



# Radium Mobility in Uranium Mine Tailings

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*We will never compromise safety*

# Presentation Plan

- Overview of the CNSC
- Why does the CNSC have an interest in radium?
- Research objectives
- Results
- Conclusions and path forward

# Canadian Nuclear Safety Commission

## Mandate:

- Regulating nuclear activities to protect the health, safety and security of Canadians and the environment, and to implement Canada's international commitments on the peaceful use of nuclear energy



Canada's independent nuclear regulator –  
65 years of experience

# CNSC Regulates All Nuclear-Related Facilities and Activities

- Uranium mines and mills
- Uranium fuel fabricators and processing
- Nuclear power plants
- Waste management facilities
- Nuclear substance processing
- Industrial and medical applications
- Nuclear research and educational
- Export/import control

...From Cradle to Grave



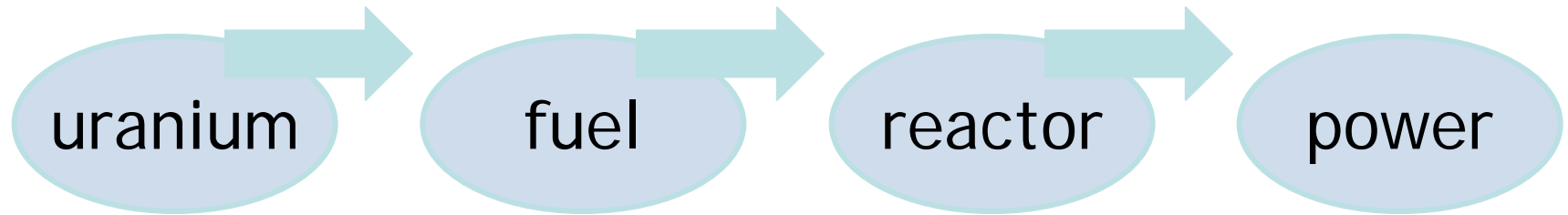
# Independent Tribunal

- Quasi-judicial administrative tribunal
- Commission members are independent
- Commission hearings are public and Webcast
- Supported by a Secretariat and independent legal services

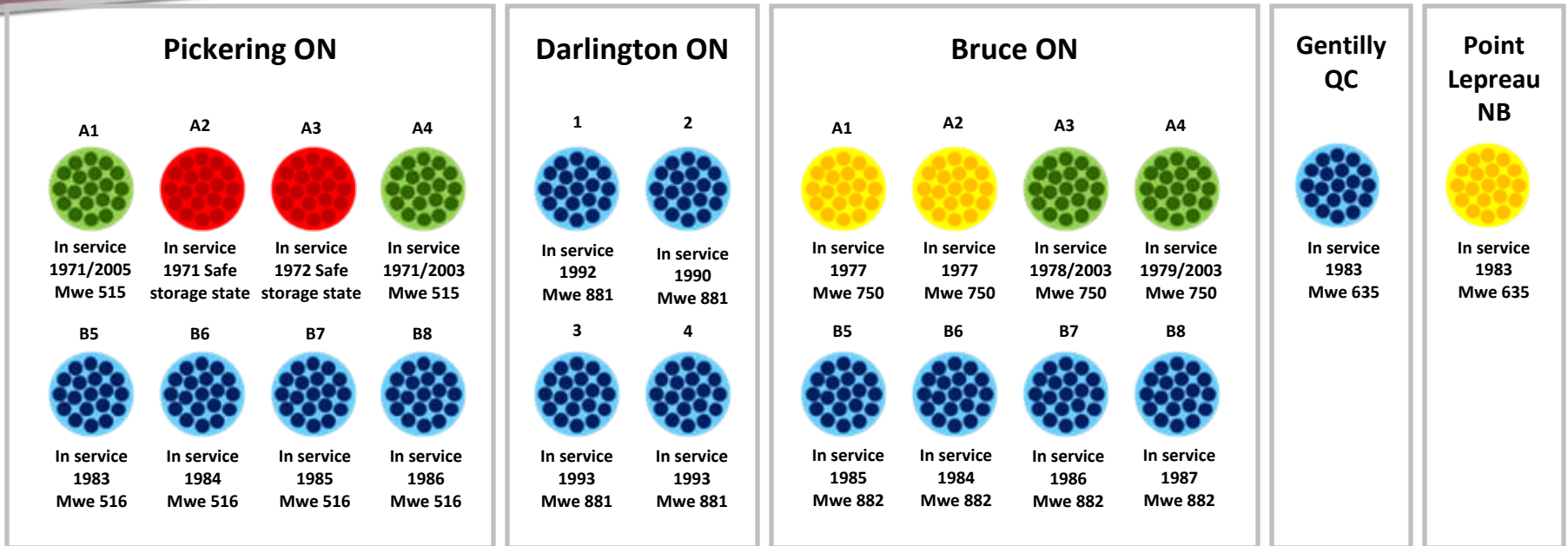


Transparent decision making

# So why all the interest in uranium?



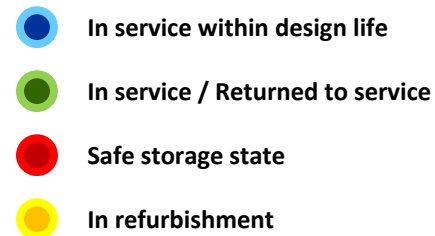
# Canada's Nuclear Energy Profile



## Typical share of nuclear energy in total electricity generation



## Operable status (Average age – 25 Years)



# Canadian Uranium Projects

## **Active projects** (all in Saskatchewan)

- Key Lake Mill (Cameco Corporation)
- McArthur River Mine (Cameco)
- Rabbit Lake Mine/Mill (Cameco)
- McClean Lake Mines/Mills (AREVA Resources Canada Inc.)

## **Under Construction** (Saskatchewan)

- Cigar Lake Mine (Cameco)

## **Proposed Projects**

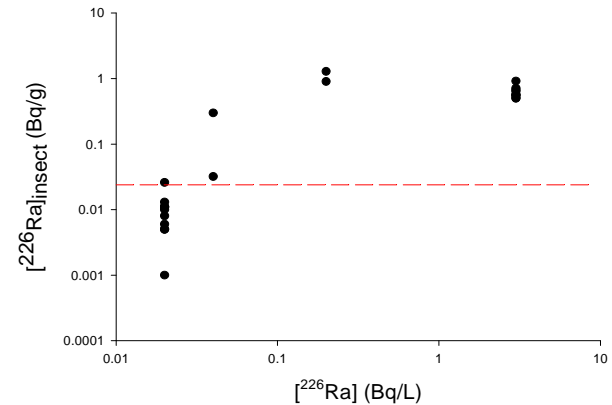
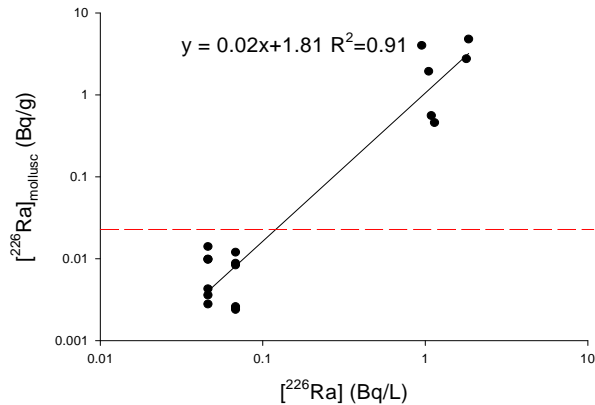
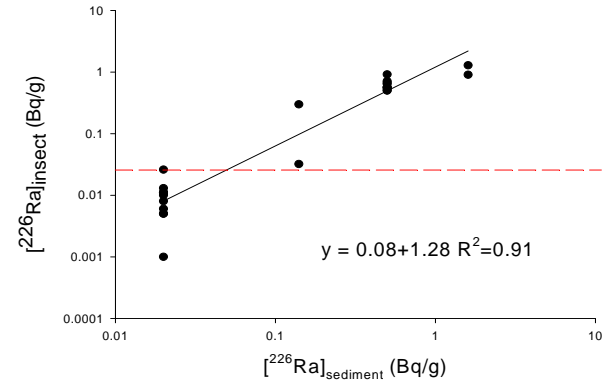
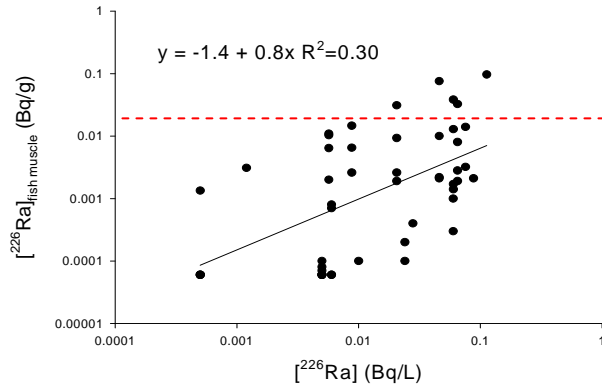
- Midwest Mine (Saskatchewan) (AREVA)
- Kiggavik Project (Nunavut) (AREVA)
- Matoush (Quebec) (Strateco Resources Inc.)
- Millennium Project (Saskatchewan) (Cameco)
- Michelin Project – Aurora (Labrador) (Aurora Energy Resources Inc)

**Supplying 25% of the world's demand**

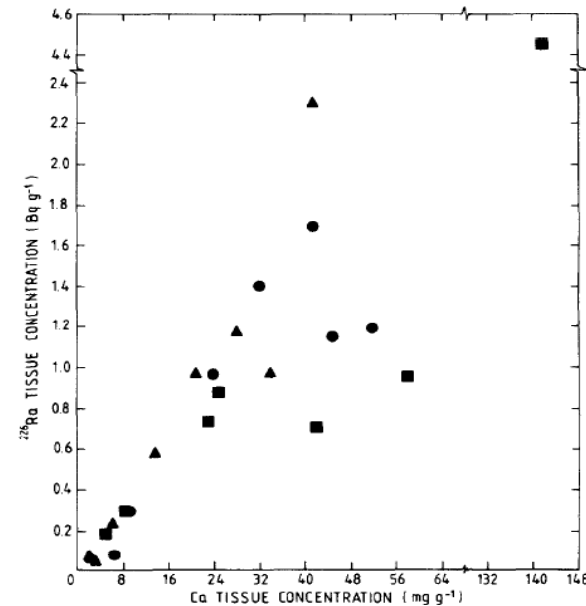
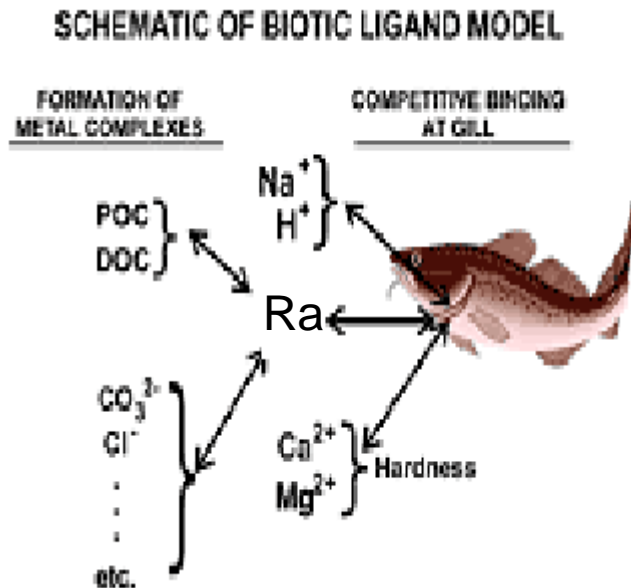
# Why does CNSC have an Interest in the Behaviour of $^{226}\text{Ra}$ in Tailings?

$^{226}\text{Ra}$  is released part of the nuclear fuel cycle

$^{226}\text{Ra}$  accumulation in nature



# Why does CNSC have an Interest in the Behaviour of $^{226}\text{Ra}$ in Tailings?



- Dissolved  $^{226}\text{Ra}$  is taken up by aquatic organisms
- Calcium competes with  $^{226}\text{Ra}$  at the uptake sites

# Environmental Hazards of $^{226}\text{Ra}$

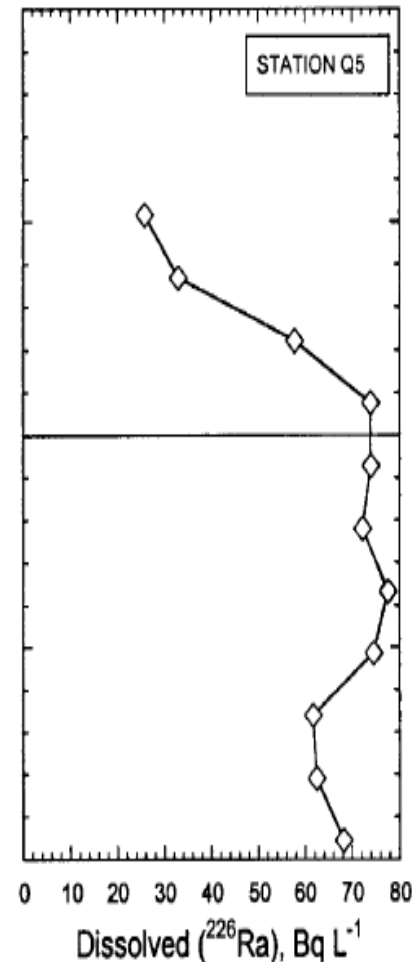
- Calculations using the ERICA model indicate that 0.1 to 1 Bq/L of  $^{226}\text{Ra}$  is hazardous to aquatic species
- Similar to Saskatchewan Surface Water Quality Objective of 0.1 Bq/L

Organisms	$[\text{}^{226}\text{Ra}]_{\text{water}}$
Algae	1 Bq/L
Invertebrate	1 Bq/L
Fish	1 Bq/L
Plants	0.1 Bq/L



# Mobility of $^{226}\text{Ra}$ in Uranium mine tailings

- Martin et al. (2003) reported levels of  $^{226}\text{Ra}$  around 70 Bq/L with evidence of upward diffusive flux out of the tailings into the overlying water column

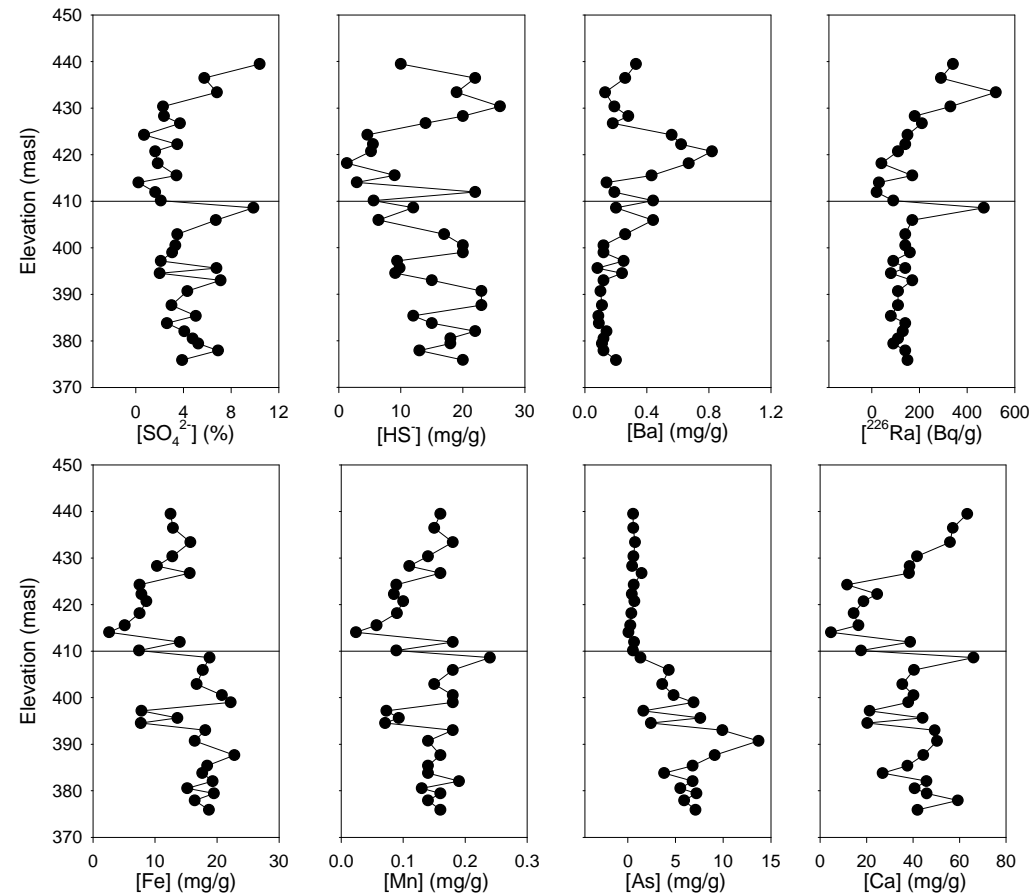


# Objectives

- Inform CNSC staff of the nature of  $^{226}\text{Ra}$  releases (i.e. sorption and/or solubility controls) from flooded uranium tailings, and determine if this represents a regulatory issue for long term management of uranium tailings in Canada
- To develop a geochemical model that could be used to predict the fate of  $^{226}\text{Ra}$  in such environments

# Data Collection Analysis

- Collected solids and porewater data from monitoring reports of 4 tailings management facilities and 2 exposed lakes
- Depicted ~80 solids and pore water depth profiles of Eh,  $\text{SO}_4$ , Ba,  $^{226}\text{Ra}$ , Fe, Mn, pH

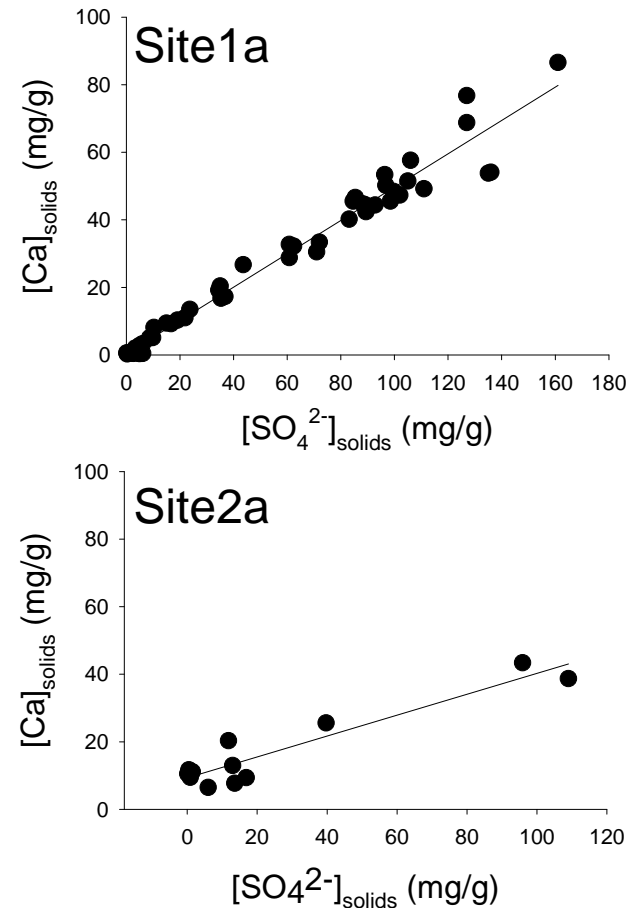


# Data Collection Analysis

- Data were then pooled per site and we conducted correlation analyses
- Ion activity products and saturation indices were also calculated with PHREEQC (USGS) using the llnl.dat file database

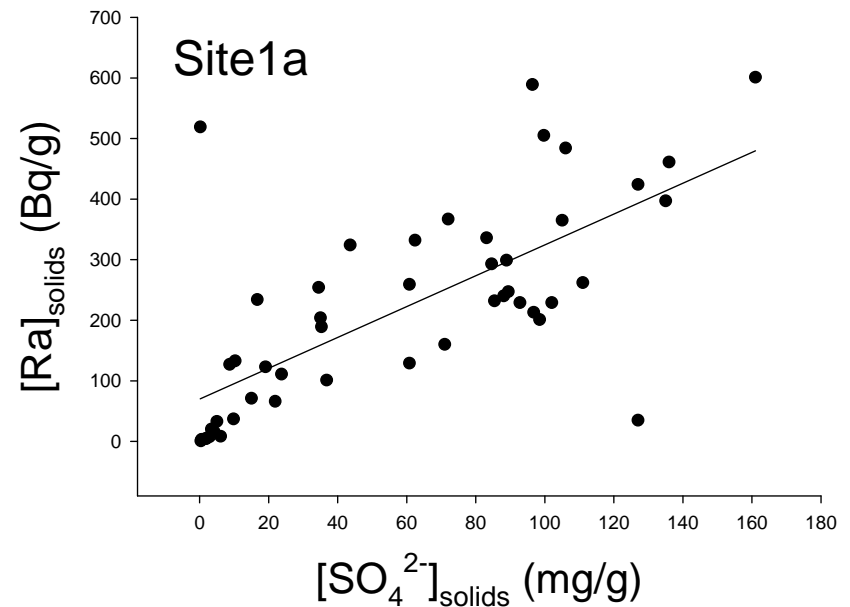
# Results

- In all tailings investigated, Ca and sulphate in the solids are significantly correlated
- Gypsum is an important mineral in uranium mine tailings



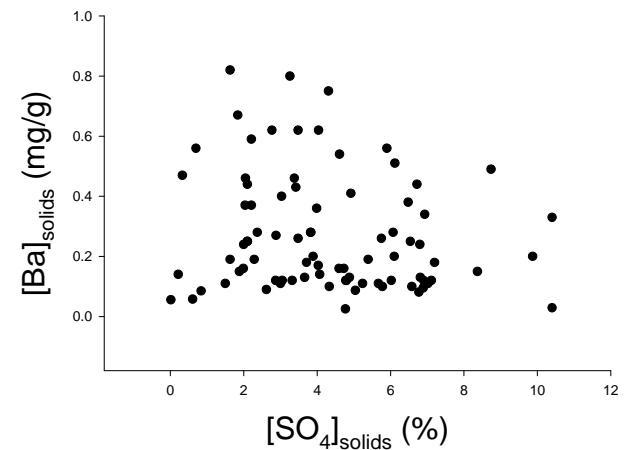
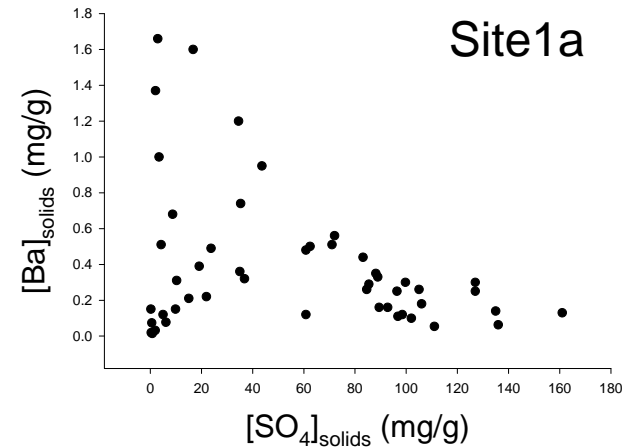
# Results

- $^{226}\text{Ra}$  is correlated with sulphate in the solids
- Provide evidence that  $^{226}\text{Ra}$  is immobilized as  $\text{RaSO}_4$  in the tailings



# Results

- Ba is not linked to sulphate levels in tailings
- Barium competes with Ca and  $^{226}\text{Ra}$  which can explain the lack of correlation
- Barium chloride is also added in excess to remove  $^{226}\text{Ra}$ ; there is no correlation with  $^{226}\text{Ra}$  and Ba in the tailings solids



## Saturation Indices (Tailings)

State	Barite	Gypsum	RaSO <sub>4</sub>
Site 1a	1	0.02	-3.22
Site 1b	0.8	0.02	-3.72
Site 1c	1.02	0.03	-3.38
Site 2a	1.05	-0.92	-4.57
Site 2b	0.97	-0.36	-5.06

- Barite is controlled by dissolution/precipitation but gypsum is not in older tailings
- RaSO<sub>4</sub> is always under saturated with solids which means that pore water <sup>226</sup>Ra levels are not controlled by dissolution/precipitation reactions

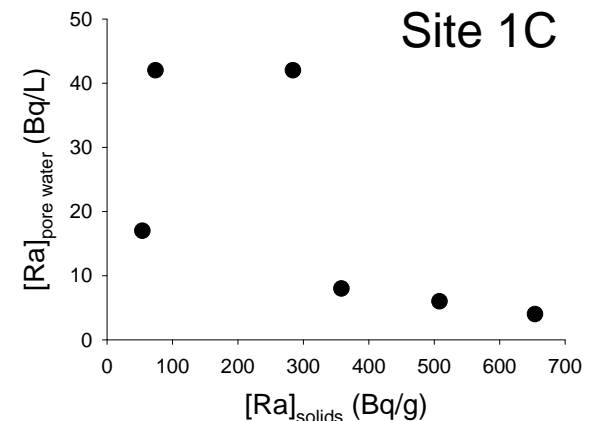
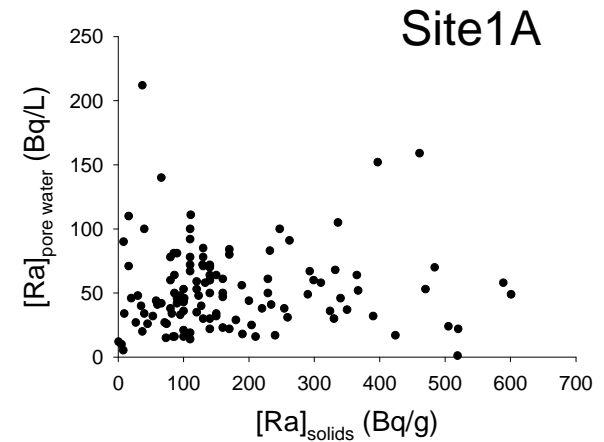
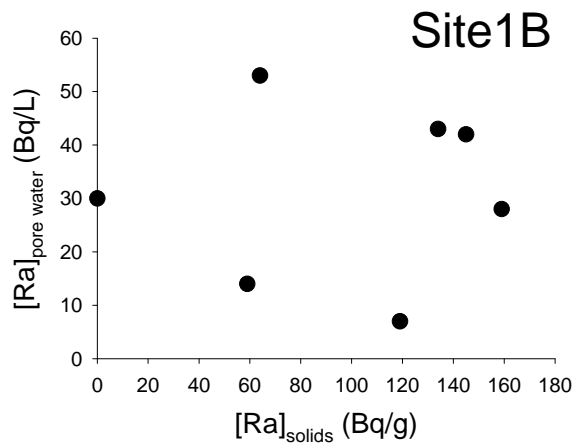
# Saturation Indices (Lakes)

Site	Barite	Gypsum	RaSO <sub>4</sub>
Lake 1	-0.25	-2.06	-5.94
Lake 2	-0.41	-1.8	-4.82
Lake 3	0.39	-1.76	-5.8
Lake 4	1.2	-0.08	-5.33

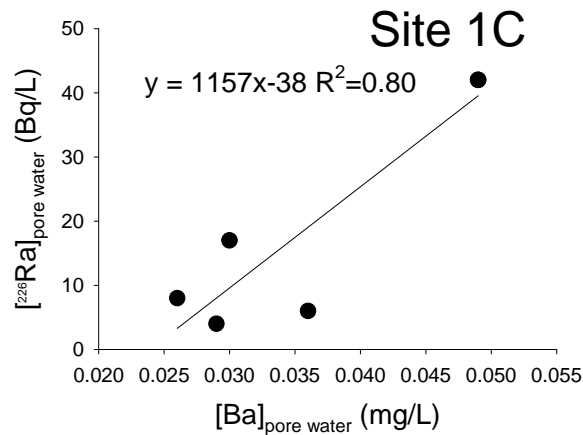
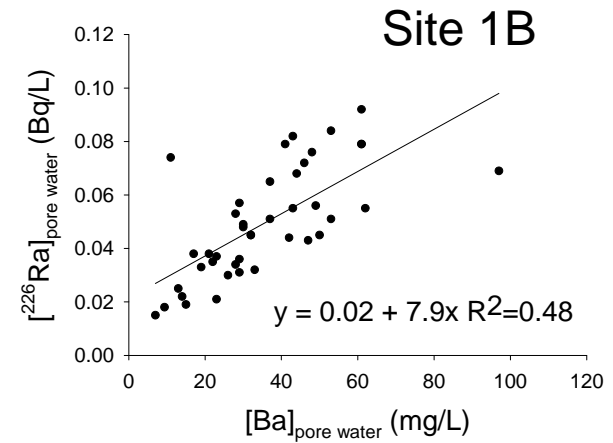
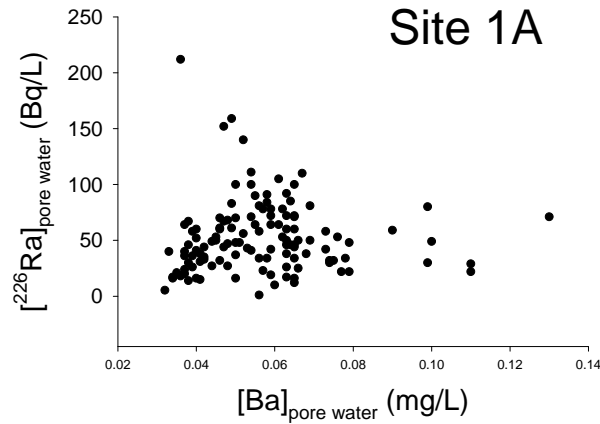
- In lakes, Barite, RaSO<sub>4</sub> and gypsum are always under saturated with solids which means that pore water levels of <sup>226</sup>Ra, Ba, Ca and SO<sub>4</sub> are not controlled by dissolution/precipitation reactions but rather by extrinsic forces in the pore water

# Results

- $^{226}\text{Ra}$  in pore water does not appear to be controlled by the solid phase
- Means that  $^{226}\text{Ra}$  once soluble, is controlled by sorption or complexation phenomena



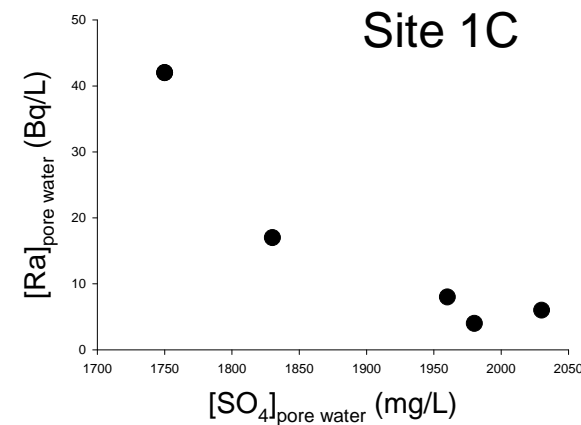
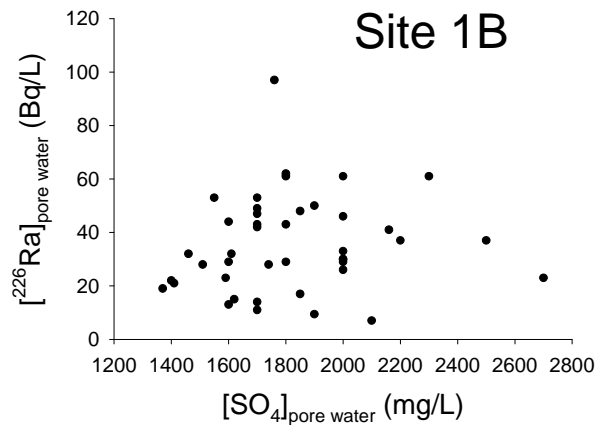
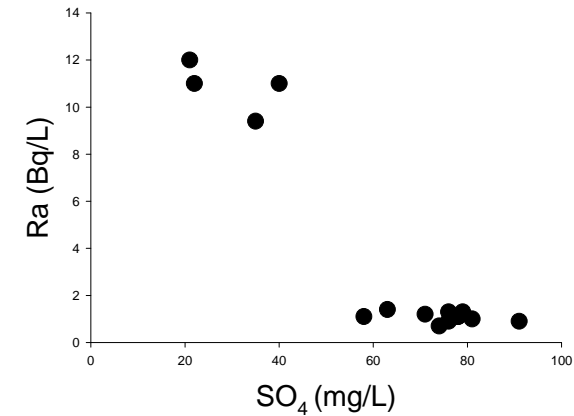
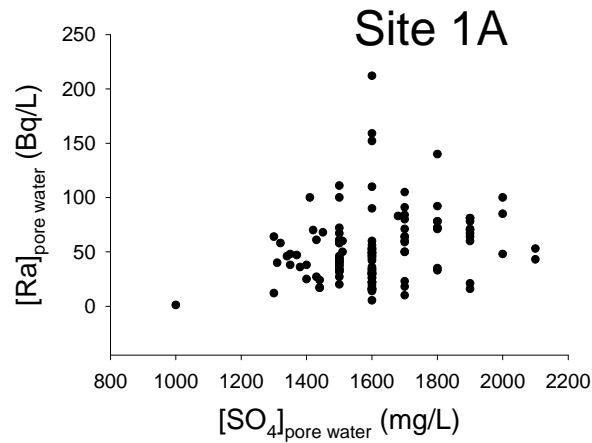
# Results



- In tailings pore water,  $^{226}\text{Ra}$  and Barium are correlated in pore water but not at all sites

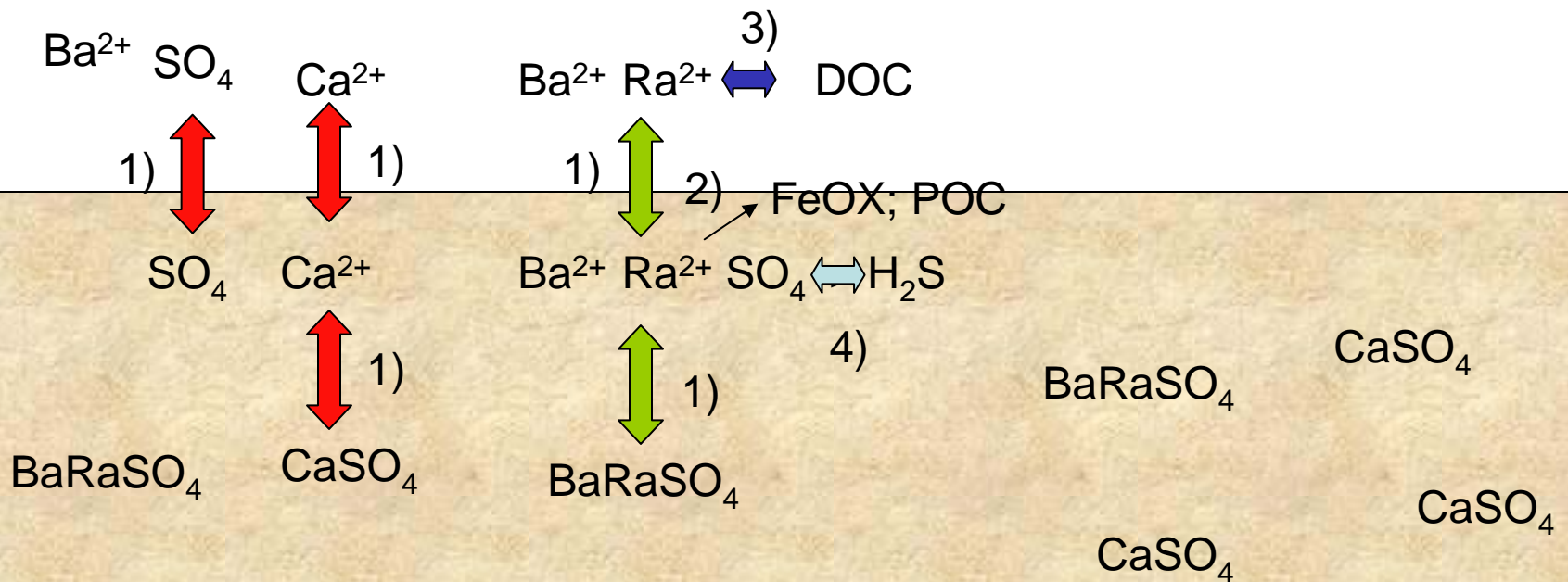
# Results

- In tailings pore water,  $^{226}\text{Ra}$  and  $\text{SO}_4$  are sometimes correlated
- Seems like below  $50\text{mg SO}_4/\text{L}$ , Ra is increased in pore water but not necessarily



# Conceptual Model

- 1) Dissolution/mineralization: does not seem as important
- 2) Adsorption: likely important
- 3) Complexation by organic carbon: likely important and overlooked since  $^{226}\text{Ra}$  has high affinity with carbon
- 4) Sulphate reduction: important if the fate of radium is linked sulphate
- 5) Age of the tailings may be an issue as solubility controls on gypsum change



# Conclusions: Research Needs and Path Forward

- Our meta-analysis suggests more research is needed to better predict the long-term fate of  $^{226}\text{Ra}$  in uranium mine tailings
- Future work will address
  - $^{226}\text{Ra}$  interaction with organic carbon
  - effect of sulphate levels affected by gypsum dissolution and sulphate reduction on  $^{226}\text{Ra}$  mobility
  - Effect of tailings age
  - Solubility product constants for  $\text{Ba}(^{226}\text{Ra})\text{SO}_4$  minerals; verification of thermodynamic constant databases



Canadian Nuclear  
Safety Commission

Commission canadienne  
de sûreté nucléaire

Thank you!

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[nuclearsafety.gc.ca](http://nuclearsafety.gc.ca)