Examining Radioactive Mineral Risk Assessment and Management in Mineral Exploration and Development Initiatives

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Outline

Introduction
Cognition And Communication Sciences
Overview: Current REE Mining Projects
  Examples: Nfld, NWT
  Geohazard Risk And REE: Radioactive Minerals?
  Risk Perceptions Of Ree As Radioactive Minerals

Answers
  Guidelines
  Limiting Chronic Exposure
  Preventing Acute Exposure
  Lessons Learnt From Radioactive Mineral Risk In Canada

What Have We Covered
Take Away Messages
Introduction

Background

To capture 20% of the global rare earth element (REE) market by 2018, Canadian REE mines will be brought into production.

Radioactive minerals - a common co-occurrence of Thorium-232, Uranium-235, Uranium-238 with REE mineralization - will be mined.

To support the REE mineral exploration industry, First Nations, Mining Watch and others, this presentation introduces the results of our research to date, and suggestions for future research.
Introduction

**Purpose:** Proactive geoscience education and public engagement. Recognise need for interactive intervention, thus promote two way communication, to increase knowledge of radioactive mineral risk

**Objectives**
- Acknowledge risk perceptions of rocks, water and soil
- Build useful content to talk about radioactive mineral risk management
- Communicate geohazard risk: Communicate potential radioactive mineral risk to prevent misunderstanding, suffering and death

**Methods**
Literature and case study of REE reports; interviews with stakeholders (email, telephone and face to face); radiation hazard event program document files and data review.
## Communication Silos

<table>
<thead>
<tr>
<th>Public Safety Specialists</th>
<th>Provincial Geoscience Providers</th>
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<tbody>
<tr>
<td><strong>Legislation</strong></td>
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<tr>
<td>Sendai Framework</td>
<td>Mines Act</td>
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<td>Federal/Provincial/Territorial (F/P/T) EM Framework for Canada</td>
<td>Mining Act</td>
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<td>Energy and Mines Act</td>
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<td>Mineral Resources Act</td>
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<td><strong>Conceptual Model</strong></td>
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<tr>
<td>Disaster Lifecycle Model</td>
<td>Mining Cycle Model (exploration, appraisal, development, restoration)</td>
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<td>(preparedness, prevention, response and recovery)</td>
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<td><strong>Substantive Focus</strong></td>
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<tr>
<td>Fit for purpose geoscience for public safety, sustainable development, climate change adaptation</td>
<td>Geoscience for mineral exploration</td>
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<td><strong>Data science</strong></td>
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<tr>
<td>open data partnerships</td>
<td>Published data sets and maps</td>
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<tr>
<td>Independent scientific advice</td>
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<td><strong>Service delivery</strong></td>
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<tr>
<td>Assist decision makers</td>
<td>Assist industry</td>
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<td>Ensure capacity to use science, diverse audiences</td>
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Using Cognition and Communication Sciences to Advance Geoscience Education Programs

- Success stories begin with basic geoscience.
- Must set a high standard for communication, research and dissemination
- Tell stories – that explain why and integrate facts
Overview

Current REE Mining Projects
**REE Resources in Development**

“Rare earth elements accumulate in several geological environments. The principal concentrations of REE are associated with igneous rocks, namely alkaline rocks and carbonatites. Potentially useful concentrations of REE-bearing minerals are found in placer deposits, residual deposits formed from deep weathering of igneous rocks, pegmatites, iron-oxide copper-gold deposits, and marine phosphates”

Long et al 2010 USGS
REE in Nlfd and Labrador

Mineralized subvolcanic veins and dykes

Mineralized volcanic flows and tuffs

Contact zones

Disseminated mineralization

Pegmatitic and aplitic lenses and veins

Late-stage enriched granites

Mineral Commodities of Newfoundland and Labrador

Rare-Earth Elements
(Including Y, Zr, Nb, Be)
North West Territories: Nechalacho Rare Earth Elements (REE) Deposit
Geohazard Risk and REE: Radioactive Minerals?

• no two REE ores are alike
• REE-bearing minerals are complex
• REE are extracted through many chemical processes
• Some REE-bearing minerals contain thorium, which imparts radioactivity to ores.

Radioactive waste products require special disposal methods and may increase production costs. May impede viable economic extraction of the more radioactive REE-rich mineral (e.g. monazite which contains thorium).

Currently: Mineral Development Initiatives Require Proactive REE Risk Communication Toolkit To Acquire Social License For REE Mining Projects
Risk Perceptions of REE as Radioactive Minerals

Case Study: SAFETY AND SOCIAL LISCENCE

Timiskaming First Nation Cancer and the Environment Project provides information about the harmful effects of REE.

This international literature review document details health impacts to mine workers and others residing in the area...
Risk Perceptions of REE as Radioactive Minerals

International Case Studies detail exposure to REE associated with:

- increased risk of heart attack
- pneumoconiosis (a lung disease) from inhaling mine dust and metal fumes.
- nephrogenic systemic fibrosis (rare condition), where excess connective tissue forms in the skin, joints, eyes, and internal organs
- people residing in an area with high levels of REE had abnormal levels of some blood proteins.
- children exposed to REE had significantly lower IQ scores. This is thought to result from disrupted brain neurotransmitters.
- altering the way human red blood cells divide and duplicate. It also affected the synthesis and repair of DNA.
- leukemia associated with REE environmental pollution
How To Limit Chronic Exposure To "Acceptable" Levels?

Concept: Living with Radiation

1. Biological Approach
2. Environmental Pathways Analysis
Threshold – lowest exposure level

Assumptions:
Incomplete knowledge of the biological effects, thus some uncertainty.
Cumulative effects do not occur
How To Limit Chronic Exposure To "Acceptable" Levels?

Biological Approach

Used to determine exposure limits
From the scientific database, a threshold exposure level is determined below which no biological effect is observed.
Useful method because it removes necessity of making a health risk assessment of the biological effects data

Assumptions: an incomplete knowledge of the interaction mechanisms.

Results:
Unduly conservative standard, creating protection against questionable risks
May restrict REE mineral exploration and production
May be unacceptable in terms of the loss of benefits accruing from REE production
Research for policy and practice: detailing acceptable radiation dose, per occupation

How To Limit Chronic Exposure To "Acceptable" Levels?

- Radiation Dose (millisievert: mSv)
  - 1,000
  - 500
  - 100
  - 50
  - 10
  - 1

- Typical annual dose received by a worker in a uranium mine or nuclear power plant in Canada: 1 mSv
- Typical annual dose from living one year within a few km of an operating nuclear power plant in Canada: 0.001 mSv
- Five-year dose limit for nuclear energy workers: 100 mSv
- Annual dose limit for persons carrying out emergency work: 500 mSv
- Average annual exposure to astronauts working on the International Space Station: 150 mSv
- Typical chest CT scan: 7 mSv
- Typical chest x-ray: 0.1 mSv
- Average annual dose from natural background radiation in Canada: 1.8 mSv
- Annual public dose limit for nuclear energy workers: 50 mSv
- Typical dose from living one year within a few km of an operating nuclear power plant in Canada: 0.001 mSv
- Typical cross-Canada flight: 0.02 mSv
- How dose may cause symptoms of radiation sickness: 1,000 mSv
- How to limit chronic exposure to "acceptable" levels?
Research for policy and practice: detailing radiation dose limits and effects

How To Limit Chronic Exposure To "Acceptable" Levels?
What Guidelines To Protect Human Health in the REE Sector?

**Human Health Management Programs: Guidelines and Standards**

- Radioactive materials are difficult to mine and handle safely. They are regulated through the *Nuclear Safety and Control Act 1997 and the Canadian Nuclear Safety Commission (CNSC)*

**Regulations for Mines:** Radioactive waste regulation

**REE Mine Liscence Applications**
- General Requirements
- Requirement for Code of Practice
- Licence to Prepare Site and Construct
- Licence to Operate
- Licence to Decommission
- Licence to Abandon
What Guidelines to Protect Human Health in the REE Sector?

Radioactive materials are difficult to mine and handle safely. They are regulated through the *Nuclear Safety and Control Act 1997* and the Canadian Nuclear Safety Commission (CNSC).
What Guidelines To Protect Human Health in the REE Sector?

Human Health Management Programs: Guidelines and Standards

Radioactive materials are difficult to mine and handle safely. They are regulated through the *Nuclear Safety and Control Act 1997* and the Canadian Nuclear Safety Commission (CNSC).
How to Prevent Acute Exposure?
Lessons Learnt from Radioactive Mineral Risk in Northern Ontario
Memorial to the Elliot Lake Uranium Miners

Memorial to the Elliot Lake Miners:
Up to 400 uranium miners (over 200 documented for workers’ compensation) are estimated to have died of lung and other cancers from over-exposure to radiation in the former uranium mines of Elliot Lake, Northern Ontario, Canada. The mines operated from the 1950’s to the late 1980’s.
— Photo courtesy of the United Steelworkers
How to Prevent Acute Exposure? : Lessons Learnt from Radioactive Mineral Risk in Canada

Currently, Mineral Exploration Sector acknowledges radiation risk: radiation exposure + health effects

Example: Mineral Exploration

Exploration crews searching for uranium will receive radiation exposure

- from uranium and its associated radioactive decay products in the drill core and cuttings.
- Gamma radiation emitted from the uranium mineralization
- Inhalation of radon (and the resulting radon progeny decay products) emanate from the core rods and drill cuttings
- The inhalation or ingestion of radioactive dust

(source: Sask OHS)
How to Prevent Acute Exposure? :
Lessons Learnt from Radioactive Mineral Risk in Canada

Historical Example: Chronic Exposure to Low Radiation Levels (Canadian Uranium Mining)
• In the old (unreformed) industry: excessive exposure to radon gas and radon progeny
• Lead time for health effect: 5 to 15 years exposure
Result: 221 documented deaths and estimated 400 actual deaths from lung and associated cancers (see Ontario Ministry of Labour: Dr J.Mueller, et al).

Currently, Mineral Exploration Sector Acknowledging Radiation Risk: Radiation Exposure + Health Effects

Current Example: Underground Mine and Mine Waster
• Exposure to gamma radiation from radioactive ores, wastes
• Workers in uranium mines are usually classified as “nuclear energy workers”
• Radiation exposures are regulated under the federal nuclear safety and control act.

*Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM) published by Health Canada endorsed by federal government, all provinces and territories.*
How to Prevent Acute Exposure?

Preparing Communities Of Practice for Radiation Risk:
Three Principles

**Time**
- limiting the time you spend near a radiation source
- Time of exposure to various levels
- Account for situations where simultaneous exposure can occur to multiple frequency fields

**Distance**
- Keep your distance from the radiation
- The closer you are, the more exposure you get. The further away you are, the less exposure

**Shielding**
- Shield yourself
- Use the appropriate material for the type of radiation
- partial body exposure is better than whole-body exposure
How to Prevent Acute Exposure?

Preparing Communities Of Practice for Radiation Risk: Build a Culture of Radiation Safety

An informed community leaders, public health education specialists and industry

- Awareness education; RSO training – industry leaders, community leaders and public health education specialists

Informed community members and workforce: Awareness education

Radiation safety hygiene

- Protective clothing, gloves, hard hats, boots, respirators
- Good housekeeping (radiation hygiene) practices

Personal, individual radiation dosimetry

- Gamma radiation dosimetry
- Radon progeny dosimetry
- Radon gas dosimetry (if high levels and volumes require)
- Long-lived radioactive dust dosimetry (LLRD)
How to Prevent Acute Exposure?

Workplace Exposure

**Radon**: underground workers (mines, tunnels), enclosed spaces in homes, buildings, warehouses

**Cosmic radiation**: aircrews, frequent fliers, astronauts, outdoor workers

Prescribed Equivalent Dose Limits

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<thead>
<tr>
<th></th>
<th>Lens of an eye</th>
<th>Skin*</th>
<th>Hands and feet</th>
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<tbody>
<tr>
<td><strong>(a) Nuclear energy worker</strong></td>
<td>One-year dosimetry period</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td><strong>(b) Any other person</strong></td>
<td>One calendar year</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Varying Degrees of Penetration by Different Types of Ionizing Radiation
How to Prevent Acute Exposure?

Methods used to Monitor Workers for External Exposure to Nuclear Substances

<table>
<thead>
<tr>
<th>Facility type or activity</th>
<th>External radiological hazard(s)</th>
<th>Monitoring method(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium mine or mill</td>
<td>Photon and beta radiation from uranium decay series</td>
<td>TLD or OSLD</td>
</tr>
<tr>
<td>Uranium processing facility</td>
<td>Photon and beta radiation from uranium compounds</td>
<td>TLD or OSLD, Extremity TLD</td>
</tr>
<tr>
<td>Industrial radiography</td>
<td>Photon and beta radiation from sealed sources such as Co-60 or Ir-192</td>
<td>TLD or OSLD, DRD</td>
</tr>
<tr>
<td>Nuclear power plant (with CANDU reactor)</td>
<td>Photon and beta radiation from various sources</td>
<td>TLD, DRD, Extremity TLD</td>
</tr>
<tr>
<td></td>
<td>Neutrons produced from fission</td>
<td>Neutron survey meter</td>
</tr>
<tr>
<td>Hospital</td>
<td>Photon and beta radiation from nuclear substances used for various diagnostic or therapeutic medical applications</td>
<td>TLD or OSLD, Extremity TLD</td>
</tr>
<tr>
<td>Nuclear research facility</td>
<td>Photon and beta radiation from uranium compounds</td>
<td>TLD, Extremity TLD, DRD</td>
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Varying Degrees of Penetration by Different Types of Ionizing Radiation
Acknowledging Risk Perceptions of Rock, Water and Soil

Lessons Learnt from Case Study: SAFETY AND SOCIAL LISCENCE
Timiskaming First Nation Cancer and the Environment Project provides information about the harmful effects of REE.

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Memorial to the Elliot Lake Uranium Miners

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– Photo courtesy of the United Steelworkers
Take Away Messages

Communicate geohazard risk: Communicate potential radioactive mineral risk to prevent misunderstanding, suffering and death

Build useful content to talk about radioactive mineral risk management

Replace misinformation or lack of information with robust, geoscience based information

- Provide radioactive mineral risk findings as they emerge.
- Provide details on radioactive REE-rich mineral

Ensure stakeholders have knowledge of new science, as the general public has poor intuition about radioactive mineral risk, earth science systems and math. Many have difficulty understanding and applying science information, especially risk and uncertainty.

SAFETY AND SOCIAL LICENCE
Timiskaming First Nation Cancer and the Environment Project (mis) information about the harmful effects of REE? no two REE ores are alike ..


Questions?

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