



Topical challenges and recent advances in the environmental management of mines

Seminar: Building trust – how to improve the communication
between mining industry and society

31.10.2017



Introduction - Mining in Finland and Fennoscandia

- Mining has occurred in Finland since the 16th century
- Finland is one of Europe's largest producers of nickel, gold, chromite, copper and zinc
 - Currently there are 40 active metallic ore mines and projects in Finland
 - Over 100 closed and abandoned mines
 - 37 mine sites/53 waste areas with severe environmental effects
- GTK has published metallogenic map of Fennoscandia in December 2009 (updated May 2015)

<http://en.gtk.fi/information/services/databases/fodd/index.html>

<http://gtkdata.gtk.fi/fmd/>

- Altogether 1700 mines, deposits and significant metallogenic occurrences
 - 61 % have not been exploited
 - might well be economic in the future
- 71 active mines, 16 large closed mines, 54 large unexploited deposits and 56 potentially large deposits in the database based on the relative value of the in situ metal contents

Active Metal Ore Mines and Current Projects

January 2017

Precious Metals

1. Iso-Kuotko gold - Agnico-Eagle Ltd
2. Hanhima gold - Dragon Mining Ltd & Agnico-Eagle Ltd JV
3. Kittilä gold - Agnico-Eagle Ltd
4. Kettukuusikko gold - Aurion Resources Oy
5. Naakenavaara gold - Sakumpu Exploration Oy
6. Kutuvuoma gold - Aurion Resources Oy
7. Rompas gold, uranium - Mawson Resources Ltd
8. Suhanko-Konttjärvi PGE - Gold Fields Arctic Platinum Oy
9. Kuusamo gold, cobalt - Nero Projects Australia Pty Ltd
10. Piilola gold - Mineral Exploration Network (Finland) Ltd
11. Taivaljärvi silver - Sotkamo Silver AB
12. Pampalo gold - Endomines Oy
13. Hattu Belt gold - Endomines Oy
14. Rämepuro gold - Endomines Oy
15. Osikonmäki gold - BR Gold Mining Oy
16. Orivesi gold - Dragon Mining Oy
17. Jokisivu gold - Dragon Mining Oy
18. Kaapelinkulma gold - Dragon Mining Oy
19. Pahtavaara gold - Rubert Resources Ltd
20. Laiva gold - Nordic Mines Ab
21. Pentinsuo gold - Stonerol Oy
22. Satulinmäki-Riukka gold - Tammela Minerals Oy

Base Metals

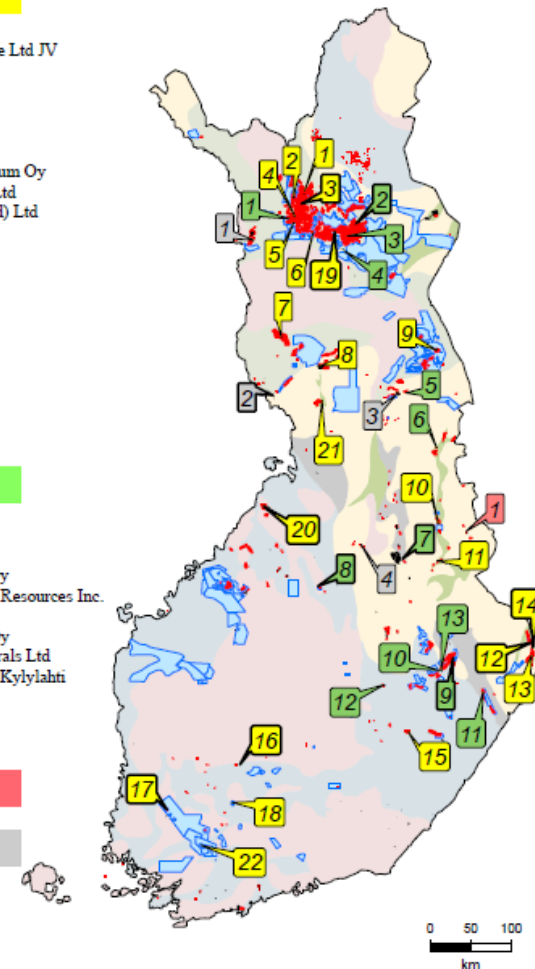
1. Riikonkoski copper, gold - Magnus Minerals Oy
2. Kevitsa nickel, copper, PGE - Boliden AB
3. Sakatti nickel, copper, PGE - AA Sakatti Mining Oy
4. Sodankylä nickel, copper, PGE - Magnus Minerals Oy
5. Läntinen Koillismaa (LK) nickel, PGE - Nickel One Resources Inc.
6. Kuhmo nickel - Boliden Kylylahti
7. Talvivaara nickel, zinc, copper - Terrafame Mining Oy
8. Pyhäsalmi zinc, copper, pyrite - First Quantum Minerals Ltd
9. Kylylahti copper, gold, zinc, nickel, cobalt - Boliden Kylylahti
10. Outokumpu copper - FinnAust Mining Plc
11. Hammaslahti copper - FinnAust Mining Plc
12. Valkeisenranta nickel, copper - Boliden Kylylahti
13. Hautalampi cobalt, nickel, copper - Alandra Oy

Diamond

1. Kuhmo - Karelian Diamond Resources Plc

Other Commodities

1. Kolari iron, gold, copper - Hannukainen Mining Oy
2. Kemi chromium - Outokumpu Chrome Oy
3. Mustavaara vanadium - Mustavaaran Kaivos Oy
4. Otanmäki vanadium, iron, titanium - Vuorokas Oy



Land Tenure 20 January 2017 (from Tukes)

- Mining Concession
- Claim/Exploration permit
- Reservation
- Mine
- Exploration



Mine specialization program - Aims to increase special know-how of mine environmental safety

- Close cooperation with research institutes and universities
 - Following latest R&D
 - Expert service - review of plans and reports, statements of EIA and permit applications
 - Participation into EU working groups (BREF document)
 - Best available techniques (BAT) and Best environmental practices (BEP)
 - Share information on BAT technologies and good practices
 - Video lectures, workshops and seminars
 - Focus in:
 - Mine waste management and recycling
 - Geotechnical waste facilities and dam safety
 - Mine water management, treatment and recycling
 - Contaminant migration in mining environment
 - Environmental effects to recipient rivers, lakes and groundwater
 - Environmental monitoring
 - Crisis/failure situations
 - Mine closure and rehabilitation
 - Juridical questions (e.g. bankruptcy situations, use of collateral security, environmental offences)
- Improve quality of EIA process, mine environmental supervision and permitting of mines



Topical environmental challenges of mining

- There are challenges during every phase of mining
 - Planning and feasibility
 - Construction
 - Production/operation
 - Closure and rehabilitation
- Recently some key challenges have been common for the mine projects
 - Construction and functionality of different geotechnical structures
 - Waste management facilities (WMF)
 - Tailings from flotation and leaching processes
 - Waste rock from mining
 - Residues from hydrometallurgical processes
 - Residues from water treatment
 - Water storage ponds
 - Waste management
 - Geochemical characteristics and long-term behavior
 - Water management and estimation of water balance
 - Management of environmental impacts (dust and water emissions)
 - Mine closure and rehabilitation





Why do we have these challenges?

- **Mine environmental safety is founded on successful planning and construction!**
- Challenges:
 - Sufficient know-how for reliable planning?
 - Limited amount of experts
 - Retirement of key persons, sharing the know-how
 - Demanding weather conditions for construction
 - Funding
- Poor assessment (wrong estimates) of environmental impacts may lead to challenges later in the mine project
 - Problems in water management and inaccuracy in estimation of water balance
 - Larger amount of waste water (increased load of contaminants)
- Lack of information on mine waste characteristics and/or hydrogeological conditions at the site
 - Wrong design (and location) for geotechnical structures
 - Waste management facilities (WMF)
 - Water storage ponds
- Inaccurate estimation of contaminant mixing and dilution in recipient waters
 - Increased effects (salinization etc)



Means to minimize the challenges and improve environmental management?

In general

- Reliable and competent consultant is needed
- Cooperation and competence of operators, consultants, authorities and contractors in key role
 - Continuous education important
- Transfer of knowledge and best environmental practices
- Activity of the operator towards the stakeholders is important for the acceptance of the mine project

Planning phase

- Sufficient initial data of the project, information on local conditions
- Integration of environmental considerations into planning (project alternatives in EIA)
- Adequate and reliable knowledge on geotechnical and hydrogeological properties of foundation strata and construction materials
- Characterization of representable waste fractions
- Determination of availability and properties of construction materials
- Geotechnical facilities needs to be designed based on actual parameters not literature values
- Realible estimates of environmental loads and effects (EIA)
- Whole mine life-cycle and long-term stability aspect in planning of geotechnical facilities and waste and water management and treatment
 - Important to predict how the project will develop → Continuous update of plans, revision of plans
 - Active sharing of information to authorities



Means to minimize the challenges and improve environmental management?

Construction phase

- Based on successful planning (design and construction standards)
- Realistic schedule to avoid changes in plans
- Competent quality control in significant role
- Important to share information between authorities, independent quality controller, mine company, contractors, etc

Production phase

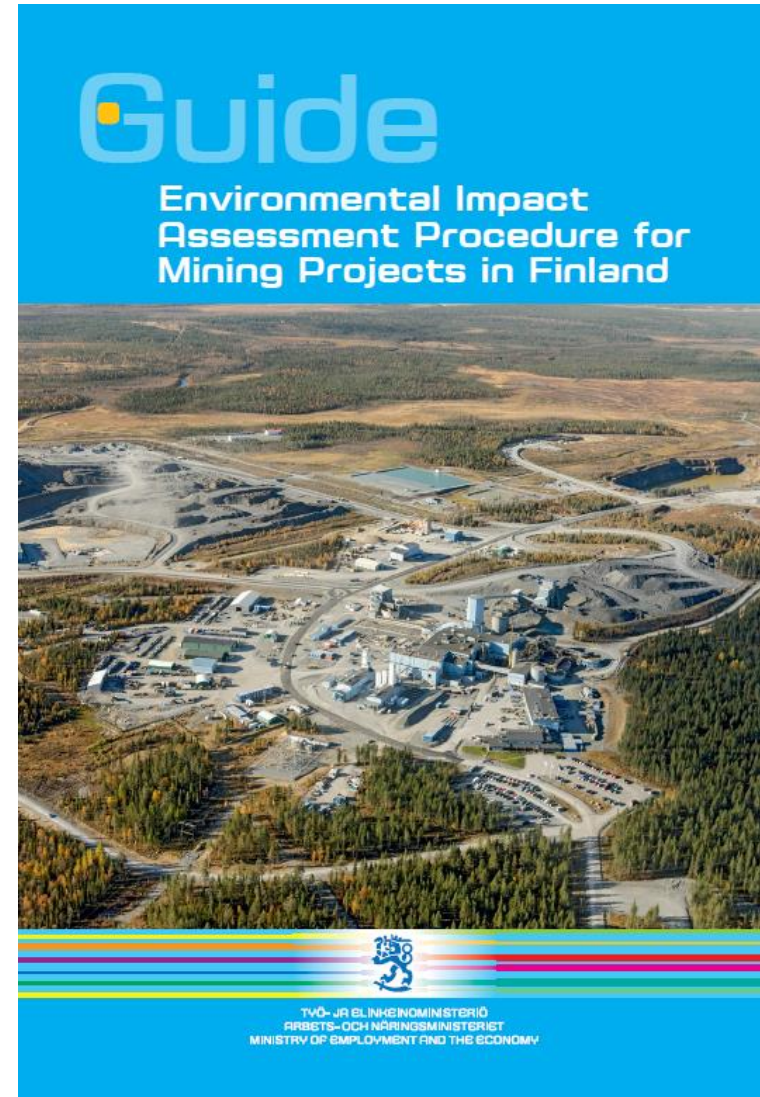
- Geotechnical facilities should be used for the planned purpose
- Environmental monitoring important to follow-up the management of environmental effects
- Up-to-date safety measures
- Life cycle approach
 - Risk and impact evaluation
 - Characterization and understanding the behavior of wastes and discharge waters
 - Iterative process - originally performed in the planning and design phase, but renewed and re-evaluated throughout the whole life cycle

→ Active sharing of expertise and knowledge on good practices



Topical reports and guides for environmental impact assessment

- Guide: Environmental Impact Assessment Procedure for mining projects in Finland (2015)
 - <https://julkaisut.valtioneuvosto.fi/handle/10024/75012> (fin)
 - <http://julkaisut.valtioneuvosto.fi/handle/10024/75001> (eng)
- Good Practices in Assessment of the Environmental Impacts of Mining Projects (2015)
 - http://tupa.gtk.fi/julkaisu/tutkimusraportti/tr_222.pdf (fin)
- Good practices on environmental impact assessment – Summary of IMPERIA-project (2015)
 - <http://hdl.handle.net/10138/159403> (fin)
 - IMPERIA project:
 - <https://www.jyu.fi/bioenv/osastot/luonnonvarat-ja-ymparisto/ymp/tutkimus-ja-julkaisut/imperia-hanke> (fin)
 - <https://www.jyu.fi/bioenv/en/divisions/natural-resources-and-environment/ymp/research/imperia-project> (eng)





Topical reports and guides for best available techniques and best practices

- Research reports and articles
- Several guide books and wiki pages published recently
 - Best Environmental Practices in Metal Ore Mining
<http://hdl.handle.net/10138/40006>
 - Mine Closure Wiki
<http://wiki.gtk.fi/web/mine-closure>
 - Guidelines for mine water management
<http://www.vtt.fi/inf/pdf/technology/2016/T266.pdf>
 - Dam safety guide
http://www.ymparisto.fi/en-US/Waters/Use_of_water_resources/Dams_and_dam_safety/Dam_Safety_Guide
- EU Commission Reference document on best available techniques (BAT)
 - Management of tailings and waste-rock in mining activities
http://eippcb.jrc.ec.europa.eu/reference/BREF/mmr_adopted_0109.pdf
 - Currently under review
 - Best Available Techniques Reference Document for the Management of Waste from the Extractive Industries in accordance with Directive 2006/21/EC (MWEI BREF)





Role of research institutes and universities

- **Applied research** is in central role to increase the knowledge on new methods and technologies and best practices in mine environmental impact assessment and management e.g.
 - Environmental monitoring
 - Hydrogeology and environmental geochemistry
 - Water treatment and waste management technologies
 - Mine closure and rehabilitation
- Annually tens of Master theses and Doctoral theses studies are finalized related to mine environmental impacts and management of impacts
- Significant amount of mining environmental R&D research is conducted in research institutes and universities
- **More cooperation is needed between the research organizations and universities and authorities and mine companies!**





Recent advances in environmental management

- Environmental monitoring
 - More reliable continuous monitoring equipment
 - Use of continuous environmental monitoring equipment is becoming more common
- Waste management
 - BAT in base structures of waste facilities
 - Geosynthetic liners, multilayers
 - Structure and quality of foundation more often studied in detail
 - More focus in waste characterization
 - R&D ongoing
 - Use of BAT methods
- Water management and water balance
 - More focus on amount of waste waters in changing operation and climate
 - Separate collection and treatment of different type of mine waters Hydrogeological and geotechnical studies
- Mine closure
 - Risk based approach
 - Proactive closure
- Focus on life-cycle approach and proactivity
 - Towards sustainable mining and social acceptance



Topical research trends

- Waste management
 - Optimizing quality and quantity of streams
 - Recycling and reuse of materials
 - Characterization of different waste fractions
 - Long-term behavior of different wastes and mixed wastes
- Environmental effects of mining to surface waters
 - Modelling tools (e.g. Kaihali project)
 - Effects, ecotoxicity of metals and metalloids (e.g. MineView project)
 - Ecotoxicity of sulphate and remains of process chemicals?
- Environmental and biological monitoring methods
 - Continuous water quality monitoring
 - Use of biological indicators
- Methods to study contaminant migration, behavior and interactions
- Utilization of the by-products in mine waste cover structures
 - Several research projects (e.g. Biopeitto)
 - Lab-scale tests
 - Field trials
- Water treatment
 - Adsorbents, biopolymers etc
 - Economically viable methods for large water volumes?





Elinkeino-, liikenne- ja ympäristökeskus
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Thank you for your attention!

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