However, large mining companies such as Zijin Mining have committed to encouraging local community engagement and participation at their mining sites[150]. Their budget for the original mining plans already includes funds for post-closure land restoration and worker and community development plans. Zijin Mining has committed to investing no less than 1% of its profits annually in community projects and providing e-funds for local people's education, healthcare and medical care. The company also supports local suppliers and provides local employment.

Academic and Research Institutions Involved in Mine Restoration

- **China University of Mining & Technology - Beijing:** The China University of Mining & Technology Beijing has a Faculty of Chemical and Environmental Engineering. It is divided into three departments, one of which is the Department of Environmental and Bioengineering. The research deals with treating environmental pollution in coal processing and the ecological rehabilitation of mines.

[148] Cheng L, Skousen JG. Comparison of international mine reclamation bonding systems with recommendations for China. Int J Coal Sci Technol. 2017;4:67-79.

[149] Company CCE. China Coal Energy Company Limited, 2022. Annual Report 2021. 2022

[150] Zijin Mining. Zijin Mining Community Development.
https://www.zijinmining.com/sustainable/Community_Development.htm%0A

- **Chinese Academy of Sciences :** The Chinese Academy of Sciences has a Research Centre for Eco-Environmental Science, which includes a Laboratory for Soil Environmental Science. It was established in 2002 in close collaboration with the University of Adelaide in Australia to develop a research cluster for ecological soil sciences. It also conducts research on sustainable soil management and rehabilitation[151].
- **Xinjiang Research Center for Mineral Resources of CAS :** The Xinjiang Institute of Ecology and Geography includes the Xinjiang Research Centre for Minerals and Resources and the Department of Desert Environment and Ecological Restoration. Its research areas include strategies for the sustainable extraction of mineral resources in China and measures for ecological restoration.

Capacity Building

The Institute of Soil and Water Conservation, the Chinese Academy of Sciences and Northwest A&F University offers 18 days training course on soil-water conservation and ecosystem restoration for advanced researchers and technicians. The training programmes covers subjects like the environmental effects of soil erosion and green catchment after ecological restoration[152]. The Institute also conducts a training course on Regional Biodiversity Conservation and Sustainable Development in collaboration with various sponsors and organisers. The training programme focuses on the biodiversity of the tropical region of Asia and the monitoring and conservation of biological resources[153].

[151] Research Center for Eco-Environmental Sciences. Laboratory of Soil Environmental Science. 2011. http://english.rcees.cas.cn/rh/rd/200906/t20090609_5371

[152] Hu Y. Training Course on Soil-Water Conservation & Ecosystem Restoration. 2018.

[153] Zhao C, Gong J, Zeng Q, Yang M, Wang Y. Landscape pattern evolution processes and the driving forces in the wetlands of lake Baiyangdian. Sustainability. 2021;13(17):9747

6 France

Key Mining Sectors

In France, key mining sectors include tungsten, gold, antimony, aggregates, gypsum, andalusite, talc, and silica. Salts, bauxite, bituminous limestone, tin-tantalum-niobium, and fluorite are also extracted. Gold comes from Guyana, while nickel and cobalt are extracted from New Caledonia. Quarries play a significant role, in supplying construction materials, ornamental rocks, and industrial minerals. France is also involved in primary mineral processing, such as cement, lime, plaster production, and various metallurgical activities. The environmental code regulates these activities, and in addition, the mining code for the extraction of certain substances (mining substances and extractive activities at sea) The mining and quarrying industry's production value decreased in 2020[154], reaching its lowest point at $3.9 billion[155]. Notably, France is a leading talc producer and ranks second in andalusite production[156].

Key Mining Areas

In metropolitan France, there are about 450 valid concessions, 20 of which are operational. French Guiana has gold reserves and New Caledonia has Nickel[157]. France no longer has any operating coal mines with the La Houve Mine closing in 2004[158]. The Pyrenees region is rich in iron ore and has a centuries-old iron-making tradition[159]. Being a leading country in nuclear power, France has a stable supply for its power plants. Its Uranium reserves are in Limousin, Morvan, and Fore-Madeleine in the Central French massif and the Vendee regions[160]. As for Aluminum, Saint-Jean-de-Maurienne, and Dunkirk, are the sources for primary Aluminum. Trimouns is the largest talc quarry in the world. It's situated at 1800m altitude above the Ax valley in the

[154] CEIC. CEIC Data, 2020. France Minetral Production. 2020. https://www.ceicdata.com/en/indicator/france/minerals-production

[155] Statista. Statista, 2020. Production value of the mining and quarrying sector in France from 2009 to 2020. 2020. https://www.statista.com/statistics/425728/production-value-mining-quarrying-sector-france

[156] Botha BW. An Overview of Andalusite from Southern Africa: Geology and Mineralogy. In: The Southern African Institute of Mining and Metallurgy, Refractories 2010 Conference, 8p. ; 2010

[157] Mineral Information France. Mineral Information France, 2022. The French Portal for Mineral Resources. 2022. https://www.mineralinfo.fr/fr/ressources-minerales-france-gestion/potentiel-du-sous-sol-francais. [Accessed 23 12 2022].

[158] Abdale, L.; M. Trimmer L. 2017-2018 Minerals Yearbook - USGS, 2017–2018 Minerals Yearbook. USGS. 2022. https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-italy.pdf

[159] Graf M, Popesku J. Cultural routes as innovative tourism products and possibilities of their development. Int J Cult Digit Tour. 2016;3(1):24-44

[160] Gerden E. Resource World- France aims to retain leadership in global uranium mining. 2020. https://resourceworld.com/france-aims-to-retain-leadership-in-global-uranium-mining/ [Accessed 23 12 2022]. %0A

commune of Luzenac in the high Ariège[161]. In France, and alusite is found in the Alps and also in Brittany (Glomel, Côte d'Armor) where this mineral (chiastolite variety), extraordinarily abundant, is exploited for the manufacture of refractories; this site is currently the second largest producer of and alusite in the world with 60,000 tons per year extracted.

Key Mining Companies

Eramet: Established in 1880 and headquartered in Paris, Eramet is a French multinational mining and metallurgy company. It is a world leader in producing ferronickel for the stainless-steel market and high-performance alloys like nickel and titanium. With 40 production sites in Europe, including France, Sweden, Norway, and Spain, Eramet is at the forefront of mineral processing, refining, and recycling innovation[162]. The company has committed to improving operational performance and sustainability, becoming a signatory of the UN Global Compact in 2019.

Orano Corp: Formed in 2017 after the restructuring of Areva S.A., Orano Corp is a multinational nuclear fuel cycle company headquartered in Châtillon, Hauts-de-Seine. It engages in uranium mining, conversion-enrichment, fuel recycling, nuclear logistics, dismantling, and engineering activities. With 17 industrial sites in France, Orano is the world's second-largest uranium producer, holding a 9% share in global uranium production. The French state owns majority of the company.

Imerys S.A.: Headquartered in Paris, Imerys S.A. is a significant French industrial minerals producer. Its 32 industrial sites in France specialize in minerals such as diatomaceous earth, kaolin, and and alusite. The Luzenac site, operating the largest talc quarry in Europe, is part of Imerys. The company exports 70% of its minerals to over 100 countries. Imerys is committed to sustainable development, taking actions to reduce CO_2 emissions, collaborate with local communities, preserve ecosystems, and engage in quarry rehabilitation. It has partnered with organizations like the Natural History Museum and act4nature to protect biodiversity and develop responsible mineral extraction processes.

Major Environmental Concerns Linked to Mining

Land Degradation: The persistence of long-term effects is unavoidable, as old mining activities did not aim to avoid long-term harmful environmental effects. Considering the large extent of underground mining works developed in large mining areas, restoring land to its initial state is impossible. For example, the Lorraine iron basin (NE of France), has 40,000 km of mine galleries drilled underground. Under such conditions, mining extraction induces an irreversible disturbance of the rock mass behaviour[163]. Gold mining sites are characterized by loss of vegetation, bare soil, water contamination, and soil contamination, resulting in degraded forest. Forest areas impacted by mining activities were identified in the Guiana Shield (Guyana, Surinam, French Guiana) in 2000, 2008 and 2014 by ONF (Office National des Forêts) and ONFI (International French Forest Service) in French Guiana, SBB (Foundation for Forest Management and Production Control) in Suriname and collaboration with the World Wildlife Fund (WWF), using high-resolution satellite images (SPOT, Landsat and Rapid Eye images, see supplementary document)[164].

[161] Graf M, Popesku J. Cultural routes as innovative tourism products and possibilities of their development. Int J Cult Digit Tour. 2016;3(1):24-44

[162] Fine Future. Eramet, France. 2020

[163] Christophe Didier, Jacques Leloup. The French experience of post mining management. 1. International seminar on mine closure, Sep 2006, Perth, Australia. pp.199-210. ffineris-00972547

[164] Gallay M, Martinez J, Allo S, et al. Impact of land degradation from mining activities on the sediment fluxes in two large rivers of French Guiana. L Degrad Dev. 2018;29(12):4323-4336

Biodiversity, Including invasive species: The mining industry is identified as a significant threat to Biodiversity in France. New Caledonia is a widely recognised marine and terrestrial biodiversity hot spot. However, this unique environment is under increasing anthropogenic pressure. Major threats related to land cover change include fire, urban sprawling, and mining. Resulting habitat loss and fragmentation end up in serious erosion of the local biodiversity. Mining is of particular concern due to its economic significance for the island[165]. After an overwhelmingly supportive vote by governments and civil society groups, a motion calling for a ban on deep-sea mining has been adopted in Marseille at the world's biggest biodiversity summit since the pandemic[166]. One of the biological indicators towards rehabilitated gravel-sand pit is bats activity. In quarries rehabilitated for more than 10 years there was a significant greater bat activity observed as compared to newly rehabilitated quarries[167].

Chemical Contamination : In France, around 6500 sites have been identified as contaminated, with about 50% concentrated in former mining regions. Abandoned mines can result in potentially harmful surface or underground water flow modifications and surface instability developments capable of affecting, sometimes dangerously, people or goods located in the surroundings[168]. The town of Salsigne, in southwest France, was once home to the largest gold mine in Europe and the largest arsenic mine in the world. The mine closed in 2004 but left in its wake one of the most polluted sites in France[169].

Legislative Provisions for Mine Restoration and Rehabilitation

The mineral industry in France is governed by the French Mining code, which includes specific regulations and decrees such as no. 80-331, 2006-648, and 2006-649. According to Law No. 99-245, rehabilitation operations are mandatory after mining activities cease, and the state requires a financial guarantee from mining operators for quarry rehabilitation. In abandoned or orphaned mines, the French State assumes responsibility and implements safety measures. Exploration and extraction of mineral resources necessitate mining titles and operation permits. In 2017, the government enacted a law (no. 2017-1839) to ban new hydrocarbon exploration in line with the Paris agreement. The French Ministry of Industry and Mines requested INERIS to develop guidelines for mining works closure applications, providing technical optimization and efficiency[170].

Key Institutions involved in the Restoration and Rehabilitation of Mines

The Minister of the Economy, in conjunction with the Minister of the Environment for energetic materials, is responsible for reviewing and granting exploration and extraction titles. The issuance of mining titles falls under their jurisdiction. Operation authorization applications and declarations are examined by the Préfet

[165] Losfeld G, L'huillier L, Fogliani B, Jaffré T, Grison C. Mining in New Caledonia: environmental stakes and restoration opportunities. Environ Sci Pollut Res. 2015;22:5592-5607

[166] The Guardian. The Guardian. 2021. https://www.theguardian.com/environment/2021/sep/09/marseille-biodiversity-summit-adopts-motion-to-ban-deep-sea-mining [Accessed 25 12 2022]

[167] Kerbiriou C, Parisot-Laprun M, Julien JF. Potential of restoration of gravel-sand pits for Bats. Ecol Eng. 2018;110:137-145

[168] Flores SS. What is sustainability in the wine world? A cross-country analysis of wine sustainability frameworks. J Clean Prod. 2018;172:2301-2312

[169] DUNDAS M. France24. 2019. https://www.france24.com/en/20190216-down-earth-france-pollution-gold-mine-arsenic-toxic-waste-salsigne-aude [Accessed 25 12 2022].

[170] Didier C. The French experience of post-mining management. In: Symposium Post-Mining 2008. ASGA. Vandoeuvre-lès-Nancy; 2008:NC

(representative of the state in the department), the representative of the State in the department, who also issues operation permits. The administrative monitoring and mining police operate within their respective departments under the authority of the Minister overseeing mines. To provide the necessary scientific expertise and risk management, a Scientific structure called GISOS has been established, comprising public organizations such as INERIS, BRGM, Polytechnical Institute of Lorraine, and the School of Mines of Paris. GISOS focuses on research in the comprehension, characterization, and modeling of mechanisms and structures, the role of fluids (water and gas), and risk analysis principles. Periodically, GISOS organizes international post-mining symposiums to share knowledge and advancements with foreign experts in the field of post-mining.

Financing Arrangements for the Restoration and Rehabilitation of Mines

Mining companies holding titles for non-hydrocarbon deposits must furnish a financial guarantee before commencing exploration and extraction, particularly for mines with waste management facilities. The guarantee amount is determined based on the permit information.

As per the 1999 "post-mining law," if technical or financial constraints prevent the identification of feasible risk treatment measures, it becomes the responsibility of the Concession-Holder to monitor and ensure public safety by preventing foreseeable accidents. Monitoring can be carried out during a transitional period when risk management measures are implemented, such as backfilling and relocating individuals. To transfer monitoring management to the State before mine closure, mining companies are required to deposit funds for ten years of monitoring hazardous areas. In the case of abandoned mines, the authorities assume permanent monitoring responsibilities[171].

Mining site rehabilitation committees (CRSM) led by municipalities have rehabilitated areas affected by mining activities before 1975 for over 20 years. The funding for these committees was provided through specific tax provisions. This tax system has supported numerous municipal environmental funds. The Nickel Fund has further supplemented these efforts through a multi-year rehabilitation program (PPR) and a multi-year intervention plan (PPI) to manage watercourse over-engraving directly linked to pre-1975 mining. Mining companies contribute to this remediation as part of their operating decree obligations[172].

Role of the Private Sector in Mine Restoration

The French private sector plays a significant role in mine restoration efforts. Companies operating in the mining industry are responsible for implementing rehabilitation measures and restoring degraded areas. They are required to comply with regulations and guidelines set by the government to mitigate the environmental impacts caused by mining activities. The private sector actively contributes to mine restoration efforts. For instance, Eramet, a multinational mining and metallurgy company, has made significant strides in rehabilitating mining sites and implementing environmental restoration measures. They prioritize the restoration of degraded areas and invest in innovative technologies for sustainable mining practices. Imerys, a major industrial minerals producer, also plays a vital role in mine restoration, focusing on quarry rehabilitation and reducing environmental impacts. These companies collaborate with local communities and government agencies to ensure effective restoration and mitigate the environmental consequences of mining activities.

[171] Didier C. The French experience of post-mining management. In: Symposium Post-Mining 2008. ASGA. Vandoeuvre-lès-Nancy; 2008:NC

[172] Bailly F, Amir H, Bart F, et al. Environnement et restauration des sites miniers. Géologues. 2021

Community Involvement and Engagement in Mine Restoration

Effective community engagement has been a key factor in successfully restoring mining-affected areas in France. In the case of the former saltworks in Camargue, a productive dialogue was established with the local actors and inhabitants of the nearby village of Salin de Giraud. Various initiatives such as public meetings, guided tours, photo exhibitions, and workshops were organized to raise awareness and foster community acceptance. Information panels, brochures, and videos were produced to educate the population about climate change issues and involve them in decision-making.

Another example is the town of Loos-en-Gohelle in northern France, which faced unemployment, poverty, and environmental challenges following the closure of its coal mines. The community took proactive measures by organizing assemblies that brought together entrepreneurs, local government representatives, and neighbors. Together, they devised innovative ideas to revitalize the town and presented a comprehensive plan to the state. As a result, Loos-en-Gohelle has become a remarkable example of how a town can embrace its mining history while transitioning to sustainable energy sources. Today, solar panels adorn the remaining spoil tips, showcasing the town's commitment to a greener future.

Academic and Research Institutions Involved

- **The École des Mines d'Alès:** Offers specialized training in ESERM (Environment,[173] safety, and exploitation of mineral resources, in addition to Its Master Environment and Mining program[174].
- **Bureau de Recherches Géologiques et Minières (BRGM):** The various roles of BRGM are as follows: technological research and development and innovation; support for public policies and citizen information; international cooperation and development aid; safety and monitoring of former mining sites. The institute works for better management of water, polluted sites and soils, waste and mineral resources. The BRGM is actively involved as a coordinator and/or partner in several European projects.
- **Water, Environment and Urban Systems Laboratory (Leesu), University of Paris-Créteil,** conduct research on the impact of restoration on the environment. The laboratory in collaboration with the Observatory of Sciences of the Universe, Géosciences has shown the positive result of the restoration of lands.

Capacity Building

The Center of Advanced Studies for Safety and Environmental Concerns in Mining (CESSEM), Ales School of Mines, and the Centred' Etudes Superieuresdes Marées Premieres (CESMAT) with the support of UNESCO, organise a cource on Environmental and Safety Concerns in Mining Activities. The course aims to integrate safety and environment in the design, management, and rehabilitation of a mine or quarry. The Alès School of Mines provides a Specialized Masters course, for Bachelor graduates and executives on, “Environmental Issues of the Extractive Industry”. The course will train executives capable of integrating the environmental issues linked to the activities of the extractive industry, by providing them with a base of knowledge in geosciences for engineers, methods and techniques of exploitation, valorization of mineral resources and preservation of the environment .

[173] Couic E, Tribondeau A, Alphonse V, Livet A, Grimaldi M, Bousserrhine N. The Impact of Ecological Restoration on Biogeochemical Cycling and Mercury Mobilization in Anoxic Conditions on Former Mining Sites in French Guiana. Microorganisms. 2021;9(8):1702

[174] Sustrac G, Cojean R. Risques naturels: retour d’expérience sur la prévention et la gestion des catastrophes. Géologues. 2014;(spécial 182):1

7 Germany

Key Mining Sectors

The Federal Republic of Germany is one of the largest consumers of raw materials, especially in terms of mineral resources. While some raw materials are obtained domestically, there is an increasing reliance on secondary raw materials acquired through recycling[175]. Notably, non-metallic resources such as potash, rock salt, stones, and soils predominantly stem from domestic production. However, Germany's access to primary metallic resources heavily relies on imports from other countries[176].

In 2021, Germany's production statistics encompassed notable figures, including 126.3 million metric tons of lignite, 1.81 million metric tons of petroleum, 6.0 billion cubic meters of natural gas, and approximately 620 million metric tons of mineral raw materials. Additionally, there were roughly 5.4 million cubic meters of peat and an estimated 200 million metric tons of mineral raw materials sourced from small, non-reporting companies. Overall, these production volumes accumulated approximately €13.5 billion, representing 0.37% of the country's gross domestic product (GDP) for 2021[177].

In terms of both volume and value, sands and gravels emerged as the most significant mineral resources, accounting for approximately 309 million metric tons and €2.82 billion, respectively. Together with quarried natural stones at 219 million metric tons, they constituted roughly 80% of the extracted raw materials. Meanwhile, lignite remained the foremost domestic fossil energy source, ranking third in production with a notable increase[177,178].

Key Mining Areas and Key Mining Companies

Germany has a long-standing mining tradition with diverse reserves of raw materials spread unevenly across the country[179]. Mining activities in Germany date back to Roman times, with iron extraction in the Alps and silver ore, tin, copper, iron and cobalt mining in the Harz and Ore Mountains[180]. After World War II, uranium mining

[175] BMWK 2023: https://www.bmwk.de/Redaktion/EN/Dossier/raw-materials-and-resources.html

[176] BGR 2023: https://www.bgr.bund.de/DE/Themen/Min_rohstoffe/min_rohstoffe_node.html

[177] BGR 2022: https://www.bgr.bund.de/DE/Themen/Min_rohstoffe/min_rohstoffe_node.html
BGR 2022: Deutschland – Rohstoffsituation 2021. 162 p., Hannover

[178] DeStatis 2021: https://www.destatis.de/DE/Themen/Wirtschaft/Volkswirtschaftliche-Gesamtrechnungen-Inlandsprodukt/Methoden/bip.html

[179] BMWK 2023: https://www.bmwk.de/Redaktion/EN/Dossier/raw-materials-and-resources.html

[180] BMWK 2023: https://www.bmwk.de/Redaktion/EN/Dossier/raw-materials-and-resources.html

became significant in the Ore Mountains, making Germany the world's fourth-largest producer. Uranium mining ceased in 1990, and the state-owned company Wismut GmbH was established for remediation[181]. Extraction of Lithium from the Ore mountains is currently being explored. Salt mining, particularly potash salts, is an ongoing tradition in Germany, ranking fourth globally in production[182]. The best-known company here is K+S AG, which is headquartered in Kassel[183].

Hard coal mining ended in 2018, while lignite mining continues in three districts: Rhenish, Central German, and Lusatian. The RAG foundation was established for managing and financing the German hard coal mining oblications[184]. In 2021, production stood at around 126.3 million metric tons. Land use amounts to around 1,800 km², of which 1,260 km² has been rehabilitated[185]. The most crucial active mining companies are RWE Power AG[186], LEAG[187] and MIBRAG[188].

To address the consequences of mining, the state-owned company LMBV ("Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH", or *Lusatian and Central German Mining Administration Company*)[189] was established, focusing on remediation. LMBV is responsible for rehabilitating over 1,000 km² of land, restoring it for reuse, eliminating hazards, and reintegrating it into natural cycles.

Major Environmental Concerns Linked to Mining

Land Degradation: The reclamation of the Deutsche Demokratische Republik or German Democratic Republic (GDR's) former lignite industry presented significant environmental challenges. Land degradation encompassed 224 abandoned mining pits, resulting in a 12.7 billion cubic meters groundwater deficit over 2,100 km^2 of land. Around 1,200 suspected contaminated sites needed remediation, and numerous obsolete facilities, such as two briquette factories, six industrial power plants, 46 refining sites, and 42 power plant facilities, required demolition. In addition, open dumping areas covering over 300 caused considerable dust pollution.

Post-mining lakes, formed from 170 leftover pits, covered 270 km^2 and became important tourist destinations. The reclamation work aimed to create equilibrated water balances and minimize anthropogenic control interventions. Approximately 670 km of embankments needed secure shaping, with only 44% being naturally grown slopes. To date, around 1.2 billion m^3 of dumped soil mass have been compacted to secure embankments, with a focus on stabilizing inadequate inner-dump sites[190,191,192,193].

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[181] https://www.wismut.de/en/

[182] Verband der Kali- und Salzindustrie 2023: https://vks-kalisalz.de/bergbau/bergwerke/

[183] https://www.kpluss.com/en-us/index.html

[184] https://www.rag-stiftung.de/en/

[185] DEBRIV 2022: Jahresbericht 2021, Annex 1, 12

[186] https://www.rwe.com/en/the-group/rwe-power/

[187] https://www.leag.de/en/

[188] https://www.mibrag.de/

[189] https://www.lmbv.de/

[190] Jantsch P. 2012: In: 20 Jahre Verwaltungsabkommen Braunkohlesanierung– Geschichten und Gesichter der Braunkohlesanierung, p.12

[191] Zschiedrich K. 2012: In: 20 Jahre Verwaltungsabkommen Braunkohlesanierung– Geschichten und Gesichter der Braunkohlesanierung, p.41

[192] LMBV 2022: Nachhaltigkeitsbericht 2021, 55 p.

[193] Drebenstedt C., Kuyumcu M. (Hrsg.) 2014: Braunkohlesanierung, Springer-Verlag, 688 p.

Pollution: The lignite refining plants caused severe pollution, including fly ash and sulphurous flue gases, resulting in altered forest and agricultural soils[194]. Forest dieback and the leaching of acid, sulphate, and iron into surface waters impaired ecological properties and affected drinking water extraction. Moreover, potash-salt tailings led to severe salt contamination in rivers.

Biodiversity: Mining, especially opencast mining, negatively affected biodiversity, reducing species abundance and variety. European law mandated implementing Continuous Ecological Function (CEF) measures to create replacement habitats for protected species. Over 88 of Fauna Flora Habitats (FFH) and more than 220 km^{2}of Special Protection Areas (SPA) were designated to protect endangered flora, fauna, and wild bird species. The reclamation efforts successfully created new habitats and refuges for indigenous plants and animals, including rare and unproductive areas.

Social: The closure of mining operations resulted in significant job losses. The lignite industry alone employed around 150,000 people in 1989, which decreased to about 10,000 by 1999. The potash, spar, and ore mining operations saw a similar decline from around 29,000 to a few hundred employees. The high impact on employment levels was a key focus of mine reclamation measures, actively supported by subsidies from the Federal Employment Agency. By 1995, the number of employees in subsidized jobs rose to more than 17,000, with an additional 7,000 jobs secured through subcontractors[195,196,197].

Despite the reclamation efforts, some migration out of the mining regions was unavoidable. Between 1991 and 2009, the labour force decreased by more than 180,000 in the Lusatian mining district and around 165,000 in the Central German mining district. This led to population declines and an aging population in affected areas, such as Hoyerswerda, which suffered a population loss of almost 60% by 2019[198,199,200].

Statutory Framework and Provisions for Mine Reclamation and Rehabilitation

The Federal Mining Act (BBergG) and state regulations regulate mining operations in Germany. Mining companies myst comply with Compliance with federal and state laws on water, environmental protection, and nature conservation. After mining operations end, companies are obligated to remediate public hazards and create suitable areas for future use. European Union environmental laws, such as the directive on the conservation of wild bird species (Special Protection Areas, or SPA), the fauna flora habitat directive (Special Areas of Conservation, or SAC), and the Water Framework Directive (WFD), which are integrated with the NATURA 2000 objective such as directives on wild bird species, habitats, and water, must be observed. Regional spatial development plans define mining boundaries, infrastructure requirements, and post-mining landscapes.

[194] Hartmann P., Fleige H., Horn R. 2009: Veränderung bodenphysikalischer Eigenschaften von Humusauflagen auf ehemals flugaschebeeinflussten Waldstandorten der Oberlausitz. In: Waldökologie, Landschaftsforschung und Naturschutz, Edition 8, pages 41– 52

[195] Drebenstedt C., Kuyumcu M. (Hrsg.) 2014: Braunkohlesanierung, Springer-Verlag, p. 12

[196] Rudolph H. 1990: Mitteilungen aus der Arbeitsmarkt- und Berufsforschung, 23.Jg./1990 Offprint, p. 474-503 24 Motzkus A. 2001: Regionale und strukturelle Aspekte der Arbeitslosigkeit in Ost und West. In: Informationen zur Raumentwicklung. Edition 1/2001, 10 p.

[197] Drebenstedt C., Kuyumcu M. (Hrsg.) 2014: Braunkohlesanierung, Springer-Verlag, p. 28

[198] Wikipedia 2023: https://de.wikipedia.org/wiki/Einwohnerentwicklung_von_Hoyerswerda

[199] Stadtverwaltung Hoyerswerda 2020: Strukturdaten der Stadt Hoyerswerda nach Stadt- und Ortsteilen, 2019

[200] Handelsblatt 2023: https://www.handelsblatt.com/politik/deutschland/hoyerswerda-die-stadt-deralten/4321432.html

- Approval procedures and environmental studies are necessary for activities that disturb natural foundations or harm the environment.
- Reclamation plans extend beyond the usual time horizon and may require adjustments.
- The example of LMBV illustrates the challenges of harmonizing mining regulations between the former GDR and the Federal Republic of Germany.
- Responsibility for mining legacies depends on whether all required work was completed during the GDR period or if reclamation was still ongoing after October 3, 1990.
- Regulations were created in the Unification Treaty to harmonize differences between GDR mining law and the Federal Mining Act.
- According to the Federal Mining Act, the LMBV is generally responsible for rehabilitating sites if reclamation work is incomplete or mining continued beyond October 3, 1990.

Institutional Framework for Monitoring and Evaluating Mine Rehabilitation

The monitoring and evaluation of mine rehabilitation is carried out at various levels in Germany.

- Mining activities, from exploration, extraction and processing to mining and reclamation, are subject to legal regulations, particularly the Mining Act (BBergG). Typically, for each step, a corresponding plan must be submitted to the relevant authorities for approval, or for subsequent authorization within an approved framework. Along with their authorisation, authorities impose conditions for the monitoring of reports and documentation that must be submitted. Supervision does not end until the relevant authority has assessed the completion of all mining reclamation obliged and that there is no longer any likelihood of danger to third parties, to other mining operations and storage sites, or of any harmful impacts to the public.
- Economic viability must be demonstrated, particularly with regard to the remediation of hazards to people and environmental assets resulting from the approved mining activities. The relevant authority may require reserves and collateral.
- Authorizations for further continuing mining activities within the approved framework are only granted for limited periods. For further continuation, evidence of compliance with the conditions imposed in a permit, e.g., progress reports on rehabilitation efforts carried out in the interim, surveying documents and environmental reports, must be submitted.
- Companies are also required to report to regional planning associations, where appropriate.
- Approvals and permits from the environmental authorities (water, immission control, soil protection, nature conservation, etc.) must be obtained from the respective authority and settled. In addition, the respective competent authorities may, issue further administrative acts in principle.

The "Steuerungs- und Budgetausschuss der Braunkohlesanierung" (*Steering and Budget Committee for Lignite Reclamation*, or StuBA) is a committee comprising of federal representatives and representatives of state ministries of the federal states of Brandenburg, Saxony, Saxony-Anhalt and Thuringia. This committee decides on the financing of reclamation projects.

LMBV, as the project management organisation for mine reclamation, plans the relevant projects and submits applications. The StuBA office examines the applications and monitors the implementation and use of funds. This is because public fund finance LMBV's reclamation work from the federal government and the four federal states involved.

Key Institutions Involved in Mine Reclamation and Rehabilitation

In the Federal Republic of Germany, responsibility for the approval, monitoring and termination of mining activities lies with the individual federal states. The mining authorities are state-level authorities and perform their duties in accordance with the Federal Mining Act.

Since mining is always a spatial undertaking, state planning must decide on the basic permissibility of a mining project. Each federal state has a state planning structure, which may be further subdivided into planning regions.

Mining cannot take place without impacting environmental systems, air, soil, water, as well as flora and fauna. Accordingly, these specialized authorities play an important role at every step of mining activities. LMBV also goes a step further here. The concrete design of a reclamation measure is presented to and agreed upon in regional working groups in the respective federal states. These regional working groups submit a vote on implementing a specific reclamation measure to StuBA. Finally, the mining companies are involved in mine reclamation and re-cultivation.

Financing Arrangements for Mine Reclamation and Rehabilitation

Following the polluter pays principle, each mining company is solely responsible for the rehabilitation of the affected areas in line with the public interest. This also applies to any resulting financial obligations. Companies are required by commercial law to set aside reserves during the operational period of mining, which is used for rehabilitation after the end of the operation. Auditors certify the amount of the reserves annually. Moreover, the mining authorities checking the reserves in terms of reason and amount and are constantly adjusted according to rehabilitation needs. In addition to the reserves, there may also be precautionary agreements between mine operators and federal states that financially secure the fulfilment of the re-cultivation obligations after the end of active mining.

The situation is different in the cases of mines with cessation of mining operations when the Federal Mining Act (BBergG) came into force on 01.01.1982. In this case, the respective federal state is obliged to implement the necessary safety and danger prevention measures following the relevant police law provisions to eliminate dangers to public safety and order. These historical mining operations pollute surface waters, for example, by releasing highly acidic runoff containing heavy metals. Remediation is, therefore, the responsibility of the respective federal state. Mining rehabilitation is carried out to the extent necessary. In principle, there is no financial restriction.

As outlined, LMBV and its financing are exceptional cases. Since revenues from mining activities flowed into the GDR's state budget and there were no reserves, the LMBV is financed by funds from public budgets.

The federal government and the four participating federal states enter into consecutive public administrative agreements with a maximum period of five years. For this purpose, the respective remediation projects are defined in advance and then financed on a project-related basis proportionally with funds from the federal government and the respective states concerned (Brandenburg, Saxony, Saxony-Anhalt or Thuringia). The first administrative agreement was signed in 1992.

The Federal Government and the four federal states share the costs for mine reclamation either 75 % Federal Government and 25 % Länder for the obligations based on the regulations of the BBergG, or 50% each for the implementation law-based hazard prevention. The difference arises from the respective legal basis of a specific reclamation project. LMBV is currently working under the seventh such administrative agreement. Activities that go beyond mine reclamation and serve the purpose of infrastructural development and subsequent use, such as harbour facilities, recreational beaches, bicycle paths, and the conversion of old industrial sites into tourist destinations, are financed in full by the respective federal state. Thirteen billion euros were spent on lignite reclamation between 1992 and the end of 2022.[201]

Role of Private Sector/Other Stakeholders and Local People in Rehabilitation

The mining industry in Germany is owned predominantly privately, but is subject to state supervision. Accordingly, rehabilitation is also the sole responsibility of the respective private mining companies.

Germany has very active citizens' movements that are critical of mining activities in particular. This concerns not only large opencast lignite mines, but also gravel quarries or the excavation of gypsum, or other minerals. The announcement of a project may lead to conflict with the population or interest groups. The relevant authorities, therefore, have a great responsibility to make legally sound decisions. In accordance with German and European law, there is the possibility of influencing a project during the planning and approval phase, as well as on the subsequent rehabilitation.

Minimising negative impacts of necessary interventions needs great efforts on the part of the mining companies, and the acceptance of the people affected. Social acceptance can be reached by a high level of transparency in the initial planning phase and a successful restoration of mining affected areas[202]. Therefore, the LMBV has established an internal process of including stakeholders, especially the people living close to a specific rehabilitation site. Informing and hearing them in the different rehabilitation stages allows for including concerns in the planning and the execution process.

Community Involvement and Engagement

An extensive planning process precedes the approval of a mining project. Various public interest groups are involved during this process. These include nature conservation groups, farmers and foresters, representatives of business and tourism, religious groups and minority groups. The planning and approval process goes through several stages in which the planning status is made available to the public and hearings are held. The development of LMBV's reclamation plans applies to the same process. They were developed as special plans within the regional development planning process.

The municipalities have planning sovereignty in their municipal area. They must draw up urban land-use plans as soon as and to the extent necessary for urban development and order. When drawing up these urban land-use plans, many public concerns, including those of regional and federal state planning, must be considered.

Municipalities have the right on the other side to participate in developing super-ordinated planning on regional and federal levels. This means that the rehabilitation objectives defined in the regional plan for an area affected by mining can be influenced by municipal demands. Alterations require the approval of the municipality.

Academic and Research Institutions Involved, and Their Contributions

In Germany, academic education and research in the field of mining takes place, among others, at the following universities:

[201] LMBV 2023: Finanzierungsgrundlagen https://www.lmbv.de/unternehmen/finanzierung/

[202] Müllensiefen K et al. Tagebau im Spannungsfeld zwischen Eingriff und Ausgleich. In: Der Braunkohlentagebau. Berlin: Springer. 2009.

RWTH Aachen University: The Institute of Mineral Resources Engineering (MRE) emerged in 2015 from two mining institutes. Mining Engineering was established in 1880 as one of the first institutes at RWTH Aachen University. According to the university's motto "Knowledge to Resource the Future", the MRE today educates mineral resources engineers and participates in inter- and multidisciplinary research on an international level[203].

Freiberg University of Mining and Technology (TUBAF): The Resource-University TUBAF is the oldest mining university in the world, founded in 1765, located in the Ore-Mountains close to Dresden. Faculty 3 educates all aspects of geoscience, geoengineering and mining with strong international connections [204].

Clausthal University of Technology: The faculty of energy and economics offer a wide range of courses onmining, energy and economics studies. It is located in the Harz Mountains[205].

Technical University of Berlin: The TU Berlin is one of the 20 biggest universities in Germany. Among other studies, it offers master´s degree programs in geo-technology energy-engineering and process engineering.

Technical University of Brandenburg (BTU), Cottbus and Senftenberg: The university in the heart of the East-German lignite-mining region, Lusatia, offers a bachelor´s degree program in environmental engineering with a strong focus on rehabilitation of mining areas[206].

Technical University Georg Agricola, Bochum: The Master programme Geo-Engineering and Post-Mining is the only one of its kind in Germany. It prepares engineers to plan and manage the complex challenges caused by the closure of mines and the resulting after-closure procedures. The internationally unique Master programme Mineral Resource and Process Engineering, offers graduates the opportunity to deepen their specialist knowledge in either mineral resource engineering or process engineering.

Research Institute for Post-Mining Landscapes: The Research Institute for Post-Mining Landscapes (FIB), founded in 1992 in Finsterwalde, is concerned with landscapes damaged by the extraction of raw materials, particularly in the Lusatian lignite mining area. For this purpose, it works on remediation solutions with the thematic priorities: Agricultural and forestry recultivation, water ecology, landscape development and nature conservation.

Research and Development Centre for the Impacts of Mining

The Federal Institute for Geosciences and Natural Resources established a branch office in the middle of the Lusatian lignite mining district in 2022, known as the "Forschungs- und Entwicklungszentrum für Bergbaufolgen" (Research and Development Centre for the Impacts of Mining), which is also focused on the consequences of lignite mining[207].

Research Projects in Lignite Reclamation:

In the specific case of lignite reclamation, a major knowledge deficit existed, at the beginning. It existed in two directions. On the one hand, the level of knowledge about the scope of the task, and the affordable technologies required for it, had to be developed. On the other hand, more ambitious solutions integrating

[203] https://mre.rwth-aachen.de/en/?noredirect=en_US

[204] https://tubaf.org/en/department/fakultat_geowissenschaften

[205] https://www.fakultaeten.tu-clausthal.de/en/faculty-of-energy-and-economics/studies

[206] https://www.b-tu.de/en/fakultaet2/studium-lehre/study-programmes 40 https://fib-ev.de/en/start_en/

[207] https://www.bgr.bund.de/DE/Themen/FEZB/FEZB_node.html

ecological, economic and social aspects needed to be pursued to achieve the sustainability goal set at the UN Conference on Environment and Development in Rio de Janeiro in 1992.

From the year 1994 to the year 2000, nearly one hundred joint and individual research projects accompanied lignite reclamation. The Federal Ministry of Research and Education has launched a research program for this purpose. Topics included geo-technology, groundwater quality and water treatment for lakes, soil and biological revegetation, nature conservation, limnology and fisheries, remote sensing and socioeconomics, and the treatment of contaminated sites. The results of this research raised mine reclamation to a new level. During the following years and up to today, research projects have accompanied mine reclamation and have led to innovations. LMBV directly facilitates applied research projects with a high probability for implementation. Advisory board representatives from universities and scientific institutions support LMBV in this endeavour. LMBV reports on its reclamation results and the technologies utilized at national and international conferences and seminars. Additionally, dissertations and post-doctoral theses at universities also accompany mine reclamation.

Capacity Building on the Rehabilitation of Mining Areas

Through consultation and project support, LMBV has also contributed to capacity building in other countries, e.g., China, Vietnam, South Korea, Mongolia, Peru and Brazil, as well as European countries.

8 India

Status of Mining in India

India continued to be wholly or predominantly self-sufficient in primary mineral raw materials like iron ore, bauxite, sillimanite, chromite and limestone. With over 3,095 mining leases for 40 major minerals, India is the second-largest producer of coal in the world and one of the world's leading producers of bauxite (aluminum ore), iron ore, zinc, and limestone. Based on the geological mapping of the country, an area of 57.10 million has been demarcated as an Obvious Geological Potential (OGP) area, where the geological potential for the occurrence of mineral deposits is higher. The majority of the mine leases are under the private sector (2858 mine leases) with a mine lease area of 205624.90 ha, and the remaining 237 mine leases under public sector with area of 73477.50 ha [208].

Key Mining Areas

Odisha, Andhra Pradesh, Rajasthan, Chhattisgarh, Jharkhand, Madhya Pradesh and Karnataka have the most mining wealth in India. Chhattisgarh, Odisha, Jharkhand, Tamil Nadu, and West Bengal are the country's major coal/lignite producing states. The major mining area of the country is Keonjhar (Odisha), where mining for iron ore and manganese currently produces more than one-fifth of India's iron ore. Bellary (Karnataka) produces about 19% of India's iron ore (most of which is exported). Gulbarga (Karnataka) is the biggest limestone producing district of India. Koraput (Odisha) alone produces about 40% of India's bauxite. Jajpur (Odisha) produces 95% of India's chromite. Bhilwara (Rajasthan) produces more than 80% of India's zinc. Cuddalore (Tamil Nadu) produces three-fourth of India's lignite. Sonbhadra (Uttar Pradesh) produces more than 20 million tonnes of coal annually, apart from thousands of tonnes of limestone and dolomite.

Key Mining Sectors

India is endowed with nearly 95 minerals, including fuel (4), metallic (10), non-metallic (23), atomic (3) and 55 minor minerals (including building and other materials). There are 38 naturally occurring minerals for which mining leases are granted in the country. The public sector plays an important role in the overall mineral production.

[208] IBM. Indian Bureau of Mines, Government of India(GOI). 2022.

Key Mining Companies

Central PSUs	State PSUs	Private Companies
• National Mineral Development Corporation (NMDC) • National Aluminium Company Limited (NALCO), • Hindustan Copper Limited (HCL), • Steel Authority of India (SAIL) • Manganese Ore India Ltd. (MOIL) • Coal India Limited (CIL) • Neyveli Lignite Corporation (NLC) • Uranium Corporation of India Ltd (UCIL	• Indian Rare Earths Ltd. • FCI Aravali Gypsum & Minerals (India) Ltd • Indian Metals & Ferro Alloys Limited, Bhubaneswar, Odisha • Rajasthan State Mines and Minerals Limited (RSMML) • Gujarat Mineral Development Corporation Limited (GMDC) • Odisha Mining Corporation Limited (OMC) • Andhra Pradesh Mineral Development Corporation Limited • Karnataka State Minerals Corporation Limited (KSMCL) • Damodar Valley Corporation	• Vedanta Limited • Bharat Aluminum Company (BALCO) • Sesa Goa Iron Ore- a Vedanta Group company • Hindalco. • Essel Mining & Industries Limited (EMIL) • Tata Steel. • Jindal Steel Power Limited • JSW (Energy) Limited- Barmer Lignite Mining Company Limited (BLMCL) • JSW Steel Ltd, • Ashapura Minechem Ltd. • Kudremukh Iron Ore Company Limited (KIOCL), • Dalmia Cement.

Major Environmental Concerns Linked to Mining

Land Degradation: Mining and its associated operations like excavation, overburden dumping, mineral stocking, formation of tailing dams due to mineral beneficiation, service buildings and roads etc,. have been proven to degrade the land. The clearing of vegetation cover/deforestation, land damage due to excavation, subsidence, erosion from OB dumps during rainy seasons, and contamination with heavy metals such as mercury, arsenic, lead, zinc, and cadmium of nearby ecosystem are the drivers of land degradation due to mining. Mining and beneficiation of ores also generates tailings and other deleterious silica minerals and phosphorous.

Biodiversity: Almost all of the country's mineral reserves are spread in regions that also hold most of its forests, river systems and tribal population. Most of India's iron ore reserves are along the courses and watershed of rivers like Indravati, Baitarani, Tungabhadra and Mandovi. Most of the coal reserves of the country are also located within river basins– Damodar, Godavari, Son, Kanhan and Mahanadi-Brahmani. The average forest cover of the 50 major mineral-producing districts stands at 28%. The total forest cover in these districts account for 1,18,90,400 ha (about 18% of the country's forest cover). The diversion of forest lands in these areas for mining stands around 1,79,892.3 ha during 2013-21 in the country. Mining in these areas have and are still degrading the catchment and affecting quantity and quality of water.

Pollution (Chemical Contamination): Mining is regarded as the primary cause of heavy metal pollution in the environment. Pollution of freshwater with industrial pollutants and heavy metal contamination is a major problem. Mining may contaminate surface and groundwater with heavy metals, if necessary safeguards are not followed. The use of large volumes of water for mine drainage, mine cooling, aqueous extraction, and other mining activities raises the possibility of chemical contamination of ground and surface water. Loss of beneficial soil microbes caused by the use of wastewater in irrigation, is also a concern. Groundwater is used as drinking water, and the presence of metals, even in low concentrations, is harmful. Environmental degradation from mining is minimized through implementing federal and state legislation, which requires operators to follow criteria for the preservation of surface and groundwater.

Statutory Framework and Provisions for Mine Restoration and Rehabilitation

- The National Mineral Policy 2019 mandates the restoration and rehabilitation of mine sites by promoting scientific mine closure and the regeneration of biodiversity. The government plays a critical role in ensuring mine decommissioning and land reclamation. The mining industry should prioritize financial provisions for the costs associated with mine closure.
- Chapter 7 of the Mines and Minerals (Development and Regulation) Act, 1957 grants the Central Government the power to issue directions for restoration and reclamation activities.
- The Coal Mines (Conservation & Safety) Act, 1974, focuses on enhancing coal efficiency, promoting eco-friendly technology, and conserving coal resources.
- Several acts and rules, including The Water (Prevention and Control of Pollution) Act, 1974; The Water (Prevention and Control of Pollution) Cess Act, 1977, The Air (Prevention and Control of Pollution) Act, 1981. The Environment Protection Act (EPA), 1986 (amended in 2006) and the Forest (Conservation) Act, manage the environment and protect it from mining activities.
- The National Environmental Policy, 2006, aims to conserve environmental resources by promoting resource efficiency, intergenerational equity, good environmental governance, and environmental protection.
- The Indian Bureau of Mines (IBM) oversees mining administration in India.
- Ministry of Environment, Forest and Climate Change (MoEFCC) is responsible for granting environmental clearance for all mines in India. State and District Environment Impact Assessment Authorities may also grant environmental clearance for mining leases up to a certain area.
- The Coal Controller Organization (CCO) and the MoEFCC regulate and monitor mine closure activities.
- Directorate General of Mines Safety (DGMS) enforces provisions related to labour welfare and health safety in mines under the Occupational Safety, Health and Working Conditions (OSH) Code 2020 and subordinate legislation like Coal Mines Regulation 1957, Metalliferous Mines Regulation 1961, Mines Vocational Rules 1966, Oil Mines Regulations 1984, Mines Rescue Rules 1985, and Mines Creche Rules 1966.

Institutional Framework for Monitoring and Evaluation of Mine Restoration

Mining companies are required to submit Progressive Mine Closure Plans and a Final Mine Closure Plan to ensure the systematic and scientific closure of mines. Financial assurances are also necessary to safeguard against liabilities. The Indian Bureau of Mines (IBM) monitors mining activities of major minerals and is implementing remote monitoring through drone images and satellite imageries to ensure compliance and effective mine closure. The Mining Surveillance System uses satellite-based monitoring to detect instances of illegal mining. The Ministry of Mines has a Star Rating System to evaluate mining lease holders' performance based on sustainable development parameters. The Sustainable Development Cell under Coal India Limited formulates environmental policies and guidelines, and subsidiary companies are responsible for implementing pollution control measures and rehabilitating mined-out areas. Mine closure plans, including reclamation and afforestation, are prepared and monitored through remote sensing techniques. The Ministry of Environment, Forest and Climate Change (MoEF&CC) monitors compliance with environmental clearance conditions and conducts regular assessments of mining projects.

Key Institutions Involved in Mine Restoration and Rehabilitation

Mine closure is a multidisciplinary activity, and the institutional structure required to regulate the process involves a number of agencies. Major thematic aspects of mine reclamation, rehabilitation and restoration during and after mine closure and post closure are environmental, financial and socio-economic. These are regulated by the key institutions like State forest department, State Pollution Control Board, MoEF&CC through its regional offices, the Indian Bureau of Mines (IBM), under the Ministry of Mines Directorate/Departments of Mines and Geology of States and UTs, the Coal Controller Organization of Ministry of Coal, District Administration and other relevant agencies like the Commissioner for Tribal Affairs, Panchayat etc.

All public, private and joint venture mining companies are involved in mine reclamation, rehabilitation and restoration works either themselves or these works are outsourced to State Forest Department/ Corporations. The Indian Bureau of Mines, Ministry of Mines and Coal Controller Organization of the Ministry of Coal provide technical support regarding guidelines and best practices. The CMPDI, Ranchi; ICFRE, Dehradun; Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi; NIT, Raipur, NIT, Rourkela etc. provide technical knowhow of mine reclamation and rehabilitation activities for their restoration. NEERI, Nagpur, IIEST, Shibpur, IIT-ISM, Dhanbad are approved agencies of IBM and COO for certification of mine closure activities.

Financing Arrangements for Mine Restoration and Rehabilitation

The mining related statute has a provision for preparing the Progressive Mine Closure Plan which is linked with the collection of financial assurance, reviewed regularly. The assurance amount is deposited in a tripartite escrow account. An amount equal to the annual cost will be deposited each year throughout the mine life compounded annually. This amount is utilized for mine restoration and rehabilitation among other mine closure activities on the production of certification of mine closure activities, including restoration and rehabilitation.

Most mining companies utilize their funds (other than those deposited for compensatory afforestation in CAMPA account) from revenue costs for mine restoration and rehabilitation.

In India, a dedicated fund raising foundation for the development of mining-affected regions outside the mine site has also been established in the name of the District Mineral Foundation (DMF) as per provisions under Section 9B of the MMDR Act, 1957. This section of the Act prescribes the establishment of a District Mineral Foundation (DMF) in any district for the interest and benefit of persons, and areas, affected by mining-related operations.

Ministry of Mines vide its order dated 23.04.2021 under Section 20A of the MMDR Act, 1957 has prohibited the transfer of District Mineral Foundation funds to the State exchequer or State level fund (by whatever name called) or Chief Minister’s Relief Fund or any other funds or schemes. The DMF funds are sanctioned for projects under various programmes/development schemes of Pradhan Mantri Khanij Kshetra Kalyan Yojana (PMKKKY). The state also collects additional money from mining lease holders based on the mineral value and associated sales. However, there is a need to generate funds for old, abandoned mines.

Role of Private Sector/Other Stake holders and Local People in Restoration

Stakeholder engagement is crucial in mine reclamation and rehabilitation (R&R) as it involves multiple parties with differing ideals and interests. The engagement process brings these stakeholders together to negotiate common interests and collaborations for effective R&R.Local stakeholder engagement plays a vital role in mined-out area restoration initiatives. Job creation, commercial possibilities, and long-term supply networks are means of engagement, supported by government policies and laws. Shifting supply chain operations of economic activities reliant on natural resources to incorporate restoration and Nature-based Solutions is essential for long-term sustainability. Private sector investment in ecosystem restoration initiatives can be encouraged by aligning perceived benefits with community organizations and academia.

Community Involvement and Engagement

Public participation is crucial during the pre-project stage, specifically during the Environmental Impact Assessment (EIA) led by the responsible state government through the district administration. The approval process for Land Acquisition and Resettlement and Rehabilitation (R&R) proposals involves a separate Social Impact Assessment (SIA) that requires public consultation to gather the views of affected communities. The state primaril oversees for the project through district administration, courts, or Grievance Redressal Cells established per national and state R&R guidelines. These processes mainly address pre-project litigation or complaints related to land acquisition, compensation, resettlement, and eligibility. There is a growing recognition of the importance of participatory techniques and community engagement in development planning and program execution.

Academic and Research Institutions involved, and their Contributions

Indian Council of Forestry and Research Education, Dehradun, is involved in a variety of technical research, including the development of reclamation and rehabilitation plans for iron ore mines in the state of Karnataka on directions of Central Empowered Committee of Hon bale Supreme Court of India; carrying capacity study of Saranda forest West Singhbhum, Jharkhand to guide balancing mining with conservation for MoEF&CC; third party environmental auditing of coal mines across the country for Coal India Ltd., and biodiversity assessment studies of coal and iron ore mines. ICFRE-FRI, Dehradun has also prepared Road Maps for eco-restoration of mined out areas for BCCL and NCL subsidiaries of Coal India Limited and developed Tetelmuri and Nighai eco restoration models at OB dumps/mined-out areas and played advisory roles for replication in other coal mines. Similarly, CSIR-National Environmental Engineering Research Institute, Nagpur has also been involved in various aspects of academic research w.r.t study on developmental projects such as carrying capacity based planning for proposed development in Sambalpur-Jharsuguda region, Odisha.

Capacity Building on the Restoration of the Mining Area

Capacity building in the restoration of mining areas involves developing and strengthening the skills, abilities, and resources of individuals, mining companies, and affected communities. It includes training courses, educational materials, workshops, and stakeholder collaborations. Academic institutions contribute through research and innovation, enhancing their capacity to address sustainability challenges and supporting sustainable development. Environmental management capacity building in the mining sector aims to promote private investment, administer regulations, monitor sector developments, and improve conditions for artisanal miners. Training and capacity building help stakeholders involved in restoration projects at different scales, sharing experiences and knowledge to achieve ambitious restoration targets. Various Indian organizations conduct training programs and workshops on technological, regulatory, fiscal, and environmental aspects of mining area restoration and rehabilitation.

- **ICFRE, Dehradun and its Institutes:** Provide technical support for eco-restoration of mining areas and conduct training programs for Coal India Limited subsidiaries.
- **Central Mine Planning and Design Institute, Ranchi:** Review mining and environmental policies, strengthen regulatory agencies through capacity building, and monitor compliance under the India-Environmental Management Capacity Building Technical Assistance Project.
- **Centre for Environment Management of Degraded Ecosystem, University of Delhi:** Conducts research and capacity building for ecological restoration of mined-out areas, recognized as a Centre of Excellence by the Ministry of Environment, Forests and Climate Change.
- **National Environmental Engineering and Research Institute, Nagpur:** Conducts training programs and environmental awareness activities for water and land conservation, river rejuvenation, and mining waste management.
- **Indian Institute of Technology-Indian School of Mines, Dhanbad:** Provides specialized manpower training for the energy, mining, and petroleum sectors, focusing on exploration, exploitation, management, and environmental protection.
- **Geological Survey of India Training Institute (GSITI):** Conducts training programs across India under the BHUVISAMVAD and Azadi ka Amrit Mahotsav initiatives.
- **Indian Institute of Technology, Kharagpur:** Offers training courses on green mining approaches and technologies for mine closure and site restoration.
- **Indian Insitute of Engineering Science and Technology, Shibpur:** Conducts verification of mine closure activities for various mining companies.
- **Indian Bureau of Mines, Nagpur:** Provides capacity building through training programs for IBM employees, mining industry personnel, and state government employees.
- **The Energy Research Institute, New Delhi:** Focuses on capacity building in sustainable resource utilization, ecosystem rehabilitation, disaster resilience, and forging partnerships for natural resources management.

9 Indonesia

Country overview of Mining Activities

The most important minerals in Indonesia are bauxite, coal, tin, copper and gold. The coal and mineral sector contributes around 5% of Indonesia's GDP[209]. Indonesia has the largest nickel reserves in the world, (approximately 21 million tons). It has the 10^{th} largest reserve of coal in the world. It is also the 4^{th} largest coal producer in the world. Indonesia exported more than 400 million tons of coal, accounted for more than 30% of coal exports in 2020. Indonesia has fifth largest gold reserves, second-largest tin reserves, and sixth largest nickel and bauxite reserves worldwide. The mining sector of Indonesia employs around 1.3 to 1.6 million people[210]. Indonesia has 2.5 billion barrels oil reserves at around[211]. Experts argue that the mining potential in Indonesia remains under utilised. Analysts say it is very less for an economy like Indonesia. Indonesia also suffers from illegal mining, which is detrimental to the economy and environment.

Key Mining Areas

Indonesia is an archipelago with over 17,000 islands. In many provinces, including Papua, Central Sulawesi, Bangka-Belitung, West Nusa Tenggara, East Kalimantan, the mining industry comprises a share economy share. Kalimantan province alone contributes to around 90% of Indonesia's coal production. Kalimantan and Sumatra islands are called supermarkets for coal in Indonesia[212]. The majority of Indonesia's bauxite reserves are in the Riau Islands (namely Bintan), the Bangka Belitung Islands, and West Kalimantan. The reserves are in the form of laterite ores

Key Mining Companies

- **Vale Indonesia :** Vale Indonesia is the largest nickel producer in Indonesia. It is a growing industry thanks partly to the growing demand for Electric vehicles. Vale Indonesia is also involved in mining restoration in Indonesia.

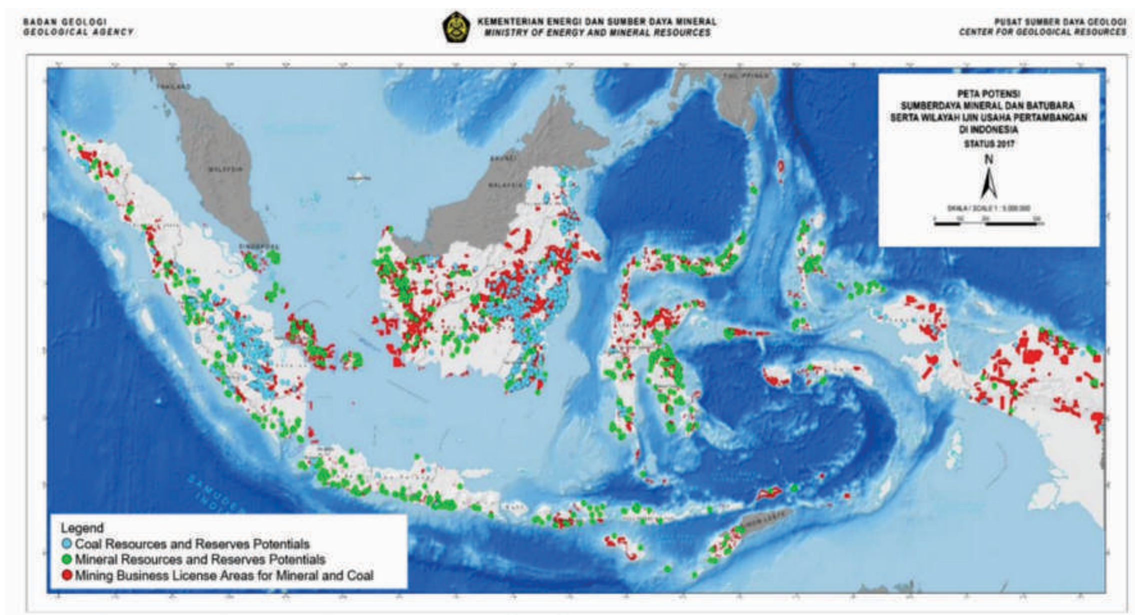
[209] Yang Z, Huang H, Lin F. Sustainable electric vehicle batteries for a sustainable world: perspectives on battery cathodes, environment, supply chain, manufacturing, life cycle, and policy. *Adv Energy Mater*. 2022;12(26):2200383

[210] Atsari A, Brent Z. The Future of Indonesia's Energy Sector

[211] Indonesia P. Mining in Indonesia: Investment and Taxation Guide. 2018.

[212] Dalton B. *Indonesia Handbook*. Bill Dalton; 1995

Figure 17: Indonesia Key mining areas



Source: The Ministry of Energy and Mineral Resources (2018)

- **T Adaro Energy Indonesia Tbk :** T Adaro Energy is one of Indonesia's largest coal mining companies in Indonesia, both by production and market capitalization. Its mining capacity 2020 was 54.53 million tons and its concession size includes 316,619 hectares spread over South Sumatra, Kalimantan and Queensland (Australia).
- **PT Bumi Resources (coal) :** The Bakrie family runs PT Bumi Resources. It is one of the largest coal mining and production companies in Indonesia. Its mining capacity in 2020 was 81.1 million tons. Its concession size includes land in East and South Kalimantan along with South Sumatra and is spread over 136,985 hectares.
- **ANTAM :** ANTAM is one of the longest and largest producer of Bauxite (along with other minerals) in Indonesia.
- **Sinar Mas Mining Group :** The mining capacity for this company in 2020 was around 60 tons of coal. Concession includes over 278.802 hectares of land spread over Jambi, Riau, West and South Sumatra (Singgih, Unearthing Indonesia's 10 biggest coal oligarchs 2022).

Major Environmental Concerns linked to mining

Mining activities in Indonesia have had significant ecological impacts, particularly on deforestation and pollution. A study by Clark University and Vienna University of Economics and Business revealed that over half of tropical deforestation in Indonesia is caused by mining[213]. Coal extraction in East Kalimantan, particularly in the Kutai district, has resulted in extensive deforestation, threatening the rich biodiversity of the region, which includes rare species like orangutans and hornbills. Surface mining techniques used in coal extraction involve the removal of all vegetation, soil, and rock, leaving behind barren and polluted pits that contribute to erosion and contaminated runoff, negatively affecting downstream fish populations and drinking water sources.

[213] Giljum S, Maus V, Kuschnig N, et al. A pantropical assessment of deforestation caused by industrial mining. Proc Natl Acad Sci. 2022;119(38):e2118273119.

The environmental pollution caused by mining operations has also had adverse health effects on local communities. In Muara Enim, South Sumatra, rivers have become polluted, and the region has experienced increased flooding, landslides, land degradation, and forest fires. The state-run company PT Bukit Asam operates in this area. In Sulawesi, mining for nickel, used in stainless steel production, has threatened fisheries and forests. The seas have been visibly impacted, turning red, and there has been a decline in biodiversity[214]. Communities in the area have also reported respiratory problems.

Legislative Provisions for Mine Restoration and Rehabilitation

Indonesia has laws and regulations governing mining activities, including requirements for reclamation and mine closure plans to ensure environmental protection and sustainable practices. The primary mining law in Indonesia is the Law on Mineral and Coal Mining No. 4 of 2009, which aims to support sustainable national development[215]. Under this law, the Central Government has the authority to determine land available for mining, although regional governments may also have the power to grant mining licenses in certain cases. Mining companies are required to include reclamation plans in their work plans, and they must provide a reclamation guarantee. Environmental protection and management are regulated under the Law on Environmental Protection and Management, which emphasizes strict liability.

Mine rehabilitation is a legal requirement, and a Mine Closure and Reclamation Plan (MCRP) must be prepared. The MCRP addresses environmental protection, remediation, management, reclamation, and social impact reduction. The environmental impact of mining must be thoroughly studied, and a financial estimate of the rehabilitation plan is necessary. Local government and communities should be consulted during the preparation of the MCRP. In 2010, the government released GR 78/2010, which focuses on post-mining reclamation and applies to both operational and exploration license holders. In 2014, PerMen 7/2014 provided implementation regulations for GR 78/2010, specifying requirements for reclamation and post-mining plans, as well as reclamation and post-mining guarantees. In 2018, PerMen 26/2018 replaced PerMen 7/2014 and now provides guidelines for reclamation and mine closure.

Key Institutions Involved in Mine Restoration and Rehabilitation

In Indonesia, the Ministry of Energy and Mineral Resources (MEMR) is responsible for administering the mining sector[216]. The country follows a decentralized system, meaning that mining administration also takes place at the provincial level. At the national level, MEMR consists of two branches:

- **Directorate General of Mineral and Coal (DGMC):** This branch formulates and implements policies related to mineral and coal activities. It is responsible for fostering, controlling, and supervising these activities. DGMC grants exploration and mining licenses nationwide, while the Indonesia Investment Coordinating Board (BKPM) provides support in this process.
- **Geological Agency:** The Geological Agency conducts research, investigations, and services related to geological resources, volcanology, groundwater, and environmental geological disasters. It also conducts geological surveys and determines mining business license areas.

[214] Morse I. Mining turned Indonesian seas red. The drive for greener cars could herald a new toxic tide. *Washington Post*. 2019;20.

[215] Saproni M, Santiago F. Law Enforcement Mining in *Indonesia Environmental Law Perspective. In: 2018 International Conference on Energy and Mining Law (ICEML 2018)*. Atlantis Press; 2018:309-312.y.com/

[216] Institute IM. *Report on Indonesia Mining Sector Diagnostic*. World Bank; 2018.

At the provincial level, there are additional bodies involved in mining administration:

- **Forestry Agency:** This agency monitors and enforces mining operation requirements within forest areas, ensuring compliance with environmental regulations.
- **Spatial Planning Office:** The Spatial Planning Office coordinates with mining authorities regarding the implementation of land use, ensuring alignment with mining activities.

Role of the Private Sector in Mine Restoration

- **PT Singlurus Pratama:** PT Singlurus Pratama operating in East Kalimantan, has successfully partnered with BALITEK and ELTI since 2012 to restore the forest on their mining sites. They have actively engaged with the local community in their sustainability initiatives.
- **SKK Migas EMP-Malacca SA:** SKK Migas EMP- Malacca SA planted and restored in Sumatra's Riau. Its part of the company's rehabilitation obligations.

Community Involvement and Engagement in Mine Restoration

JATAM is an Indonesian NGO focused on protecting communities from mining and deforestation. They are actively advocate for mining related issues and mobilizing people to protect nature. They also raise awareness about the impacts of illegal mining[217]. In addition, there are collaborative efforts between the Indonesian Peatland Restoration Agency, "Badan Restorasi Gambut," NGOs, and local communities to retain and restore peatlands in Indonesia. Their restoration initiatives are particularly active in the Kalimantan province.

Academic and Research Institutions Involved in Mine Restoration

- **Agency for the assessment and Application of Technology (BPPT) :** Established in 1978, it is an Indonesian government research institute, which carries out government duties in the field of assessment and application of technology.
- **Bandung Institute of Technology:** Established in 1959, they have one of the best courses in mining and mining engineering in Indonesia
- **Gadjah Mada University :** Gadja Mada University is a public research university located in Slemen. It was founded in 1949. It is one of the most premium research institution in Indonesia.
- **Capacity Building :** LTI's Indonesia permanent training site is a cooperative initiative of the ELTI, Balai Penelitian Konservasi Sumber Daya Alam (Balitek-KSDA, a branch of the Ministry of Forestry's Forest Research & Development Agency). The ELTI permanent training site consists of a network of smaller sites managed by partner organizations, including 1800 ha forest restoration site owned by the Borneo Orangutan Survival Foundation (referred to as Samboja Lestari), a timber plantation and eco-tourism site managed by PT Inhutani I, Balitek-KSDA's research forest, two protection forests managed by the city of Balikpapan, and PT Singlurus Pratama coal mines.

[217] Morse I. Mining turned Indonesian seas red. The drive for greener cars could herald a new toxic tide. *Washington Post.* 2019;20

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Italy

Mining Activities in Italy

Mining in Italy contributes to around 2.1% of the country's GDP, with approximately 20,000 people employed in the sector[218]. Italian exports of metal bases and products reached $58.8 billion, while exports of quarrying and mining products totaled $1.4 billion. Italy is the third-largest producer of feldspar and nepheline syenite, accounting for 14% of global production. It also plays a significant role in industrial sand and gravel production, accounting for 5.1% of global output. Italy is a major producer of construction materials, mineral manufacturing components, and stone. However, the country has primarily ceased mining for metals and relies on secondary scrap recovery or imports for necessary materials. Apart from rock salt, petroleum, and natural gas, the production of most mineral resources in Italy has declined since the late 20th century. Mining is not a critical sector for Italy's economy, and the industry has experienced a decline in recent years.

Key Mining Area

The Italian peninsula is a young land formation, resulting in a scarcity of mineral resources, particularly metalliferous minerals. The available minerals are sparse and widely dispersed. Mining has traditionally been more prevalent in the South than in the North, and many mines in Italy have been closed down. Italian iron production is primarily concentrated on the island of Elba, with another region in the Alps, specifically Valle d'Aosta. Coal is found in limited quantities in Tuscany but is insufficient to meet the country's needs, leading to imports. In the 1970s, pyrites were produced in Tuscan Maremma, asbestos from the Belangero mines near Tulin, and fluorite from Sicily. Gargano in Puglia was a source of aluminum, sulphur from Sicily, and zinc from Sardinia. Natural gas reserves are found in the Northern plain, Sicily, Basilicata, and Puglia. Carrara and Massa quarries in Tuscany are renowned for producing the most famous white Italian marble.

Mining Companies

- **Italcementi :** Italcementi, is one of the biggest companies in Italy which specializes in producing cement, ready-mix concrete and construction materials.
- **APS AROSIO EXTRUSION SpA :** APS Arosio extrusion produces custom-designed and standard profiles in the aluminium extrusion sector.

[218] O'Neill A. Italy - distribution of Gross Domestic Product (GDP) across economic sectors 2021, Statista Database. 2023. https://www.statista.com/statistics/270481/distribution-of-gross-domestic-product-gdp-across-economic-sectors-in-italy/ (Accessed: January 12, 2023).

- **Altamin Limited :** Altamin Limited is an ASX-listed mineral company focused on base and battery metal exploration and brownfield mine development in Italy, with advanced mines in Lombardy and copper, cobalt, and manganese-rich mining districts in Monte Bianco and Corchia.

Major Environmental Concerns Linked to Mining

The Vallalta mine in North Italy has caused water acidification, soil contamination, and plant damage from mining activities[219]. High concentrations of Cu, Zn, Pb, Fe, and Hg were released into the ecosystem as waste materials. In Liguria, mining in Petronio and Gromolo Valleys resulted in contaminated water and soil, waste rock dumps, land erosion, deforestation, and decaying mining buildings[220]. The Val Malenco chrysotile mine, despite being inactive for 40 years, still has significant amounts of chrysotile in the tailings, along with other minerals present in contaminated soil and stream sediments[221].

Legislative Provisions for Mine Restoration and Rehabilitation

Italy's mining legislation is governed by mining law No. 1443 of July 29th, 1927, which categorizes minerals into first and second categories. The state owns the first category of minerals, including most minerals, while quarrying minerals fall under the second category. With Italy's entry into the European Union, government involvement in the mining sector decreased. Reimbursement of the state by mining concessionaires is regulated by law No. 752 of June 10, 1982, while quarrying operations are regulated by law No. 44 of September 1982. Additional laws include Presidential Decree 128/59 for mining and quarrying police rules, Legislative Decree 152/06 for environmental protection, and Law of 23 December 2000 no. 388, Art. 114 for mine remediation and environmental recovery[222]. Management of extractive waste is governed by Legislative Decree no. 117/08, and National Decree 152/06 focuses on environment protection in mining. Italy has a decentralized administration, so regional Governments can also adopt laws for mine protection and restoration. For example, 1) Umbria Regional Law 9/1995 – Environment protection and reserve areas. 2) Tuscany Regional Law 30/2015 – Rules on protection and management of environment 3) Marche Regional Law 15/1994 – Rules for the institution and management of protected areas.

Key Institutions involved in Mine Restoration and Rehabilitation

In Italy, the issuance of permits for mineral mining is the responsibility of the regions, governed by regional administrative regulations. The national government has limited involvement in this process. However, activities related to petroleum and natural gas are supervised by the Ufficio Nazionale Minerario per gli Idrocarburi e la Geotermia (UNMIG), under the Ministry of Economic Development[223]. In 2021, there was a restructuring that led to the establishment of the Ministry for Ecological Transition, replacing the earlier Environmental ministry. This change reflects Italy's focus on the future and includes responsibilities such as waste management, water

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[219] Wahsha M, Maleci L, Bini C. The impact of former mining activity on soils and plants in the vicinity of an old mercury mine (Vallalta, Belluno, NE Italy). *Geochemistry Explor Environ Anal.* 2019;19(2):171-175

[220] Marescotti P, Brancucci G, Sasso G, et al. Geoheritage values and environmental issues of derelict mines: Examples from the sulfide mines of Gromolo and Petronio valleys (Eastern Liguria, Italy). *Minerals.* 2018;8(6):229

[221] Cavallo A. Environmental asbestos contamination in an abandoned chrysotile mining site: the example of Val Malenco (central Alps, northern Italy). *Episodes J Int Geosci.* 2020;43(3):851-858

[222] Grandi S. MINLEX - Italy Country Report - Europa. European Commision. *Eur Commision Publ.* 2019. https://rmis.jrc.ec.europa.eu/uploads/legislation/MINLEX_CountryReport_IT.pdf.

[223] Abdale, L.; M. Trimmer L. 2017-2018 Minerals Yearbook - USGS, 2017–2018 Minerals Yearbook. USGS. 2022. https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-italy.pdf

resources management, and environmental protection, alongside energy and mineral resources, business, trade, and tourism[224].

Role of the Private Sector in Mine Restoration

- **SGS Italy:** SGS Italy is a consulting company that provides a wide range of services, including exploration, plant design, production, and closure, to support companies throughout their operation's life cycle. They assist in meeting regulatory requirements and minimizing the environmental impact of water, tailings, and waste.
- **IMI Fabi:** IMI Fabi is a talc manufacturing company that ensures compliance with regulations and works closely with authorities to address public health, ecosystem, and waste disposal concerns. They focus on mine restoration and progressively identify closure objectives, monitoring and reviewing progress.
- Minerali Industriali is the result of a merger between Maffei and Gruppo Minerali. Recognized for sustainability, the company recovered an old mine in Masserano and transformed it into two parks, dedicated to restocking birds and butterflies.

Community Involvement in Mine Restoration

Gavorrano, situated in the Tuscan Maremma on the Metalliferous Hills of Grosseto, became a significant mining centre after discovering a large pyrite deposit in 1898. The municipality of Gavorrano held a public debate on quarry restoration, focusing on production residue. Various stakeholders, including mining companies and the municipality, collaborated and invested in hosting the event to facilitate restoration efforts.

The Tuscan Mining Park, in Grosseto, Tuscany, has obtained UNESCO Global Geopark status. It encompasses seven municipalities namely, Follonica, Scarlino, Gavorrano, Massa Marittima, Montieri, Monterotondo Marittimo, and Roccastrada. The region has a relatively low population density, and the local community actively engages in tourism and promoting the area. Their initiatives involve the maintenance, promotion, and guided tours of the mining park, aiming to educate visitors about mining activities in the region[225].

Academic and Research Institutions Involved in Mine Restoration

- **Facoltà di Ingegneria Civile e Industriale, Sapienza Universita Di Roma:** The first Engineering Study Programme in Rome, established by Pope Pius VII in 1817. It is the first school for professional training in engineering in Italy. They have a program in mining engineering.
- **Master course in Petroleum and mining engineering, Polytechnic University of Turin:** The Mining Engineering Track aims to train professionals with a multidisciplinary background in scientific and technical aspects of mining engineering. Sustainability and the environment are strong pillars of this course.
- **Selinus University of Science and Literature, Bologna:** It has a PhD program in mining technology. This focuses on the life of a mine. Deposit exploration, site value determination, and ore extraction post-mining reclamation are also fields in which extensive research has been done *(Thesis: Selinus University 2023)*.

Capacity Building

Stantec Academy : Provides training solutions based on the latest technical and educational innovations. Nearly 20,000 workers have been trained on health, safety, environment and management systems, development of safe behaviour, etc.

[224] UNEP. Cooperation agreement the Italian Ministry of Ecological Transition, Cooperation Agreement the Italian Ministry of Ecological Transition | UNEPMAP. 2023. https://www.unep.org/unepmap/who-we-are/partnerships/cooperation-agreement-imels

[225] Magliacani M, Francesconi A. How to feed a culturally sustainable development plan over time: evidence from the Tuscan Mining UNESCO Global Geopark. *J Cult Herit Manag Sustain Dev.* 2022;(ahead-of-print).

11 Republic of Korea

Key Mining Sectors

Korea has become a leading global producer of cadmium, slab zinc, and steel, and a top regional producer of refined copper, pyrophyllite, cement, zeolites, and talc[226]. In 2017, the Republic of Korea was the world's second-largest producer of refined indium, cadmium, mined zeolites, and refined zinc, with 32%, 22%, 11%, and 7%, of the global production, respectively and the fifth-ranked producer of mined talc and pyrophyllite (8%). The country is the fifth-largest producer of pig iron, the sixth-largest producer of raw steel, and the third-largest exporter of raw steel[227].

Due to the rise in domestic demand for metals, the Republic of Korea tends to depend more on imports to meet its requirements. The state was ranked the seventh-largest steel importer in the world in 2018. With a reported 8.8 million tons of steel in 2018, there has been a 15 percent increase in the Republic of Korea's import activities since 2017.

Key Mining Areas

In 2017, South Korea had 375 active mines operated by private or state-owned companies, showing an increase from the previous year. These mines focused on extracting industrial materials, metals, and anthracite coal. The mining industry employed 6,715 people, slightly lower than the figure in 2016. Golden Sun Co. Ltd. managed the country's two gold mines, while Handok Iron & Steel Co. Ltd. oversaw the only iron ore mine. The primary pyrophyllite-producing mine was Wan-Do Mine, followed by Nohwa-Do Mine and HyunMoo Mine. However, metalliferous mining activities declined significantly after the closure of the Sangdong tungsten mine, Yeonwha base metal mines, and Muguk gold mine in the 1990s. Coal mining operations were also phased out completely in 1999. These changes reflect South Korea's evolving mining landscape, with a shift towards other minerals and the closure of major mines in the past few decades.[228]

[226] Thomas G. AZO Mining. https://www.azomining.com/Article.aspx?ArticleID=60 [Accessed 03 01 2023]. Published 2012.

[227] Chung J. The Mineral Industry of the Republic of Korea, s.l.: U.S. Geological Survey

[228] Ramdass N. Mining Weekly

Figure 18: Tae Hwa Mine, Neungam-ri (Neung Am-ri; Noungam-ri), Angseong -myeon, Chungju City, North Chungcheong Province, Republic of Korea

Key Mining Companies

- **Korea Zinc Co., Ltd:** Established in 1974, Korea Zinc is a leading producer of non-ferrous metals, including zinc, lead, gold, silver, copper, and rare metals like indium and gallium. They offer a diverse range of approximately 18 metal types[229].
- **Almonty Industries Inc.:** Almonty operates the Sangdong Mine in South Korea, hosting one of the world's largest tungsten resources. They have been a global tungsten producer for over 40 years and have the potential to supply 50% of the world's tungsten[230].
- **Korean Metals Exploration Limited (KML):** KML is an Australian company with a Shin Han Mine Inc subsidiary. They specialize in polymetallic mineral projects in South Korea, leveraging 28 years of operational exploration expertise. KML has secured mining rights in the Uiseong, Haman, and Goseong districts, offering low-risk exploration targets with the potential for commercial production[231].

Major Environmental Concerns Linked to Mining

- **Land Degradation:** Measures to protect land resources from pollution include installing dust and gas collection systems, safe dumping areas, and refilling mining pits. There are currently 7 operating mines, 1 dormant mine, and 341 disused mines in Korea. However, the local economies in mining areas have stagnated due to the decline of the mining industry and the implementation of coal-industry rationalization plans.

229 https://www.koreazinc.co.kr/en/

230 https://almonty.com/tungsten/

231 https://koreanmetals. com/

Figure 19: Chungju deposit, Mt. Eorae, Joongwon-gun, Chungju City, North Chungcheong Province, Republic of Korea

- **Biodiversity, Including Invasive Species:** Urban sprawl and habitat loss continue to threaten biodiversity[232]. Ecosystem degradation is accelerating due to land use change and development in natural green areas and coastal regions. The areas of forests, farmland, and mud flats have decreased significantly over the past two decades. Protected areas for biodiversity conservation in Korea comprise 11.57% of the country's terrestrial area.
- **Chemical Contamination:** Former mining sites in Korea used for agriculture often have soil contaminated with toxic elements like arsenic, cadmium, copper, lead, and zinc[233]. Measures have been taken to examine the cadmium and lead content in crops, such as rice and Chinese cabbage, in heavy metal pollution areas. Crops that fail safety standards are bought out and destroyed by local governments, and the circulation of these contaminated crops is banned. These measures apply to both disused mines and open fields.

Legislative Provisions for Restoration and Rehabilitation of Mines

The "Special Act on Assistance to the Development of Abandoned Mine Areas" was enacted in December 1995, providing legal support for developing disused mine areas. The Mine Reclamation Corporation (MIRECO) was established in 2005 under the "Act on the Prevention and Recovery of Mine Damage" to complete the mine damage prevention project within 20 years. The first phase of the Framework Plan for Mine Damage Prevention (2007-2011) was implemented for 1,344 seriously damaged sites with a funding of $433.6 million.

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232 Uetake T, Kabaya K, Ichikawa K, Moriwake N, Hashimoto S. Quantitative analysis of national biodiversity strategy and action plans about incorporating integrated approaches in production landscapes. J Environ Plan Manag. 2019;62(12):2055-2079.

233 Lee S-H, Ji W, Yang H-J, Kang S-Y, Kang DM. Reclamation of mine-degraded agricultural soils from metal mining: lessons from 4 years of monitoring activity in Korea. Environ earth Sci. 2017;76(20):720

The Mining Damage Prevention and Restoration Act No. 16936, enacted on February 4, 2020, aims to actively prevent mining damage, protect the natural environment, and promote public health. Its purpose is to manage mining damage properly, ensuring a pleasant living environment for people.

The Enforcement Rules of the Mining Damage Prevention and Restoration Act No. 229, established on December 30, 2011, prescribe matters delegated by the Act and necessary enforcement details.

Under the Soil Environment Conservation Act (SECA), disposing of soil pollutants, spilling or discharging soil pollutants, and installing facilities that could severely contaminate soil are prohibited. Those intending to install a soil-contaminating facility must report the details to the relevant government, and the installation requires a soil-contamination prevention facility along with maintenance[234].

Key Institutions involved in the Restoration and Rehabilitation of Mines

The Ministry of Trade, Industry, and Energy (MOTIE) in South Korea implements mineral laws and policies. The Korea Mining Industry Act provides guidelines for mineral extraction. Under MOTIE, the Mine Reclamation Corporation (MIRECO) specializes in mine reclamation and has restored damaged mining areas.

Among the 5,396 mines in South Korea, 2,871 face pollution issues, and 2,631 have ceased operation or closed permanently. Operating mines focus on limestone, kaolin, coal, and silica stone. MIRECO has been surveying since 2015 to collect accurate data on mine hazards from 3,123 mines[235].

Korea Mine Rehabilitation and Mineral Resources Corp. (KOMIR), formerly KORES, is a state-owned company established in 1967. It provides strategic minerals to support Korean industries and aims to promote sustainable development in mining regions. KOMIR offers integrated services, including technological development, resource exploration, production, and mine rehabilitation. They focus on mine hazard prevention and support alternative industries for mining regions' self-reliance.

The Ministry of Environment (MOE) monitors soil contamination levels, while local authorities conduct investigations in suspected contaminated areas.

Financing Arrangements for the Restoration and Rehabilitation of Mines

The government of Republic of Korea invests to prevent damage from mines through the Mine Reclamation Corporation. The Jangseong-dong area has been designated the test-bed for an urban regeneration project called 'Eco Job City Taebaek'. Led by Mireco, the project plan to invest $200 million to boost the local economy. This is the third urban regeneration project in Jangseong-dong, which was once a prominent coal industry symbol with over 6,000 miners.

KOMIR collaborates with local governments to promote Urban Regeneration in mining areas, attracting private and public investment, creating local jobs, and strengthening economic self-reliance. Specific projects include the UNKRA Mungyeong Factoria, focusing on sports, culture, and eco-friendly hydrogen fuel-cell power-plants, and the Yeongwol and Deokpo Project, creating a base for the marsh snail industry and Donggang River ecological trips. These initiatives aim to revitalize closed mine areas, repurpose abandoned buildings, and enhance the well-being of local communities.

[234] Tong Keun Seol SKJJL a. YSKL&. K. Practical Law-Thomson Reuters. https://uk.practicallaw.thomsonreuters.com/w-026-8600?transitionType=Default&contextData=(sc.Default) [Accessed 05 03 2023]. Published 2021.

[235] MIRECO. Mine Reclamation Corp. (MIRECO) Sustainability Report, Gangwon-do: Korea Mine Reclamation Corp. 2014.

Role of the Private Sector in the Restoration of Mines

- Halla Cement Corp. received the Environmental Protection Award for its eco-friendly quarry rehabilitation efforts.
- An international initiative led by Almonty Industries, the Korean Mine Rehabilitation and Resource Corporation, aims to recycle rare metals like tungsten and molybdenum, enhancing the domestic supply chain for semiconductors and batteries.
- The partnership between KOMIR and private businesses, exemplified by the GMC project, demonstrates a successful collaboration for sustainable mining.

Community Involvement and Engagement in the Restoration of Mines

MIRECO has implemented community support projects to revitalize abandoned mine areas. Initiatives include constructing wall-painting villages, promoting renewable energy distribution, and developing cultural content to boost the local economy and enhance the image of these areas. The wall painting village project, which began in 2014 in Namdong Village, Taebaek, garnered community praise and proved effective for marketing. This project has expanded to other regions, such as Samcheok, Yeongwol, Jeongseon, and Mungyeong. MIRECO has also focused on energy self-sufficiency by installing photovoltaic and hydro power generation systems, benefiting low-income families through the Zero Energy Village projects. These efforts, in collaboration with renewable energy companies, contribute to improving community welfare in closed mine areas[236].

Academic and Research Institutions Involved

The Korea Environment Institute (KEI) is dedicated to environmental policy research and environmental impact assessment evaluations, aiming to effectively address and solve environmental problems. KEI conducted a case study on coal ash as a mine reclamation filler and its implications for updating Korean policies[237].

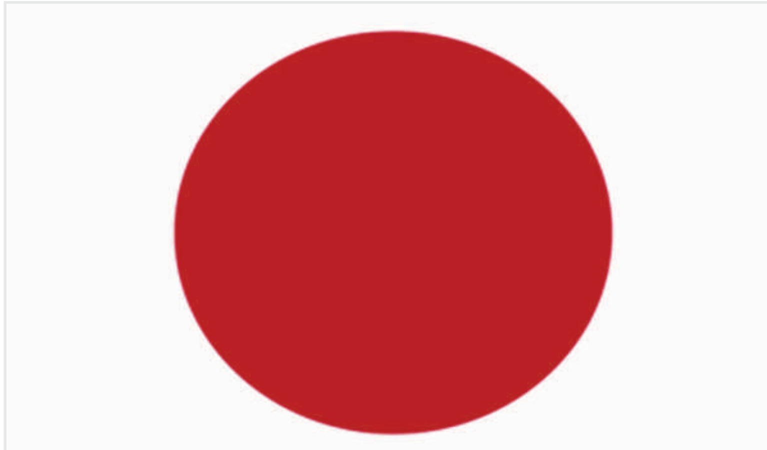
Capacity Building

The Korea International Cooperation Agency (KOICA) organized the Advanced Training Course on Capacity Building of Mine Hazard Management for Sustainable Development. The course aims to enhance capacity in planning and implementing strategic policies and management technologies for mine reclamation. The KOICA Fellowship Program, known as CIAT (Cooperation Program for Inviting Policy Makers, Public Servants, and Experts), seeks to share knowledge and provide technical training to promote development in participating countries.

[236] MIRECO. Mine Reclamation Corp. (MIRECO) Sustainability Report, Gangwon-do: Korea Mine Reclamation Corp. 2014.

[237] Cho H, Ji S, Shin H, Jo H. A case study of environmental policies and guidelines for the use of coal ash as mine reclamation filler: relevance for needed South Korean policy updates. Sustainability. 2019;11(13):3629

12 Japan



Key Mining Sectors

Japan has a very small occurrence of mineral resources[238], so the Japanese mining industry is relatively small compared to the other G20 countries. The most essential mineral extracted in Japan has historically been gold, for which it was known in the Western world as the land of gold because of its large deposits, such as in the Sado Island gold mine[239].

Key Mining Areas

Copper mines are mainly located in the northeastern part of Japan and on the island of Shikoku, where the altitude is relatively low, while the two largest iron ore production sites are located in higher altitude areas[240]. Gold is mined throughout the country, albeit also tending to be mined predominantly in lower-altitude areas rather than in mountainous regions[241].

Major Environmental Concerns Linked to Mining.

- **Land Degradation:** Japan heavily depends on imported materials and thus has examined various alternative resource supply strategies to improve resource security[242]. Except for Kushikino and Hishikari goldmines, most metallic and non-metallic mines were closed. Mining activity presently is in a dormant state in Japan, where some 5,000 inactive or abandoned mines are located all over the country.
- **Biodiversity loss:** The Main cause of biodiversity loss with species over-exploitation, pollution, invasive species and disease, and climate change as an additional factors.

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238 CIA.Gov. The World Factbook

239 Japan Government. Japan government-KIZUANA. https://www.japan.go.jp/kizuna/2022/06/sado_island_gold_mines.html [Accessed 11 01 2023].%0A. Published 2022.

240 Didier C, Van der Merwe JN, Betournay M, et al. Mine Closure and Post-Mining Management, International State-of-the-art report, International Commission on Mine Closure, International Society for Rock Mechanics. 2008

241 Ii H. University of Waterloo-WAT ON EARTH. https://uwaterloo.ca/wat-on-earth/news/outline-japanese-gold-and-silver-production [Accessed 11 01 2023]. Published 2002

242 Motoori R, McLellan BC, Tezuka T. Environmental implications of resource security strategies for critical minerals: a case study of copper in Japan. Minerals. 2018;8(12):558

- **Chemical contaminations:** Around the 20th year of the Meiji Period, the mineral pollution case of the Ashio Copper Mine came to be known as the first pollution case in Japan. The effects of the mine's effluent on fish and vegetation have been apparent since the 1930s. A local doctor reported the first official cases of an itai-itai disease in 1946. Later in 1968, the Japanese government acknowledged the link between itai-itai disease and industrial pollution from local mining and smelting operations.

Legislative Provisions for Mine Restoration and Rehabilitation

The first major pollution incident in modern Japan began in the 1880s at the Ashio Copper Mine, located 120 km north of Tokyo in the mountains of Tochigi Prefecture. It was the circumstances surrounding and reactions to this disaster that established a structured pattern of political-economic development and environmental response that, in many respects, continues to this day[243].

There are three laws primarily related to the rehabilitation of closed mineral mines: the Water Pollution Prevention Act enacted in 1970, the Act on Special Measures for Pollution Caused by the Metal Mining Industry, etc. ("Mine Pollution Prevention Act" in short hereafter) enacted in 1973, and the Basic Environment Law enacted in 1993. Based on the enactment of the Mine Pollution Prevention Act, the Ministry of Economy, Trade, and Industry (METI) started a 10-year-term mine pollution prevention program in 1973 to promote the rehabilitation works of the 540 closed mines that had pollution problems. About 40% of them do not have responsible owners. In such cases, the local government must take over rehabilitation.

Scheme of Japan's Policy of Mine Pollution Control Japanese Government (METI) set up the basic laws regarding mining safety, environmental Protection, and pollution control. Based on these laws, METI has decided on the basic initiative concerning the Mine Pollution control works every 10 years. According to these initiatives, mine equity holders must implement the proper constructive works to control mine pollution. Without mine equity holders, these non-owners abandoned mines must be controlled by Local Government regarding mine-site environmental protection under the Financial Support by METI's Subsidy and Technical Support by JOGMEC.

Key Institutions involved in Mine Restoration and Rehabilitation

Japan organisation for Metals and Energy Security (JOGMEC) is an industrial organization representing mining, smelting, and refining companies producing and recycling non-ferrous metals such as gold, silver, copper, lead, zinc, and nickel in Japan. They address a wide range of issues, including securing of stable supply of non-ferrous mineral resources, recycling, environmental protection and promoting best practices and new technical developments.

JOGMEC is a semi-governmental organization under the jurisdiction of the Ministry of Economy, Trade and Industry and the main organization that executes the Japanese Government's policies related to the mining industry.

The organisation has been conducting various exploration operations for mineral resources both within and outside Japan, and other worldwide activities, such as technical cooperation in resources development for developing countries with mineral resources, technological research and development in the field of mining, rare metal stockpiling in Japan, mining-related environmental pollution control activities, and international exchange through the collection and analysis of information concerning mineral resources. From a long-term

243 Matanle P. Japan and the environment: industrial pollution, biodiversity loss, and climate change. 2020.

viewpoint, the Agency has also been exploring deep seafloor mineral resources in the Pacific Ocean. Through these activities, the Agency has contributed to the stable supply of nonferrous metal resources in Japan and other countries.

Agency for Natural Resources and Energy (ANRE) is part of the Ministry of Economy, Trade, and Industry. It is responsible for Japan's policies regarding energy and natural resources.

Financing Arrangements for Mine Restoration and Rehabilitation

The Ministry of Economy, Trade, and Industry (METI) provides financial support to the local governments that had to take over the rehabilitation works. METI provides a subsidy of 75% of the total expenses for the rehabilitation works at a closed mine to the local government or the private company. However, the subsidy to the company can be applied only to the pollution problems for which the company is not responsible.

The company of a currently operating mine has to pay a pre-defined amount of the Reverse Fund for Preventive Operation of Pollution to JOGMEC every year to secure the fund for conducting the pollution prevention works after the closure of the mine in the future. The paid amount is tax-deductible for the company. JOGMEC is responsible for managing the Fund.

Capacity Building

The Japan International Cooperation Agency offers a Program on Environmental Measures for Mining Development. The participants can either join online or in person in Japan. The course is conducted in English and capped at 15 participants. The course aims to share experiences and develop sustainable mining management. It is conducted through field surveys, site visits, and briefings.

13

Mexico

Key Mining Sectors

Mexico's geological understanding of minerals dates back to 1938 when oil exploration spurred advancements in cartography, geological-mining, and mapping software advancements by the Mexican Geological Service[244]. According to the National Resource Governance Institute, mining activity has grown in Mexico recently, focusing on gold, copper, silver, zinc, iron, molybdenum, lead, and fluorite[245]. Gold holds the highest production value, accounting for 28.4% of the mining and metallurgy sector, followed by silver at 20.4% and copper at 27.7%. In Q3 of 2021, the mining sector's GDP reached $68 million, marking a 4.02% increase from the previous quarter and 37.3% from the same period in 2020. With its contribution of 3% to the country's GDP and 9.6% to the industrial GDP, the mining industry plays a vital role in Mexico's economy.

Key Mining Areas

The Mexican Geological Survey reported that in December 2019, 24,066 mining concessions were operating in an area of approximately 16.83 million ha, equivalent to 8.59% of the national territory. There are 1,190 mining projects in 16 states, mainly concentrated in Sonora, Chihuahua, and Durango. CAMIMEX, in 2021, noted that 307 are in the exploration stage, 78 are in production, 43 are in development, 754 are on hold, and eight operations have reported their closure.

Key Mining Companies

- **Americas Mining Corporation (AMC):** Headquartered in Tucson, Arizona, AMC is part of Grupo México and operates Buenavista del Cobre, the world's fourth-largest copper mine. It focuses on the extraction of copper, gold, and silver, generating a net revenue of $12.9 billion in 2021.

[244] IGF. Indigenous Consultation and Mine Closure Workshop in Mexico. Intergov Forum. 2022. https://www.igfmining.org/workshop/indigenous-consultation-and-mine-closure-workshop-mexico/ [Accessed 17 Dec. 2022].

[245] Statista. Mexico: mining production value by commodity 2021. [online] Statista Database. 2022. https://www.statista.com/statistics/863411/mexico-mining-production-value-commodity/ [Accessed 17 Dec. 2022].

- **Industrias Peñoles S.A. de C.V:** A subsidiary of Grupo BAL, Industrias Peñoles operates in multiple Mexican states, producing refined silver, gold, lead, zinc, and sodium sulphate. It is a prominent player in Latin America's gold, lead, and refined zinc production.
- **Fresnillo PLC:** As Mexico's largest gold producer and the world's leading primary silver producer, Fresnillo PLC operates mines in Sonora, Chihuahua, Durango, and Zacatecas. Their product range includes silver, gold, lead, and zinc[246], with a net revenue of $2.8 billion in 2021.

Major Environmental Concerns Linked to Mining

Land Degradation: Large-scale mining projects contribute to land degradation by destroying minerals-rich land and leaving behind contaminated rubble and massive craters. This leads to a loss of habitat for wildlife and deprives local communities of land for agriculture and forestry[247].

Loss of Biodiversity: Mexico, known for its high biodiversity, has approximately 12% of the world's biological diversity[248]. However, the increasing rate of mining concessions has resulted in about 25% of Mexico's total area being included in mining concessions[249]. This has negatively affected protected areas, leading to the degradation of natural habitats and threatening wildlife health. Pollution from mining activities, such as river contamination, acid drainage, and vegetation removal, further increases the risk of species extinction.

Chemical Contamination: Mexico has numerous abandoned mines, accumulating of toxic waste that poses environmental risks. Lack of vegetative cover exposes these waste materials to erosion, dispersing potentially toxic elements (PTE) through wind-blown dust and drainage water. This contributes to the acidification of soil, groundwater, and surface water. Studies have shown excessive lead, arsenic, and zinc accumulation in nearby soil, threatening food security[250]. The Rio Sonora watershed has also been affected by mining operations for over a century, deteriorating the quality of surface and groundwater in the region due to emissions of potentially toxic elements.

Legislative Provisions for Mine Restoration and Rehabilitation

Acts and Policies

The Mexican Mining Law of 1992 outlines mineral exploration, exploitation, and beneficiation requirements. Under this law, specific articles highlight the importance of adhering to balance and environmental protection

[246] Statista. Mexico: mining production value by commodity 2021. [online] Statista Database. 2022. https://www.statista.com/statistics/863411/mexico-mining-production-value-commodity/ [Accessed 17 Dec. 2022].

[247] Tetreault D. Social environmental mining conflicts in Mexico. *Lat Am Perspect*. 2015;42(5):48-66.

[248] Nam CW. World economic outlook for 2022 and 2023. In: *CESifo Forum*. Vol 23. München: ifo Institut-Leibniz-Institut für Wirtschaftsforschung an der …; 2022:50-51.

[249] Armendáriz-Villegas EJ, de los Ángeles Covarrubias-García M, Troyo-Diéguez E, et al. Metal mining and natural protected areas in Mexico: Geographic overlaps and environmental implications. *Environ Sci Policy*. 2015;48:9-19

[250] González-Méndez B, Webster R, Loredo-Portales R, Molina-Freaner F, Djellouli R. Distribution of heavy metals polluting the soil near an abandoned mine in Northwestern Mexico. *Environ Earth Sci*. 2022;81(6):176.

provisions. Article 27 stipulates that mining concession holders must comply with general provisions and technical regulations for ecological balance and environmental protection[251]. Article 37 applies similar requirements to individuals engaged in beneficiation works. Article 39 emphasizes the responsibility of mining concessionaires to protect the environment and ecology during exploration, exploitation, and beneficiation activities.

Furthermore, Article 28 of the General Law of Ecological Balance and Environmental Protection (LGEEPA) establishes the procedure for environmental impact assessments. This assessment is crucial for establishing conditions to prevent or minimize adverse effects on the environment during mining operations[252]. As a result, prior environmental impact authorization from the Secretariat is required to explore, exploit, and utilise minerals.

Restrictions in Mining Activities (Compliances and Licensing):

Mining activities in Mexico are subject to various permitting and compliance requirements. The Ministry of Environment and Natural Resources mandates acquiring an environmental impact authorization and a forestry land use change authorization. The exploration stage necessitates compliance with the Mexican official standard number 120-SEMARNAT-2010, which ensures environmental protection during mining exploration.

An Environmental Impact Statement (MIA) and authorization for the Change of Use on Forest Land (CUSTF) must be submitted during the operation stage. Additional obligations include registering as a hazardous waste generator, developing a Hazardous Waste Management Plan, obtaining environmental insurance, and reporting any loss of hazardous waste to the authorities.

Closure of mines also comes with specific obligations, outlined in the Closing Programme authorized by the Ministry of Environment and Natural Resources. These obligations include ensuring the safety and stability of mined lands, closing all entrances to underground mines, and controlling hazardous materials and waste.

Water concession titles from the National Water Commission (CONAGUA) are required for water extraction or wastewater disposal purposes. Applicants must verify that the extraction area is not restricted by CONAGUA. Construction of mining project infrastructure on riverbeds also necessitates a permit from CONAGUA.

Key Institutions involved in Mine Restoration and Rehabilitation

Mexico has two key ministries directly regulating mining policy: the Ministry of Economy (SE) and the Ministry of Environment and Natural Resources. The Ministry of Economy oversees mining activity through the General Directorate of Mines (DGM) and two deconcentrated agencies: the Mexican Geological Service (SGM) and the Mining Development Trust (FIFOMI). The Ministry of Environment and Natural Resources, through the Federal Environmental Protection Agency (PROFEPA), oversees environmental regulation in mining activities[253]. These institutions play essential roles in ensuring the compliance, regulation, and protection of the environment in the mining sector in Mexico.

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[251] Gutiérrez Haces MT. The Growing Presence of Canadian Mining Companies in Mexico and the Dominance of Mexican Business Groups. Lat Am Policy. 2016;7(2):241-266.

[252] Machine Translation of "General Law Of Ecological Balance And Environmental Protection" (Mexico).

[253] OECD. Organization for Economic Cooperation and Development: Mexico. 2020.

- The General Directorate of Mines (DGM) grants mining concessions, monitoring compliance, and promoting, sustainable mining practices. It manages inspections, sanctions non-compliance, and can suspend or cancel mining works.
- The General Directorate of Mining Development (DGDM) conducts studies, diagnoses issues, and proposes solutions for the mining sector's problems.
- The Federal Environmental Protection Agency (PROFEPA), under the Ministry of Environment and Natural Resources, enforces federal environmental legislation and promotes environmental justice. PROFEPA conducts inspections, verification, and oversight, and responds to public complaints to protect natural resources.
- The National Water Commission (CONAGUA) regulates and manages national water bodies. CONAGUA grants water concession titles for water extraction and permits for wastewater discharge in mining operations.

Financing Arrangements for Mining Restoration and Rehabilitation

Mine closure regulations do not adequately cover planning and financial assurance for mine closures that would avoid increasing environmental liabilities and the number of abandoned mines in the country. Despite the efforts made through the Extractive Industries Transparency Initiative (EITI), the distribution of financial benefits is neither consistent nor transparent and does not reach the communities or mining authorities. Hence, the Mining Policy Framework Assessment 2022 recommended that the government take care of abandoned mines and their environmental and social liabilities. This involves planning and seeking financial resources and partners. Finally, the government should be able to differentiate abandoned mines from liabilities . [254]

Role of the Private Sector in Mine Restoration

Mining companies in Mexico, such as Torex Gold and Covia, are actively engaging in environmentally responsible projects for mine restoration. Torex Gold, operating in the Guerrero Gold Belt, prioritizes environmental protection and compliance with regulations. They conduct impact assessments, implement reforestation programs, and include conservation areas in their mine planning. Their comprehensive mine closure and waste management plan ensure restoration and proper disposal. Similarly, Covia, a minerals provider, focuses on restoration and non-disruptive practices. Their certified restoration program in Veracruz showcases successful reclamation efforts, supported by partnerships with experts. Covia's commitment is evident through reforestation, habitat preservation, and the conversion of mining areas into wildlife habitats, promoting sustainable practices.

Community Involvement and Engagement

Greenpeace Mexico

Greenpeace is an international non-governmental organization that emphasises the role of people's participation in building a green and peaceful world[255]. In 2014, Greenpeace Mexico played an active role in documenting the spills of millions of gallons of copper sulphate, and sulphuric acid from a Grupo Mexico mine

[254] IGF. Indigenous Consultation and Mine Closure Workshop in Mexico. Intergov Forum. 2022. https://www.igfmining.org/workshop/indigenous-consultation-and-mine-closure-workshop-mexico/ [Accessed 17 Dec. 2022].

[255] Pasos MA. Greenpeace México, AC-SEM-09-001 (Maíz transgénico en Chihuahua). 2020.

into the Sonora River in Sonora state, Mexico. The organization also carried out sampling in different areas of the Bacanuchi River. It published data on the quality of drinking water and the quantities of heavy metals in the water.

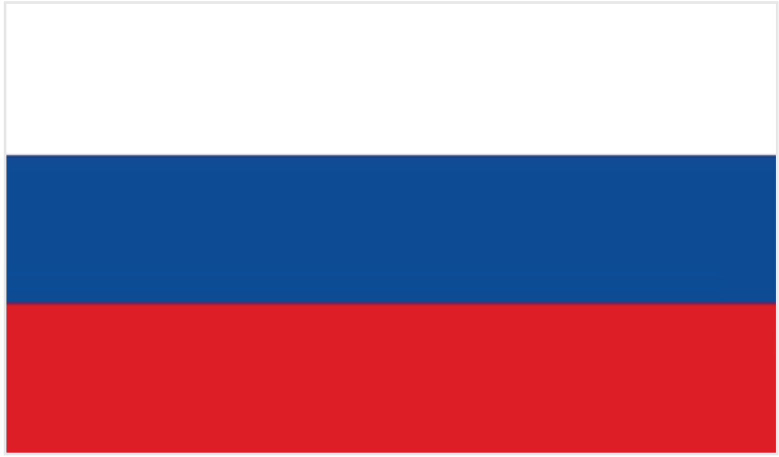
Academic and Research Institution Involved

- **Mexican Georgical Survey:** The Mexican Geological Survey aims to generate and disseminate geological knowledge to promote the sustainable use of mineral resources and prevent adverse environmental impacts. They collaborate with national and international academic and scientific institutions through agreements on ecological geology, risk, hydrogeology, and geotechnical studies.
- **SGS Offices and Labs:** SGS offices and labs offer services to mining companies, including sustainable process design, geotechnical studies, and closure scenario animations. Their expert analysis of various sample types ensures compliance with regulations and minimal environmental impact during all stages of mining operations.
- **United Nations Environment Program (UNEP) :** The United Nations Environment Program (UNEP) focuses on promoting sustainable mining in Queretaro's Sierra Gorda region. UNEP mobilizes resources to assess the impact of mercury and artisanal mining on human health and soil. They collaborate with government entities like SEMARNAT and the Ministry of Sustainable Development to identify gold mining sites and develop alternative economic opportunities for local communities to avoid hazardous activities.

Capacity Building

- The Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development organized a workshop in Mexico City to help government officials enhance their mining policy knowledge, focusing on indigenous consultation and mine closure. The workshop utilized the Mining ESIA Tool (MET) to discuss legal frameworks, environmental impacts, and mining's lifecycle. It emphasized integrating closure requirements early in the environmental impact assessment process and successful post-mining transitions.
- FICEMIN offers a short course on hydrogeology for mining projects, aiming to raise awareness among stakeholders about effective water management strategies. The course covered data generation, interpretation, and utilization to address issues caused by inadequate management.

14 Russia



Country Overview of Mining Activities

Mining plays a significant role in the Russian economy, accounting for nearly 14% of global mineral extraction. It contributes approximately 4% of the world's iron ore production and over 10% of the world's nickel. In the second quarter of 2022, mining GDP reached 1,904 billion Rubles, making it the second-largest contributor to the Russian economy after natural gas and oil exports[256]. The graph below shows the gains of Russia from mining. The Y-axis is Billion Rubbles (Figure 22). Russia possesses abundant untapped natural resources, estimated to be worth over 75 trillion USD[257]. The country produces minerals like iron ore, nickel, diamonds, coal, aluminium, palladium, uranium, platinum, and gold. The mining sector employs around 10% of the Russian population and attracts significant investment[258]. Russia holds substantial reserves of gold[259], ranks sixth in coal production, and leads in nickel production[260]. Additionally, it possesses 10% of the world's copper reserves.

Key Mining Area's

Gold is one of the main resource extracted from Russia. The Olympiada gold mine is one of the largest mines in Russia. It is located in the Krasnoyarsk region, Eastern Siberia. The mine has reserves of 30 million oz of gold. More than 90% of Russia's coal reserves are in Siberia and the Far East, Russia also has 6% of the World's oil deposits and more than a third of the World's natural gas reserves. Russia also has the massive copper deposit, most located in Kola peninsula and the Urals. A huge iron ore deposit exists in Kursk Magnetic Anomaly in Southwestern Russia. There are estimates that this might contain a sixth of the global reserves. Other area's with a large iron deposit include the Kola Peninsula, South Central Siberia, Far East etc. The largest Zinc and lead reserves are located in North Ossetia. Regarding Uranium, there is a mine in Krasnokamensk in the Altai

[256] Yang J, Rizvi SKA, Tan Z, Umar M, Koondhar MA. The competing role of natural gas and oil as fossil fuel and the non-linear dynamics of resource curse in Russia. Resour Policy. 2021;72:102100.

[257] Casey JP. Casey, J.P. (2021) Huge reserves and huge potential: Mining in Russia, Mining Technology. 2021. https://www.mining-technology.com/features/huge-reserves-and-huge-potential-mining-in-russia/ (Accessed: January 13, 2023).

[258] Russia M& E. Russia, Mining & Environment. 2016. https://www.miningsee.eu/russia-mining-environment/ (Accessed: January 13, 2023).

[259] Harder J. Russia's mining industry on an upswing, Mineral Processing. 2020

[260] Mudd GM. Global trends and environmental issues in nickel mining: Sulfides versus laterites. Ore Geol Rev. 2010;38(1-2):9-26.

Figure 20: Russia mining-based GDP and trade economics[261]

region. Most of the minerals in Russia are now found in the Siberia and Ural regions. The forests of Siberia contain an estimated one-fifth of the world's timber, mainly conifers. Many of Russia's mineral resources are in the remote, freezing north. The coal deposits are located on the territory of 85 municipalities in Russia. Today, coal is extracted in 16 basins. The Kuznetsk and the Kansk-Achinsk Basins are the largest ones[262].

Key Mining Companies

- **Alrosa:** One of the world's largest diamond producers, with 36.7 million carats in 2018.
- **Polyus Gold:** Moscow-based gold mining company, among the top 10 global producers. Mainly operates in the Russian Far East.
- **SUEK:** Russia's largest coal company, owning 27 active coal mines, primarily in Siberia and Far East.
- **Metalloinvest:** Moscow-based iron ore mining company. Russia's largest iron ore producer.

Environmental Concerns

Mining has been a leading cause of pollution in Russia. It negatively affects the plants and animals. In addition to industrial value, many chemical elements in waste products cause toxic effects on the ecosystem[263]. Ore processing usually produces a lot of waste. The waste includes chemicals that are extremely harmful to nature and human health. The soil and water contamination from this waste, leads to land degradation and

[261] Federal State Statistical service. Russia GDP from MINING2022 data - 2023 forecast - 2003-2021 historical - chart, Russia GDP From Mining - 2022 Data - 2023 Forecast - 2003-2021 Historical - Chart. 2022. https://tradingeconomics.com/russia/gdp-from-mining (Accessed: January 13, 2023

[262] Chanturiya V, Matveeva T. Applied Mineralogy for Complex and Profound Mineral Processing. In: 1*4th International Congress for Applied Mineralogy (ICAM2019) Belgorod State Technological University Named after VG Shukhov, 23–27 September 2019, Belgorod, Russia 14*. Springer; 2019:45-48

[263] Levchenko E, Spiridonov I, Klyucharev D. Environmental Pollution Problems in the Mining Regions of Russia. *In: 14th International Congress for Applied Mineralogy (ICAM2019) Belgorod State Technological University Named after VG Shukhov, 23–27 September 2019, Belgorod, Russia 14*. Springer; 2019:453-456

biodiversity loss. Mining causes erosion and form sinkhole. In Russia, many mines were shut during the 90s due to economic difficulties, and these mines contributed to soil pollution, strong oxidation of the land has been observed. Soil colloids become weak, and the soil absorbing complex is affected[264]. The mine water in Russia is another contributor to pollution. Discharging contaminated mine water (mainly from coal) is a major source of pollution in natural reservoirs. The mining of coal also has a negative impact on the air quality. It releases fine particles, methane, and ash. Kemerovo Oblast in Russia experienced an anthropogenic earthquake[265]. Nikel, a town in the Pechengsky district, has been affected by sulphur dioxide pollution. The toxic fumes cause breathing problems for the population. In the far East, mining has led to biodiversity loss in the Primorye's. This region has a rich diversity of threatened species.

Legal Provisions for Mine Restoration and Rehabilitation

The primary Russian laws related to activities associated with the mining of minerals are:

1. The law "On Subsoil", dated 21 February 1992 (Subsoil Law).
2. Federal Law "On Precious Metals and Precious Stones", dated 26 March 1998.
3. Federal Law "On Production Sharing Agreements", dated 30 December 1995.
4. Federal Law "On the Procedure for Making Foreign Investments in Business Entities of Strategic Importance for the National Defence and Security of Russia", dated 29 April 2008 (Strategic Investments Law).

The following federal laws establish the main ongoing requirements for environmental protection:

- Federal Law No. 7-FZ, "On Environmental Protection", dated 10 January 2001 (Environmental Protection Law).
- Federal Law No. 174-FZ, "On Environmental Expert Review", dated 23 November 1995 (Environmental Expert Review Law).

Under the Russian Constitution, environmental protection is within the joint competence of Russia and its constituent entities. Therefore, environmental legislation is also passed by the respective regional authorities[266]. According to Russian legislation, a group of residents can find a so-called territorial public self-governmental organization (TOS) to defend their rights. The Russian constitution provides basic environmental rights to all human beings. These rights included 1) a favorable environment 2) access to reliable information on its state 3) Compensation for damage caused to health/ property by the environmental offence (monova, N. 2015). The mining companies in Russia are obliged to follow environmental and rehabilitation laws.

Key Institutions involved in Mine Restoration and Rehabilitation

- **Ministry of Natural Resources and Environment:** The Russian Ministry is responsible for administering the licensing regime and supervising agencies regulating mining operations[267].

[264] Levchenko E, Spiridonov I, Klyucharev D. Environmental Pollution Problems in the Mining Regions of Russia. In: *14th International Congress for Applied Mineralogy (ICAM2019) Belgorod State Technological University Named after VG Shukhov, 23–27 September 2019, Belgorod, Russia 14*. Springer; 2019:453-456

[265] Samarskaya N, Lysova E, Paramonova O, Yudina N. Ensuring the Environmental Safety of Coal-fired Power Plants for the Flue Gases Purification. In: *IOP Conference Series: Earth and Environmental Science*. Vol 459. IOP Publishing; 2020:22074

[266] Josefson, J., Rotar, A. L. Mining in the Russian Federation: Overview, Thomson Reuters Practical law. *Thomson Reuters*. 2021. https://uk.practicallaw.thomsonreuters.com/w-011-1888?contextData=%28sc.Default%29&transitionType=Default (Accessed: January 13, 2023)

[267] http://www.mnr.gov.ru/

- **Federal Service for Ecological, Technological and Nuclear Supervision (Rostekhnadzor):** Ensures compliance with industrial safety requirements in mining through inspections, issuing mandatory orders to address violations, and granting operational licenses and permits.
- **Federal Supervisory Service for Nature Management (Rosprirodnadzor):** Monitors compliance with environmental protection and resource use regulations in mining, conducting inspections and issuing mandatory orders to rectify violations.
- **Federal Agency for Subsoil Use (Rosnedra)**: Conducts tenders and auctions for subsoil licenses, with the authority to suspend, restrict, or terminate subsoil use rights.

Private Involvement in Mine Restoration

Amur Minerals Corporation: Russian nickel sulphide exploration company in the Amur region, collaborating with Aerocraft Corporation to use heavy lift vehicles for their environmental-friendly nickel sulphide copper project.

Nornickel: Leading metals and mining company in Russia, producing palladium, nickel, platinum, copper, cobalt, and more. Implemented sustainability strategies, reduced sulphur dioxide emissions, cleaned up diesel fuel spills, and carbon-neutral nickel production.

SRK Consulting: Global mining consulting company with a Russian office, offering comprehensive services from resource mapping to mine closure and rehabilitation. Provides environmental and social impact assessments, stakeholder engagement, and management planning.

Bellona Murmansk: Environmental protection NGO focused on the Northern Region of Murmansk. Their main goal is to address environmental degradation, pollution-related health risks, and ecological impacts of economic development.

Dauria: Russian green group (NGO) advocating for environmental rights for over 20 years. They lead ecological campaigns in Russia's far east, particularly in Chita and the Zabaikalsky region. In 2016, they faced government scrutiny and were designated as a foreign agent, restricting their activities.

Ecodefense: Founded in 1989 in Kaliningrad, this environmental NGO operates from offices in Moscow, Kaliningrad, Yekaterinburg, and Vilnius. Ecodefense works to combat human rights violations, solve environmental problems, and encourage citizen participation through environmental campaigns, non-violent actions, information dissemination, and environmental education. It is also facing intense scrutiny from the Russian government.

Academic and Research Institutions Involved in Mine Restoration

Research Institute of Mining Geomechanics & Mine Surveying (VNIMI): VNIMI is a leading research centre specializing in mining sciences, including mining geology, hydrogeology, geophysics, geodynamics, geomechanics, and mine surveying.

Saint Petersburg Mining University: As a National Research University, it is renowned for teaching and research in mining, underground construction, and tunnelling.

Federal State Budgetary Institution of Science Mining Institute FEB RAS: The institute focuses on mining efficiency and strategic scientific problems in the Far East region. It is considered a leading academic mining organization in Eastern Russia.

Research Laboratory of Disturbed Lands' and Technogenic Objects' Reclamation, Ural State Mining University: Located in Yekaterinburg, this university offers education in various mining-related fields and houses a research laboratory dedicated to land reclamation and technogenic objects.

Russian Academy of Sciences, Kola Science Centre: This centre encompasses research institutes, including the Institute of Industrial Ecology Problems of the North and the Institute of Chemistry and Technology of Rare Elements and Mineral Raw Materials.

Capacity Building

Saint Petersburg Mining University provides courses in mining engineering and Mining and Environmental Studies.

15 Saudi Arabia

Key Mining Sectors

The mining sector in Saudi Arabia employs around 250,000 employees and contributes to about $US 17 billion of Saudi's GDP[268]. By 2030, the development of the mineral industry is projected to increase the sector's contribution to GDP to over $US 64 billion, reduce imports by about $10 billion, and generate more than 200,000 jobs to transform the mining sector as the third pillar of the Saudi industry. The key mineral commodities that Saudi Arabia mines are aluminium, ammonia, ammonium phosphate [diammonium phosphate and monoammonium phosphate], copper in concentrate, crude petroleum, gold, iron and steel, refined petroleum products, silver, sulphur, urea, and zinc. The country also produces basalt, coke, dolomite, feldspar, granite, gypsum, kaolin, industrial sand, limestone, magnesite, marble, refined lead, salt, sand and gravel, schist, and talc[269]. The Central Department of Statistics and Information, Saudi Arabia reported that GDP from mining in Saudi Arabia, increased to $76,2 billion in the third quarter of 2022 from $71,2 billion in the second quarter of 2022.

Key Mining Areas

Data shows that Saudi Arabia has 330 mining sites with a total exploration and extraction area of about 118,000 square kilometres[270].

Key Mining Companies

Saudi Arabian Mining Co. (Ma'aden): Ma'aden is the largest mining and metals company in the Middle East. It extracts various commodities, including phosphate, aluminium, gold, copper, and industrial minerals like low-grade bauxite, kaolin, and caustic calcined magnesite.

Al-Masane Al-Kobra Mining Co. (AMAK): AMAK is a private mining company in the Najran region. It focuses on mining gold, silver, copper, and zinc.

Muadinoon Mining Company: The company specializes in industrial silica and conducts geological and feasibility studies for new materials. They prioritize mine site reclamation, including demolishing structures, sealing mine openings, re-grading the area, re-vegetation, and water treatment.

[268] Al Rawashdeh R, Campbell G. Mineral policy in the Gulf Cooperation Council (GCC) countries: The case of Saudi Arabia. Extr Ind Soc. 2022;9:101042

[269] Taib M. The Mineral Industry of Saudi Arabia. US Geological Survey, Report. 2022:1-13.

[270] Zmami M, Ben-Salha O, Almarshad SO, Chekki H. The contribution of mining sector to sustainable development in Saudi Arabia. J Sustain Min. 2021;20.

Major Environmental Concerns Linked to Mining

The 2030 vision of the Kingdom of Saudi Arabia aspires to develop the mining sector to become the third pillar of its gross domestic product[271]. Increased exploration and mining activities will lead to increased waste production. Contamination of the environment with heavy metals is another consequence of mining. Higher concentrations of heavy metals can lead to bioaccumulation and biomagnification[272].

Legislative Provisions for Mine Restoration and Rehabilitation

Acts and Policies

New Mining Investment Law: The Ministry of Industry and Mineral Resources developed the New Mining Investment Law as part of Saudi Vision 2030, a strategic framework to reduce Saudi Arabia's dependence on oil and diversifying its economy[273]. The New Mining Investment Law has three main objectives: governance and transparency, investment attractiveness, world-class sustainability that incorporates provisions like mandatory rehabilitation and closure plan, security for rehabilitation costs, community engagement and local content, and streamlining environmental and social reporting requirements[274].

The law also provides for establishing a national geological database, a "Mining Fund" to support the mining sector, streamlining the procedure for obtaining mining licenses and introducing certain financial incentives for investors. Utilization/Exploitation License holders now need to provide a financial guarantee for rehabilitation and closure of the license site. Applications now require the submission of environmental and social impact studies while the old law only required an environmental study. In addition to proving the economic feasibility of a project and compliance with relevant environmental regulations, applicants will need to demonstrate how they intend to contribute to the development of local communities and support local content.

The new amendments to the law also included determining the lands excluded from the application of the new law on them, as well as the lands that require the prior approval issued by the Ministry before granting an exploitation license, or discovering them, or even reserving them for mining investment activities, such as lands occupied by holy, historical and archaeological sites, or those on which cities, streets and railways are built and pipelines, public roads, or other places where mining investment is not permitted, as well as lands, marine areas, pastures and forests, which are decided to be excluded from the application of the provisions of this law as agreed by the Council of Ministers .

The new amendments also prohibited the license holders from owning, using, selling or disposing of any radioactive materials discovered in the lands where the mining investment activity is practised.

Key Institutions involved in Mine Restoration and Rehabilitation

- **Ministry of Industry and Mineral Resources:** The ministry oversees industrial and mining sectors, encourages investment, and issues licenses in Saudi Arabia.

[271] Hefni M, Ahmed HAM, Omar ES, Ali MA. The potential re-use of Saudi mine tailings in mine backfill: A path towards sustainable mining in Saudi Arabia. Sustainability. 2021;13(11):6204

[272] Almalki AM, Ajarem J, Altoom N, et al. Effects of mining activities on gerbillus nanus in saudi arabia: A biochemical and histological study. Animals. 2019;9(9):664

[273] Meehan L. New Mining Investment Law in Saudi Arabia. Baker McKenzie Report. 2020:1-5

[274] Ministry of Industry and Mineral Resources. Saudi Arabia Mining Overview. Saudi Arab Minist Ind Miner Resour. 2022:6-29

- **Saudi Geological Survey:** Responsible for geological surveying, mineral exploration, and promoting mineral resources and investment opportunities.
- **National Industrial Development and Logistics Program (NIDLP):** Aims to transform Saudi Arabia into a leading industrial powerhouse and global logistics hub, maximizing mining and energy sectors' value and promoting local content and the 4th Industrial Revolution. It supports economic diversification and fosters an attractive investment environment.

Financing Arrangements for Mine Restoration and Rehabilitation

The Ministry of Industry and Mineral Resources will establish a "Mining Fund" to support the mining sector by depositing financial considerations, fines, and rentals[275]. The fund aims to provide sustainable financing for mining activities, including exploration, rehabilitation of abandoned mines, and support for specialized mining companies. The ministry will create special entities using the fund's capital to provide sector services. Additionally, the National Industrial Development and Logistics Program will establish a mining excellence centre and a metal alloy development centre to promote technological advancements in the industry.

Role of the Private Sector in Mine Restoration

SGS Inspection Services Saudi Arabia Ltd. : provides a range of services for mine site reclamation, including reclamation programs, site investigation, visual impact studies, landscape architecture, and technical reports. They also specialize in Acid Rock Drainage (ARD) mitigation strategies.

3B Mining Company: A private Mauritanian company, that offers various mining services, including closure and reclamation, prospecting, exploration, and extraction.

Academic and Research Institutions involved in Mine Restoration

King Abdulaziz University: King Abdulaziz University provides an undergraduate program in mining engineering that covers various subjects related to the field. These include "Principles of Mining and Metallurgical Engineering," which considers the environmental impact of mining. The program also covers "Mine Law, Planning and Management" and "Mine Environment," which delve into surface vegetation control, legislative regulations, implementation, reclamation, and regional restoration.

Capacity Building

Saudi Mining Polytechnic (SMP)

The SMP Institute is a collaborative effort between Saudi Arabian Mining Company, (Maaden) and Technical and Vocational Training Corporation (TVTC) to provide training and qualification for Saudi youth in technical roles within the mining industry. The institute offers courses such as the underground mining program, above-ground mining program, mineral processing software, and maintenance programs in mechanics and electricity.

[275] Meehan L. New Mining Investment Law in Saudi Arabia. Baker McKenzie Report. 2020:1-5

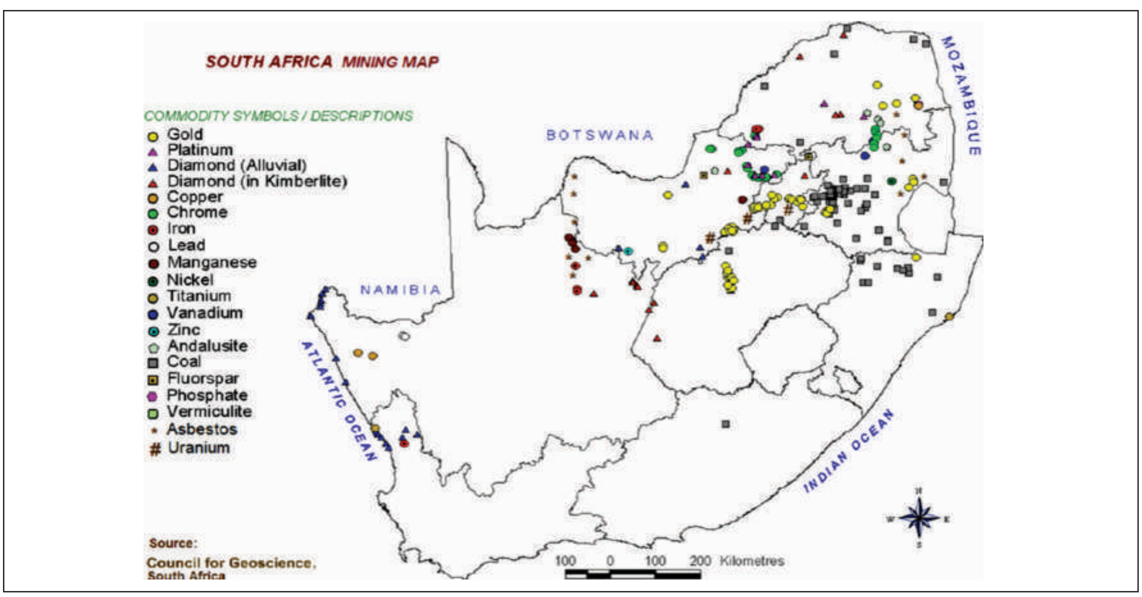
16

South Africa

Key Mining Sectors

South Africa is rich in mineral resources, with over 1700 active mines producing 53 minerals. The country's leading mining sectors include coal, platinum, gold, and diamonds[276]. Coal mining employs a significant number of people, with 92,230 employees in 2019 and sales exceeding $8 billion. Platinum is mainly extracted from the Bushveld Complex, which accounts for 75% of global output. Gold mining in the Witwatersrand Basin, the world's largest gold resource, generated sales of $4.2 billion in 2019, employing 95,130 individuals. The diamond industry produced 7.2 million carats, with sales totalling $763 million, and employed 15,728 people. The main mining areas are located in the northeast, while some mines are situated on the west coast along the Atlantic Ocean, particularly for diamonds, copper, and iron. Gauteng and Mpumalanga are the provinces with the highest number of mines[277].

Figure 21: South Africa Mining Map[278]



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[276] Minerals Council South Africa. Minerals Council South Africa, Government of South Africa. 2022. https://www.mineralscouncil.org.za/sa-mining [Accessed 28 11 2022]

[277] Utembe W, Faustman EM, Matatiele P, Gulumian M. Hazards identified and the need for health risk assessment in the South African mining industry. Hum Exp Toxicol. 2015;34(12):1212-1221

[278] Council for Geoscience South Africa (CGSA).Selected active mines. http://www.geoscience.org.za/images/stories/selectedactivemines.gif (accessed 20September 2014). *(15) (PDF) Hazards identified and the need for health risk assessment in the South African mining industry.*

Key Mining Companies

- Anglo American is a prominent mining company based in Johannesburg, South Africa, specializing in Platinum Group Metals (PGMs), base metals, and precious metals. The company is the leading global primary producer of PGMs.
- Impala Platinum Holdings (Implats) has a rich mining history spanning over a century and is a significant producer of PGMs.
- Sibanye-Stillwater is a major primary producer of platinum, palladium, rhodium, and gold. With operations in South Africa, the company has established PGM and gold mining operations.

Major Environmental Concerns Linked to Mining

- **Land Degradation:** The South African mining companies in Mpumalanga have neglected environmental responsibility, resulting in severe land degradation[279]. The province, accounting for 83% of the country's coal production, suffers from infertile soil, water scarcity, and pollution due to open mines left behind.
- **Biodiversity:** Mining activities in South Africa cause irreversible loss of natural habitat, leading to significant biodiversity decline. Trade-offs often fail to compensate for the value lost, putting immense pressure on ecosystems and long-term impacts on biodiversity[280].
- **Chemical Contamination:** Mining operations in South Africa contribute to chemical contamination, particularly in regions like Witwatersrand and Welkom[281]. Groundwater is heavily contaminated and acidified near mining districts, posing health risks to communities. Toxic levels of elements like lead and iron are found in the groundwater, the primary source of drinking water[282].
- **Impacts on Ecosystems:** The growth of South Africa's mining industry comes at the cost of toxic waste, impacting ecosystems and causing diseases. The industry's development has significant environmental consequences, affecting not only the environment and animals but also humans, as highlighted by a study on heavy metal pollution and mining impacts[283].

Legislative Provisions for Mine Restoration and Rehabilitation

The Mineral Act 50 of 1991 includes a chapter on rehabilitation, covering layout plans, rehabilitation programs, building removal, and land use restrictions. It also addresses land acquisition and compensation in specific situations.

The National Environmental Management: Biodiversity Act No. 10 of 2004 empowers the South African National Biodiversity Institute to coordinate ecosystem rehabilitation programs, potentially involving civil

[279] Pretty MM, Odeku KO. Harmful mining activities, environmental impacts and effects in the mining communities in South Africa: a critical perspective. *Environ Econ.* 2017;8(4):14.

[280] Brownlie S, Botha M. Biodiversity offsets: adding to the conservation estate, or 'no net loss'? *Impact Assess Proj Apprais.* 2009;27(3):227-231.

[281] Belle G, Fossey A, Esterhuizen L, Moodley R. Contamination of groundwater by potential harmful elements from gold mine tailings and the implications to human health: a case study in Welkom and Virginia, Free State Province, South Africa. *Groundw Sustain Dev.* 2021;12:100507.

[282] Naicker K, Cukrowska E, McCarthy TS. Acid mine drainage arising from gold mining activity in Johannesburg, South Africa and environs. *Environ Pollut.* 2003;122(1):29-40.

[283] Sedibe M, Achilonu MC, Tikilili P, Shale K, Ebenebe PC. South African mine effluents: Heavy metal pollution and impact on the ecosystem. 2017.

society. Minister Barbara Dallas Creecy published proposed regulations in July 2022, focusing on financial provisioning for mitigating and rehabilitating environmental damage caused by mining activities.

Key Institutions involved in Mine Restoration and Rehabilitation

- **Department of Mineral Resources and Energy:** Promotes sustainability and social equity in South Africa's mineral resources sector through policy formulation and implementation.
- **South African National Biodiversity Institute:** Researches on indigenous biodiversity and coordinates ecosystem rehabilitation programs for mines, contributing to the restoration process.
- **Minerals Council South Africa:** Represents mining industry employers, focusing on environmental concerns, and research needs, and providing advice on topics like mine closure and sustainable development.
- **Coaltech Research Association:** A non-profit organization collaborating with the government, educational institutions, research organizations, and mining companies to develop a safer and more sustainable coal industry in South Africa.

Financing Arrangements for Mine Restoration and Rehabilitation

The costs for rehabilitation need to be covered by the mining companies. Before production starts, they need to make provisions to cover liability that the value of the mine covers the costs for rehabilitation[284]. There are two sides to the balance sheet: assets and liabilities. The mining company creates a provision on the liabilities side of the balance sheet, to cover the current estimates of future rehabilitation costs. The mining company also has to develop specific plans comprising the different steps and scopes of the environmental rehabilitation work. Annual adjustments need to be conducted as mining plans develop further. On the other side of the balance sheet are the assets, whose value decreases as the land of the mine is degraded. The mining company needs to ensure that it puts aside an adequate amount to cover the rehabilitation costs. The funds are subsequently used for the rehabilitation of the degraded land.

Role of the Private Sector in Restoration

The mining companies are private companies and thus pay for the rehabilitation of the mining sites. Private companies also assist mining companies with rehabilitation through their expertise in mine rehabilitation design. Guardrisk is an insurance company that supports mining rehabilitation with guarantees. Agreenco provides mine rehabilitation and environmental improvement services to the mining sector. The company also has expertise in productive land rehabilitation land.

Community Involvement and Engagement

According to the National Environmental Management Act, socio-economic impacts must be assessed before implementing the projects. This includes Environmental Impact Assessments (EIA) that evaluates environmental, socio-economic, and cultural effects. Public involvement, particularly from disadvantaged communities, is mandatory in social impact assessments. However, many communities lack awareness and participation opportunities. Engaging with these communities is vital, considering their expectations and valuable knowledge for rehabilitation. The involvement of locals is also emphasized in the guidelines for species

[284] Tambo, O.;Theobald S. Financial provisioning for rehabilitation and mine closure: A study of South African platinum and coal mining companies, Intellidex. 2018.

selection and management in mine land rehabilitation. Their expertise contributes to successful restoration efforts[285].

Academic and Research Institutions Involved

- The University of the Witwatersrand's Centre for Sustainability in Mining and Industry offers research programs for MSc and PhD students, focusing on responsible mining and achieving a net positive environmental impact.
- The University of Venda's Department of Mining and Environmental Geology provides degrees and diplomas in mining and environmental geology, covering geo-environmental health and mine rehabilitation.
- The Mining Resilience Research Centre at the University of Pretoria promotes research and innovation across multiple disciplines, aiming to contribute to the United Nations Sustainable Development Goals.

Capacity Building

North-West University

North-West University offers a short course on Ecological rehabilitation and mine closure, providing personnel and managers with knowledge on legal requirements and technical aspects. The course includes a site visit and expert panel discussions.

University of Pretoria

The University of Pretoria offers an 11-day Mine Closure and Land Rehabilitation course, aimed at preventing misunderstandings and educating participants on legal requirements, challenges, and opportunities in mine restoration. The course fee is $1762.67. These courses enhance understanding and competence in mine closure planning and ecological rehabilitation.

[285] Africa C of M of S. Guidelines for the rehabilitation of mined land. 2007

17 Türkiye

Country Overview of Mining Activities

Türkiye's mineral potential is diverse but has limited reserves on a global scale, with only 13 out of 90 types of minerals remaining unidentified. However, Türkiye is one of the world's richest countries in boron minerals, trona, marble, magnesite, pumice, perlite, and strontium minerals. Over the past 20 years, the mining sector's contribution to Türkiye's GDP has averaged around 0.98, gradually increasing from below 0.9 to over 1.1 in recent years. In 2022, the share of mining in GDP was recorded as 1.33 (7,248,788,983 Turkish Liras), according to MTA data.

Key Mining Areas

Türkiye's mineral resources are distributed across the country. In the Northwestern part (Marmara), minerals such as iron, marble, boron, lignite, natural gas, and tungsten can be found. The Western region (Aegean) is known for mercury, salt, chromium, sandstone, and boron. The Southern region (Mediterranean) has chromium, bauxite, iron, lignite, and wolframite deposits. The Northern parts (Black Sea) are rich in copper, lignite, coal, chromium, and manganese. The Eastern region has resources like iron, lead, copper, oltu stone, rock salt, and chromium. The Southeastern region is abundant in chromium, zinc, iron, copper, oil, and lignite. Lastly, the Central and central region holds reserves of iron, manganese, lignite, zinc, chromium, lule stone, boron, mercury, rock salt, and salt, according to the Mineral Research and Exploration General Directorate (MTA).

Key Mining Companies

In the 2020 ranking of the top 500 industrial companies in Türkiye, Türkiye Sise ve Cam Factories Inc. secured the first position among mining and mining-related companies. Eti Bakır AS held the second spot, followed by the General Directorate of Eti Mining Enterprises in third place. Other notable organizations in the mining sector were EÜAS Electricity Generation Co., Afsin Elbistan Electricity Generation and Trade Co., Kazan Soda Electricity Production Co., Türkish Coal Authority, OYAK Cement Factories Inc., Eti Aluminyum AS, and Limak Cement San. ve Tic. AS.

Major Environmental Concerns linked to Mining

The biggest environmental concerns related to mining activities in Türkiye include the degradation of land morphology, disruption of water balance, damage to agricultural and forest areas, harm to recreational areas, noise pollution, dust, increased traffic due to trucking, soil erosion and sedimentation, concussions from blasting, improper disposal of solid waste, air and water pollution, and the impact on flora and fauna[286]. Open mining activities also raise concerns about land degradation, noise pollution from blasting, dust pollution during transportation, and high truck traffic. These issues have sparked debates and concerns among various stakeholders in the country.

Legislative Provisions for Mine Restoration and Rehabilitation

Mining companies are required to submit rehabilitation plans to these institutions, which must be approved before they can commence operations. In cases where companies fail to comply with these plans or neglect rehabilitation altogether after mine closure, the state takes charge of the rehabilitation process through provincial governorships and recovers the costs from the mining companies.

Several key legislations govern the rehabilitation of open mine sites, including Environmental Law No. 2872, Mining Law No. 3213, Turkish Petroleum Law No. 6491, Forest Law No. 6831, Law No. 2873 on National Parks, Law No. 2863 on the Protection of Cultural and Natural Heritage, Pasture Law No. 4342, and relevant regulations.

In addition, three important legislations related to the rehabilitation of open mine sites (re-cultivation, land restoration) are:

- **Ministry of Forestry and Water Affairs:** Implementation of Article 16 of the Forest Law Regulation (April 18, 2014)
- **Ministry of Environment and Urbanization:** Regulation on Environmental Impact Assessment (November 25, 2014)
- **Ministry of Environment and Urbanization:** Restoring Lands Degraded by Mining Activities to Nature Regulation on Re-acquisition (January 23, 2010)

Key Institutions involved in Mine Restoration and Rehabilitation

Mining activities in Türkiye are primarily regulated and supervised by three ministries: the Ministry of Agriculture and Forestry, the Ministry of Environment, Urbanization, and Climate Change, and the Ministry of Energy and Natural Resources. The Turkish Mining and Petroleum Affairs General Directorate, and the General Directorate of Forestry, are responsible for monitoring restoration activities. In certain cases, the Turkish Petroleum Corporation and the Institute of Mineral Research and Exploration also participate in the restoration process.

Financing Arrangements for Mine Restoration and Rehabilitation

In Türkiye, mining companies are responsible for the costs of rehabilitating mining sites. If the companies fail to perform the required rehabilitation, the governorates step in and perform the activities, collecting the expenses from the mining company. A new draft mining law has been prepared by the Ministry of Energy and Natural Resources in 2022. The proposed law aims to establish a fund dedicated to rehabilitating mining sites and restoring degraded lands to their natural state, independent of the mining companies' involvement. Under the draft law, companies will contribute to the fund through taxes, salaries, state rights, license fees, and

[286] Tekayak D. An overview of environmental impact assessment in Turkey: Issues and recommendations. *Ankara Avrupa Calsmaları Derg*. 2014;13(2):133-151

rehabilitation fees. The General Directorate of Mining and Petroleum Affairs will then oversee the tender process and allocate funds from the relevant fund to restore the sites once the work is completed.

Role of the Private Sector in Mine Restoration

Within the scope of the current legal regulation in Türkiye, mining companies carry out land rehabilitation activities themselves, within the framework of their contracts. Two of them are;

Tüprag Metal Madencilik San. Ve Tic. Inc. is an established company involved in metallic mineral exploration and exploitation, operating significant gold deposits like Usak-Kisladag and izmir-Efemcukuru. The mine undertakes the restoration of the mining-affected area, as part of the mining plan. Eti Bakir A.S., part of Cengiz Holding, engages in copper mining and smelting activities in various facilities, with ongoing rehabilitation works in stages. The rehabilitaion work is carried out throughout the life of the mines.

Community Involvement and Engagement in Mine Restoration

Civil Society Organizations (CSOs) and non-governmental organizations actively advocate for nature preservation and monitor rehabilitation activities alongside local communities. CSOs raise awareness about the potential damages caused by mining activities to the environment and people's lives, while supporting economically beneficial land rehabilitation efforts. The mining platform, led by Istanbul Mineral Exporters' Association and comprising 14 CSOs, focuses on the rehabilitation of mining sites.

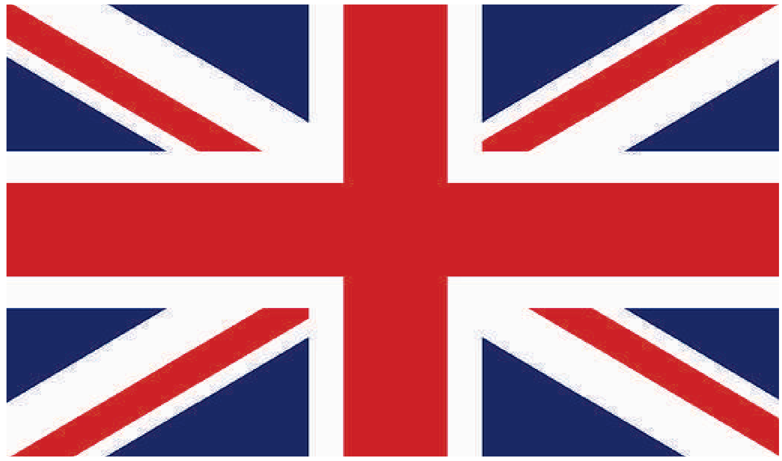
Academic and Research Institutions Involved in Mine Restoration

In Türkiye, training in mine site restoration is provided by forestry faculties under the landscape architecture program "Ecological land restoration and landscape restoration".

Capacity Building

Government institutions and universities organize workshops on land restoration, such as the Rehabilitation of Mining Sites workshop led by the General Directorate of Combating Desertification and Erosion and the General Directorate of Forests.

18 United Kingdom



Key Mining Sectors

One of the most important resources in Britain's mining history is coal. Coal helped fuel the industrial revolution and the economic growth of the British Empire[287]. In 1913, coal production in the UK peaked at 292 million metric tons. However, due to the rising cost, global competition, and climate targets, this production dropped to 1.054 million metric tons in 2021. The largest bulk market for non-energy minerals is construction. Aggregates account for approximately 85% of the non–energy minerals extracted in the UK. The total mass of produced minerals in the UK in 2020 was divided in percentage into 66.6% crushed rock, 25.9% for construction minerals, 5.5% for industrial minerals, and only 1 percent for both coal and oil and gas[288]. Additionally, recycled, and secondary sources of aggregates accounted for 28% of the total aggregate supply in the UK, which is a leading position in the recycling and secondary use of aggregates[289].

Key Mining Areas

Britain's last deep coal mine, North Yorkshire's Kellingley Colliery, closed in December 2015. Instead, more than a dozen open-cast coal mining sites are currently operating. The main sites for coal mining are South Wales (Glynneath, Tairgwaith, Merthyr Tydfil, and Coelbren area), Scotland (West Lothian and Ayrshire area), Tyne and Wear (the Brenkley Lane surface mine) and Northumberland (The Shotton surface mine). The Cornwall and Devon counties are the UK's source of tin and Kaolin (china clay), and the fourth-largest known tungsten deposit in the world. Other base metals found in Cornwall are copper, tin, lithium, cobalt, indium, zinc, and silver. Finally, minerals such as salt, potassium, and fluorine are extracted from Cheshire, England, Southern Pennine ore field, and Boulby, Yorkshire, respectively.

Key Mining Companies

- **Anglo American Plc:** Largest producer of platinum (40% global output) and major producer of diamonds, copper, nickel, iron ore, and coal. Operating in North Yorkshire since 2010, focusing on

[287] Garside M. Mining industry in the United Kingdom - statistics & facts. 2021. https://www.statista.com/topics/7156/mining-industry-in-the-uk/#dossierContents__outerWrapper [Accessed 31 November 2022].

[288] Database CEIC Data Global. CEIC Data Global Database, U. K., 2021. United Kingdom Coal Production. 2021. https://www.ceicdata.com/en/indicator/united-kingdom/coal-production.

[289] Tangtinthai N, Heidrich O, Manning DAC. Role of policy in managing mined resources for construction in Europe and emerging economies. J Environ Manage. 2019;236:613-621

developing the world's largest polyhalite resource as a fertilizer.

- **Antofagasta Plc:** Mining assets include copper, gold, molybdenum, and silver. Actively exploring in Chile, Ecuador, and Pakistan.
- **Glencore:** Operates in 60 mines globally, producing metals like copper, cobalt, zinc, nickel, and ferroalloys. Also markets aluminum/alumina and iron ore. Committed to reducing emissions and involved in recycling end-of-life electronics and critical metal-containing products.

Major Environmental Concerns linked to Mining

Land Degradation: The UK has a long mining history, resulting in thousands of abandoned metal mines. Mine tailings can lead to land contamination, particularly through acid mine drainage.

Biodiversity, Including Invasive Species: Mining activities cause habitat destruction and soil degradation, leading to biodiversity losses. Failings in waste storage facilities have other damaging impacts. Coal mining contributes to dust, noise, vibration, and disruption of groundwater regimes, affecting wildlife habitats[290]. Invasive species like Japanese knotweed can be found in soil tips from mining and quarrying.

Chemical Contamination: Mining pollution has long-lasting effects on soil, water, plants, animals, and human health. Abandoned metal mines pose risks to water quality, with many rivers at risk of not meeting targets. Some abandoned mines are protected as biodiversity reserves or heritage sites, complicating remediation efforts[291]. Tin and copper mining areas in Cornwall and West Devon are UNESCO World Heritage Sites.

Legislative Provisions for Mine Restoration and Rehabilitation

Despite the UK's exit from the EU, many EU mining regulations remain in force as part of UK domestic law. Scotland, Wales, and Northern Ireland have the power to enact their own laws and regulations within their respective assemblies. The Mineral Working Act 1951 was the UK's first significant attempt to control the environmental impact of mining. It established the Ironstone restoration fund, financed by fees from producers for land restoration. In Wales, the Town and Country Planning Act 1990 regulates the restoration and aftercare of mineral sites, requiring the use of subsoil, topsoil, and soil-making materials for restoration. Northern Ireland follows the North Down and Ards Area Plan 1984-1995 and Belfast Metropolitan Area Plan 2015, aiming to restore previously unregulated mineral workings. Scotland implemented the Environmental Liability Directive in 2009 to prevent and remediate damage to protected habitats, species, and land contamination affecting human health and water resources.

Key Institutions involved in the Restoration and Rehabilitation of Mines

- **Coal Authority:** Established in 1994, the Coal Authority is a regulatory body that owns the majority of coal and former coal mines in Great Britain. Its main focus is protecting the public and the environment by managing the impacts of past coal mining, ensuring public safety, and preserving the landscape. The authority is responsible for licensing coal mines, addressing subsidence issues, and managing property and historical liabilities. The Department of Environment, Food and Rural Affairs (DEFRA) has developed guidelines for mine reclamation, covering planning considerations, restoration proposals, soil management, equipment, monitoring, drainage, and aftercare.

[290] Mamurekli D. Environmental impacts of coal mining and coal utilization in the UK. Acta Montan Slovaca. 2010;15(2):134.

[291] The Geological Society of London. Metal mining who pays for the clean up? 2012. https://www.geolsoc.org.uk/Geoscientist/Archive/July-2011/Metal-mining-who-pays-for-the-cleanup [Accessed 7 12 2022].

- **Forestry and Land Scotland:** As a Scottish Government agency, Forestry, and Land Scotland manages national forests and land. It has undertaken land reclamation projects on former coalfield sites, aiming to create woodlands, sequester carbon, and improve the environment for wildlife and local communities. Collaborating with partners, the agency has focused on reclaiming vacant and derelict land for woodland creation. Specific sites like Mainshill (South Lanarkshire) and Blairhouse (Fife), previously Scottish Coal sites, are being restored in partnership with the Scottish Mines Restoration Trust and local planning authorities.
- **Mineral Rights in Northern Ireland:** In Northern Ireland, mineral rights, with exceptions, are vested in the Department for the Economy (DfE). The DfE outlines the process for awarding Mineral Prospecting Licences (MPLs) and seeks public consultation on applications. MPLs are granted on a "first come, first served" basis, but in cases where multiple interests exist, a competitive process may be employed.

Financing Arrangements for the Restoration and Rehabilitation of Mines:

The British government covers restoration and aftercare costs in certain cases, such as large limestone quarries, novel approaches or techniques, or instances of financial or technical failure. Operators are encouraged to seek guarantees against potential financial loss through the Mineral Products Association Restoration Guarantee Fund and the British Aggregates Association Restoration Guarantee Fund. The 1944 Town and Country Planning Act and the 1951 Mineral Working Act provide funding for restoring land affected by surface mining[292]. The Scottish Government's Vacant and Derelict Land Investment program aims to regenerate abandoned sites as part of their transition to net-zero by 2045. Grants from this program target long-term vacant and derelict lands. The Welsh government follows the International Financial Corporation's Performance Standard on Environmental and Social Risks and Impacts, which includes closure and restoration requirements. The IFC's guidelines for mining emphasize early consideration of closure and post-closure plans, including a Mine Reclamation and Closure Plan[293]. In Northern Ireland, the Mining Waste Directive outlines the management requirements for waste from extractive industries and quarries[294].

Role of the Private Sector in Mine Restoration

In Great Britain, mineral rights for all minerals except oil, gas, coal, gold, and silver belong to landowners rather than the state. Therefore, there is no national licensing system for the exploration and extraction of these privately owned minerals. The Scottish Mines Restoration Trust is an independent non-profit organization that focuses on old opencast mine sites, involving key stakeholders in the restoration processes. Banks Group and Aggregate Industries are private companies recognized for their successful restoration and biodiversity efforts in surface mineral sites. Recycoal is another leading business in restoring disused coal tips, with projects like Rossington and Langton Colliery showcasing their expertise in recovering coal and transforming the areas into attractive habitats for nature conservation. Overall, these initiatives demonstrate a commitment to responsible restoration and biodiversity enhancement in various regions of the UK[295].

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[292] Scottish Land Commission. Review of the funding sources for the re-use of vacant and derelict land. 2022

[293] The Welsh Government ERM. The Welsh Government ERM, 2014. Research into the failure to restore opencast coal sites in south Wales. 2014. https://gov.wales/sites/default/files/publications/2019-07/failure-to-restore-opencast-coal-sites-in-south-wales.pdf [Accessed 9 12 2022].

[294] Legalization UK. The Planning (Management of Waste from Extractive Industries) Regulations (Northern Ireland). 2015. https://www.legislation.gov.uk/nisr/2015/85 [Accessed 10 12 2022].

[295] Sloss L. Coal mine site reclamation. IEA Clean Coal Cent. 2013:978e92

Community Involvement and Engagement in Mine Restoration

The Coalfield Communities Landscape Partnership focuses on community-led projects in former coal mining villages and towns in East Ayrshire. They celebrate the area's natural and cultural heritage, improving and animating landscapes affected by open-cast mining. Their projects involve the conservation, enhancement, and restoration of peatlands and creating new habitats for flora and fauna. Local communities have a strong connection to the mining sites and see them as a potential tourism asset and a source of local pride. However, they often feel excluded from restoration if their opinions and views are not considered[296]. The Land Trust is an independent charitable trust that manages open spaces in partnership with local communities, providing long-term management and design services. Northumberlandia, a community park, was created in collaboration with Blagdon Estates and the Banks Group as part of the Shotton surface coal mine development, offering a unique public art opportunity.

Academic and Research Institutions Involved

Cardiff University, along with the National Trust and Gwent College of Higher Education, worked on the abandoned Dolaucothi Gold Mine for 21 years, ensuring its safety. They also collaborated on an education project involving primary school teachers and children, creating teaching resources based on Welsh literary heritage and the Romans. The reprofiling of the Garrigill Burn spoil tip in Cumbria was a joint effort between Nottingham and Swansea universities. The British Geological Survey (BGS) is a globally recognized geological survey organization that provides impartial and independent geoscience advice and data. They collaborate with academic institutions, governments, industry, and the public to understand earth and environmental processes. Plymouth University assisted in screening Devon and Cornwall for potential mine water impacts using a GIS prioritization tool, as the BGS lacked sufficient geochemical data[297].

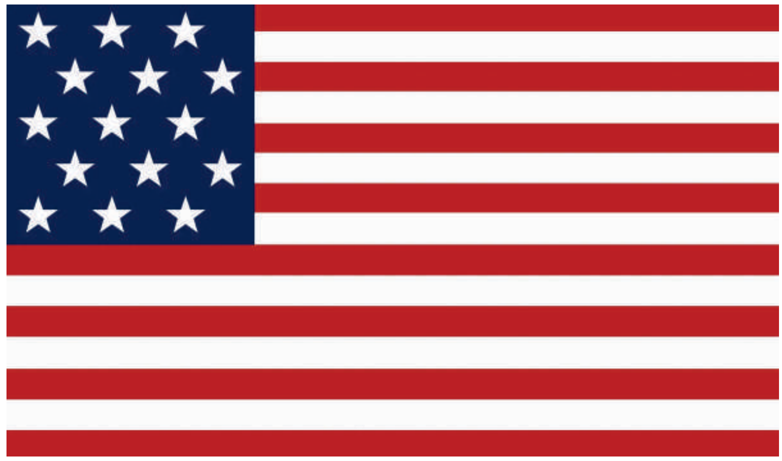
Capacity Building

- The University of Exeter offers a one-year master's degree program in Mining Environmental Management, providing students with practical experience of working with the environment industry and on real-case mining environmental issues.
- Camborne School of Mines, University of Exeter trains students who are interested in the mining industry the sustainable mining practices and mine reclamation for capturing of carbon.

[296] Sinnett DE, Sardo AM. Former metal mining landscapes in England and Wales: Five perspectives from local residents. Landsc Urban Plan. 2020;193:103685

[297] The UK Government-Inventory of closed mining waste facilities. Inventory of closed mining waste facilities- Version II. 2014. https://www.gov.uk/government/publications/inventory-of-closed-mining-waste-facilities [Accessed 15 12 2022]

19 United States of America



Key Mining Sectors

The U.S. mining sector constitutes the search for, extraction, beneficiation, and processing of naturally occurring solid minerals from the earth. Mined materials form an important part of consumer and industrial technologies and play an influential role in shaping American national security. The most common commodities produced by the US mining sector include metals (iron, copper, steel, uranium), precious metals (gold, silver, platinum), and minerals (sulphur, crushed stone, cement, gravels, industrial sand)[298]. The United States is ranked among the world's largest producers and consumers of minerals and metals. In 2021, the country was the world's largest producer of gypsum, 2nd largest producer of rhenium, sulphur, kyanite, limestone, and salt, 3rd largest producer of phosphate, molybdenum, and lead, 4th largest producer of gold, and coal, and 5th largest producer of copper, platinum, and zinc. The mining industry contributed $194.4 billion to the US GDP in 2021[299].

Key Mining Areas

There are mining activities in all 50 states based on the economic viability of the identified minerals. Since, minerals occur based on varying geological conditions, the same minerals won't be found everywhere. In 2021, the top 10 mining states in descending order of rank were Arizona, Nevada, Texas, California, Minnesota, Alaska, Utah, Florida, Missouri, and Michigan[300].

Key Mining Companies

Newmont Corporation: The world's leading gold company with mining operations across North America, South America, Australia, and Africa.

Peabody Energy Corporation: Prominent coal producer supplying energy and steel.

Arch Resources: Global supplier of metallurgical coal for the steel industry. The company operates major mines like Leer, Beckley, Mountain Laurel, and Powder River Basin.

Major Environmental Concerns Linked to Mining

Land Degradation: Metal and coal mining operations have caused environmental damage in remote regions, with quarries and industrial mines being significant offenders. Mining practices involve clearing forests, removing

[298] American Mine Services. US Mining Industry | Mining in America - Industry Statistics. [online] AMS. 2021

[299] National Mining Association. Environmental, Social, and Governance. Natl Min Assoc Rep. 2021. https://nma.org/esg/ [Accessed 26 Dec. 2022

[300] Burton J. U.S. Mines Produced an Estimated $90.4 Billion in Nonfuel Mineral Commodities During 2021. 2022

overburden, and reshaping the land surface, leading to soil degradation and loss of forest habitat. Mountaintop removal coal mining has driven land-use change in the Central Appalachian region[301]. Metal mining also impacts soil through mine tailings disposal and aerial contamination, resulting in acidification, reduced fertility, and trace element contamination.

Loss of Biodiversity: Mining affects biodiversity at various scales through direct extraction and indirect processes. Hardrock mining releases toxic substances, causing water pollution, wildlife habitat destruction, and fish kills[302]. Effluents from mines have polluted rivers, streams, lakes, and reservoirs, impacting drinking water supplies and wildlife habitats. Coal mining has contributed to biodiversity loss in Appalachian rivers, leading to alkaline mine drainage and the extinction of 40% of biodiversity in affected rivers[303].

Chemical Contamination: Mining generates waste containing potentially toxic elements that can pollute air, water, and soil even after mining ceases[304]. Abandoned mine waste poses contamination threats worldwide[305]. Erosion of mineralized waste rock leads to metal concentrations in stream sediments, affecting plants and animals[306]. The tri-state mining district remains affected by toxic mine waste contamination despite remediation efforts.

Legislative Provisions for Mine Restoration and Rehabilitation

Acts and Policies:

Acts and Policies: The United States has a comprehensive regulatory system for mining, governed by federal laws since the late 1960s. State agencies also have their own environmental regulations and standards. Permits are required for mining operations, ensuring compliance with environmental standards and developing operation and closure plans for mine reclamation[307].

- **National Environmental Policy Act (NEPA):** NEPA, established in 1969, provides a framework for evaluating and communicating the environmental consequences of federal decisions, including mining permits on Federal lands. NEPA ensures that environmental considerations are integrated into decision-making processes[308].
- **Resource Conservation and Recovery Act (RCRA):** RCRA, a public law, sets guidelines for the proper management of hazardous and non-hazardous solid waste. Mining operations, including metal and nonmetal mines, are regulated under RCRA to ensure responsible waste management[309].

[301] Lutz BD, Bernhardt ES, Schlesinger WH. The environmental price tag on a ton of mountaintop removal coal. PLoS One. 2013;8(9):e73203.

[302] Sonter, L.J., Ali, S.H. and Watson JEM. Mining and biodiversity: key issues and research needs in conservation science. Proc R Soc B Biol Sci. 2018;285(1892):20181926. https://doi.org/10.1098/rspb.2018.1926

[303] Simonin M, Rocca JD, Gerson JR, et al. Consistent declines in aquatic biodiversity across diverse domains of life in rivers impacted by surface coal mining. Ecol Appl. 2021;31(6):e02389

[304] Rieuwerts JS, Mighanetara K, Braungardt CB, Rollinson GK, Pirrie D, Azizi F. Geochemistry and mineralogy of arsenic in mine wastes and stream sediments in a historic metal mining area in the UK. Sci Total Environ. 2014;472:226-234

[305] Gutiérrez M, Collette ZJ, McClanahan AM, Mickus K. Mobility of metals in sediments contaminated with historical mining wastes: Example from the Tri-State Mining District, USA. Soil Syst. 2019;3(1):22

[306] American Geosciences Institute. How can metal mining impact the environment? [online] American Geosciences Institute. 2019. https://www.americangeosciences.org/critical-issues/faq/how-can-metal-mining-impact-environment.

[307] American Geosciences Institute. What are environmental regulations on mining activities? 2014. https://www.americangeosciences.org/critical-issues/faq/what-are-regulations-mining-activities.

[308] American Geosciences Institute. What are environmental regulations on mining activities? 2014. https://www.americangeosciences.org/critical-issues/faq/what-are-regulations-mining-activities.

[309] Van Bever GC. Mining Waste and the Resource Conservation and Recovery Act: An Overview. J Nat Resour Environ Law. 1992;7(2):7

- **Surface Mining Control and Reclamation Act (SMCRA):** SMCRA, enacted in 1977, is the primary federal law regulating the environmental effects of coal mining. It includes provisions for reclaiming abandoned mine land and regulates active coal mines to ensure environmentally responsible practices and adequate reclamation.

Directives

The Office of Surface Mining Reclamation and Enforcement has certain policy directives that are written communication provided in the form of instructions, manuals, notices, guides, policies, and procedures.

a) **Abandoned Mine Land Inventory System:** This Directive establishes the policies and procedures for developing and maintaining the Abandoned Mine Land Inventory and implements the "Abandoned Mine Land Inventory Manual". It contains background information and Office of Surface Mining Reclamation and Enforcement (OSM) policy and responsibilities related to the Inventory.

b) **Evaluation of State/Tribe Abandoned Mine Land Programs:** The directive and its appendices establish policies, procedures, and responsibilities for monitoring, assisting, and evaluating State/Tribe Abandoned Mine Land (AML) Programs.

c) **Use of Wetland Treatment Systems for Coal Mine Drainage:** The directive establishes guidelines for the use of wetlands to treat acid or ferruginous discharges from surface coal mining and reclamation operations.

d) **Post-Act Reclamation Program:** The directive establishes the policies and procedures for the administration of the Post-Act Reclamation Program which is also called the Civil Penalty Reclamation Program (CPRP). This program is for the reclamation of lands adversely affected by coal mining practices that occurred after August 3, 1977.

e) **Construction of Wetlands as a Postmining Land Use:** The directive clarifies policy and procedures for the construction of wetlands to supplement and enhance postmining land .

f) **Reforestation of Title IV and Title V mined lands:** The purpose of the directive is to promote reforestation where existing forests were removed by mining and encourage forest establishment after reclamation wherever coal is mined.

Compliances and Licensing

Depending on the proposed level of mining activity, permits and licenses required to conduct mining activities include a mine plan of operations, a reclamation plan, bonding and permits, water pollution permits, hazardous waste materials storage and transfer permits, etc[310].

Key Institutions involved in Mine Restoration and Rehabilitation

In the United States, mining activities are regulated by multiple entities due to overlapping laws, regulations, and jurisdictional roles. The regulatory requirements for each mine are unique and depend on factors such as the location (state, federal, tribal, or private land), local regulations, the type of mining operation, and specific environmental considerations. The key institutions involved in regulating mining activities in the U.S. include the U.S. Environmental Protection Agency (EPA), Office of Surface Mining Reclamation and Enforcement, U.S. Geological Survey (USGS)[311], U.S. Army Corps of Engineers (USACE), Bureau of Land Management (BLM),

[310] Kahalley K. Mining Laws and Regulations USA 2023. [online] International Comparative Legal Guides International Business Reports. 2022. https://iclg.com/practice-areas/mining-laws-and-regulations/usa

[311] Epa U. United States environmental protection agency. Qual Assur Guid Doc Qual Assur Proj Plan PM Ambient Air. 2001;2:12

National Park Service (NPS), and the Forest Service (USFS). These agencies oversee various aspects of mining, including exploration, permitting, environmental protection, and site reclamation and reuse.

- **United States Environmental Protection Agency (EPA):** EPA plays a crucial role in regulating mining activities by enforcing effluent guidelines for coal mining, ore mining, and mineral mining. They work with authorized states to address violations and ensure compliance with clean water standards[312]. EPA also develops frameworks and promotes environmental protection and fiscal responsibility at mine sites[313].
- **Office of Surface Mining Reclamation and Enforcement (OSMRE):** OSMRE is responsible for reclaiming abandoned mine lands and regulating coal mines. They work in partnership with states, tribes, and industry to clean up abandoned sites and ensure the proper reclamation of mined lands.
- **U.S Geological Survey (USGS):** USGS provides essential information on minerals and materials, including research on mine waste characterization and environmental effects. They offer scientific expertise to help minimize the adverse impacts of abandoned mine lands.
- **U.S. Army Corps of Engineers:** The Corps addresses water quality issues caused by abandoned and inactive non-coal mines through their RAMS Program, which provides technical assistance and planning for projects aimed at mitigating drainage-related problems.
- **U.S. Department of Interior's Bureau of Land Management (BLM):** BLM prevents unnecessary degradation of public lands and requires operators to submit plans of operations and reclamation plans. They also fund the cleanup of abandoned hard rock mines to address safety hazards and environmental contamination [314].
- **National Park Service (NPS):** NPS focuses on the restoration of abandoned mineral lands, addressing environmental concerns, safety hazards, and the preservation of bat habitat in mine shafts.
- **U.S. Agriculture's Forest Service:** The Forest Service regulates mining activities on public lands and administers regulations for exploration and mining. They ensure compliance with specific statutes and authorities.

Financing Arrangements for Mine Restoration and Rehabilitation

- **Abandoned Mine Land Economic Revitalization (AMLER) Program:** The AMLER Program, funded annually by Congress since FY 2016, aims to restore legacy coal mining sites through economic and community development. Administered by OSMRE, it supports local investment opportunities for the long-term rehabilitation of coalfield economies.
- **Comprehensive Environmental Response Compensation and Liability Act (CERCLA):** Established by Congress in 1980, Superfund empowers the EPA to clean up sites contaminated by hazardous waste from mining[315]. Responsible parties are required to perform clean-ups or reimburse the government. The goals include protecting human health, involving communities, and returning sites to productive use.

[312] United States Environmental Protection Agency. Effluent Guidelines Implementation & Compliance. 2014. https://www.epa.gov/eg/effluent-guidelines-implementation-compliance

[313] Management USEPAO of W. Response to Congress on Use of Decentralized Wastewater Treatment Systems. US Environmental Protection Agency, Office of Water; 1997

[314] Bureau of Land Management and Forest Service. Abandoned Mine Lands: A Decade of Progress Reclaiming Hardrock Mines. [online] Bureau of Land Management. 2007. https://www.blm.gov/sites/blm.gov/files/uploads/AML_PUB_DecadeProgress.pdf

[315] United States Environmental Protection Agency (2017). What is Superfund? [online] US EPA. 2017

- **Reclamation Bonds:** Surface Mining Control and Reclaimation Act (SMCRA) mandates posting reclamation bonds as a prerequisite for coal mining permits. Bonds ensure sufficient funds for site reclamation if the permittee fails to complete the approved plan. Three major types of bonds include corporate surety bonds, collateral bonds, and self-bonds.

Private Sector Role in Mine Restoration

- **Ledcor Group:** A construction company involved in mine reclamation projects, providing services such as erosion control, revegetation, and tailings storage facilities' construction. Completed projects include the Rand Mine Reclamation in California.
- **RECON:** This company specializes in innovative environmental and geotechnical solutions. Their mine-related services encompass remediation, regrading, revegetation, pit backfilling, groundwater treatment, and more.

Community Involvement and Engagement in Mine Restoration

- **Tribal Lands Assistance Center (TLAC):** TLAC serves as a centralized resource for federally recognized tribes, providing information and support related to contaminated sites on Tribal lands. It focuses on training tribal professionals, strengthening Tribal capacity, and facilitating meaningful engagement in the cleanup decision-making process.
- **Indian Lands Program:** OSMRE's Indian Lands Program engages with tribal governments in Surface Mining Control and Reclamation Act permitting and enforcement activities.

Academic and Research Institutions Involved in Mine Restoration

- **University of Arizona:** The university offers programs and conducts research in sustainable mining and development, with a focus on the entire mining life cycle, including reclamation and recycling.
- **Colorado School of Mines:** The school's center for environmental risk assessment focuses on advancing knowledge and developing improved approaches to assessing and mitigating environmental risks associated with mining.
- **National Mining Association (NMA):** The NMA promotes progress on Environmental, Social, and Governance (ESG) issues in the mining sector through its CEO-led ESG Task Force.

Capacity Building

- **Graduate Certificate in Mine Reclamation (University of Missouri):** This program provides formal education in mine reclamation, equipping professionals with the skills needed for mine reclamation projects.
- **National Technical Training Program (OSMRE):** This program offers training on OSMRE technologies and practices, enhancing mining and reclamation practices through courses on topics like AML reclamation, soils, revegetation, and wetlands awareness.
- **Mine Reclamation (University of Victoria):** A course focused on mine reclamation, covering legislation, site preparation, re-vegetation, contaminant remediation, and reclamation ecology.

2.2 BEST PRACTICES AND SUCCESS STORIES OF THE RESTORATION OF MINING-AFFECTED AREAS FROM G20 MEMBER COUNTRIES

AUSTRALIA

Best Practices

Case Study: Rehabilitation of the Ranger Uranium Mine

Responsible Organizations

Department of Climate Change, Energy, the Environment and Water. Keith Tayler (Supervising Scientist) Keith.Tayler@dcceew.gov.au

Brief Summary

The Ranger Uranium Mine (Ranger) is located approximately 250km east of Darwin in the Northern Territory of Australia. Ranger is situated on aboriginal land and is surrounded by the World Heritage listed Kakadu National Park which presents significant cultural and environmental challenges for its operation and restoration. Ranger was operated by Energy Resources of Australia Ltd (ERA) from 1980 to 2021 and produced a total of 132,000 tonnes of uranium oxide. The disturbed area at Ranger, including supporting infrastructure and water management areas, is approximately 800 Ha. In recognition of the significant cultural and environmental values of the surrounding region, Ranger is required to be rehabilitated to the highest possible standard[316].

Description

Environments Requirements

To ensure the protection of people and the environment, stringent environmental objectives have been established for the operation and rehabilitation of Ranger.

The Environmental Requirements for Ranger stipulate that:

- Ranger must be rehabilitated to a standard that would allow it to be incorporated into Kakadu National Park.
- Ranger area must be revegetated with local species to create an environment that is similar to the surrounding areas of Kakadu National Park.

[316] ERA released its most recent version of the Ranger Mine Closure Plan on 1 October 2022 which is available for download from www.energyres.com.au.

II

Figure 22: Aerial view of Ranger mine area with Pit 3 in the background (with water in it behind the dam).

- Uranium tailings must be isolated from the environment in the mined-out pits.
- As far as can reasonably be achieved, the erosion characteristics of the rehabilitated landform should be similar to comparable landforms in surrounding undisturbed areas.

Rehabilitation Work

Rehabilitation works at Ranger must also ensure that:

- There is no change to biodiversity or impairment of ecosystem health in Kakadu National Park because of mining at Ranger area.
- Environmental impacts on the Ranger Project Area are as low as reasonably achievable.
- Radiation dose to people is as low as reasonably achievable and complies with all relevant Australian standards and codes of practice.

Rehabilitation work at Ranger mining area commenced in 1996 with the direct deposition of tailings into Pit 1 which continued until 2008. The waste rock backfill of Pit 1 took place between 2013 and 2020. Revegetation work on Pit 1 commenced in 2021 and includes the construction of "rock-pile habitats" designed in consultation with the Traditional owners to create points of cultural connection across the landscape. Pit 1 is now serving as a revegetation trial to optimize worker safety, the efficiency of planting methods and maximize seedling survival.

From 2012 to 2014, waste rock was placed into the base of Pit 3 to create a level surface for tailings deposition, which commenced in 2015. Vertical wick drains are currently being installed into the tailings in Pit 3 to allow waste rock backfill to commence in 2024. The former tailings dam will be retained as a water storage facility for several years, before being demolished as part of the final landform construction.

The remaining major works, including the revegetation, are scheduled for completion in 2028. Following this there will be a protracted period of monitoring and maintenance that should last for many decades.

Environmental Impact Assessment

Significant predictive modeling has been completed at Ranger mining area to inform rehabilitation designs and determine if rehabilitation work is likely to achieve the required environmental outcomes. Many years of revegetation trials indicate that native vegetation will generally grow quite well in waste rock, although it will take many decades for the ecosystem to fully mature and some species may be difficult to establish.

Comprehensive, multi-decade monitoring programs will be required to test and verify the modeled predictions and ensure the rehabilitating ecosystem remains on a trajectory toward the desired end-state.

Mine Closure

Energy Resources of Australia (ERA) is required to keep a Ranger Mine Closure Plan which sets out the activities required to meet the rehabilitation objectives. This closure plan is updated annually for review by the Traditional Owners of the land (the Mirarr people) and Ministerial approval. ERA cannot relinquish responsibility for Ranger until all closure criteria have been met.

Figure 23: Pit rehabilitation -Pit 1 surface showing revegetation at about 12 months old

Lesson Learned:

There are many lessons that can be taken from the operation and rehabilitation of Ranger, including:

- Ensuring a central role for the Traditional Owners in the regulatory process and overseeing rehabilitation has been critical.
- Even the best predictive models can contain significant uncertainty. A precautionary approach to decision-making and rigorous long-term monitoring programs are essential.
- Significant costs are associated with mine site rehabilitation and long time frames are required. Mining companies must plan from the commencement of operations to ensure sufficient funding is available to complete rehabilitation once production has ceased.
- Ranger mining area operated for over 40 years without impacting on the offsite environment due to the strict regulatory regime and oversight.
- The rehabilitation requirements for Ranger were detailed from the commencement of operations and were proportionate to the risks posed by the operation and the significance of the surrounding region.
- Regulatory transparency has been critical in building public support for Ranger, which faced strong opposition when initially proposed. The large amounts of information published by the Supervising Scientists provide confidence that the environment has remained protected.

The Supervising Scientist's assessment of the Ranger Mine Closure Plan and the results of the Supervising Scientist's monitoring program in the Supervising Scientist Annual Technical Report are available at www.dcceew.gov.au/science-research/supervising-scientist.

Figure 23: Plantation of native vegetation near Ranger mine area.

CHINA

Best Practices

Ecological Restoration of the Geological Environment in Lvjin Lake Mines

Responsible Organizations:

Ministry of Natural Resources, China
No.64 Funei Street, Xicheng District,100812 Beijing, China

Brief Summary:

The coal mining subsidence area in the Huaibei City of Anhui Province is a hard nut to crack in the city's economic and social development because of its large area and serious harm. Under the guidance of Xi Jinping's thoughts on eco-civilization, Huaibei City has achieved remarkable economic and ecological benefits by strengthening the treatment of coal mining subsidence areas, solving the problems of funds and technology, and finding the path for ecological restoration in mining areas and the key to sustainable development of coal resource-based cities. The geological ecological improvement project in the Lvjin Lake mining area is a typical case among those efforts. The project is one of the national key mining areas geological environment treatment projects approved by the Ministry of Natural Resources (former Ministry of Land and Resources) and the Ministry of Finance. The project solved the founding problem through the Public-Private Partnership (PPP) model, bringing social capital up to 2.22498 billion RMB. Meanwhile, the problem of long-term desolation of collapsed land due to unsteady settlements has also been solved by the implementation of advanced and innovative treatment measures.

Description:

I. Introduction

Huaibei City, Anhui Province, is a city that suffers from serious damage from coal mining subsidence. By the end of 2020, the accumulated coal mining subsidence land in the city amounted to 27,700 hectares, accounting for 10.1% of the total land area of the city. To improve the damaged ecological environment and restore land use value, Huaibei City has been exploring and practicing comprehensive management of coal mining subsidence areas since the early 1980s. In 2016-2017, Huaibei City implemented the Green Gold Lake Mine Geological Environment Treatment Project, with a total treatment area of about 2,406 hectares, a total excavation volume of about 30 million cubic meters, a total investment of 2.224.98 billion yuan and a total construction period of 20 months. After the treatment, 1633 hectares of usable land and 773 hectares of usable water will be formed, with a total storage capacity of 36.8 million cubic meters. It is being built into an urban central park integrating ecological restoration, scientific research, tourism and leisure, and cultural creativity.

II. Problems

Before project management the area was a coal mining sinkhole that was more than 7 meters deep, a perennial waterlogged area, and more than half a meter shallow, a seasonal waterlogged area. Houses collapsed, roads sank and bridges broke in the sinkhole, which had a serious impact on the production and life

Figure 24: Before the treatment of coal mining subsidence area

of people in the mine area and sustainable economic and social development. Coal mining subsidence caused by the land, water, and other natural resources and its ecosystem function impairment problem is still prominent. First, the mining geological environment deep-seated serious damage resulting in poor ecosystem stability; second, degradation of water bodies network, water resources and its ecological function; third, land resources and other serious damage; fourth, the situation of environmental pollution prevention and control is still serious.

III. Measures

(A) The use of PPP model: To solve the governance funding problems, the municipal government decided to use the PPP project financing model. Through legal bidding and consultation and negotiation, the successful bidder was identified and a PPP cooperation agreement was signed, successfully financing 2.224.98 billion yuan.

(B) Multi-planning integration: The project organically combines the overall land use planning, overall urban planning, wetland protection planning, municipal road network construction planning, forestry planning, etc. to achieve overall design, unified deployment, and integrated construction, which guarantees that the land and water resources in the project area are maximally used scientifically and reasonably.

(C) Implementation of Scientific Governance:

1. **Carry out over-the-top governance:** Based on scientific prediction of the final sinking amount of the sinkhole area, engineering means such as digging deeper and padding shallower are used to pre-fill the unstable sinkhole area with high soil to reach the design elevation after sinking. The advance treatment not only makes use of the high-quality soil layer to be sunk in advance, but also

solves the problem that the sunken land is deserted for a long time due to unstable sinking, shortens the treatment cycle, improves the treatment efficiency, and saves the treatment fund.

2. **Implementation of topsoil stripping:** In the project implementation, the way of stripping the topsoil of the cultivation layer and centralized piling is adopted to protect and utilize the high-quality soil resources of the cultivation layer. Topsoil coverage is carried out on the backfilled area with a thickness of 300-500 mm to ensure that the quality of the land in the treatment area does not deteriorate.

3. **Conduct coal mining impact assessment:** At the time of project governance, the underground coal resources in the governance area are still endowed with certain coal resources, and there are still mining activities in the area. To ensure the implementation of the over-the-top governance model, it is necessary to clarify the impact of mining activities on the ground in the governance area. The coal mining impact assessment was carried out before the treatment, and the proposed subsidence was scientifically predicted and organically integrated with the project design and construction, which effectively avoided the adverse consequences caused by secondary subsidence.

(D) **Fulfill the agreement and repay the money on time according to the law:** The operation mode of the Green Gold Lake Treatment PPP Project is "investment - construction, maintenance and transfer" integrated government purchase services. Since December 28, 2017, the project passed the municipal acceptance the next day into the maintenance period, the government of Huaibei City has paid the government purchase service costs for four consecutive years as scheduled, with a cumulative payment of 1.31 billion yuan, ensuring good cooperation between the local government and enterprises, and

Figure 25: Before the treatment of coal mining subsidence area

making the later maintenance and development of the project into a virtuous cycle.

IV. Effectiveness

(A) Restored land resources and promoted urban development after the completion of the project, a total of about 1,633 hectares of usable land will be formed, including about 533 hectares of developable construction land around the lake, expanding the space for urban development. As Lvjin Lake is in the core articulation zone between the old city in the west and the new city in the east, together with the six sunken lakes that have been and are being treated, more than 100 square kilometers of high-quality land space will be formed, helping to promote the development of Huaibei City from building a city by the mountains to embracing the lake, enhancing the city's taste and improving the human living environment.

(B) Improved ecological environment and biodiversity. Through comprehensive treatment, the damaged

Figure 26: Before the treatment of coal mining subsidence area

Figure 27: Slurry pump filling

Figure 28: Water operation of large dredger

ecosystem has been repaired, and the dirty and black smelly coal mining sinkhole has been turned into a central park with clear water, green shore, and blue sky. The continuous lake formed after the treatment has claimed 773 hectares, becoming a large continuous ecological water area. Ecological islands such as Dream Island, Heart Island, Green Gold Island (Bird Island), and One Tree Island have been built, providing habitats for more than 100 species of animals and nearly 100 species of plants, making it an important transit point for migratory birds in northern Anhui. Every year, many kinds of wild birds, such as white swans, and egrets, resupply and roost in the Lvjin Lake area. The planting of trees and grasses covers more than 666 hectares, making it a veritable green lung of Huabei and playing a role in improving the microclimate of the Huabei region.

(C) Social value has been revealed and ecological products have been enriched. After the treatment, Lvjin Lake has been transformed and upgraded into a new modern development area of ecological tourism, creative culture, education, and technology. The regional residential land price has increased by 2-3 times, realizing the spillover of ecological product value, and also becoming a hitting net red place for tourists coming to Huai. According to statistics, the annual reception of visitors to Yuanmeng Island alone has reached more than 200,000 per year, forming a number of boutique tourism lines and regional tourism brands and promoting the value of the ecological products to become visible. With the improvement of ecological environment, villagers around Lvjin Lake have gradually transformed and upgraded from traditional industries to urban citizens engaged in catering, scenic services, greening, and other industries, realizing the joint development of various industrial forms such as "ecology + tourism" and "ecology + culture", driving the development of various industrial forms, such as "ecology + tourism" and "ecology + culture", has led to an industrial revitalization.

Figure 29: After the treatment of coal mining subsidence area (Lvjin Lake Yuanmeng Island)

Lessons Learned:

As a city with few resources, Huaibei actively looks for new ways to manage coal mining collapsed land. It insists on combining the government with an effective market and uses the government and social capital

Figure 30: After the treatment of coal mining subsidence area (Lvjin Lake Yuanmeng Island)

Figure 31: After (Lvjin Lake has become a habitat for migratory birds)

Figure 32: After (Yellow Bittern inhabiting in Lvjin Lake)

cooperation (PPP) method. The government and social capital share the benefits and risks, using the government's strengths in planning, policy and management and the social capital's strengths in construction operation and maintenance.

European Union

Best Practices

LIFE in Quarries

Responsible Organizations:

Belgian Federation of Industry Extractive (FEDIEX), University of Liège, Natagora, the Parc naturel des Plaines de l'Escaut (PNPE) and the Walloon region info@fediex.be

Brief Summary:

Between 2015 and 2020, 27 quarries were targeted in the Wallonia region of Belgium. The originality of this project was based on the implementation of biodiversity management measures during the extractive phase and not only as part of rehabilitation at the end of the works. A network of temporary habitats was managed dynamically in time and space across each quarry, in parallel with the extractive activity, ensuring constant availability of suitable habitats for the development of biodiversity. The dynamic management of biodiversity targets several rare and protected species in Wallonia which benefits from habitats generated by quarrying activities.[317]

Description:

The extractive activity of quarries represents an exceptional opportunity to maintain rare and endangered habitats with its associated pioneer species. Indeed, the operation of a quarry produces a wide variety of temporary habitats, sometimes evolving towards more permanent communities. On its initiative, the extractive industry requested more understanding of biodiversity management on its sites. To answer this demand, a partnership was created between the Belgian Federation of Industry Extractive (FEDIEX), the University of Liège, Natagora, the Parc Naturel des Plaines de l'Escaut (PNPE), and the Walloon region in the framework of LIFE in Quarries project (LIFE14 NAT/BE/000364).

For 6 years, the project has lead the private sector, public authorities, and non-governmental associations to work together to demonstrate that operational solutions can be proposed for biodiversity management and implemented through limited investments benefiting the industrial sector and stakeholders interested in nature.

The overall objective was to define acceptable measures for operators, being legally and scientifically valid, and of course favorable to biodiversity. In doing so the project aimed at creating a win-win for nature and the industry situation where quarries could act as a network of sites: (i) significantly contributing to the management of pioneer biodiversity at the regional level; (ii) promoting post-exploitation restoration during the exploitation phase that would enhance both biodiversity per se and ecosystem services provisions - thus participating to the development of a regional Green Infrastructure; (iii) promoting awareness of its members on biodiversity stakes at play and means to favor it in quarries; while, (iv) securing the long term management through the legal securing of the dynamic management of biodiversity throughout the exploitation phase and

[317] http://www.lifeinquarries.eu/wp-content/uploads/2022/06/2022_04_06_Life-in-Quarries_Final-report_Abbreviated_FINAL.pdf

the provision of adequate tools for monitoring outcomes, allowing for protected species to co-exist with the exploitation. Favoring in return a better understanding from the Laymen on the role quarries could play for biodiversity, through dissemination actions. The project was characterized by the launching and implementation of concrete conservation actions in 27 quarries.

Concrete conservation actions were implemented on 27 sites and disseminated in 7 EU sites:

After a testing period for the implementation of concrete conservation actions, the pilot phase run in 14 quarries with individually adapted action plans by the quarry operators with close supervision of the LIFE project's team. Actions were mostly implemented behind initial expectations

The transfer to 13 Phase II quarries in a smoothened scheme allowed for confirming the feasibility of the process, further exceeding expectations.

With experience and multiple case studies in mind, the project could then propose a way forward in 7 EU quarries from 3 different countries with positive outcomes and propositions for future implementation.

Lesson Learned:

The monitoring of biological outcomes confirmed the rapid interest in temporary nature actions while providing a good omen for the trajectories taken by permanent nature restorations. The assessment of the ecosystem services development throughout the project provided much interesting information on the positive and negative impacts quarries can have on the development of ecosystem services and on ways these could be influenced through specific information, habitats restoration and exchanges between the sector and other stakeholders favoring integration into a regional Green Infrastructure. Associated with the development of a strong framework of management plans, derogations and commitments under charters, the development of the Ambres platform for the basic monitoring and its appropriation by quarries personnel will allow for the actions to live on in the After-LIFE. The increased awareness of the sector on the role they can play for biodiversity present on their site, as a result of Communication actions, is further expected to allow quarry staff to become stewards of their sites' biodiversity. Accompanied by guidance on the evaluation of means and costs necessary for the implementation of dynamic management of biodiversity these outcomes are expected to encourage and facilitate new quarries to join the process.

FRANCE

Best Practices

1 Post-Mining Water Treatment in France

Responsible Organizations:

French Geological Survey (BRGM)

Ministry of Environment / Direction générale de la prévention des risques (DGPR) / Bureau du sol et du sous sol

BAILLY Guillaume (Chief of Unit) - DGPR/ – Unit of soils and subsoils: Guillaume.Bailly@developpement-durable.gouv.fr

Brief Summary:

Mining activities can adversely affect water resources for decades after mine closure and decommissioning. The oxidation of sulfide minerals and the release of acid mine drainage (AMD) into the environment may cause toxic elements like Arsenic (As) to move around again, polluting water resources and strongly affecting aquatic

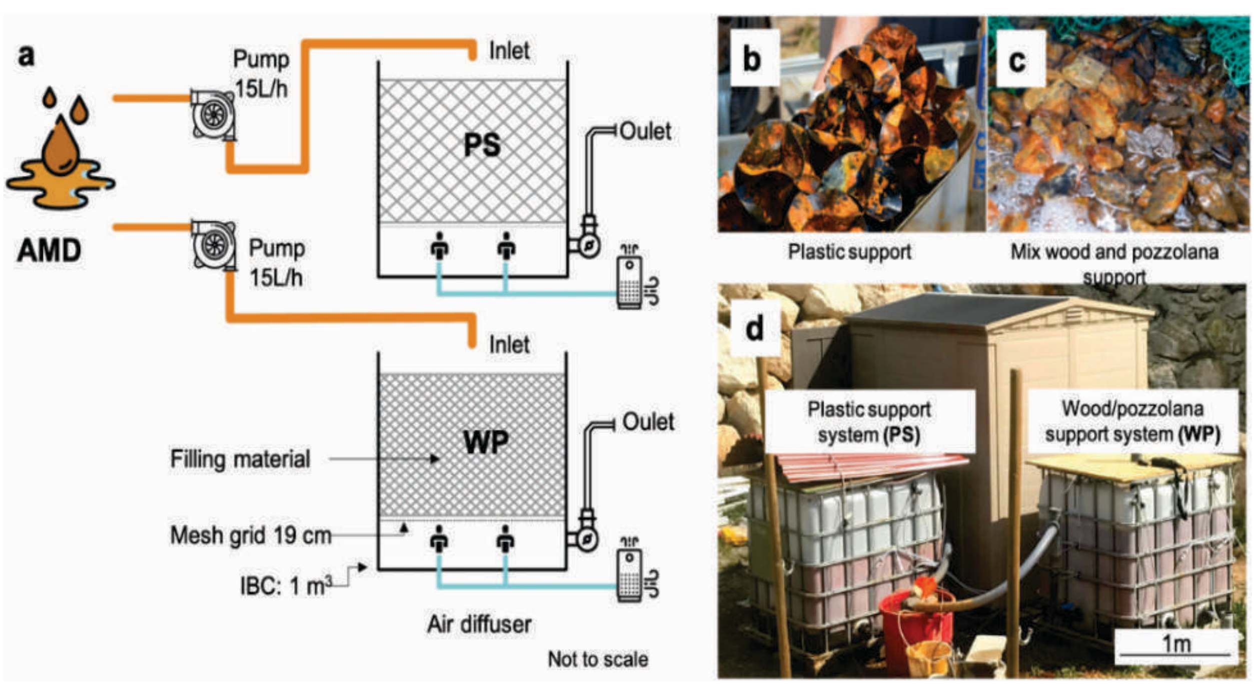


Figure 33: Schematic representations of the biological oxidative devices, one device filled with
a. plastic support (PS) and the second device filled with pozzolana and wood mixture (WP),
b. plastic support,
c. wood and pozzolana mixture support and d. in-situ devices (Diaz-Vanegas et al. 2022)

Figure 34: Vouters Coal Mine water treatment station ($450\ m^3/h$ - Pumping + Precipitation of iron and manganese with oxygenation cascade and series of basins)

ecosystems. The BRGM manages seven coal mine water treatment stations, five polymetallic mine water treatment stations in France and three polymetallic mine water treatment pilots. This Best-Practice Collection Template presents 2 examples of pilots.

Description:

In the Carnoules site, 2 semi-passive treatment pilots for iron (Fe) and arsenic (As) removal in AMD were installed and monitored in-situ for more than a year[318]. These technologies were designed to treat the As-enriched AMD (- 1 g/L Fe(II) and 100 mg/L As(III)). The treatment was based on Fe and As being broken down biologically by native bacteria, and then As being immobilized by ferric hydroxysulphfates. The system performance ranged from 86 to 98% for Fe oxidation, 30 to 60% for Fe removal, and 50 to 80% for As removal at a hydraulic retention time of 9 h.

On another site about 8 million metric tons storage of cyanidation tailings from a former French gold mine produces a $10\ m^3/h$ mine drainage that contains around 8 mg/L of As and 1 g/L of SCN– and is currently treated with a lime process[319]. The existing treatment plant produces large amounts of sludge reflecting the large amounts of sulfate present in water and calcium from lime. On-going studies are aims to developing a semi-passive mine water treatment process that would produce a lower amount of sludge and improve the treatment efficiency with a target discharge level under 100 μg/L of Arsenic.

[318] Diaz-Vanegas, C., C. Casiot, L. Lin, L. De Windt, M. Héry, et al., Performance of Semi-Passive Systems for the Biological Treatment of High-As Acid Mine Drainage: Results from a Year of Monitoring at the Carnoulès Mine (Southern France) . Mine Water and the Environment, 4 juillet 2022. https://doi.org/10.1007/s10230-022-00885-4

[319] Vaxelaire S., Jally B., Battaglia-Brunet F. and Jacob J. 2019. The Development Of A Treatment Process For The Mine Water Containing Arsenic And Thiocyanate From Lab Scale To Pilot Plant Scale. Proceedings of International Mine Water Association Conference 2019, (15-19 July 2019, Perm, Russia)

Regarding the coal mine water treatment, the objectives are to treat As and Mn and to control the underground mine water levels. Coal water flows vary between 100 and 450 m^3/h with a waterfall and a series of precipitation basins (with reeds). These stations are semi-passive as they still need active maintenance (reed fording and red mud removal).

Lessons Learned:

Any action to reduce the quantities of water to be managed should be taken as soon as possible. Water treatment stations should be as passive as possible to avoid long-term maintenance costs. However active water treatment may be required in some situations (high level of contaminants, high flow, limited area, etc.). A pilot is a necessary step before implementing a station and the period of monitoring should be long enough (2 years for example) to observe significant variations of the main parameters (water flow, contaminant concentration, pH, etc.).

When transferring a station from a company to an organisation in charge of its long-term management (for example from a mining company to a public organisation in case of relinquishment to the state) an audit should be carried out (performance, maintenance, history, etc.).

Figure 35: France mining site lead, zinc and arsenic field measurements using pXRF on a pyrite mining wastes (BRGM, 2019)

2 Phytostabilisation for Tailings Deposits Remediation

Responsible Organizations:

French Geological Survey (BRGM)

BAILLY Guillaume (Chief of Unit) - DGPR/– Unit of soils and subsoils, email: Guillaume.Bailly@developpement-durable.gouv.fr

Brief Summary:

Phytostabilisation relies on the use of plants and amendments to reduce mobility of pollutants in soil and transfers trough the environment. The BRGM has implemented such solutions on former Ag-Pb mines.

Description:

France is currently rehabilitating a number of legacy deposits. Amongst them, a former Ag-Pb mine (3 ha of waste rock and tailings, Several weight percent Pb, and above 100mg/kg As) was partially covered by vegetation and subject to severe erosion. The site was monitored (contamination, water, sediment, porewater, vegetation, erosion) for 18 months to build a conceptual site model and evaluate fluxes. Laboratory and in situ tests were implemented (different plants, different amendments). Cost-benefit analysis of phytostabilisation was implemented using five criteria (technical aspects, costs of rehabilitation and maintenance, environment and security, and social and juridical aspects).

The conventional confinement scenario had a better cost-benefit ratio for the zone with the highest transfers (less than 25% of the total surface). Other zones with patchy vegetation, rather low erosion rates, difficult access and sensitive habitats had a much better cost-benefit ratio with a phytostabilisation scenario.

Lessons Learned:

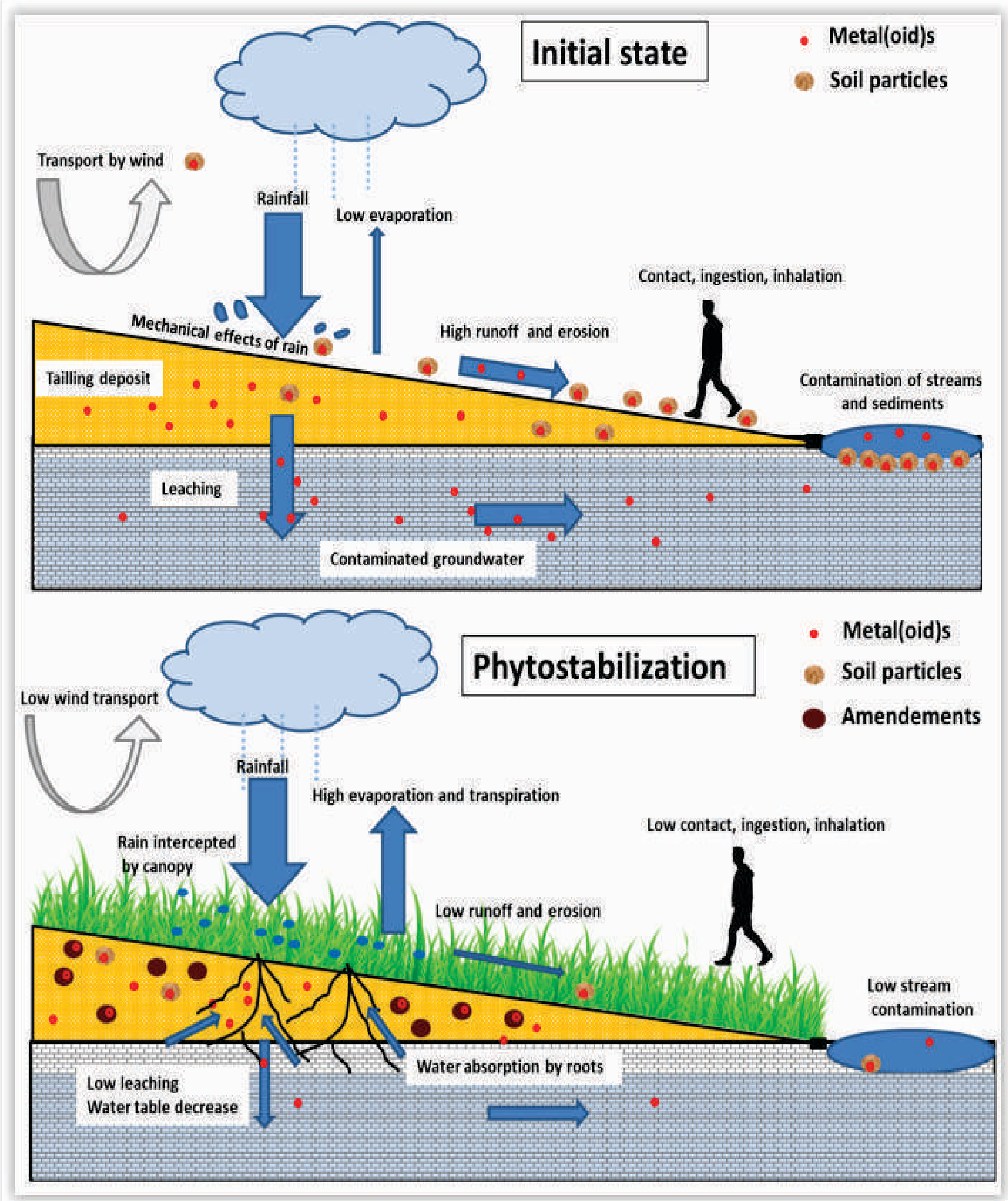
Compared to traditional solutions, phytostabilisation advantages lie in the fact that this is a nature-based solution and therefore it has a priori of a low environmental footprint and it may be sustainable. In the medium or long-term, the maintenance of the phytostabilised site should be minimal; the interest of phytostabilisation is to benefit from natural regeneration capacities so as to limit the need for intervention.

However, interventions may be necessary to enable a good growth of vegetation over the long-term and in the event of excessive deterioration.

This solution, although simple in appearance, requires in-depth studies to be adapted to the site and to verify the extent to which it allows the rehabilitation objectives to be achieved with minimal work. Nevertheless, several difficulties must be managed (sensitivity to drought, lack of operational feedback, need to carry out tests, potential residual transfers to water or living beings through vegetal consumption). Thus, this solution was found complementary to traditional confinement.

Even if phytostabilisation is based on natural solutions, it is advisable to set up site monitoring after the works, in particular to monitor the evolution of the plant cover, check the absence of degradation and verify that the residual impacts remain acceptable, and improve the solution feedback.

Figure 36: Conceptual models for tailings management by phytostabilisation (de Lary de Latour et al. 2022)



3 InSAR Assets in Ground Movements Survey on Abandoned Coalfields

Responsible Organizations:

French Geological Survey (BRGM) Ministry of Environment / Direction générale de la prévention des risques (DGPR) / Bureau du sol et du sous sol BAILLY Guillaume (Chief of Unit)-DGPR/-Unit of soils and subsoils: Guillaume. Bailly@developpement - durable.gouv.fr

Brief Summary:

Rising groundwater in abandoned mines may result in ground movements at the surface overlying underground works. An InSAR retro-analysis of ground movements was done on an abandoned coalfield in France more than 20 years after mining stopped. This was done to : 1) Improve the ability to fine ground movements in areas not covered by leveling; and 2) compare InSAR analysis to levelling data to figure out the robustness of displacement measurements.

Description:

The Nord-Pas de Calais coal basin is located in the North of France. It extends from East to West for approximately 100 km and has a width of 10 to 20 km. The basin was exploited between 1750 and 1990, for a total production of 2400 Mt. Coal extraction, down to more than 1000 m deep, and along superimposed seams, has generated during the mining period subsidence that can reach in some places more than 20 m. At the end of the mining period, the termination of pumping operations initiated a progressive flooding of underground works, which will last more than one century. Back experience on several abandoned coalfields (e.g., France, Belgium and UK) shows that this uplift can reach several tens of centimeters.

Spaceborne SAR interferometry (InSAR) is a technique for processing of Synthetic Aperture Radar (SAR) images acquired from Earth Observation satellites. The interferometric processing of a sequence of SAR acquisitions imaged from approximately the same location at different dates allows the measurement of ground displacements, with a precision of a few millimeters.

This study was carried out using the entire archive of ERS, ENVISAT and Copernicus Sentinel-1 SAR data. The InSAR analysis was able to highlight ground movements of a few millimeters/year, with the same order of precision as classical levelling methods. The observed ground displacement patterns expand well beyond the coalfield, indicating the influence of non-mining-induced phenomena as well. Natural factors, such as local geology (clay content) or surface morphology (e.g., riverbeds), seem to be correlated to areas exhibiting relatively higher displacement rates[320].

Lessons Learned:

Effective monitoring of potentially mining-induced ground movements at the scale of a coalfield needs to consider also non-mining-induced mechanisms, particularly the influence of local geological conditions. The

[320] Morel J., Foumelis M. Raucoules D. and Lemal S. 2022 InSAR assets in ground movements survey on abandoned coalfields. Mine Closure 2021 – AB Fourie, M Tibbett & A Sharkuu (eds)© 2021, Qualified Mining Consultants LLC, Ulaanbaatar, ISBN 978-9919-25-266-3

InSAR analysis offers the opportunity to cover much larger regions than with standard levelling methods, with a comparable level of precision, thus revealing potential ground movements that would not be seen by local levelling.

The ability to cover a wide area, frequency of data availability, accuracy of the measured displacement rates and the opportunity to perform retro-analysis are strong assets in post-mining monitoring context.

4 The Management of Water Resources in France

Responsible Organizations:

Ministry of Ecological Transition and Territorial Cohesion
Ministry of Ecological Transition and Territorial Cohesion/Directorate for Water and Biodiversity maryvonne.phantharangsi@developpement-durable.gouv.fr

Brief Summary:

The French water model is structured around governance by river basins: For many years, France has had a strong water policy based on major principles: public responsibility, technical and financial management by catchment area, participation of all stakeholders and co-construction, project management on a local level, and decentralization[321].

Description:

The French experience is marked by a unique form of governance that brings together the whole range of stakeholders, and is based on principles of solidarity and equity. It is characterized by the wealth of approaches and tools developed to ensure constant improvement and address the environmental and societal challenges it faces.

Planning for Integrated Water Resources Management (IWRM) at the basin level is the fundamental principle of the French experience.

IWRM is an approach to management and sustainable development that aims to reconcile the availability of sufficient quantities of quality water with the balance of uses of water and the preservation of the biodiversity-related to aquatic environments and wetlands. It aims to incorporate the various policies linked to water policy: land use planning, agriculture, urban planning, energy, environment, and so on.

Lessons Learned:

What makes France's management of water resources and aquatic biodiversity unique is that it acts in a spirit of solidarity at every level by including both the small water cycle (drinking water and sanitation) and the large water cycle (management of natural resources and aquatic biodiversity, etc.). The benefits of such an approach to management, which can adapt to a changing context, makes a major contribution to the implementation of the 2030 Agenda and its 17 Sustainable Development Goals.

[321] https://www.oieau.fr/eaudoc/system/files/34225-eng.pdf

5 Mining Sites Investigations before Restoration, French Case Study

Responsible Agencies/ Institutions:

French Geological Survey (BRGM)
BAILLY Guillaume (Chief of Unit) - DGPR/SRT/SDRCP/BSSS – Unit of soils and subsoils : Guillaume.Bailly@developpement-durable.gouv.fr

Brief Summary:

The Directive 2006/21/EC of the European Parliament (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0021) dictated the implementation of an inventory and a ranking (considering environmental and human health impacts) of the mining waste facilities in each member country. In France 2100 metallic waste deposits were inventoried (11% presenting environmental and/or human health risks) and more than 2000 coal mining waste deposits.

Following this inventory, Geoderis (a French public expert in post-mining risk) is in charge of the site's environmental and sanitary studies. It is strongly supported by BRGM (French Geological Survey) and Ineris (public expert on industrial and environmental risk management).

The BRGM field site investigation strategy relies heavily on the use of portable field technologies (portable X-ray fluorescence spectrometry, pXRF) and soil, water, sediment sampling and laboratory analysis. This strategy aims to define the site's geochemical background and the impact due to the mining activities. More than 75 studies were carried out by BRGM for Geoderis between 2006 and 2022.

Description:

These studies aim to determine the mechanism of geochemical dispersion of potential pollutant metals and metalloids from both natural deposits (e.g. remaining ores) and mine residues. The objectives of the study are:

- Determine the geology of the area and localize lithologies with remaining ores, by the constitution of a GIS from existing bibliography and field mapping
- Definition of the geochemical baseline for each lithology by both laboratory and in situ (pXRF) analyses
- Hydrogeological study: residual impact of mining activity on groundwater and surface water
- Characterization of the sources of contamination (tailings and impact on soil, water and sediment with pXRF measurement and lab analysis)

Lessons Learned:

Inventory and ranking of mining sites is the first necessary step with sufficient information to inform planning and management.

Site investigations shall be planned and implemented to address critical knowledge gaps essential for evaluating risks and opportunities and developing a remediation plan. Mobile, portable, and real-time data-gathering methods shall be applied for the efficient selection of samples to be analyzed.

In France and for metallic mine wastes, a large part of the studies has been achieved. The next step is to develop a methodology to study sites impacted by coal mining wastes.

Future site investigations should rely on satellite surveys (large-scale sites) and UAV surveys (LIDAR, photogrammetry, multispectral, etc. sensors).

GERMANY

Best Practices

Rehabilitation of open-cast lignite mine Espenhain
– Transforming an industrial mining region into a near-natural post-mining area

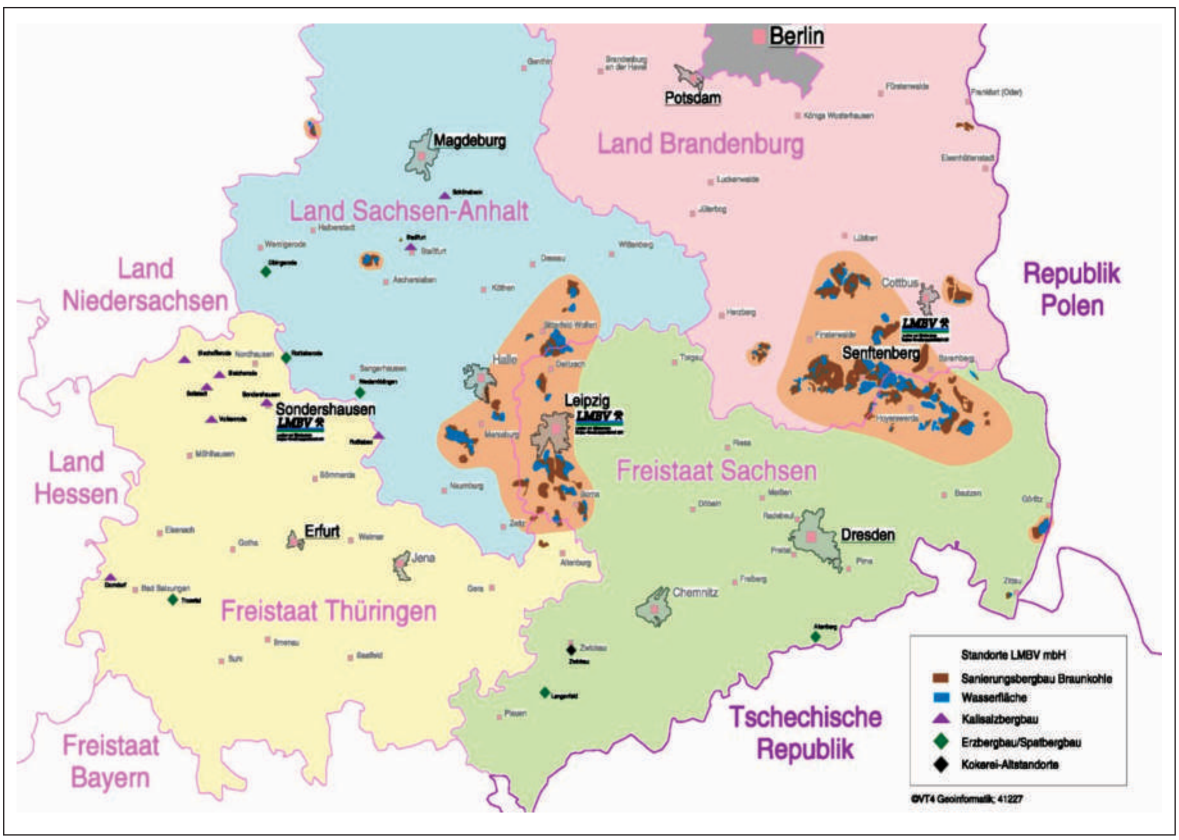
Responsible Agencies/ Institutions/ Contact:

Federal Ministry of Finance (BMF) and Federal Ministry of Environment (BMUV) in cooperation with the four affected Federal States (Länder), based on a joint Administration Agreement (Funding Provider), Lusatian and Central German Mining Administration Company (LMBV) (Responsible project agency).

Brief Summary:

Using the example of the state-owned Lausitzer und Mitteldeutsche Bergbau- Verwaltungsgesellschaft mbH (LMBV), the following case study describes at first the tasks and experiences in the reclamation of the lignite industry of the former GDR in a highly condensed, multi-project format. Afterward, a specific best practice project of the LMBV has been presented: the rehabilitation of the former opencast lignite mine Espenhain.

Figure 37: Location of LMBV responsible sites



Description

After the reunification of Germany in 1990, non-market competitive mining activities of the former GDR were terminated within a few years. To manage the rehabilitation of state-owned opencast lignite mines of the former GDR, the German Government established the state-owned mining rehabilitation company.

LMBV for this unique case. The LMBV is responsible for 100 former industrial sites, 224 pit-holes spanning 1000 km^2, 1,200 legacy-sites and a dewatered groundwater-cone of 2,600 km^2. Additionally, LMBV is responsible for the restoration of closed down potash, salt, and ore mines of the former GDR.

One example of their work is the rehabilitation of the former opencast mining area "Espenhain" close to the city of Leipzig, which had active mining activity from 1937 to 1996. At a size of around 40 km^2, 570 million tons of lignite were extracted, 1.7 billion cubic meters of overburden were removed and 14 villages were destroyed. The Espenhain mining and large power plant complex was one of the most important lignite-based industrial complexes in Germany combining a power plant, briquette factory, smelter, and facilities for processing smelter products. At the end of the GDR, the complex was regarded as the "nation's industrial polluter". Mining and production activities caused a severe impact on the water regime south of the city of Leipzig as well as massive air and water pollution.

The rehabilitation work was carried out to normalizing the area's water balance, integrate the resulting lakes into the post-mining landscape, and offering the surrounding communities conditions for attractive recreational areas.

The overall results are the creation of two lakes with a size of 12km^2 in total, new forests of 10km^2, and designated nature-protected areas. The creation of two lakes was for reasons of public acceptance and a result of the involvement of locals in the planning process. Additionally, there are now high-quality touristic resorts and public leisure areas, which benefit the local population. Furthermore, the former mining area is now being used for photovoltaic power plants as well as industrial parks and the University of Leipzig has built a science campus on the former mining grounds.

Looking at Some Specifics of Rehabilitation Work:

One of the central tasks in mine rehabilitation was the construction of geotechnical safe slopes. For this purpose, more than 80 million cubic meters of soil were moved along the more than 30 km long embankments. The existing mining technology was used for this purpose.

Carrying out the flooding, 220 million cubic meters of water – by rising groundwater, water from the adjacent rivers, and drained water from an adjacent privatized opencast lignite mine – create two lakes. Active flooding shortened the time of filling of the two lakes by 50 to 60 years. The flooding was accompanied by extensive monitoring of the groundwater in terms of quantity and quality. A large-scale hydrological model was used to forecast the effects in the area surrounding the opencast mine. Today, it is used for further water management control. Acidification of one lake due to acid mine drainage (AMD) caused by pyrite, is a challenge. Regular liming by a special rehabilitation vessel counteracts this process.

140,000 cubic meters of soil was compacted to establish geotechnical safety in the former opencast mine area. Different technologies for vibro-compaction were used.

Dismantling of buildings, demolition, and scrapping of equipments resulted in 141,000 tons of waste. In total, 427,700 tons of waste had to be disposed of in the former industrial complex.

The total costs of the rehabilitation project Espenhain covered by LMBV, are about 290 million Euro.

Lessons Learned

The experience gained from the reclamation of the lignite industries of the former GDR shows that undertaking rehabilitation work at the end of mining processes is the most complex and expensive option. It is therefore, crucial to consider rehabilitation as early as the planning stages of a future mine, to incorporate rehabilitation measures while excavation and the dumping of overburden are still ongoing, to accompany this with the creation of vegetation-friendly soils as well as their greening, and to intensively examine the effects of any interventions on the water balance.

The involvement of the local population and professional authorities is also important. Local knowledge and expertise as well as the consideration of legitimate concerns generate trust for sound planning processes.

Figure 38: The area of the open -cast mine "Espenhain" in the 1990s and results of rehabilitation activities:

Mining and rehabilitation activities reach far into the future. Good forecasts are therefore important. Consequently, studies of alternative scenarios under different climatic conditions are necessary. Moreover, the generation of knowledge and innovation was crucial for the success of LMBV.

Mining reclamation projects are complex, costly, and of long duration. Financing that is aligned with the progress of reclamation and the strict control of cash flows is crucial in this context. For this purpose, LMBV has a close-knit, multi-level monitoring system consisting of internal and external control.

INDIA

Best Practices

1 Developing Ecological Restoration Model in the Mine Spoils at Tetulmari under Sijua Area

Responsible Agencies/ Institutions/ Contact:

Forest Research Institute and Bharat Coking Coal Limited, India

Brief Summary:

Mining activities, from exploration to production and transport, have significant negative impacts on the environment, including deforestation, soil erosion, water resource depletion, and air pollution. Ecological restoration efforts were undertaken to stabilize overburden dumps, conserve and enhance biodiversity, generate natural resources for local communities, and improve the visual appeal of the site. Different ecological restoration methods were applied, resulting in the planting of 13,000 plants of various species, including forestry, horticultural, medicinal, and grass species. The restoration process successfully enriched the site with diverse vegetation cover, catering to the fodder needs of the local community, and reversing the environmental damage caused by mining.

Description:

The model restoration of the mined-out area in Tetulmari was initiated as the site, which was around 14 years old, was heavily infested with exotic weeds such as *Lantana camara, Eupatorium odoratum*, and *Heptis suaveolens*. As no prior interventions were made to tackle the weed growth, it was necessary to eradicate them before starting the restoration program. This was crucial to achieving the objectives of the restoration program, which included stabilizing overburden dumps, conserving and enhancing biodiversity, generating natural resources for local communities, and improving the visual appeal of the site. The restoration program began with an action plan that involved eradicating weeds, conserving soil moisture, selecting suitable species, performing earthwork, selecting appropriate methods to propagate and multiply the selected species, and monitoring the survival rate, growth of planted species, and any changes in soil physical and chemical properties.

Lantana camara, Eupatorium odoratum, and *Heptis suaveolens* had heavily infested the site. To prepare for the restoration program, these weeds were removed in a phased manner. Additionally, parts of the uprooted weed material were used as mulch on the exposed overburden dump areas, which aided in conserving soil moisture and preventing erosion. By removing the weeds and using them as mulch, the site was prepared for the next stage of the restoration program.

To ensure the success of the restoration program in the Tetulmari area, a number of plant species were identified based on the existing climatic conditions, substratum quality, and socio-economic factors. Depending on the seed source, seed size, and regeneration capacity of the species, various methods such as direct seed sowing, seed mixed soil ball, planting of seedlings, stem cutting, bulbils, and culms/slips planting were adopted for propagation. The growth and survival rate of the species were closely monitored throughout the study. Despite heavy biotic disturbances, such as cattle grazing and movement of local people, there was sufficient regeneration of seed broadcasted and growth of planted species.

Soil samples were collected and analyzed for their physico-chemical characteristics to ensure that the restoration process was successful. Indigenous species were preferred for ecological restoration because of their ability to colonize hostile environments, enhance soil fertility, and meet the livelihood and cultural needs of the local communities. The restoration program was designed to not only enhance the visual appeal of the site but also to generate natural resources for the local communities and conserve and enhance biodiversity.

At present, the site is enriched with a total of 105 plant species of which 37 are trees, 18 shrubs, 28 herbs, 9 grasses, 2 fern, 1 creeper and 10 climber species with an estimated biomass of 99.05 ton/ha, and 259.09 ton /ha carbon sequestration. The enhanced biodiversity has promoted the species introduction as many species of birds, butterflies, insects, and reptiles have been noticed at the site indicating the autogenic recovery of multi-trophic levels.

Lessons Learned:

1. Removal of weeds is an essential first step to preparing the site for restoration activities.
2. Selecting appropriate plant species based on climatic conditions, substratum quality, and socio-economic factors is crucial for the success of the restoration program.
3. Adopting different propagation methods for different plant species can increase the chances of success in restoring the site.

Figure 39: Mine overburden dump before restoration

Figure 40: Mine overburden dump after restoration

4. Close monitoring of growth and survival rates is necessary to ensure the success of the restoration program.
5. Indigenous species should be preferred for ecological restoration to meet the needs of the local communities and enhance soil fertility.
6. The restoration program should be designed not only to enhance the visual appeal of the site but also to generate natural resources for local communities and conserve and enhance biodiversity.
7. Despite biotic disturbances such as cattle grazing and human activity, the restoration program can still be successful with proper planning and implementation.

2 Aravalli Biodiversity Park

Responsible Agency:

Delhi Development Authority and Centre for Environmental Management of Degraded Ecosystems (CEMDE) of Delhi University

Summary:

Decades of mining in the Aravalli mountains on the South Central Ridge and Northwest of Vasant Vihar resulted in a degraded landscape filled with numerous voids, depressions, and cut-slopes. After the Supreme Court issued orders in 1996 to halt and restore the area, the Delhi Development Authority (DDA) along with the Centre for Environmental Management of Degraded Ecosystems (CEMDE) of Delhi University, took to restoring and revitalizing the area. Work started in the 692 acres Aravalli Biodiversity Park (ABP) in 2004, and the restoration of this once-degraded area has led to the recovery of various species of flora and fauna – from a multitude of plant communities native to the Aravalli mountain range to an increase in jackal and porcupine populations, this landscape has been completely transformed into a lush green sanctuary.

Description:

DDA in collaboration with CEMDE took an innovative and natural approach to restoring this landscape. The operation was spearheaded by Dr. CR Babu of the CEMDE who utilized the principles of ecological restoration by firstly conducting extensive research on plant, and ecological diversity of the surrounding unmined Aravalli areas. Establishing soil was the next priority. No topsoil was brought in from external landscapes, instead native species of grass and legumes were selected to colonize the landscape. Utilizing small quantities of manure, these grasses took to the nearly barren landscape to promote biophysical processes leading to soil formation, nutrient enrichment, and soil moisture retention which enabled other plant species to survive, establish and grow. The topography of the landscape has not been changed, apart from the gradual weathering of the cut-slopes and colonization of plants onto them, there has been no backfilling or ripping. The landscape was notified as a water catchment and recharge zone before the ABP was established, and so the DDA and CEMDE team focused on improving the recharge capabilities by letting natural ecological succession take place inside mining voids so that water retention increases.

The Aravalli Biodiversity Park has become a nature reserve for Delhi, harboring 1200 species of plants and animals living in 35-40 biological communities, which support 115 butterflies and moths, 216 avifauna, 31 reptiles, and 19 mammal species. From a near barren mined-out landscape to a lush green forest area with tree canopies reaching upto 45 feet, the ecological restoration in the ABP has proven to be a blessing for residents of New Delhi. A large component of the ABP has been its emphasis on environmental and ecological education. Citizen and enthusiast bird- watching groups along with butterfly counts and tree walks are a daily occurrence at the ABP. The Aravalli Biodiversity Park is the only place in Delhi that provides unique camping facilities to school children for imparting environmental education in a natural ambiance. Several schools and colleges in Delhi have been availing this facility since the inception of this park. For students interested in ecology research and academia, the ABP has supported more than 50 PhD students and has been the area of research for countless research papers. The ABP also hosts a medicinal garden, a sacred grove, and separate conservatories of orchids, ferns, and butterflies. There are a vast variety of landscapes and plant communities ranging from grasslands, shrubland, and tropical thorn forest to broad-leaved deciduous forests, all of which are native to the Aravalli Mountain range. Thereby, the ABP also proves to be a unique "eco-museum" of the various indigenous Aravalli plant communities.[322]

Lessons Learned

1. **Collaborative efforts:** The success of this restoration initiative was due to the collaboration between the government, non-governmental organizations (NGOs), and local communities. This collaboration helped in the mobilization of resources and the effective implementation of the project.
2. **Restoration of degraded land:** The restoration of degraded land is essential for conserving biodiversity and restoring ecosystem services. The Aravalli Biodiversity Park is an excellent example of how degraded land can be restored through the use of native plants and careful management practices.
3. **Community participation:** Involving local communities in restoration projects is crucial to ensure long-term success. The Aravalli Biodiversity Park restoration initiative included local communities in the planning, implementation, and monitoring of the project.
4. **Public awareness:** The restoration of the Aravalli Biodiversity Park has raised public awareness about the importance of biodiversity conservation and the need for ecosystem restoration.
5. **Sustainable management:** The restoration project's success will depend on the sustainable management of the park over the long term. This involves ongoing monitoring, maintenance, and adaptive management to ensure the park's ecological integrity and functionality.

[322] https://www.delhibiodiversityparks.org/aravalli-biodiversity-park.html

3 Ecological Restoration in Jharia Coal-fields, BCCL

Responsible Agency:

Bharat Coking Coal Limited, Dhanbad

Summary:

The Jharia Coalfield in India, which was under private mine owners until nationalized in the 1970s, suffered severe land degradation due to unscientific mining methods that prioritized profit over safety and conservation. The Bharat Coking Coal Limited (BCCL) has since taken up ecological restoration efforts to establish a natural forest ecosystem with biodiversity and bring back normal ecosystem functions. The restoration process involves three-tier plantations with native species, and efforts were made to select species that generate biomass, stabilize soil structure, and benefit the local community. BCCL has restored over 1534.73 Ha of degraded land and plans to restore 226 ha in the next five years. The restoration process improves the local climate regime and socio-economic conditions, enhances biodiversity, and serves as an example of corporate responsibility for environmental degradation.

Description:

The Jharia Coalfield, located in Jharkhand, India, was under private mine owners until it was nationalized by the government in 1971-73. However, the mining methods used were unscientific and focused solely on profit-making, leading to severe land degradation and disturbance of biodiversity. The landscape is now marked by remnants of old abandoned quarries, spoil dumps, subsided depressions, mine fires, and baked soil due to mine fires.

To address the issue of land degradation, the Bharat Coking Coal Limited (BCCL) has taken up the pioneering task of conducting ecological restoration of the degraded and mined-out lands. The objective is to establish a natural forest ecosystem with biodiversity and to bring back the normalcy of function, structure, potential, service, and process of the ecosystem as it existed before mining activity.

The ecological restoration process involves three-tier plantations with native species consisting of lower-level grasses, middle-level shrubs/bushes, and top-level trees. The restoration process is aimed at establishing a three tier vegetation comprising of native species grasses as the lower tier, shrubs and bushes as the middle tier, and trees as the upper tier to establish biodiversity and food chain; to improve the local climate regime and socio-economic condition.

Through the state forest department, BCCL undertook extensive plantation work in the coalfield. However, such single-tier plantations only show a green canopy in aerial view and are not effective in checking erosion, recharging groundwater, and establishing biodiversity. Further, the selection of species was not considered to meet the socio-economic requirements of the local community.

Ecological restoration is the process of short-circuiting the natural recovery of degraded ecosystems through ecological interventions. Removal of invasive weeds and the addition of biomass to the degraded land creates an opportunity for the native species to germinate and establish biodiversity. Ecological restoration enhances biodiversity at a faster rate, and over time, 300 species may develop, creating a natural forest over the OB dump. Therefore, ecological restoration of mined-out areas is the most appropriate ecologically and socio-economically compatible measure.

The mined dumps were composed of big and small boulders of shaly sandstone, sandstone, shale, and traces of soil. Earlier, these dumps were profusely invaded by exotic weeds like *Parthenium hysterophorus, Croton bonplandianus, Eupatorium odoratum* and *Lantana camara*. Due to more than 100 years of mining and severe land degradation, there is no soil cover on the dumps.

BCCL has started ecological restoration since 2011-12 departmentally and is continuously increasing the mined-out degraded land/OB dumps under ecological restoration. In 2011, BCCL, in association with Forest Research Institute (FRI), Dehradun, and Prof. CR Babu, Centre for Environmental Management of Degraded Ecosystem (CEMDE), Delhi University, started ecological restoration of the mined-out degraded land and overburden dumps.

Efforts were specially made in selecting species that are native to the region, generate a large quantity of biomass to enrich the soil, ability to stabilize soil structure, and utility to the local community. Therefore, species of trees, shrubs, herbs, and grasses with multiple use value like fuel, fodder, fruit, and medicine were used during the process of ecological restoration.

After the success of the above pilot projects, BCCL has identified surplus manpower for taking up ecological restoration departmentally. BCCL has drawn up a plan for the ecological restoration of about 226 ha of mine-degraded land in 5 years. Till 2021-22, BCCL has done biological reclamation over 1534.73 Ha consisting of 32,98,920 no. of plants including 32,036 gabion plantation along different transportation routes, mine boundaries, etc.

Ecological restoration of mined-out areas in the Jharia Coalfield is an excellent example of how corporations can take responsibility for environmental degradation and take proactive measures to restore the natural balance. The restoration process not only improves the local climate regime and socio-economic conditions, but also enhances biodiversity, which is essential for the survival of human civilization.

Lessons Learnt

Ecological restoration of the Jharia Coal Field has been an ongoing effort to mitigate the environmental damage caused by mining activities in the area. Lessons learned through this process include the importance of sustainable mining practices that reduce environmental impacts,[323] and the need for systematic study on environmental impact assessment (EIA) to assess both positive and negative effects of coal mining on the environment[324]. The highlights of the eco restoratin of BCCL mines are

a. Plantation with monoculture is not ecologically appropriate and thus plantation of multiple native species should be promoted.

b. There should be three-tier plantations, i.e. plantation of grass, shrubs and trees.

c. Seed sourcing from the local native species increase the chances of successful restoration.

d. The plantations on inaccessible mined-out areas can be done by the “hydro-seeding” method.

e. Seed-balls consisting of Local species seeds mixed with FYM, soil, and bio fertilizers perform well on mine spoil

f. Rain-water harvesting and soil conservation practices should be integrated with plantation work

[323] https://www.ijert.org/research/environmental-consequences-of-a-burning-coal-mine-a-case-study-on-jharia-mines-IJERTCONV5IS12008.pdf

[324] https://www.bcclweb.in/environment/Ecological%20restoration%20in%20BCCL.pdf

4 Restoration of mining-affected land of Tikak Coillery, Margarita, Assam with Integrated Biological Approach

Implementing Agency:

Rain Forest Research Institute, Sotai, Jorhat in collaboration with Tikak Colliery, North Eastern Coal Field

Summary:

A study was conducted in Tikak Colliery, Margherita, Assam, India, to evaluate the performance of 42 native plant species in a revegetation experiment with an integrated biological approach between 2018 and 2021. The experiment took place at a backfill area of a coal mine overburden dump (OBD). To prepare for the plantation, lime was applied at a rate of 15 gm per pit, and farmyard manure (FYM) was applied at a rate of 2 kg per pit. The planting of nursery-raised inoculated seedlings with arbuscular mycorrhizal fungi (AMF) and plant growth-promoting rhizobacteria (PGPR) followed a series of pot experiments to determine the best treatment combination for the field trial. Seed ball technology was also used in the first year to stabilize the area with green herbaceous cover and to improve soil parameters. The results showed that herbaceous species grown from seed ball sowing were able to survive in the OBD area, and a total of 26 naturally colonizing plant species, dominated by the Poaceae family, were recorded from the site three years after seed ball sowing. Callicarpa arborea and Schima wallichii were among the tree species, while *Chromolaena odorata* and *Lantana camara* were invasive species that naturally colonized the OBD. The best-performing treatment combination was AMF + PGPR + Lime + FYM. Seventeen out of a total of 42 native plant species achieved 60-70% survival after two years of planting on the OBD site. These practices replaced the need to apply topsoil in the coal mine site's revegetation program and can be replicated for the successful reclamation of OBD sites for a plantation program.

Description

While the application of topsoil in a revegetation program for coal mine-degraded land has been successful in some areas, it can lead to degradation in other areas due to the need for a large quantity of topsoil. An alternative source of topsoil is stockpiled topsoil obtained from surface mining, but this practice is limited by the need for large storage space and the deterioration of nutrient and soil microbial status over time. Revegetation of mine spoils is also limited by the lack of nutrients in OBD spoils, high acidity, poor water holding capacity, and accelerated erosion rates. Rain Forest Research Institute (RFRI) conducted a pilot study at a backfill area of a coal mine overburden dump (OBD) in Tikak Colliery, North Eastern Coalfield, Margherita, Assam, India, to restore post-coal mine areas with native plant species using an integrated biological approach. The study aimed to develop a package of practices for future plantation programs in coal- mined areas. The technology is divided into two components: site stabilization and raising plantation.

For site stabilization, physical earthwork was done by making bench dumping not exceeding 3.0 m in height, ensuring that the angle of slope of overburden dumps was less than 29° from the horizontal, and contouring the area with clips of grass species such as *Cymbopogon nardus, Thysenoleana latifolia* and *Veteiveria zizanoides* to prevent soil erosion and increase seepage of rainwater. Rills, small channels caused by runoff water, were plugged with rhizomes of *Melocanna baccifera* and clips of grasses planted in a spiral way. Mulching with natural fibers such as straw from Saccharum munja and *Vetiveria zizanioides* was done immediately after broadcasting seed balls on the slopes to reduce removal of seed balls by runoff. Finally, a suitable fencing was

Figure 41: Steps of restoration of Tikak Coillery, Margerita

installed around the dump to restrict unauthorized activities and protect from grazing by animals.

For raising plantations, an integrated biological approach was adopted, including soil amendments, plant growth-promoting rhizobacteria (PGPR), and arbuscular mycorrhizal fungi (AMF). Native plant species were used for the revegetation experiment, and seed balls were prepared using a mixture of clay soil, organic manure such as cow dung and vermicompost, and various additives such as humus, compost, microbial inoculants, cotton-fibers, Alginate, etc. were broadcasted on the slopes. The use of seed ball technology is an eco-friendly and low-cost technique for propagating plants without opening up the soil with cultivation tools.

The study was successful in raising a pilot plantation in Tikak Colliery of North Eastern Coalfield, Coal India Ltd., during 2018-2021. This integrated approach can be a promising solution for restoring degraded post-coal mine areas with native plant species in the North Eastern region of India.

Lesson Learned

- **Use of Integrated Biological Approach:** The integrated biological approach, which involves the use of soil amendments, plant growth-promoting rhizobacteria, and arbuscular mycorrhizal fungi, proved to be effective in restoring degraded land. This approach can be useful for other restoration projects.
- **Seed Ball Technology:** The use of seed ball technology, which involves the preparation of seed balls mixed with clay soil and organic manure, proved to be a low-cost and eco-friendly technique for propagating native plant species in the degraded site. This technique can be useful in other restoration projects, particularly in areas where traditional cultivation methods are not feasible.
- **Site Stabilization:** The use of physical earthwork techniques such as bench dumping, contouring, and planting grass species and rhizome of *Melocanna baccifera* helped to stabilize the site, reduce soil erosion, and increase the seepage of rainwater. This can be useful in other restoration projects where site stabilization is critical.
- **Community Involvement:** The involvement of local communities in the restoration project was crucial for its success. The project provided employment opportunities for the local people and also helped to raise awareness about the importance of conservation and restoration of degraded ecosystems.

ITALY

Best Practices

1 Using organic amendments for the recovery of mining soil polluted by potentially toxic elements (PTEs)

Responsible Agencies/ Institutions/ Contact:

Desertification Research Centre (NRD) – UNISS Prof. Quirico Migheli (qmigheli@uniss.it); Prof.ssa Paola Castaldi (castaldi@uniss.it);Prof. Giovanni Garau (gggarau@uniss.it)

Brief Summary:

Organic amendments made from the recycling of waste biomasses (such as compost, biochar, water treatment residues, and others) can help restore the chemical and biological properties of mining soils that have been contaminated by PTEs. The case study demonstrates the use of municipal solid waste compost for immobilizing the labile fraction of different PTEs (i.e., Pb, Zn, Sb, and Cd) present in a dismissed mining site. This reduced the bio-chemical stress that PTEs put on plants and soil microorganisms, helping to speed up the natural process of attenuation. After 5 years since compost was applied, plant growth and microbial activity increase

Figure 42: A view of the site before intervention in 2015 (upper panel) and plant cover in MSWC - amended and unamended plots after 5 years (lower panel)

significantly. Overall, compost addition revealed a successful strategy to limit the environmental and health risks associated with the presence of Pb, Zn, Sb, and Cd in soil and promote its (bio)chemical recovery.

Description:

The example brought here refers to an area located within the dismissed mining site of Argentiera (NW Sardinia, Italy) where argentiferous galena (PbS) and sphalerite (ZnS) were industrially extracted from 1867 to 1963. The site (40°44'10"N and 8°08'53"E) is contaminated by PTEs resulting from the weathering of tailings and waste rocks accumulated around the area. The average concentration of PTEs at the site under discussion is: Zn 5400 mg kg^{-1},Pb 1200 mg kg^{-1},Sb 100 mg kg^{-1},Cd 25 mg kg^{-1}. Substantial labile concentrations of PTEs (i.e., water-soluble and exchangeable fractions) were also detected and quantified in the soil (REF lavoro con Lombi).

The main problem with this site was the high PTEs concentration (total and labile fractions) combined with low fertility (e.g., total N 0.7 g kg^{-1}) and a sandy texture which were co-responsible for the very limited presence of vegetation (see picture below). This implied substantial environmental and health risks due PTEs spreading in the surrounding area and dust inhalation by the people living and/or working there (the area is constantly affected by winds coming from the sea).

The intervention carried out: Municipal solid waste compost (MSWC) was added (0.0-4.5% w/w) in 2015 to an area of approx. 5000 m^2 and different plant species (*Helichrysum italicum, Euphorbia pithyusa, Rosmarinus officinalis*) were planted. Assessment and monitoring were carried out relative to: common soil chemical parameters, labile PTEs in soil, soil respiration, selected soil enzyme activities, and plant cover. After 5 years since the intervention, all the monitored parameters were significantly enhanced in the compost-amended plots (see picture below) indicating substantial chemical, biological and functional recovery of the site as well as reduced environmental and health risks.

Lessons Learnt

The organic amendment obtained from recycling waste biomass (i.e., MSWC) has proven to be a key environmental resource capable of improving the health of degraded mining soils contaminated by PTEs.

2 Geological Path of Baiso Clays

Responsible Agencies/ Institutions /Contact:

Municipality of Baiso (RE), Emilia-Romagna Region Christian Marasmi Email: christian.marasmi@regione.emilia-romagna.it

Brief Summary:

Historically Baiso area was one of the most important exploitation sites for the ceramic industry of Sassuolo. Since the last 20 years changes occurred in the formulation of the ceramic paste, this type of clay (Varicolori clays) is not more used in the ceramic process. These abandoned quarries, (not yet recovered), are inserted in a particular landscape characterized by coloured gullies and by natural aspects of high value. This environmental heritage the area is part of MAB Unesco site, regional park and landscape regional heritage.

Description:

The project, financed by the regional law on extractive activities (LR 17/91) had the objective of creating a path to promote sustainable tourism in areas previously affected by extractive activities. At the same time, the goal was to enhance the naturalistic emergencies that allowed the area to be included in the UNESCO MAB. The itinerary, inaugurated in 2021, starting from the mining history, allows to tell the geology and above all the new eco-tourist vocation of the area, enhancing the environmental aspects related to the particular environment of the gullies.

Lessons Learned:

- Creating a local awareness on the tourist potential of the area.
- Updating the description of the geology, flora and fauna heritage of the area.
- Proposing new uses for closed quarries, both under restoration or not yet restored.

3 CIRAN- Critical Raw Materials Extraction in Environmentally Protected Areas

Responsible Agencies/ Institutions /Contact:

INTRAW, ISPRA, Mauro Lucarini, Email: mauro.lucarini@isprambiente.it

Brief Summary:

CIRAN has the purpose of developing, testing and validating processes to arrive at balancing policies between, environmental protection and the needs of society for access to critical raw materials (CRM). Duration: January 1, 2023- December 31, 2025.

Description:

Finding policy-level solutions that take into account the balance between environmental protection and societal needs for access to mineral raw materials, protecting environmentally sensitive areas and increasing socio-economic resilience.

ISPRA has been involved for about ten years in activities concerning resources, both in international projects and at a national level. The repercussions deriving from participation in this Project would be positive as the Institute is an active member of the Critical Raw Materials at the MISE and also coordinates the Quarries and Mines Table belonging to the RISG (Italian Network of Regional Geologic Services), addressing precisely the issues linked to Sustainable Mining and the social acceptability of extractive activities.

Lessons Learned:

Catalogue of low-impact extraction methods; Protocol on Environmental Assessment of CRMs extraction in protected areas.

4 Isola Giarola Natural Park

Responsible Agencies/ Institutions:

Municipality Villanova sull'Arda (PC), Emilia Romagna Region

Brief Summary:

Isola Giarola Park is located in the floodplain of the Po River in the Municipality of Villanova sull'Arda (Province of Piacenza). The river's course and some human intervention have shaped the natural and semi-natural environments.

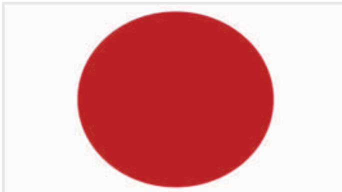
The lake that dominates the floodplain is an artificial basin that originated from mining activities that ended in 1995. Since then numerous environmental restoration interventions have been carried out. Thanks to these, its banks have now recovered their total naturalness and host the typical flora and fauna of peri-fluvial wetlands.

Description:

It is a large quarry area, depleted and restored since 1995. It is located between the current course of the river Po and its ancient bed, located further south, known as Lanca di Po. Before the excavation, the area was largely subject to agricultural use. Currently the excavation has ceased, and the area has been recovered from an environmental point of view and not reverted to the previous agricultural use. The project envisaged the creation of a "natural oasis", with the maintenance of the quarry basin, which came to be formed with the excavation, recovering the area as a semi-natural wetland. In rearranging the basin, most of the banks were remodelled, leaving a gentle slope of about 25°, on which the top soil, previously set aside, was redistributed. At the same time, the perimeter areas were also arranged, with the use of meadows or woods. The vegetation was partly already present in the areas left free from mining for the longest time, such as along the banks of the western side; here there is a bank vegetation of sedges and willows. This initial vegetation was then enriched with the planting of numerous woody, shrubby and tree species.

Lessons Learned:

- Restitution to the river environment of its natural space.
- Improving the eco-tourism of the area.



JAPAN

Best Practices

Restoration of Degraded Landscape: Ashio Copper Mine

Responsible Agencies/ Institutions:

Forestry Agency of Japan

Brief Summary:

In the Ashio Copper Mine area, the forest had been seriously damaged due to excessive logging and smoke pollution emitted from the refinery. Due to the forest loss, sediment runoff/mudslides and other problems had occurred frequently, and it was causing severe damage to residents in the downstream area. As a result of many years of greening efforts, the vegetation and ecosystem has recovered. The site is now used by many citizens for environmental education.

Description:

In the Ashio Copper Mine area, the forest had been seriously damaged due to excessive logging, forest-fire and smoke pollution by sulphurous acid gas emitted from the refinery. Due to the forest loss, sediment runoff/mudslide and other problems had occurred frequently, and it had been causing severe damage to residents in the downstream area.

In 1956, the Forestry Agency of Japan initiated a greening project to restore forests and reduce damage. Restoration of the degraded land was extremely difficult as the soil had been acidified by years of smoke damage. The project made great progress by improving the greening method using a vegetation board, combining soil with fertilizer and seeds into a sheet. Helicopters were also introduced to seed deep in the mountains and on steep slopes, where revegetation was difficult to implement manually. These methods contributed greatly to the development of greening technology in Japan.

Today, the vegetation and ecosystems are steadily recovering, rivers get rarely murky after rainfall, and sediment runoff/mudslide is no longer seen. Wild animals and fish have returned to the mountains and rivers.

In recent years, the site is now used by many citizens for environmental education, where many citizens and students visit and participate in tree planting activities as volunteers.

Lessons Learned:

In the Ashio Copper Mine area, the forest suffered damage not only by deforestation for mining, but also by sulfurous acid gas emitted from the refineries. The vegetative board technique, in which soil with added fertilizer and seeds are processed into sheets and constructed on-site, is effective in restoring degraded areas that have lost healthy soil as a result of soil runoff or acidification of soil.

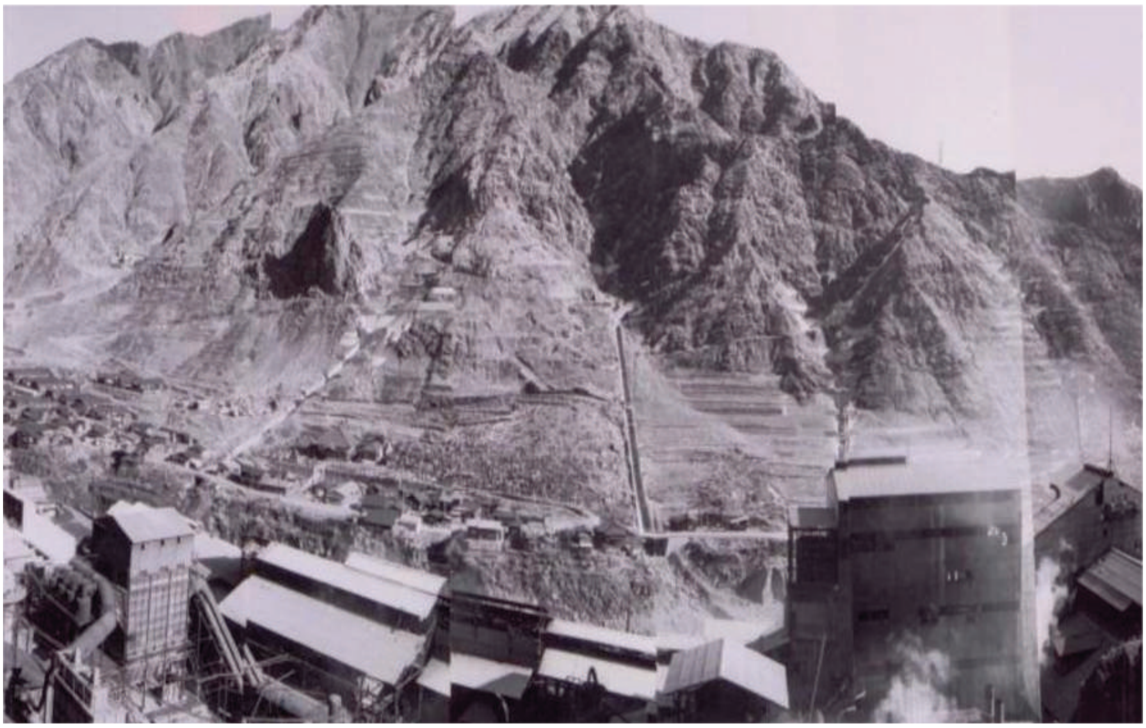


Figure 43: Ashio copper mines in early 1950s

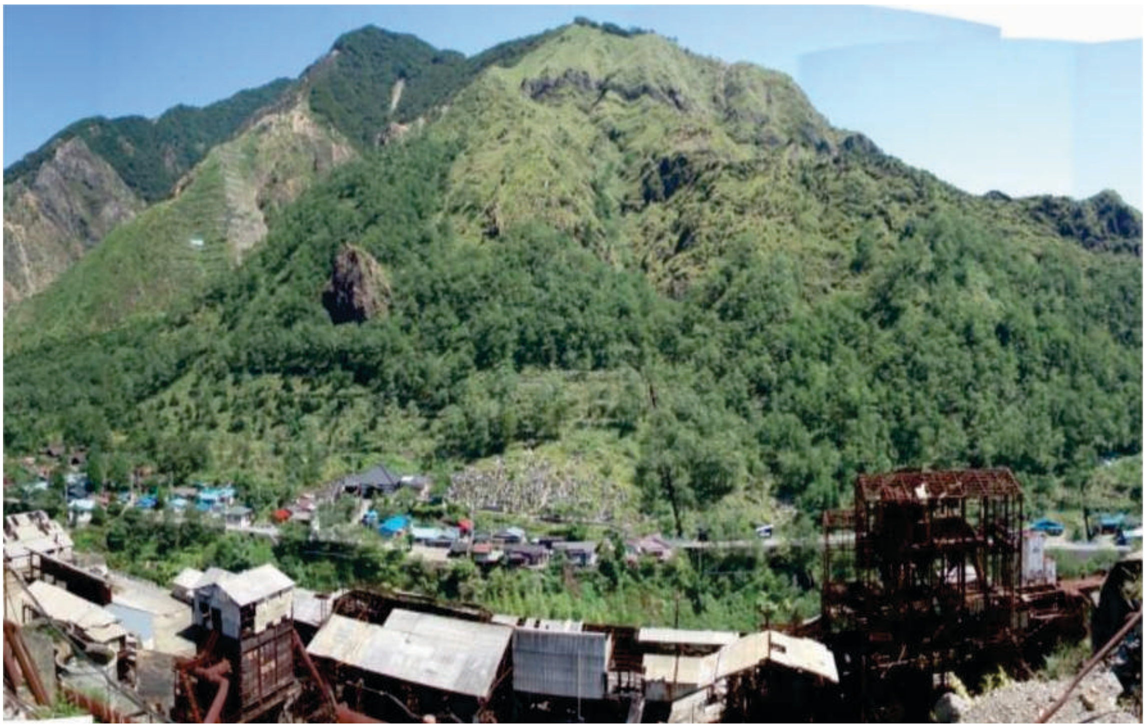


Figure 44: Ashio copper mines 50 years after the greening project

UNITED STATES OF AMERICA

Best Practices

United States Environmental Protection Agency – Abandoned Lands

Responsible Agencies/ Institutions /Contact:

U.S. Environmental Protection Agency

Brief Summary:

Abandoned Mine Lands: Abandoned mine lands (AMLs) are those lands, waters and surrounding watersheds where extraction, beneficiation or processing of ores and minerals has occurred. AMLs can pose serious threats to human health and the environment. The EPA conducts and supervises investigation and cleanup actions at a variety of mine sites. The Agency has a range of resources related to the environmental risks and challenges present in investigating and cleaning up AMLs. The EPA also pursues opportunities to explore innovative reuse opportunities at mine sites.

Description:

Abandoned Mine Lands (AMLs) are: "Those lands, waters, and surrounding watersheds contaminated or scarred by extraction, beneficiation or processing of ores and minerals, including phosphate but not coal*. Abandoned mine lands include areas where mining or processing activity is temporarily inactive."

EPA's AML Program identifies ways to protect human health and the environment by using all of the non-regulatory and regulatory approaches available to the Agency. These approaches include:

- Voluntary cleanups
- Agency-managed emergency responses
- Involvement of Brownfields partners
- Cleanups based on redevelopment/revitalization
- Agreement on Consent remediation
- Superfund Alternative Site designation
- NPL listing
- Innovative reuse/remediation

To best coordinate the risk reduction and cleanup of abandoned mine lands, the AML Program partners with: Other federal land management agencies

- States
- Tribes
- Mine owners and operators
- Community stakeholders

The EPA-AML Program is coordinated through the Agency's National Mining Team (NMT) and Abandoned Mine Lands Team (AMLT). These teams provide EPA headquarters and a Regional core of expertise on issues at abandoned mine sites. The teams together serve as a focal point for coordinating and facilitating national technical, policy and process issues with stakeholders on abandoned/inactive mine research, characterization, cleanup and redevelopment activities.

*Although acid mine drainage/acid rock drainage caused by coal mining commonly results in significant environmental impacts, Congress has designated the Department of the Interior's Office of Surface Mining as the federal authority responsible for addressing these coal mining contamination problems.

Lessons Learned:

EPA has issued "Best Practices to Prevent Releases from Impoundments at Abandoned Mine Sites while conducting CERCLA Response Actions." EPA developed these best practices to prevent and minimize the potential for sudden uncontrolled releases of fluid mine waste that could result from the Agency's Superfund response actions at tailings impoundments located on abandoned hardrock mine and mineral processing sites.

https://semspub.epa.gov/src/document/HQ/100002586

Good Samaritan Cleanup Example Administrative Settlement Agreement and Order on Constent (ASAOC): To facilitate Good Samaritan cleanups at AMLs, EPA is sharing an example ASAOC and associated documents from the Black Swan Restoration Reach Good Samaritan Project in Colorado. https://www.epa.gov/node/226439/

2.3 SOME COMMONALITIES AMONG G20 COUNTRIES - RESTORATION OF MINING AFFECTED AREAS

Based on the country profiles and best practices from G20 countries, a simple review of commonalities was attempted under broad categories of governance, ecological restoration and or rehabilitation, stakeholder involvements, soil and water reclamation, phytoremediation and bioremediation. The points below helps in providing a quick and broad overview of the enabling environment and factors among the G20 countries on the restoration of mined areas are presented below.

GOVERNANCE

Statutory legislations in the form of acts, statues, or codes requiring permit for mining, submission of Environment Management Plans, Obtaining necessary clearances etc.

Regulatory legislation procedural requirements for enactment of the law

Policies guiding methods for achieving the legislative objectives

Guidance, defining the regulatory agency's view of regulatory legislation or acceptable methods of demonstrating compliance

Countries have strong governance frameworks on mine closure, restoration, and preventing illegal mining. Some examples include

- Environment Protection Agency of United States of America - "Best Practices to Prevent Releases from Impoundments at Abandoned Mine Sites while Conducting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Response Actions."
- The Minerals Council of South Africa. 2018260 - Land Rehabilitation Guidelines for Surface Coal Mines for Southern Africa.
- Italy- Protocol on Environmental Assessment of CRMs Extraction in protected areas.
- EU - A ranking (considering environmental and human health impacts) of the mining waste facilities in each member country. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0021).
- India-Mines and Minerals (Development and Regulation) Act, 1957. Coal Mine (Conservation & Safety) Act, 1974, and the National Environmental Policy, 2006, provide a Statutory framework for mine restoration and rehabilitation.
- India-Under Sustainable Development Framework of the Ministry of Mines has a Star Rating System mandated by Rule 35 of Mineral Conservation and Development Rules (MCDR, 2017) for the mapping of mining footprints from the viewpoint of sustainability.

II

ECOLOGICAL RESTORATION

The process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity, involves a wide continuum of practices, depending on local conditions and societal choice.

The ecosystem is often restored to the native reference ecosystem and or repurposed to the alternative ecosystem informed by the reference ecosystem. The restoration and or rehabilitation takes into account the social aspiration and the ecological integrity of the ecosystem while increasing the productivity of the mining-affected areas. Examples include;

- Isola Giarola Natural Park of Italy – being restored since 1995, wherein land was recovered as a semi-natural wetland, while the native vegetation was enriched through plantations of woody species.
- The Belgian Federation of Industry Extractive managed a network of temporary habitats dynamically in time and space across each quarry throughout the life of the mine, ensuring constant availability of suitable habitats for the development of biodiversity. The dynamic management of biodiversity targeted several rare and protected species in Wallonia in habitats generated by quarrying activities.
- Ranger Uranium Mines, Australia: Predictive modeling is being used to plan the restoration and revegetation of Ranger Uranium Mines. The mine aspires to be rehabilitated to the standards of Kakadu National Park.
- In the Ashio Copper Mine area of Japan, the Ecorestoration of the mine was undertaken using an improved greening method using vegetation board, seeding through helicopter.
- Ecological restoration efforts successfully reversed environmental damage caused by mining in the Dhanbad coalfields of India by planting diverse vegetation.
- Decades of mining in the Aravalli mountains of India resulted in a degraded landscape. Restoration efforts by DDA and CEMDE in the Aravalli Biodiversity Park since 2004 led to the recovery of various flora and fauna, transforming the once degraded area into a lush green sanctuary.

INVOLVEMENT OF STAKEHOLDERS

Effective closure planning and management necessitate an early and ongoing collaboration with external and internal stakeholders.

Stakeholders' perspectives, their local knowledge and expectations from mine closure and the ecological and economic benefits of mine closure are collaborative.

Resource mobilization through public-private partnerships for mine restoration and post-mining land management through equity from stakeholders, debt from banks or bonds and other financial instruments also has social benefits.

- Ecological restoration of geological environment in Lvjin Lake Mines, China- The Coal mining subsidence area in Huaibei City of Anhui province was solved through geological and environmental improvement, advanced and innovative treatment measures and funding from Public Private Partnerships.
- Ecological restoration of mined out areas in the Jharia Coalfield, India is an excellent example of how corporations can take responsibility for environmental degradation and take proactive measures to restore the natural balance.

SOIL AND WATER RECLAMATION

Soil Reclamation

In recent years, many methods and measures regarding mine soil restoration have been validated. Rebuilding soil structure and improving soil fertility by applying techniques such as replacing topsoil and adding amendments to improve and restore soil are currently the most important steps in the ecological restoration of mine sites.

Reconstructing topsoil, especially in coal mine disposal sites, helps restore soil vitality and change soil microbial diversity quickly.

- Department of Agriculture, University of Sassari, Italy - Recovery of the chemical and biological properties of degraded mining soils contaminated by potential toxic elements through organic-based amendments.
- The integrated biological approach, which involves the use of soil amendments, plant growth-promoting rhizobacteria, and arbuscular mycorrhizal fungi, was used effectively for restoring the Mine burden dumps in Margerita coal fields of India. This approach can be useful for other restoration projects.

PASSIVE WATER TREATMENT

These are used for treating mining wastewater to purge impurities by employing organic matter, sand, and natural materials like limestone to treat the contaminated water.

Passive water treatment systems, are an essential component of ecological restoration. They produce TSS (Total Suspended Solids) for metal binding in open ponds within the wetlands and serve as a carbon source for the microbial ecology of the sediments, which supports biomineralization.

- The French Geological Survey (BRGM) manages over 15 mine water treatment stations that treat contaminated water biologically for oxidation of iron and arsenic.
- Cyanidation tailings from a former French gold mine produce is treated using the lime process.

PHYTOREMEDIATION

Phytoremediation is a method that effectively manages and remediates contamination of soil and ground water and often carried out by

Phytostabilization (for the reduction of heavy metals),

Phytovolatilization (to absorb heavy metals and emit harmless volatile gases and chemicals), and

Phytofiltration (to absorb contaminations from water by hydroponically grown plants)

- The French Geological Survey (BRGM) has implemented Phytostabilization on former Ag-Pb mines. The site was monitored (contamination, water, sediment, porewater, vegetation, erosion) for 18 months to build a conceptual site model and evaluate fluxes.
- The use of physical earthwork techniques such as bench dumping, and contouring, coupled with Phytostabilization through the plantation of grass species and rhizome of *Melocanna baccifera* helped to stabilize the site, reduce soil erosion, and increase seepage of rainwater in Margerita mines of India.

BIOREMEDIATION

Bioremediation

This uses microorganisms, bacteria and plants to remediate mine-affected areas.

This often plays a key role in purifying water sources, creating healthier soil, and enhancing air quality.

- Post-mining water treatment in France's Carnoules mining sites: Semi-passive treatment pilots for iron and arsenic removal in AMD are set up and monitored on-site to improve the quality of the water. The treatment was based on iron and arsenic being broken down biologically by native bacteria, and then the harmful ions were locked away[325,326].

NATIVE SEED TECHNOLOGY

The Native Seed technology is the method to grow locally adapted plants species, which are naturally growing in the mine surrounding region.

Cost-effective method for large-scale rehabilitation and restoration, is self-sustaining ecosystem post-mining and promotes restoration of the degraded mine area to the reference ecosystem:

- The Jharia, Dhanbad coalfields in India found that a combination of topsoil replacement and the use of organic amendments and fertilizer resulted in significant improvement in soil properties and vegetation cover.
- Native seed technology has been used to rehabilitate coal mines in The Hunter Valley in New South Wales, Australia.
- Seed ball technology, is being used by Mining industries of India as a low-cost and eco-friendly technique for propagating native plant species in the degraded site.

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[326] Vaxelaire S, Jally B, Battaglia-Brunet F, Jacob J. The Development Of A Treatment Process For The Mine Water Containing Arsenic And Thiocyanate From Lab Scale To Pilot Plant Scale. In: *International Mine Water Association Conference-IMWA* 2019. ; 2019.

III

CONCLUSIONS & WAY-FORWARD

3.1 CONCLUSIONS

The mining sector has always struggled with its image as a "dirty" industry as the mines are hazardous for those who work in them, produce greenhouse gas and damage the surrounding environment. However, mining is also the key to the economic growth of countries. Importantly it is critical for global ambitions on renewable energy as this is heavily reliant on certain metals and minerals that need to be mined. Therefore, for mining companies and projects to be successful, they need to include remediation of legacy impacts, implementation of better water resource protection, and caring for the environment and human health (better than in the past) through greater community engagement and helping to overcome poverty.

Ecological restoration of mines is often a long-term and complex process wherein vegetation restoration and soil improvement measures are key components. Often progressive restoration (restoration carried out during a mine's operational phase) is desirable as this reduces the mine-end closure costs and risks and reduces the necessity for long-term management of mineral wastes (as waste rocks and soil excavated during mining are re-used in the progressive restoration practices).

The following directions for future mine restoration and laying the foundation for green and sustainable development of our collective future are proposed.

Governance and Policies

Ecologically sound mining is guided by policies, regulations, and globally accepted standards that provide guidance for Environmentally and Socially Responsible Mining. Mining and mine restoration is a cross-sectoral issue involving, land, water, social, and environment sectors, and therefore, Policies, Laws, Regulations and Acts enabling and facilitating collaboration across sectors are necessary and should provide for clear goals and priorities to promote ecological restoration effectively.

Given the international agendas requiring more minerals but less biodiversity loss, mining firms, policymakers, and conservation organizations must collaborate for establishing a robust governance system with a multi-dimensional network of restoration policies, technologies and funds drawing on successful mine governance projects, advanced technologies and innovative ideas from developed and developing countries.

Community Involvement

Involving local communities in the context of mining site restoration, industry guidance increasingly reflects the necessity for early consideration of social factors and community relations. Mining businesses have an ethical obligation to leave a sustainable legacy and to co-create opportunities that will benefit future generations. The Social Aspects of Mine Closure Research Consortium (https://www.mineclosure. net/) provides valuable resources for considering people and communities beyond the project lifecycle and for developing integrated closure options that achieve sustainable ecosystems (ecological and social/human), thereby empowering communities to co-develop post-mining options.

III

Research

Mine ecosystems include complicated geological, geomorphological, climatic, hydrological, and pedagogical aspects and this makes the theory, practice and technology of mine restoration complicated. Restoring mining-affected areas usually takes time, capital and manpower, but in the long term, improved resource use through advancement in technology can make a huge difference in the restoration efforts. Towards this end, there is a need for undertaking detailed simulations, lab analysis and the use of high-resolution remote sensing photos, UAVs, to aid dynamic monitoring in the planning, evaluation, use, and maintenance of mines. Continuous monitoring of these results can further assess ecological restoration success[327]. There is a need to accelerate research and development in restoration technologies and integrate them to solve the relatively complex problems in mining areas[328], including technologies for sites with arid climates, alpine and steep slopes, landform reshaping, groundwater/surface water treatment, and ecological damage monitoring. Carbon collection, utilization, and storage are other low-carbon renewable energy solutions.

Mine Restoration and Climate Change

Changes to core ecosystem processes like hydrology, soil conditions, and nutrient cycling must be considered in the context of climate change when planning for climate resilience in mine site rehabilitation. Towards this, there is a need to develop a set of indicators to monitor climate change and assess its impact on post-mining restoration[329]. For instance, landscape metrics (e.g. structural connectivity[330] and climatic metrics (temperature and rainfall gradients[331] can be developed in conjunction with measurements of ecological attributes to assess the alteration of site conditions by both mining and climate change. In addition, linking climate change projections with landscape evolution models could provide the scientific foundation for effective post-mining restoration design and planning in the context of climate change. For instance, river restoration studies demonstrated that the construction of response curves of biophysical components to climate change can increase the prediction power[332,333].

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[331] Higgs E, Falk DA, Guerrini A, et al. The changing role of history in restoration ecology. Front Ecol Environ. 2014;12(9):499-506.

[332] King J, Beuster H, Brown C, Joubert A. Pro-active management: the role of environmental flows in transboundary cooperative planning for the Okavango River system. Hydrol Sci J. 2014;59(3-4):786-800.

[333] Wohl E, Lane SN, Wilcox AC. The science and practice of river restoration. Water Resour Res. 2015;51(8):5974-5997

Globally, the mining industry is investing in adapting ecological restoration strategies to a changing climate. Yet, such toolkits will rely on empirical knowledge and testing of species and ecosystem resilience to climate change; hence, it is crucial to invest in the generation of information regarding climatic tolerance and species adaptability. In certain jurisdictions, such as biodiverse regions with high endemism or developing countries with a dearth of climate change information, gathering knowledge regarding climate change pertinent to mine site restoration is likely to be more difficult[334]. Owing to the fast-evolving understanding of climate change and its effects on the environment, knowledge sharing (e.g. monitoring programs and evaluation frameworks) is essential for advancing the worldwide practice of mine site restoration in a changing climate.

Knowledge Sharing

Every restoration project generates information, thus organizations and enterprises must share lessons learned with the restoration research and practice community. Websites, films, stakeholder meetings, reports, best practice databases, and peer-reviewed publications are all ways to share results. Ecological restoration and related activities have many web-based sharing mechanisms. They include:

- RRC is run by the Association for Ecological Restoration (SER). https://www.ser-rrc.org/resource-database/
- World Overview of Conservation Techniques and Technologies hosts the Global Database on Sustainable Land Management (WOCAT). https://www.wocat.net/ en/about
- PANORAMA - Solutions for a Healthy Planet involves many partner organizations. https://panorama.solutions/en/explorer.

Project-specific forums for discussing lessons learned exist. Yet, sharing lessons learned is unlikely without a restoration plan. Presenting results requires scheduling time and resources in advance. Restoration funds are often confined to implementation and monitoring expenditures without specific objectives, leaving little money to share what was learned.

Technology

In recent years, green mining and smart mining techniques have emerged as environmentally friendly and sustainable mining practices that reduce the industry's environmental impacts, optimize production and conserve biodiversity. Green-mining encourages the use of renewable energy sources, recycling, and efficient extraction techniques, through less invasive methods while Smart mining uses advanced technologies, sensors and data analytics to improve mining efficiency, productivity, and safety, with mining environment damage.

Over the years various technologies have been developed by G20 countries for restoration, rehabilitation and ecological Restoration of mining-affected areas. These techniques can be broadly categorized in (i) Water treatment techniques viz. passive water treatment, passive treatment systems for mine waste water, artificial wetlands for mine waste water treatment, and mine water treatment technologies etc. (ii) Soil amendment techniques viz. soil conditioners, soil amendments, soil stabilization, ecological engineering etc. (iii) Phytoremediation techniques for remediation of soil and water, viz. phyto-stabilization, phytoextraction, soil bioengineering, and green infrastructure etc. and (iv) Other mine reclamation techniques include native seed technology, soil microbial remediation, eco-restoration, carbon capture and utilization, bioleaching, hydroseeding, and geochemical modeling. These techniques aim to restore mining-affected areas to a more

[334] Ruttinger L S V. Climate change and mining: A foreign policy perspective. 2016. https://www.climate-diplomacy.org/publications/climate-change-and-mining-foreign-policy-perspective (accessed 31 January 2021).

natural state by mitigating negative impacts such as erosion, pollution, and loss of biodiversity. Collaboration between G20 countries and multiple stakeholders can achieve Land Degradation Neutrality and promote sustainable practices in mining-affected areas. A partnership between various stakeholders can support capacity building, implementation monitoring, and knowledge gaps, among others, and complement G20 activities and initiatives. By adopting these measures, we can protect the environment, create employment opportunities, and promote economic growth in mining-depleted areas.

Box 4: Green Mining and Smart Mining

Green mining is environmentally friendly and sustainable mining, it aims at reducing environmental impacts of mining and promote effective use of natural resource. Green mining encourages use of renewable energy sources, (solar and wind energy) energy efficient technologies to reduce GHG emissions, recycling and efficient use of water, efficient extraction techniques, reducing waste, less invasive method to optimise production and conserve biodiversity, reduce habitat destruction and reduce pollution, promote social responsibility.

Smart mining uses advanced technologies and data analytics to improve mining efficiency, productivity, and safety. Sensors, automation, and machine learning algorithms optimise mining operations. Sensors and machine learning algorithms can optimise water and energy use, reducing waste and cost. Smart mining technology has potential to reduce pollution and greenhouse gas emissions through efficient planning based on the data generated by sensors. The use of emerging technology, sensors, machine learning, artificial intelligence can further help for mapping and planning eco-restoration at the initial stage of mining; real time monitoring evaluation and management of eco-restoration plan and make necessary course correction if required; automate planting, restoration of degraded soils

Finance

The amount of money required for ecological rehabilitation in mining sites exceeds present demands. Inadequate finances may result in subsequent outcomes. (i) impedes the proper implementation of restoration projects, making it impossible to continue initiatives for an extended period of time and preventing the development of nationally applicable restoration expertise and methods. (ii) decreases investments in science, technology, innovation, and ecosystem monitoring, and (iii) deprives restoration initiatives of the scientific grounding and fundamental data required for adaptive management. Once restoration and treatment are accomplished in some mining regions, there is little monitoring and follow-up; there is also a phenomenon of unmanned management following costly reclamation, which results in a double waste of cash and resources.

The United States and European nations created the concept of a Green Economy to promote environmental sustainability and alleviate the shortage of cash. The EU established the Global Energy Efficiency and Renewable Energy Funds, while the United States implemented the Comprehensive Environmental Response, Compensation, and Liability Act. G20 nations must push to promote green mine development, and actively manage the geological environment and ecological restoration initiatives by promoting the sustainable development of the Green Fund, increasing the investment of restoration funds, establishing diversified financing channels, and encouraging and guiding multiparty participation. Also, the market forces provide a viable alternative for generating the required transformative change. In this regard, governmental policies and pronouncements, such as the voluntary SDG targets, can play a crucial role in conveying a signal to market participants, the efficacy of which will ultimately depend on the subsequent public commitments.

Nowadays, mining firms conduct restoration primarily to comply with legally obligated regulatory frameworks and occasionally for convenience. With business case provisions for SLM/LDN, mining corporations can be further motivated to engage in restoration initiatives. Such a conducive environment may be the outcome of governmental and private sector policies and strategies, and would not necessarily require centralized governance structures or organizations. Market-driven solutions, such as industry standards for sustainable land management or land stewardship certificates, along with innovative finance solutions to mobilize sufficient money, could provide the appropriate incentives to elicit the required response.

Metals and minerals are at the core of human and economic development. Demand for several metals will rise, shifting mining operations to more dispersed and biodiverse locations. Traditional, site-based conservation measures will not prevent biodiversity loss against a rising mining footprint, but long-term strategic evaluation and planning can enhance outcomes. Given the international agendas requiring more minerals but less biodiversity loss, mining firms, policymakers, and conservation organizations must start talking. A fundamental challenge remains in resolving the dilemma of greater demand for mineral resources and the need to safeguard and restore environmental goods and services. Restoring mining-affected areas usually takes a long time, the focus of the mine restoration should go beyond the mine site. It should also address the nearby waste-disposal sites, nearby areas that are affected by water pollution, faraway areas that are affected by dust emissions, and infrastructure (e.g. roads and railways). To reduce global environmental degradation from mining, circular economy, material efficiency and substitution strategies should be prioritized for the metals/minerals, that have low economic gains and high environmental impacts (e.g. Manganese, Aluminium,), or that have high down-stream impacts (eg. Fossil energy carriers like Coal and Uranium). It is important to adopt a community-based approach to restoration efforts by strengthening the capacities of communities and institutions, developing eco-restoration plans, implementing restoration models, and sustainable use of natural resources. Restoration of mining-affected areas can help revive traditional knowledge systems, improve the livelihood of local communities, and engage with the private sector. This will help biodiversity to recover, ensure food security, bring economic resilience, and provides protection against the impacts of climate change.

3.2 WAY-FORWARD

The consultation held with G20 member countries, their detailed feedback as well as detailed review of literature on the ecological restoration of mining landscapes has helped in identifying opportunities to strengthen cooperation and partnerships among G20 member countries on the following aspects for a robust response to restoration of mining affected areas that require urgent action. These include:

- A collaborative framework for technology transfer, capacity building and knowledge sharing
- Innovative financing and incentive mechanisms involving multiple stakeholders
- Framework for promotion of circular economy, material efficiency and substitution strategies for metal and minerals that have low economic gains and high environmental impacts
- Consensus on Principles and Standards for the Ecological Restoration and Recovery of Mine Sites and Mine Site Restoration Framework
- Promotion of Eco Restoration through Policies, Legislation, Rules and Acts

To protect biodiversity from mining, long-term strategic planning is necessary, including legal controls, sustainable resource management, sustainable resource use, and integrated environment management during mine operations and closure. Collaboration between mining firms, policymakers, and conservation organizations is necessary to balance the demand for mineral resources with environmental protection. Metals and minerals with low economic gains and high environmental impacts should prioritize the circular economy, material efficiency, and substitution strategies to reduce global environmental degradation from mining.

Building global partnerships for ecological restoration of mining-degraded ecosystems to achieve sustainable development goals and G20 land degradation ambitions

For millennium, the mining sector has been the source not only for the mineral extraction for industrialization, economic expansion, and urban sprawling, but also for numerous socio-environmental concerns. It is therefore not surprising that mining industries are getting involved with the concerns such as carbon emissions mitigation and carbon accounting to govern a rhetorical shift towards “sustainable mining”.

Ecological restoration of post-mining degraded sites is a “green and sustainable strategy” to achieve climate change mitigation, socio-economic benefits, biodiversity conservation, soil and hydrological stability, as well as ecosystem goods and services. Proper management plans in restored sites are required to recover and increase carbon sequestration potential to combat partially with global climate crisis. It is the high time to implement sustainable restorative land use policy and soil carbon management systems to reinforce (i) provisioning of ecosystem goods and services (e.g. food and nutritional security, climate change mitigation, and water security) and (ii) the UNSDGs by re-carbonization of the terrestrial biosphere. The process involves a two-pronged approach: (i) restoration of mine degraded ecosystems and (ii) adoption of best management practises after restoration to increase the net primary productivity of degraded and restored ecosystem.[335]

The mining sector is pivotal in addressing the global threats of climate change and biodiversity loss and has an unprecedented opportunity to excel in and mobilise significant societal, technological, and financial resources to implement global restoration commitments and pledges.

In this backdrop, the Indian Presidency of the G20 has proposed to prioritise the ecological restoration of mined out areas by 2040 and support the progress in meeting these national and global restoration commitments.

Gandhinagar Implementation Roadmap (GIR) and Gandhinagar Information Platform (GIP)

In order to bring forward the implementation of various initiatives and targets on restoration of degraded land, India's G20 Presidency has proposed the Gandhinagar Implementation Roadmap (GIR) enabled by the Gandhinagar Information Platform (GIP) to collaborate on restoration action on the identified landscapes of forest fire and mining affected areas. Countries may choose to, on a voluntary basis, adopt the roadmap to ensure globally aligned actions on restoration of mining degraded lands.

Under this initiative, several institutes such as GEODERIS from France, the Department of Climate Energy, Environment and Water, and the Department of Agriculture, Fisheries, and Forestry from Australia, the Instituto Superiore per la Protezione e la Ricerca Ambientale and the Italian Institute for Environmental Protection and Research of Italy, the Republic of Turkiye Ministry of Agriculture and Forestry, the General Directorate of Forestry, the Department of Afforestation, the Permission and Easement Department, the Aegean Forestry Research Institute Directorate, and the Western Mediterranean Forestry Research Institute Directorate from Turkey, as well as the Indian Council of Forestry Research and Education and the Indian Institute of Forest Management have been identified as nodal agencies to cooperate and collaborate for the restoration of mining-affected areas.

Global Coordination especially among the G20 countries to develop protocols on monitoring the restoration of these mined landscapes and sharing of best practises is fundamental in meeting these ambitions. In addition to collaborating on working on the opportunities identified above, additional areas of collaborations should include;

[335] Lal, R., Smith, D., Jung Kunst, HF., Mitsch, WJ., Lehmann, J., Nair, PR., Mc Brathney, AB., de Meraes Sa JC., Schneider, J., Zinna, YL., Scroupa, AL., (2018). The carbon sequestration potential of terrestrial ecosystem. J. of Soil and Water Conservation, 73(6):145-152

- In assisting the establishment of national centres and upkeep of national databases. The database can include information on mine size, restoration efforts, successes, and lessons learned. They can also provide periodic reporting towards UNCCD and CBD.
- Prioritize the application of data openness principles in order to enable collaboration among various stakeholders and levels of governance. This practice can facilitate transparency and build trust, ultimately contributing to the effective implementation of the 2030 Agenda and its goal of leaving no one behind.
- Enhance the sharing of best practices on the ecological restoration of mined areas, with community level support and participation
- Promote the adoption of Ecosystem-based Approaches, which benefit all aspect of vulnerability reduction, and more generally risk reduction (also called Eco-DRR). This can be achieved either through ecosystem restoration or through the conservation of species or natural areas.

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