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EIT RawMaterials
Connecting matters

"Industrial and Mine Wastes as a Source of Technology Critical Elements"

Educational Workshop of EIT RM Morecovery project

Mining water treatment and recovery strategies

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GTK

May 5, 2020

Content

Consumption of water and impacts of discharged wastewaters

Water in the extractive industry

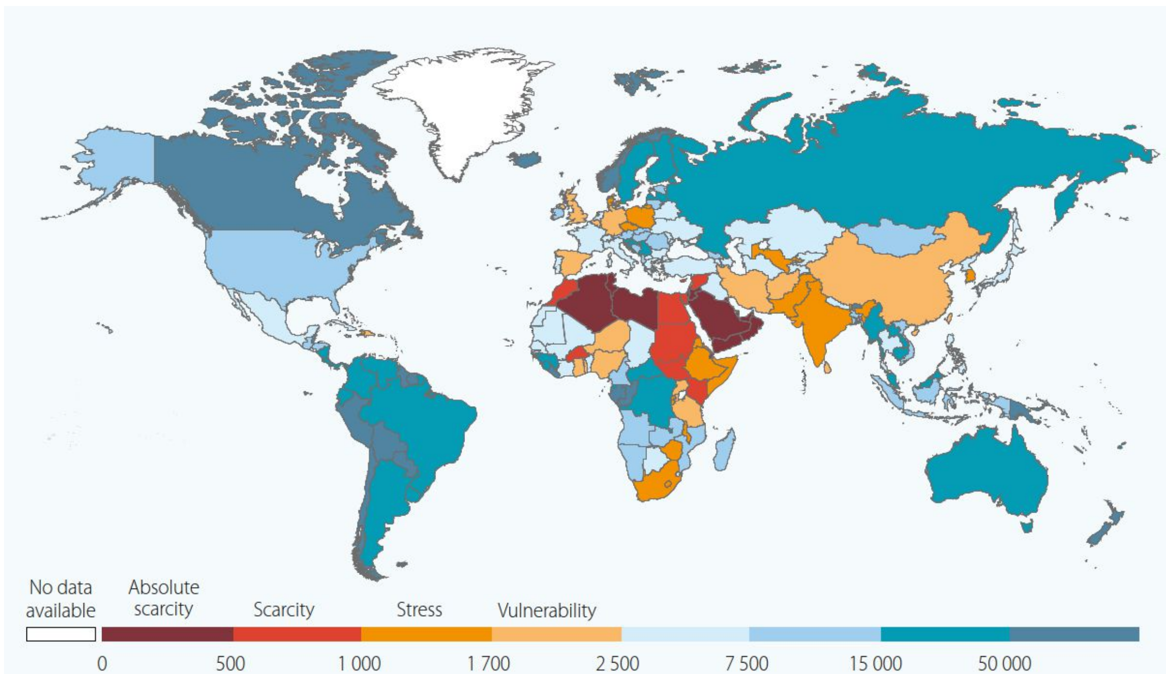
Active and passive treatment systems

Morecovery project - water treatment and metals recovery strategies

Final words

Water at the core of sustainable development

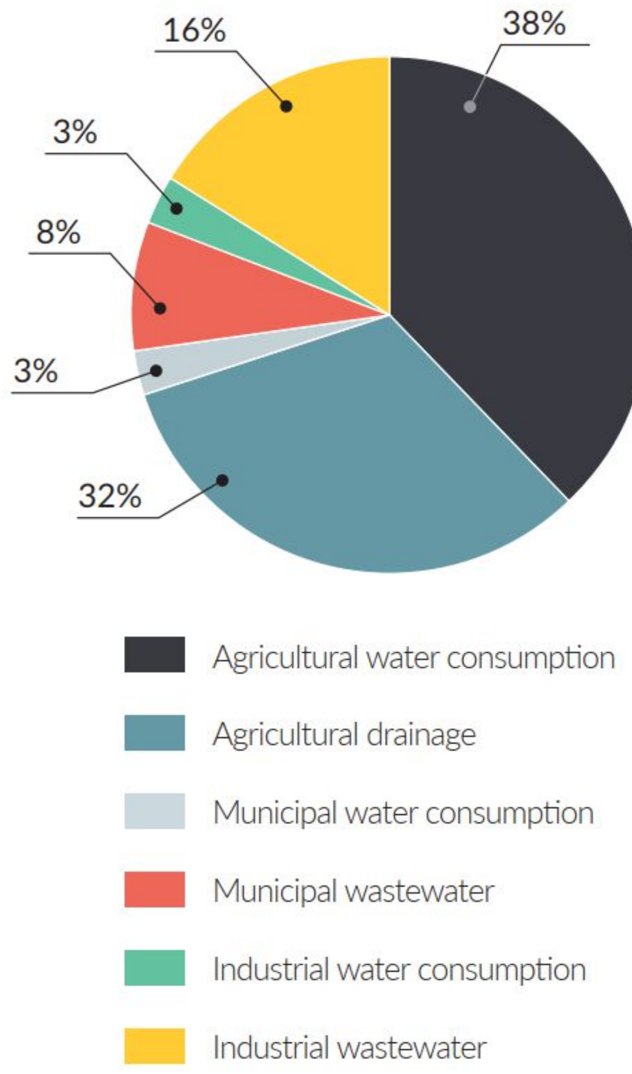
Population growth, continued economic development and climate change are major factors that will drive water stress to increase in some parts of the world



Total renewable water resources per capita in m^3

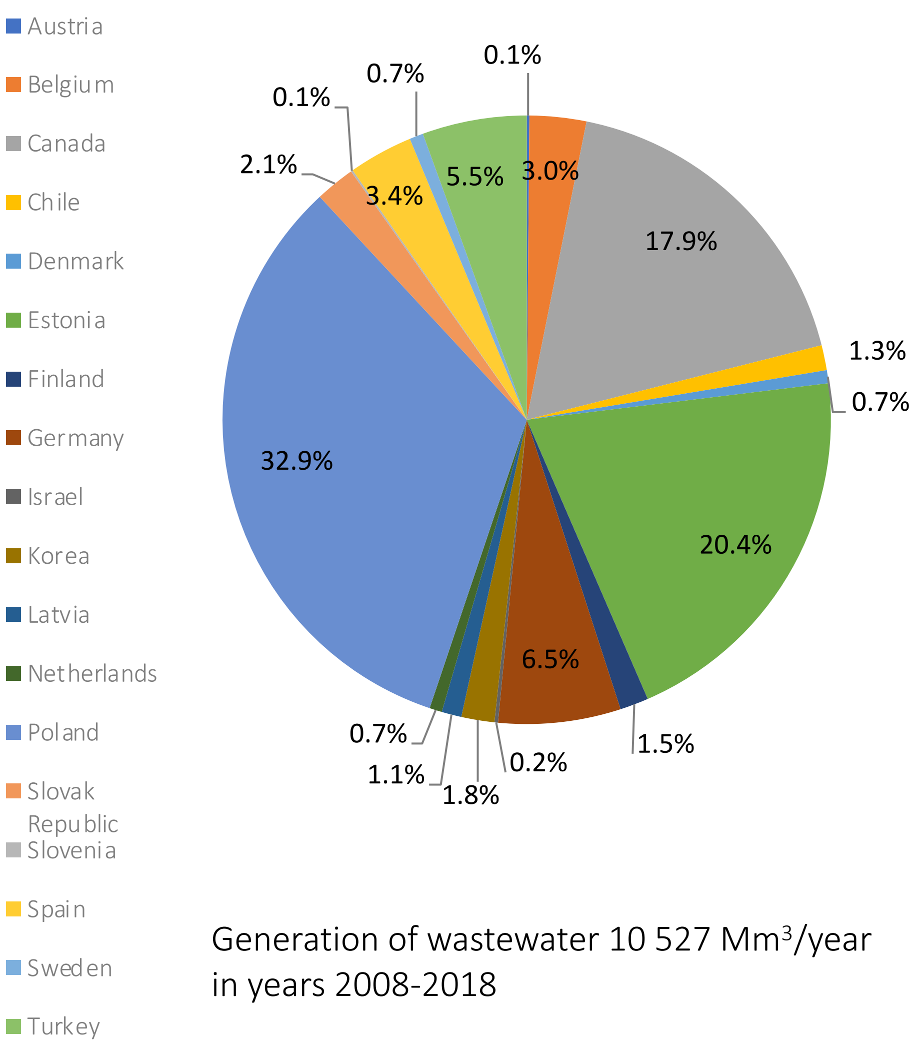
Source & Photo: The UN World Water Development Report, 2015

Global water consumption & wastewater production by major sectors



Source & Photo: The UN World Water Development Report, 2017

Generation of wastewater originating from mining and quarrying

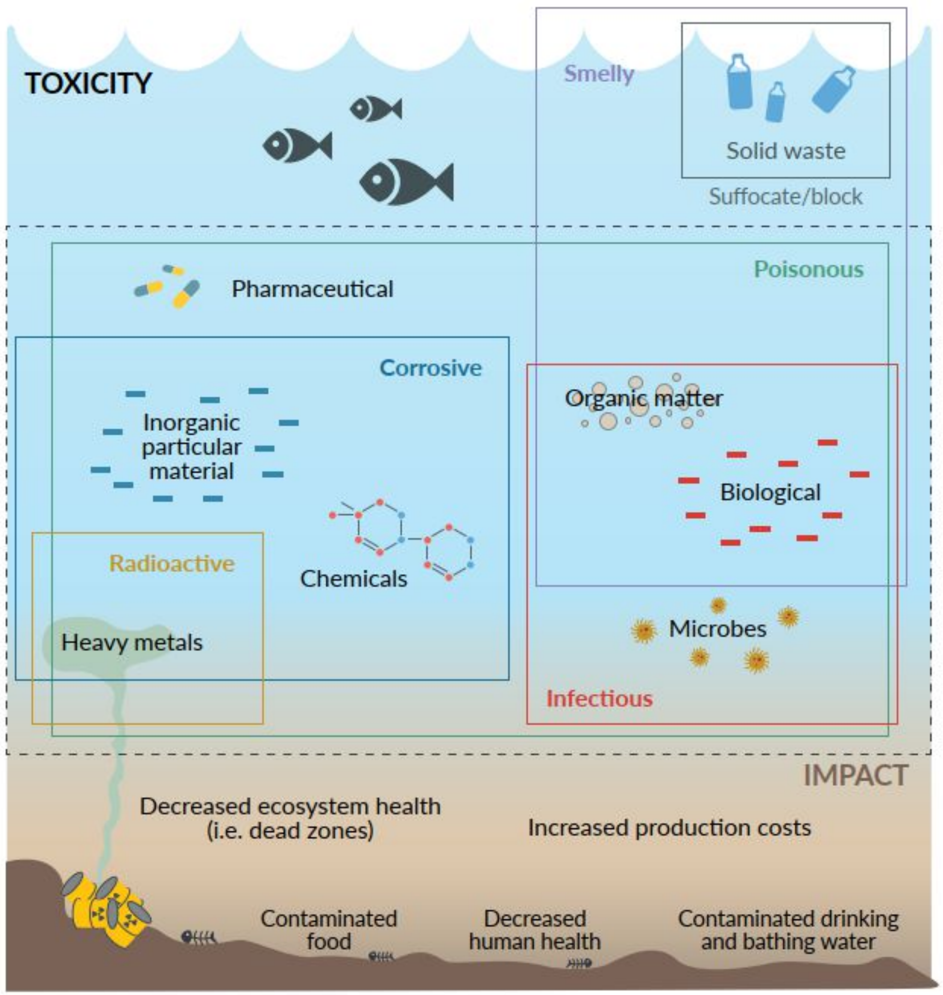


Generation of wastewater 10 527 Mm^3/year in years 2008-2018

- **Planned water discharges**: monitored and controlled to ensure compliance with regulations
- **Undesired but anticipated discharges**: leakage from waste dumps, spillage of chemicals, failure of tailings dams, and other events (e.g. due to the natural events)

Source: OECD.Stat; Photo: mining-journal.com

Impact of untreated or inadequately treated discharges



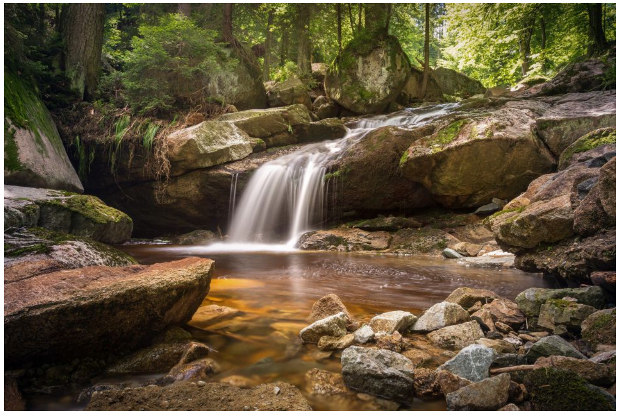
- Adverse **human health effects** associated with the poor water quality
- **Negative environmental effects** due to the degradation of ecosystems
- Potential **effects on economic activities** that use water systems

Photos: The UN World Water Development Report, 2017; Shutterstock

Water resources and usage for mining operations

Water sources:

- Fresh water - groundwater, streams, rivers and lakes
- Fresh water - commercial water suppliers
- Dewatering water
- Recycling water



Mining uses water primarily for:

- Mineral extraction and processing
- Dust suppression
- Slurry transportation
- Cooling
- Washing equipment
- Employee’s needs

Source: ICMM; Photos: fondationcndf.com, Shutterstock

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Types of mine waters (terminology review)

Mine water
Any surface water or ground water present at a mine site

Mining water
Water that had contact with any of the mine workings

Mill water
Water that is used to crush and size the ore

Process water
Water that is used to process the ore using hydrometallurgical extraction techniques; it commonly contains process chemicals

Leachate
Mine water that has percolated through or out of solid mine wastes

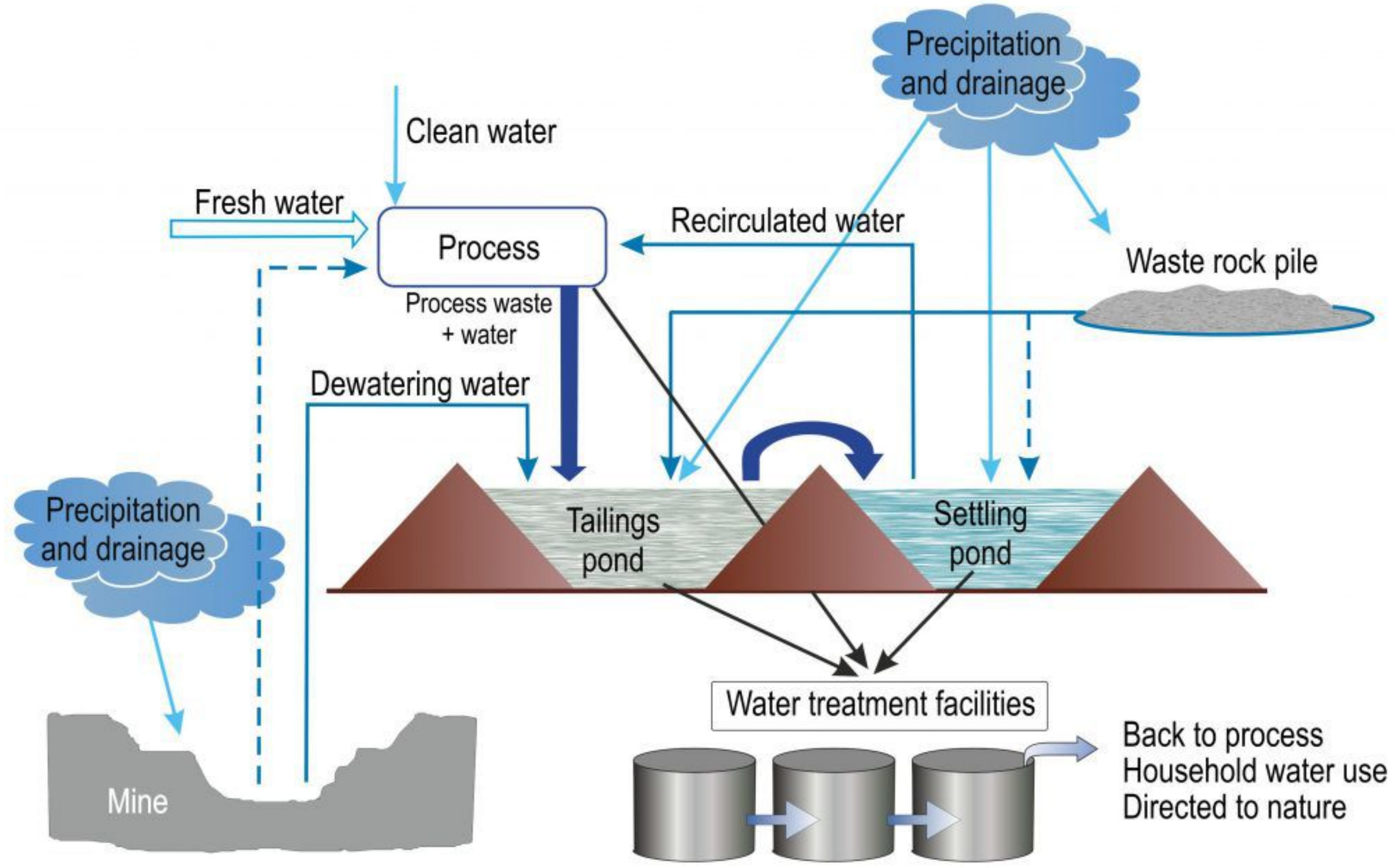
Effluent
Mining, mill or process water that is discharged into receiving waters

Mine drainage water
Surface or ground water that flows from the active or abandoned mine site into surrounding areas

Acid Mine Drainage
Low pH surface or ground water that formed from the oxidation of sulfide minerals and flows from the mine site into surrounding areas

Source: Lottermoser, Mine Wastes: Characterization, Treatment and Environmental Impacts, Springer 2010

Flow of water at the typical mining site



Source & Photo: Kauppila et al.: Best Environmental Practices in Metal Ore Mining, 2013

Need for treatment

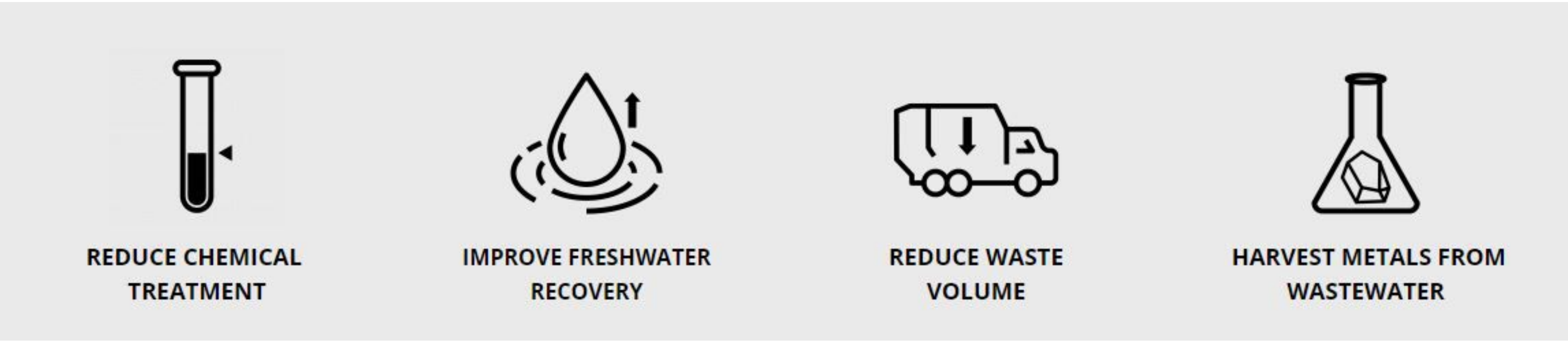


Photo: Saltworks Technologies

Gap between treatment and recycling

Mining is one of the few industries that is able to use **lower quality** water for operations, than that for human consumption

Mining require **tailored technologies** that enable fit-for-purpose treatment to optimize water resource utilization

Efficient water recycling and process technologies lead to:

- closing of the water loop, while reducing the use of water
- reducing/eliminating wastewater discharge
- reducing/eliminating solvents and toxic chemicals

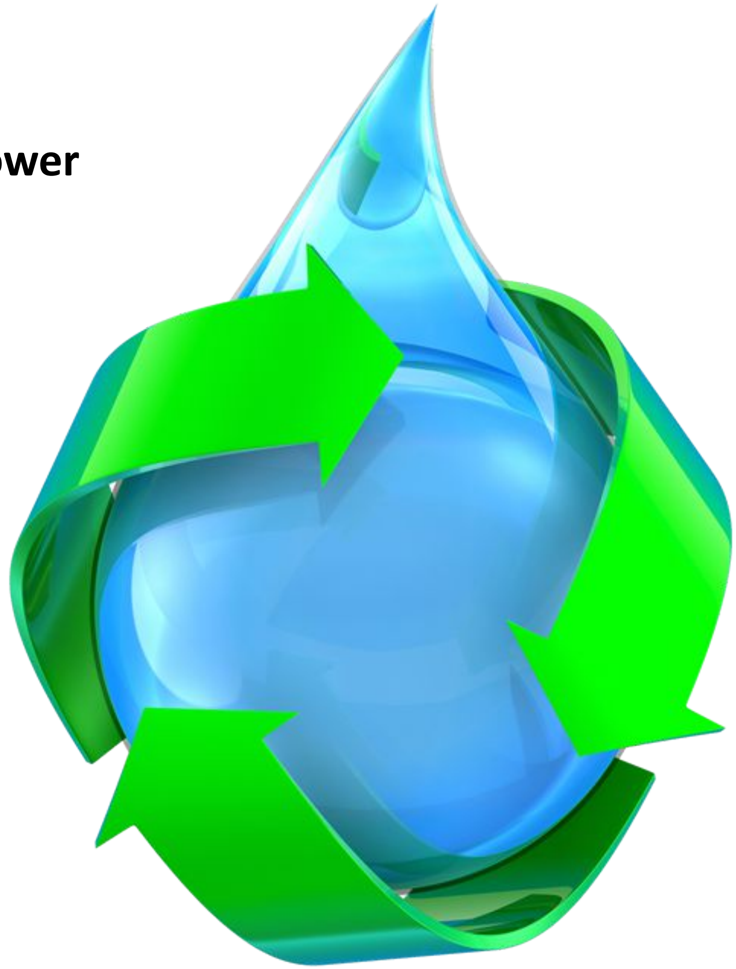


Photo: East African Mining

Categorisation of treatment technologies

Active treatment

The improvement of water quality by methods which require inputs of artificial energy and/or (bio)chemical reagents

Passive treatment

The improvement of water quality using only naturally-available energy sources, in systems which require only infrequent maintenance in order to operate effectively over the entire system design life

Active or passive approach

Deciding Factors: water chemistry, flow rate, objectives of the treatment, technical aspects (space), sludge management, capital and operating costs

Source: Younger et al., Mine Water: Hydrology, Pollution, Remediation, Springer 2002; Photos: CC BY 4.0, Shutterstock

Active treatment		Passive treatment
Most appropriate to operating mines. Closure and post-closure applications mainly associated with large flows		Most attractive to the closure and post-closure phases
Active and ongoing plant operations and maintenance systems and personnel		Constant operations not required, but regular maintenance essential
Requires chemicals, maintenance, electrical power, continuous and/or regular monitoring	VS	Self-sustaining processes, periodic maintenance, intermittent monitoring
Application to all flow rates and any constituent of interest		Mainly applied to low flow rates and acidity, metals, and sulphate removal
Treatment process can be engineered to deal with any requirements		Treated water quality poorer and more variable than other options
High capital investment and periodic capital replacement required		Moderate capital investment with periodic reinvestment
High operating and maintenance cost, with some potential for cost recovery by sale of product water, metals and by-products		Low operating cost

Source: INAP

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Types of passive treatment systems

Aerobic Systems (Wetland Types)

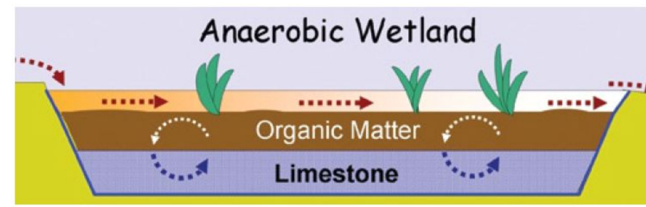
- Natural Wetland
- Sedimentation Pond
- Aerobic Wetland

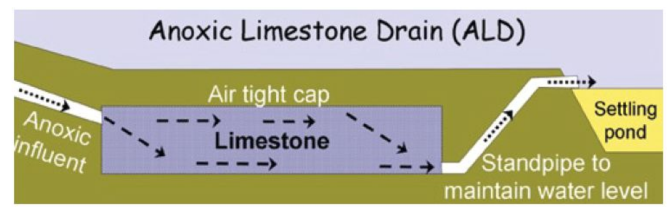
Anaerobic Systems (Substrate Based Wetland Types)

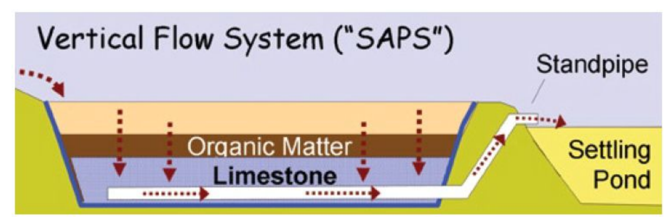
- Vertical Flow Wetland
- Sulphate Reducing Bioreactor
- Bio(geo)chemical Reactor
- Successive and Alkalinity Producing System
- Reducing and Alkalinity Producing System

Limestone Based Systems

- Oxic Limestone Drain
- Anoxic Limestone Drain
- Vertical Anoxic Limestone Drain
- Open Limestone Channel
- Limestone Leaching Bed
- Horizontal Flow Leaching Bed
- Diversion Well







Source: Zipper et al., Passive Treatment of Acid-Mine Drainage, 2011; McCauley, Assessment of passive treatment and biogeochemical reactors…, 2011

Active treatment technologies

Alkaline treatment
- Oxidation, dosing alkali, sedimentation (ODAS)

Chemical precipitation/co-precipitation
- Coagulants, flocculants, lime
- Polymers, inorganic salts

Adsorption, ion exchange
- Organic/inorganic adsorbents
- Selective resins

Membrane separation
- Reverse osmosis (RO)
- Nanofiltration (NF)

Biological treatment
- Sulfidization, sulphate reduction in bioreactors (SBR)

Electrochemical methods
- Electrocoagulation

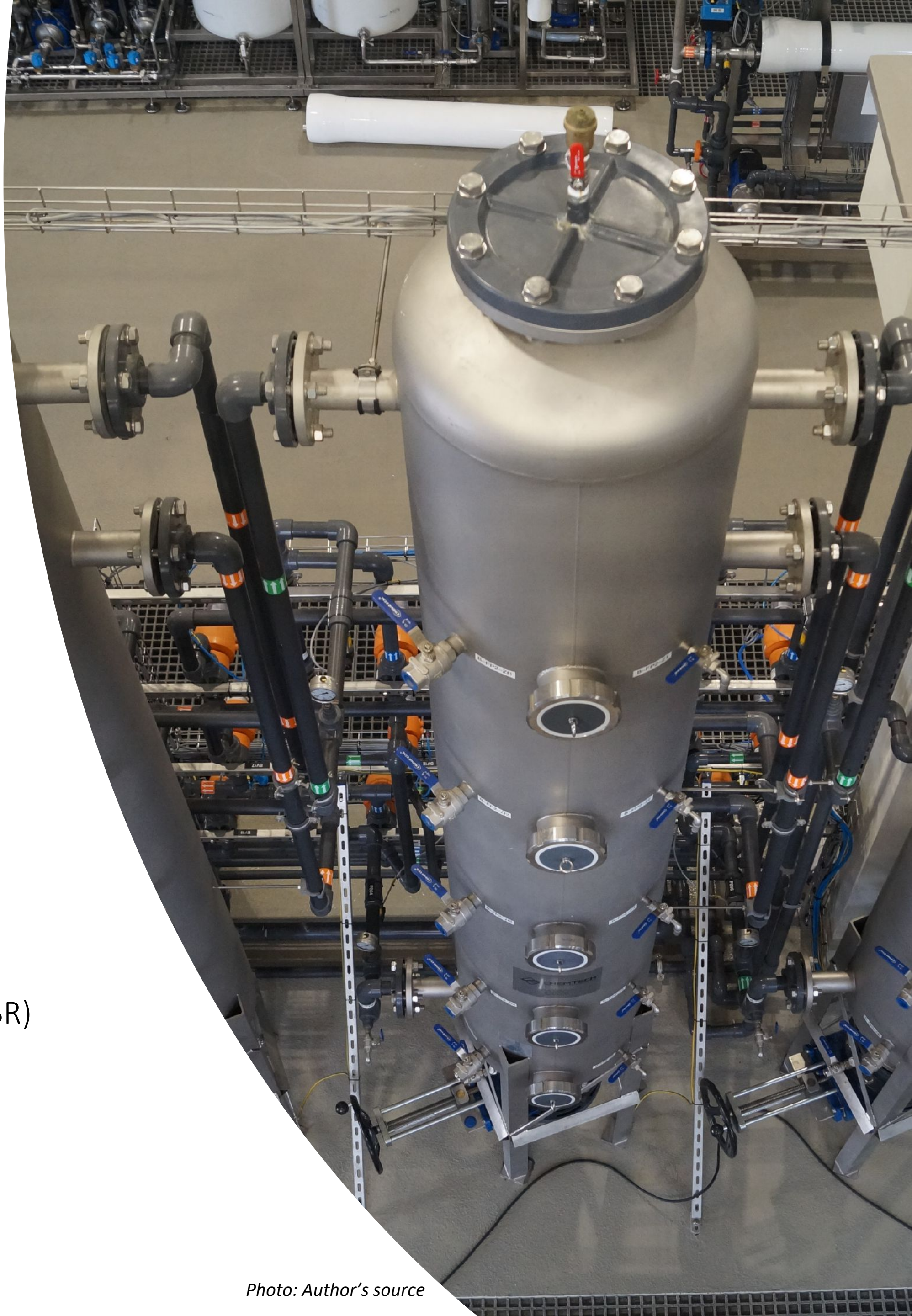


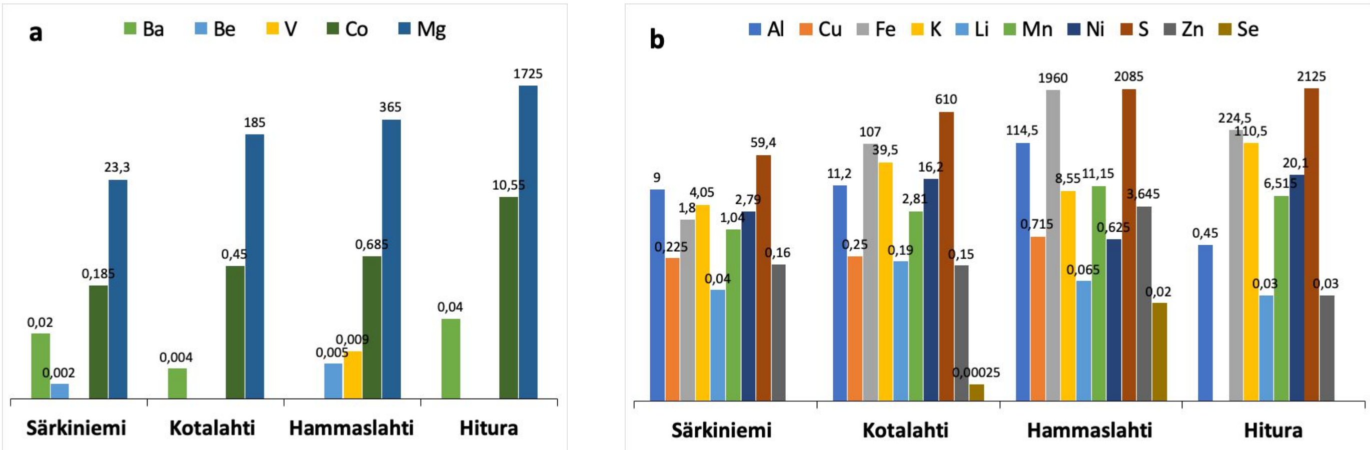
Photo: Author's source

Morecovery project – improving water quality & recovery elements of economic value

Sampling at the Hitura mine site

- Looking for potentially suitable cases for water treatment and metals recovery piloting campaign in Finland and Spain
- Site survey measurements results and archive data used for the assessment of the recovery of valuable elements and selection the cases of the highest potential
- Development reliable and cost-effective water treatment and metals recovery strategies for the most representative cases (at laboratory- and pilot-scale)

Finnish cases – drainage water



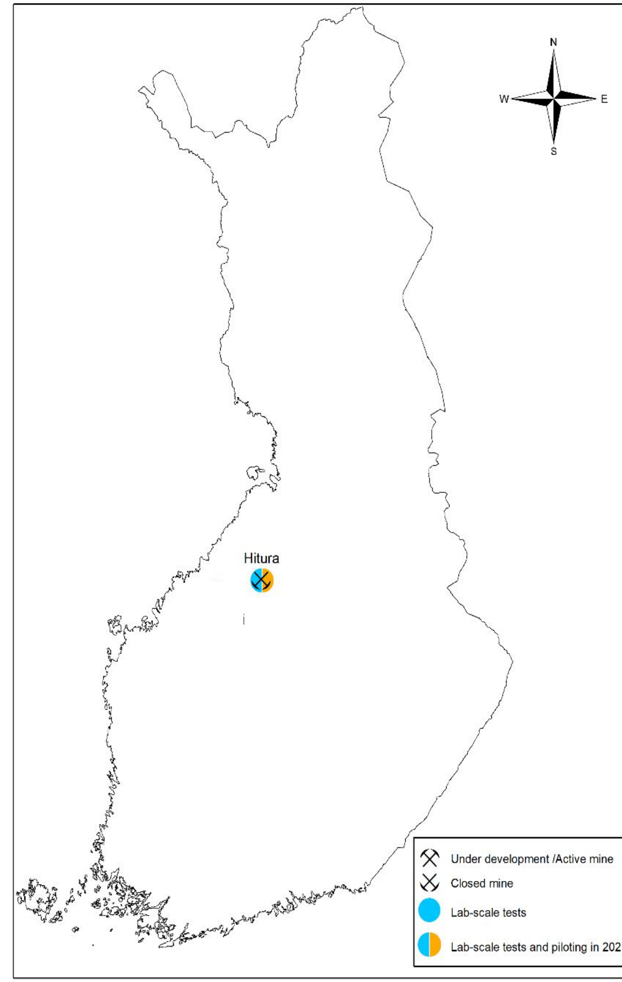
Composition of drainage water from examined mine sites (concentration is given in mg/L and presented in logarithmic scale); (a) selected CRMs, (b) other valuable metals

Total concentration of rare earth elements (REEs), light rare earth elements (LREEs), heavy rare earth elements (HREEs) and scandium in liquid samples from the four mine sites

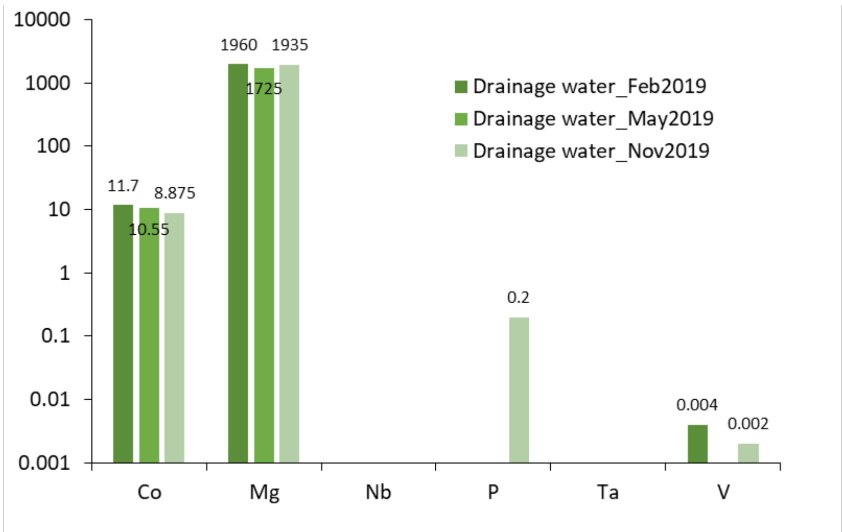
	Särkiniemi	Kotalahti	Hammaslahti	Hitura
Total REEs, mg/L	0.07215	0.2484	4.484	0.247
Total LREEs, mg/L	0.055	0.208	3.965	0.214
Total HREE, mg/L	0.01715	0.0404	0.515	0.033
Scandium, mg/L	< 0.002	< 0.002	0.004	< 0.04

Hitura mine site

- **Location**: Nivala, Northern Ostrobothnia, Finland
- **Mine in operation**: 1970-1993
- **Commodity**: Ni, Co
- **Deposit type**: Palaeoproterozoic (1.9 Ga) magmatic ultramafic intrusion-hosted nickel deposit, consisting of closely-spaced serpentinite massifs surrounded by migmatised mica gneiss
- **Sampling**: February, May, November 2019
- **Sample type**: Waste rock - composite sample from the mica schist pile, composite sample from the serpentinite pile, tailings, tailings drainage water



Hitura mine site – drainage water characteristics



Content of selected CRMs in the drainage water collected in February, May and November 2019 at Hitura mine site (concentration in mg/L plotted on a log-scale)

Seasonal variation in composition:

- Cobalt, 9-12 mg/L
- Nickel, 17-23 mg/L
- Iron, 220-300 mg/L
- Sulphate, 6300-7500 mg/L
- Magnesium, 1700-2000 mg/L
- Chloride, 1400-1550 mg/L
- Calcium, 410-470 mg/L
- pH 5.9

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Hitura case: development Co & Ni recovery method (UEF, lab-scale work)

Criteria used for the development Co and Ni recovery method:

- Increase Co and Ni content in resulting water treatment sludge
- Separate most of the dissolved Fe from dissolved Co and Ni
- Use basic, relatively cheap chemicals in the process
- Use basic unit processes and robust equipment
- Keep major elements (S, Mg, Cl and Ca) in the solution
- Develop strategy suitable for modular recovery
- Developed method easily modifiable to other cobalt and/or nickel containing water streams

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Hitura case: development Co & Ni recovery method (UEF, lab-scale work)

A two-stage recovery method was developed and tested in the laboratory:

First phase:
Fe successfully removed (up to 90%) by oxidation of Fe(II) to Fe(III) and precipitation Fe(III) , while Ni and Co remained in the solution (up to 100%)

Second phase:
Co and Ni precipitated from Fe-free drainage water resulting in a sludge containing most of the Ni and Co

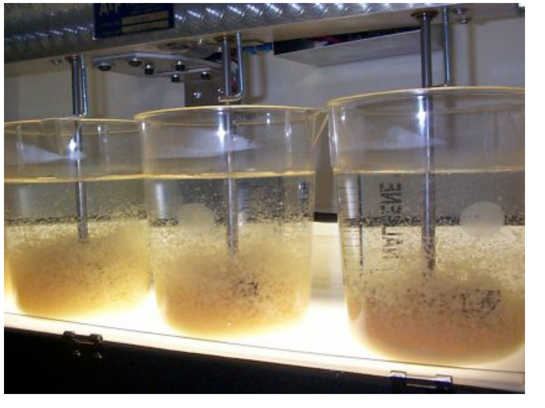
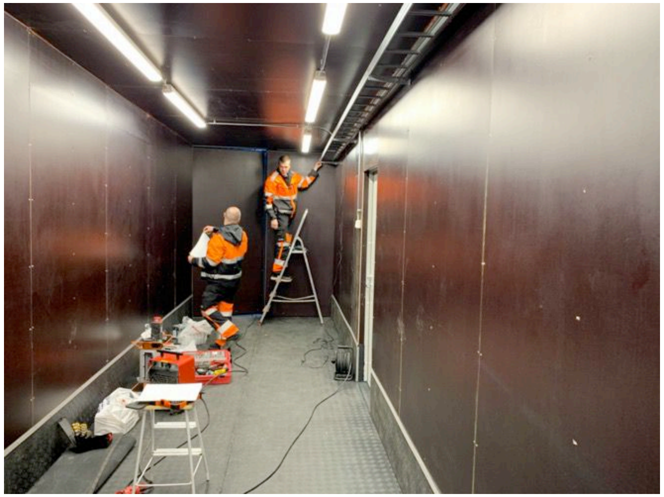


Photo: Shutterstock

Hitura case: Co & Ni recovery in pilot-scale (Savonia AMK, GTK)

- The lab-scale methods upscaled to custom and modular containerised pilot system
- Pilot will be deployed at the designated mine sites to validate the proposed recovery strategies in the operational environment (at TRL 7)
- Piloting allows for assessing scale-up effect on overall system performance and technical feasibility of the full-scale solution



Kick-off of furnishing works in pilot container (Author’s photo)

Hitura case: Co & Ni recovery in pilot-scale (Savonia AMK, GTK)

A pilot test rig designed to meet the following assumptions and requirements:

- Nominal capacity: 1 m^3/h (adjustable)
- Mode of operation: continuous or batch operation
- Pumped + gravity flow system
- Temperature control environment (inside container)
- Process automation: full process automation
- Process monitoring: full process monitoring, logging and diagnostics; video surveillance of the process, process visualisation (web service); remote access and remote operation; data post-processing and archiving (cloud)
- Measurements on-site: online and grab sampling

Adjustable operational and process parameters:

- Flow rate
- Retention time
- Mixing intensity
- Chemicals dosing (oxidation agents, pH control, additives for process enhancement)
- Sludge recirculation

Photo: Shutterstock

Morecovery project – next steps

Piloting campaigns at target sites:

- Keliber case, Finland (2020)
- Hitura case, Finland (August/September 2020)
- Tharsis case, Spain (March/April 2021)

Photo: Shutterstock

Thank you

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