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Make Mining Sustainable:
Risks and Impacts

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Background: A. N. Rencz

- Geologic Survey of Canada for 37 years
- Research Scientist , Program Manager, Head of Labs

Research Scientist

Disciplines:	Biogeochemistry, remote sensing Natural and Anthropogenic Geochemical variation
Application:	Mineral Exploration Environmental Protection
Field studies:	Mainly in northern Canada India, Egypt, Brazil, Sri Lanka, China, Mongolia

Program Manager

Metals in the environment

Climate change

Head of Analytical Labs

Geochronology, Inorganic Chemistry, Organic Chemistry

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Make Mining Sustainable:
Risks and Impacts

Purpose: To provide information to support sustainable mining through better understanding of:

- environment,
- potential environmental and health risks from mining,
- mitigation and remediation practises.

Method: Identify potential risks and impacts at various phases in the mining life cycle[1].

Note:
This presentation builds and uses material presented by Mike MacPherson on Life Cycles of Mining.

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Why:

- Mining is important to Mongolia
    - Mining sector in Mongolia accounted for over 28% of GDP, 30% of government revenues, and over 84% of export earnings (2011).

Mining is important

- 563 people employed in mining sector
- 32 active mining companies in Tuv province, as 2017
- 240 inactive mines
- Number exploration license holders : 272
- Number of mining license holders : 187
- Types of common mines: Gold, coal, fluorspar

- There are identified risks to the environment from mining.

- Planning, for sustainable mining, should be based on an understanding of both the risks and benefits of mining so that all Mongolians can benefit.

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The Mining Lifecycle

The purpose of this section is to:

1. Understand environmental risk at each of the phases of a mines life cycle
    - Exploration
    - Development and Construction
    - Production
    - Mine Closure and Reclamation

2: Needed to prepare a checklist of concerns to monitor.

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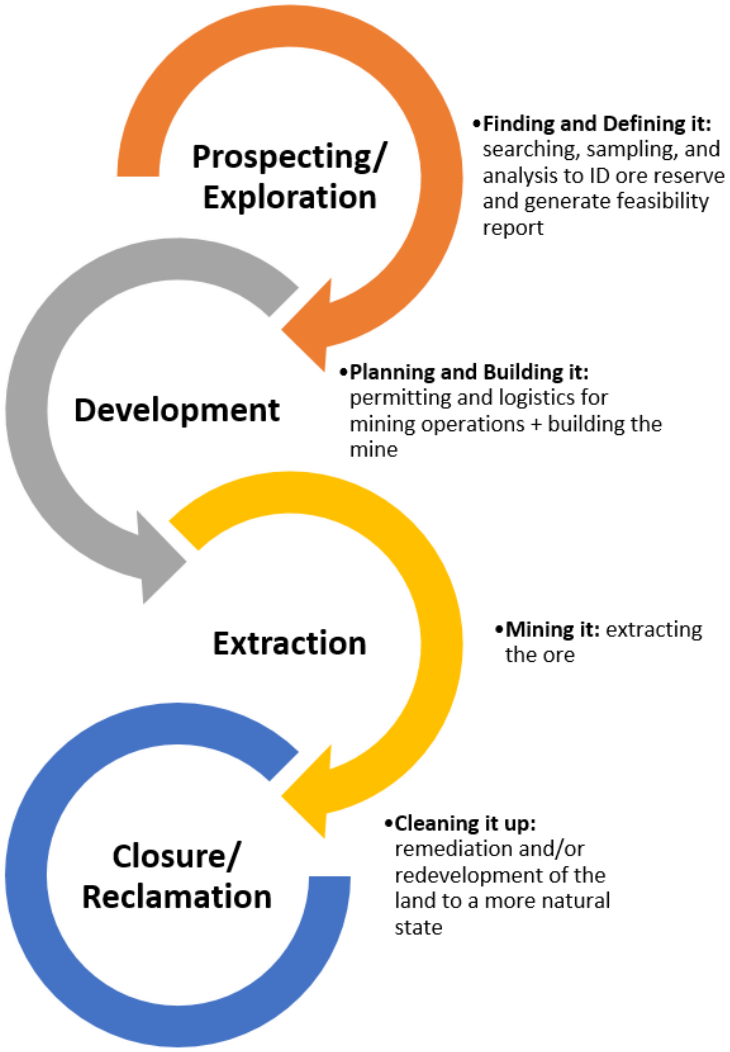
Phases of mining life cycle



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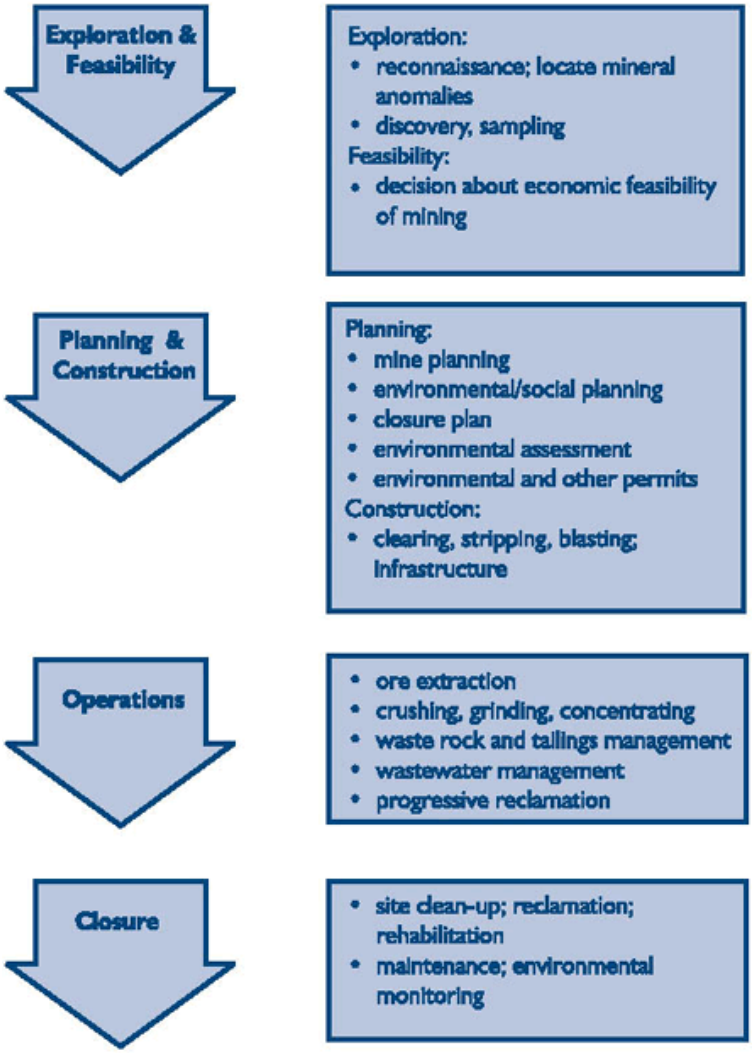
Phases of mining life cycle

Processes:



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Stage 1: Mineral Exploration Phase

Exploration

- Reconnaissance to locate mineral anomalies
- Discovery sampling techniques

Feasibility

- Decision about economic feasibility of mining

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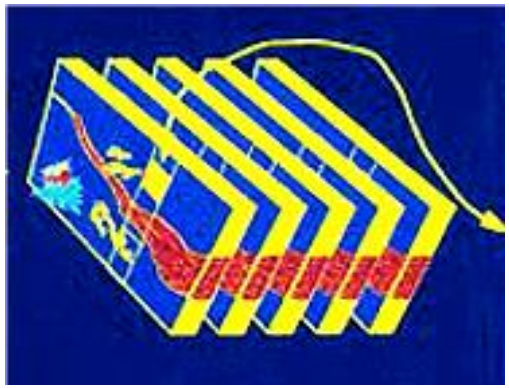
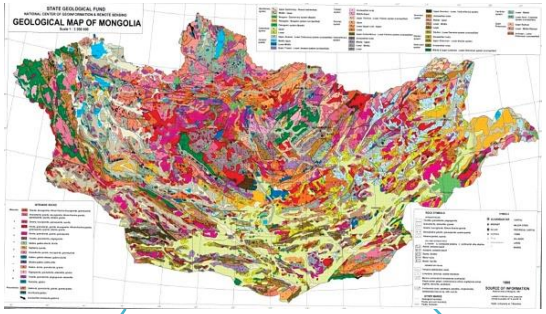
Exploration and Feasibility Stage
Potential Environmental Concerns

Activity	Potential Environmental Concerns
Access/Line Cutting	• Possible concerns with terrestrial/wildlife habitat and stream crossings
Geophysical Surveys	• Possible impacts on wildlife from airborne surveys
Field Camps	• Sewage and garbage disposal, water supply, fuel storage • Impacts on terrestrial/wildlife habitat, access to remote areas
Trenching/Pitting	• Physical scarring/land disturbance • Acid generation from exposed sulphide minerals • Metal leaching • Sediment erosion • Impacts on wildlife of blasting
Drilling	• Water supply, drilling fluid disposal, fuel storage/risk of spills, groundwater contamination • Physical scarring/land disturbance • Acid generation from exposed sulphide minerals • Release of metal-bearing groundwater
Bulk Sampling	• All of the above but potentially greater impacts are possible, and reclamation needs to be considered • Dewatering of historic mine workings may have impacts on receiving water quality
Exploratory Mining	• Potential impacts can occur that are similar to those during full-scale mining operations, albeit on a smaller scale

Building of a baseline data set:



Layers of Geographically Aligned Data
Geologic,
Geographic
Geochemical
Geophysical
Ecologic



Why needed?

Economic Feasibility Analysis

Environmental Impact Assessment

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Stage 2: Mine Development and Construction

1) **Deposit Evaluation and Mine Planning** - collecting and analyzing more technical, environmental and socio-economic information and developing the mine plan.

2) **Obtaining permits and licences** – obtaining the approvals required to build, operate and close the mine.

3) **Government/Community Engagements**– engagements with mining companies, governments and communities often take place to ensure communities and governments have input into mines in their areas.

4) **Construction** – constructing the mine and the required facilities such as camps in order to start operations.

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Stage 2: Mine Development and Construction
Permitting

Environmental assessment

An environmental assessment (EA) is mandated by government and is used to examine the potential impacts that a project may have on the environment during its lifetime.

EA's include land, water and wildlife studies and an assessment to determine the possible impacts of the mine on the environment.

Before and after obtaining mining license, a body is liable to have environmental impact assessment done and annual environmental management plan developed.

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Mine Development and Construction Stage
Potential Environmental Concerns

Potential Sources of Concern	Nature of Potential Concern
Air Quality	
Operation and maintenance of vehicles and any on-site power generation facilities	Potential releases of particulate matter, carbon monoxide, oxides of nitrogen, sulphur dioxide, and volatile organic compounds
Fuel and chemical transportation, handling and storage	Potential releases of volatile organic compounds and other harmful substances
Site preparation and construction activities	Potential releases of particulate matter

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Potential Environmental Concerns During Mine Development and Construction

Potential Sources of Concern	
Water Quality and Aquatic Ecosystems	
Operation and maintenance of vehicles and any on-site power generation facilities	Potential releases of substances such as suspended solids, trace metals, oil, degreasers, and detergents and other harmful substances that could affect water quality and aquatic ecosystems
Fuel and chemical transportation, handling and storage	In the event of spills, potential releases of petroleum products or chemicals that could affect surface waters or groundwater as well as aquatic ecosystems
Site preparation and construction activities	Potential release of sediments, increasing concentrations of total suspended solids in receiving waters
Sewage and wastewater disposal	Potential releases of nutrients and other contaminants
Construction of site access roads and power lines	• Potential release of sediments along the routes, increasing total suspended solids in receiving waters • Potential for acidic drainage if sulphide-bearing minerals are exposed during construction • Stream crossings for access roads may affect aquatic ecosystems, particularly those of migratory or spawning fish • Increased road access in remote areas may lead to increased fishing, stressing fish populations

Potential Environmental Concerns

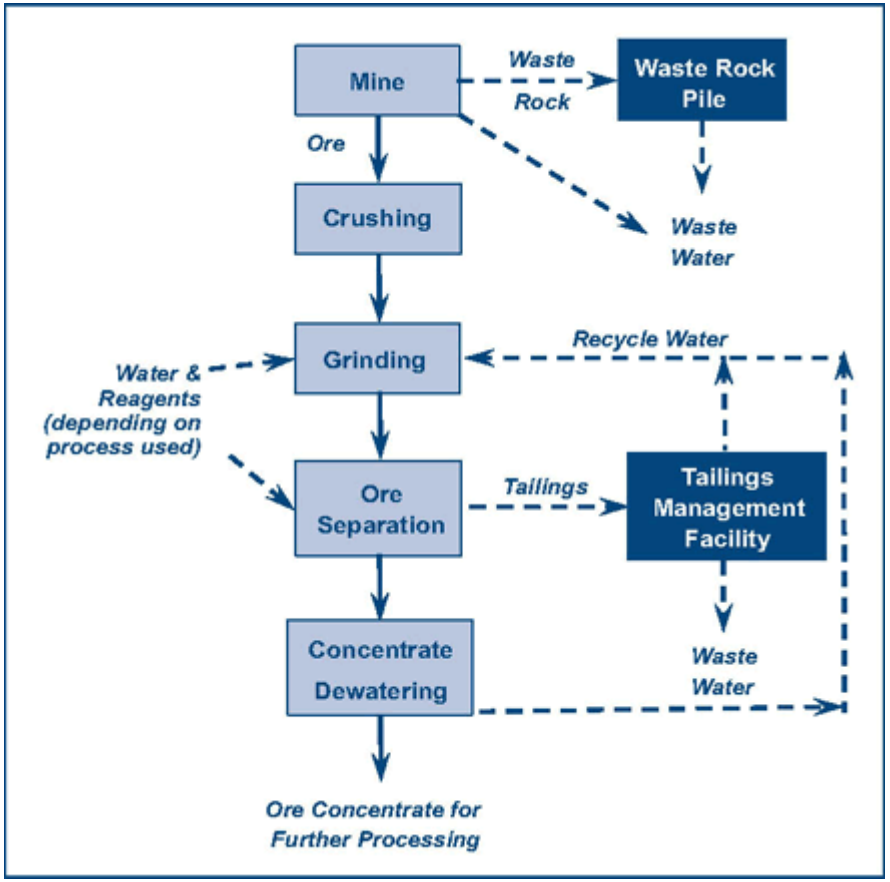
Site Preparation and Construction

Potential Sources of Concern	Nature of Potential Concern
Soil Quality and Terrestrial Ecosystems	
Fuel and chemical transportation, handling and storage	• In the event of spills, potential releases of petroleum products or chemicals could affect soils, vegetation and wildlife
Operation of vehicles	• Collisions with wildlife • Low altitude aircraft operations could disrupt wildlife
Site preparation and construction activities	• Clearing of vegetation on site may have impacts on biodiversity, particularly if any rare, threatened or keystone species are present • Activities on site may disrupt and dislocate local wildlife and any migratory wildlife in the area • Animals may be drawn to the site as a result of improper waste disposal or kitchen odours, which could lead to potential hazards for both workers and the animals
Construction of site access roads and power lines	• Construction activities may disrupt and dislocate wildlife • Increased road may lead to increased hunting • Collisions with wildlife
Noise	
Noise from exploration activities, including vehicle operations, drilling, and blasting	• Noise may affect local wildlife populations, and well as people living in communities

Stage 3: Production

Production

It is a range of process involved in producing a metal or other product and delivering it to a market.



Production Stage

Mineral/Ore Processing

The processing plant (mill) separates the rock that contains saleable material (**ore**) from the surrounding rock that is not saleable (**waste rock**).

Mineral processing is done in multiple stages (e.g., concentrator or mill, wash plant) and uses different processes depending on what is being mined.

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Potential Sources of Contamination in Wastewater

Acidic Drainage: Sulphide minerals are ore minerals for many base metals e.g. Cu, Pb and Zn. and are ubiquitous in ore deposits. In the presence of H_2O and O_2 they oxidize to create H_2SO_4.

Alkaline Effluents: Many ore separation processes, particularly flotation separation, operate at an alkaline pH, and chemical additives are used to ensure an alkaline pH, sometimes as high as 10 or 11.

Metal Leaching: Wastewater from mining and ore processing facilities can contain metals that naturally occur in the rock. Most metals are more soluble in water at low pH, so the concentrations of metals are frequently elevated in acidic drainage.

Cyanide: Cyanide is used in the recovery of gold in many facilities that process gold ore and some cyanide is discarded in tailings. Cyanide is also used in small amounts in some flotation separation circuits and thus, cyanide compounds may also occur in wastewater.

Ammonia: Ammonia may be present in wastewater from mining operations as a result of the use of ammonium nitrate and fuel oil (ANFO) as a blasting agent..

Suspended Solids: Wastewater may contain suspended solids ranging from colloidal (non-settleable) to settleable materials. The discharge of effluents with high levels of suspended solids impact aquatic environments by impeded oxygen intake by fish and reduced light availability for aquatic plants.

Thiosalts: Thiosalts are sulphur oxide compounds, including thiosulphate (S_2O32-) and polythionates (SxO62-), that are formed when partial oxidation occurs during the milling, grinding and floatation of some sulphide ores under alkaline conditions. Thiosalts are a concern because they can oxidize in water to form sulphuric acid,

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Waste Rock and Tailings Disposal

- Effluents originate from both waste rock and tailings
- Effluent from waste rock is often sent to the tailings disposal area for treatment prior to final discharge, but it may also be directed to a separate treatment facility.
- Key concern is the control of the release of contaminants
- Groundwater seepage is possible
- Failure of dams or other containment structures for tailings management facilities can be serious

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Water Management

- Segregate clean and contaminated water flows in order to help reduce the requirement for the treatment of effluent;
- Control and address seepage losses from tailings containment structures;
- Reduce water usage;
- Recycle water for further process use; and
- Reduce impacts on the groundwater regime.
- Mitigation using drainage ditches to divert off-site water and drainage ditches and diversions to control the flow of on-site water and prevent contamination in order to prevent contaminated waters from leaving the site before treatment.

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Concerns Related to Air Quality

Source:

- Mainly associated with the releases of airborne particulate matter.
- Various air contaminants, including sulphur oxides, nitrogen oxides, carbon monoxide

Mitigation

- Spraying water
- Environmentally acceptable chemical sprays to stabilize the surface;
- Revegetating;
- Controlling dumping or transfer rates of materials;
- Covering dump trucks or rail cars
- Establishing speed limits on unpaved surfaces
- Storing ore or concentrate in storage bins, hoppers or other building
- Covering or enclosing conveyor lines;
- Using baghouses or precipitators for point sources of releases such as stacks from ore concentrate driers;
- Covering stockpiles
- Temporarily ceasing operations if weather conditions pose a risk

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Effects on Wildlife

- Mining activity can affect wildlife as a result of habitat loss and habitat degradation.
    - E.g., mining activity may affect migration routes, breeding grounds, or nesting areas and species that carry special cultural significance to local communities.
- Ecological offsetting is the replacement of a species lost in the mining process with a new species.

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Effects on Plants

- physical impact on presence of plant communities.

- contamination with metals of plants from airborne particulate matter, surface or groundwater
  - Can reduce health of vegetation
  - Can impact on humans who eat effected plants .

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Summary of Concerns of Production Stage:

Comparison of open pit and underground mines: environmental risks and management concerns		
Environmental Aspect	**Open Pit Mine**	**Underground Mine**
Land Disturbance	Relatively large area	Smaller disturbed area than for open pit mines
Waste Rock Disposal	Can require large area; involves trucking, runoff and leachate management, dusting and aesthetic considerations	Less waste rock than open pit mines, but may involve similar management considerations
Tailings	Tailings volumes generally larger due to large volume of ore processed	Tailings volumes generally smaller
Acid Drainage	May be associated with both mine & waste rock areas	May be associated with both mine and waste rock areas
Reclamation	Both mine and waste rock area can represent major concerns due to the extent of the waste rock and pit	Waste rock can be a concern, as can seepage or overflow of water from the mine workings
Land Subsidence	Not a concern	Can be a concern
Truck Noise	Truck traffic between pit and waste rock dumps and mill can be a serious noise problem	Normally not a concern
Vent Fan Noise	Not a concern	Requires careful consideration/mitigation
Blasting Effects	Noise and vibration can be a concern requiring careful management	Noise and vibration could also be a concern at underground mines, particularly when the mine workings are relatively shallow
Dust	Can be a concern due to pit operations, haulage roads and waste rock piles	Can be a concern due to haulage roads and waste rock piles
Mine Water	Mine water volume influenced by precipitation, surface and groundwater ingress. Elevated ammonium levels from blasting can be a concern. High sediment loadings are common. Mine water may contain metals and may have a low pH. Chemicals from processing are a risk.	Mine water volume normally quite stable. Elevated ammonium levels from blasting can be a concern. High sediment loadings are common. Mine water may contain metals, and may have a low pH. Spilled chemicals from processing are a risk

Production Stage
Environmental Monitoring

Companies and governments continually monitor the mining operation to test environmental performance, demonstrate compliance with environmental legislation, refine operational practices, and safeguard the interests of both the mining company and the surrounding community.

In Mongolia the report on the implementation of the EM Plan must be submitted to the aimag Environmental department prior to Nov. 1. It must be at 80% compliance with the EM plan to maintain license to operate the following year.

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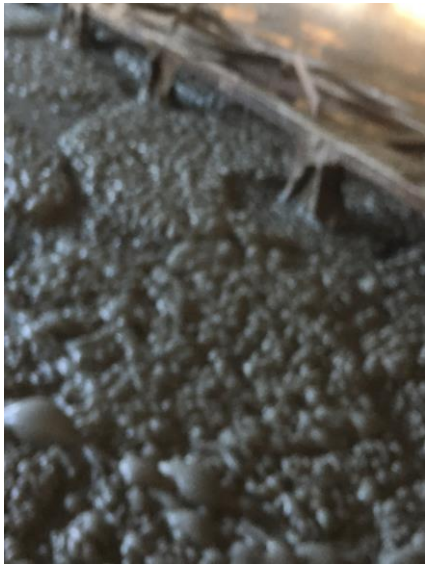
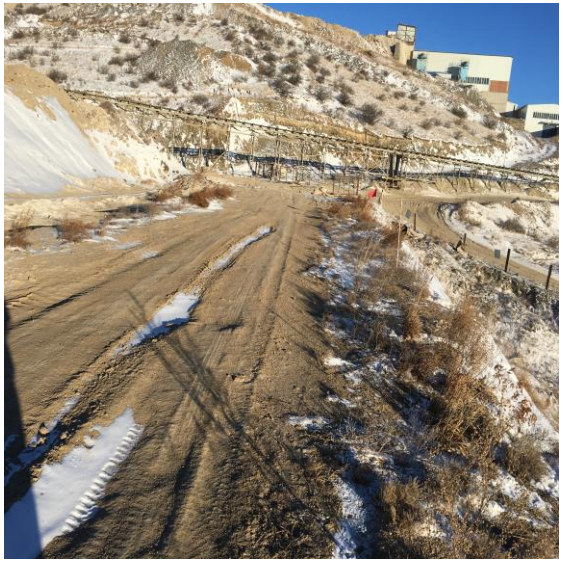
Gold processing- Tinkhun

Нунтаглах
Бутлах



Chemical Extraction- Cyanide Уусган баяжуулалт

Gold processing- Tinkhun



Tailings dump.

Conveying the tailings to dump

Хаягдал чулуулгийн овоолгоос үүссэн налуу

Stage 4: Mine Closure
Mineral Law of Mongolia

45.1.1.. take all necessary measures to ensure safe use of the mine area for public purposes and reclamation of the environment;

45.1.2. take preventive measures if the mine claim is dangerous for public use;

45.1.3. remove all machinery, equipment and other property from the mining area except as permitted by local administrative bodies or the professional inspection agency.

45.2. Mining license holders shall prepare a detailed map of an appropriate scale showing dangerous or potentially dangerous areas created by mining operations by **placing necessary warnings and markings in the vicinity of the mining claim** and shall submit the map to the professional inspection agency and the local Governor.

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Stage 4: Mine Closure

The objectives of mine closure are:

- to ensure public and wildlife
- to provide for the stable, long-term storage of waste rock and tailings
- to ensure that the site is self-sustaining and to prevent or minimize environmental impacts
- to rehabilitate disturbed areas for a specified land use (e.g., return of disturbed areas to a natural state or other acceptable land use)

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Mine Components to be Addressed in the Closure Plan (1 of 3)

Components Aspects to be Addressed

Underground Mines

- Sealing of shafts, inclines and declines, or ventilation raises.
- Effects of seepage from backfill
- Mine water drainage
- Formation of potentially unstable ice plugs

Open Pit Mines

- Slope and bench stability
- Groundwater and rainwater management
- Security and unauthorized access
- Wildlife entrapment
- Effects of drainage into and from the pit

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Mine Components to be Addressed in the Closure Plan (2 of 3)

Components Aspects to be Addressed

Ore Processing Facilities	
	Removal of buildings and foundations
	Disposal of scrap and waste materials
	Re-profiling and revegetation of site
Waste Rock Piles	
	Slope stability
	Effects of leaching and seepage on surface and groundwater
	Dust generation
	Visual impact
	Special considerations for some types of mines such as uranium mines
Tailings Management	
	Facilities
	Dam stability
	Changes in tailings geochemistry
	Surface water management and discharge
	Dust generation
	Access and security
	Wildlife entrapment
	Special considerations for some types of mines such as uranium mines

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Mine Components to be Addressed in the Closure Plan (3 of 3)

Components Aspects to be Addressed

Water Management Facilities	
	Restoration or removal of dams, reservoirs, settling ponds, culverts, pipelines, spillways or culverts which are no longer needed
	Surface drainage of the site and discharge of drainage waters
	Maintenance of water management facilities
Landfill/Waste Disposal Facilities	
	Disposal or removal from site of hazardous wastes
	Disposal and stability of treatment sludge
	Removal of sewage treatment plant
	Prevention of groundwater contamination
	Prevention of illegal dumping
	Security and unauthorized access
Infrastructure	Removal of power and water supply
	Removal of haul and access roads
	Reuse of transportation and supply depots

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Section 4: Mine Closure

Decommissioning: Decommissioning follows mine shut-down

Process to take apart the mining operations:

- Draining hydraulic fluids and oils from mobile equipment
- Draining pipelines
- Removal and recovery of saleable equipment and parts
- Clean-up and salvage of buildings
- Recovery of warehouse materials, tools and consumables (i.e., oils, grease, etc.), and
- Disposing properly of all waste.

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Conclusion

"When you have been given the responsibility to look after the land, you do it with honour, you do it with pride. The land has been referred to as Mother Earth. And you would treat your mother the same way. You would look after her. This is the thinking of our people and how we look after the land, with great respect, with much love."

Daryl Redsky, Shoal Lake No. 40 First Nation

Thank you and comments.

Acid Rock Drainage-Metal Leaching (ARD/ML):

- Natural oxidation process occurs when rock surfaces containing sulphides are exposed to air and water
- Metals and other contaminants leach from waste is referred to as metal leaching (ml).
- As water becomes more acidic, its capacity to leach other elements from the rock, such as metals, increases.
- Leaching is accelerated by the action of acidophilic bacteria that are activated at decreased ph. The resulting acidic drainage may contain increased levels of harmful constituents.
- Process may last hundreds, even thousands of years.
- Contaminated water drains away from the mine site and may affect the receiving environment (rivers, lakes, coastal areas, and groundwater…)

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Sludge Disposal
Treatment

- Acidic drainage from mines is commonly treated with lime. A by-product of this treatment is sludge.
- Sludge may contain a wide range of metals. The volumes of sludge produced are large, and in some cases they may exceed the volume of tailings produced over the life of an operation.
- Sludge is generally disposed of on site, but it may also be sent to smelters for recycling.
- **There are uncertainties about the long-term chemical stability of many sludges, and there are risks that sludge could become an additional source of releases of metals.**

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