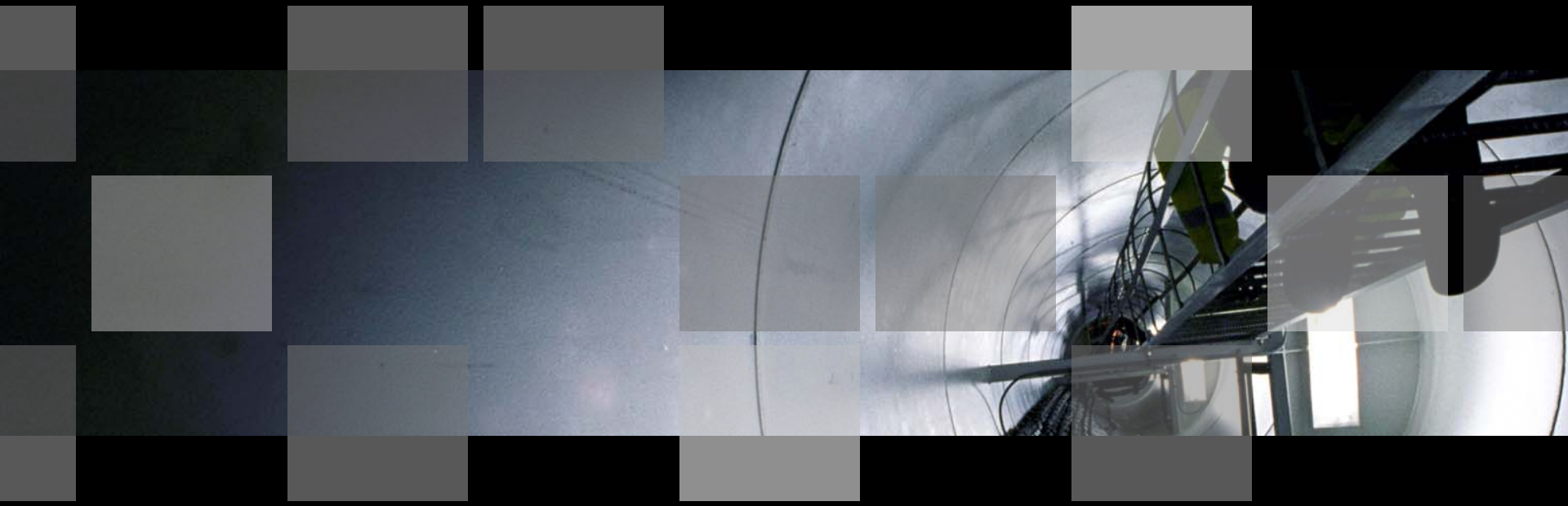

Technical Session on Arsenic in the Environment:
Sources, Guidelines, Risks and Treatment

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March, 2010

Overview of Arsenic

- Widely distributed in the earths crust
- In water by dissolution of ores/minerals
- Concentrated in areas based on bedrock type
- Becomes available by erosion or by movement within fractures

Sources of Arsenic

- Natural Sources of arsenic
  - Contained in 250 naturally occurring minerals (particularly sulphides)
  - Present in volcanic-derived sediment
  - Present in rivers and streams
  - Aquifer materials high in iron oxides and sulphide minerals

Sources of Arsenic

- Human Sources of arsenic
  - Mineral extraction and processing
  - Glass manufacturing
  - Wood preservation
  - Pesticide production and application
  - Waste burning and leachate
  - Coal/oil production and processing

Forms of Arsenic

- Metallic arsenic – not absorbed by the body
- Organic arsenic – primary form of arsenic in fish and shellfish (shows little to no toxicity)
- Inorganic arsenic – Arsenate (As^{+5}) and Arsenite (As^{3+}) are the most prevalent forms in drinking water

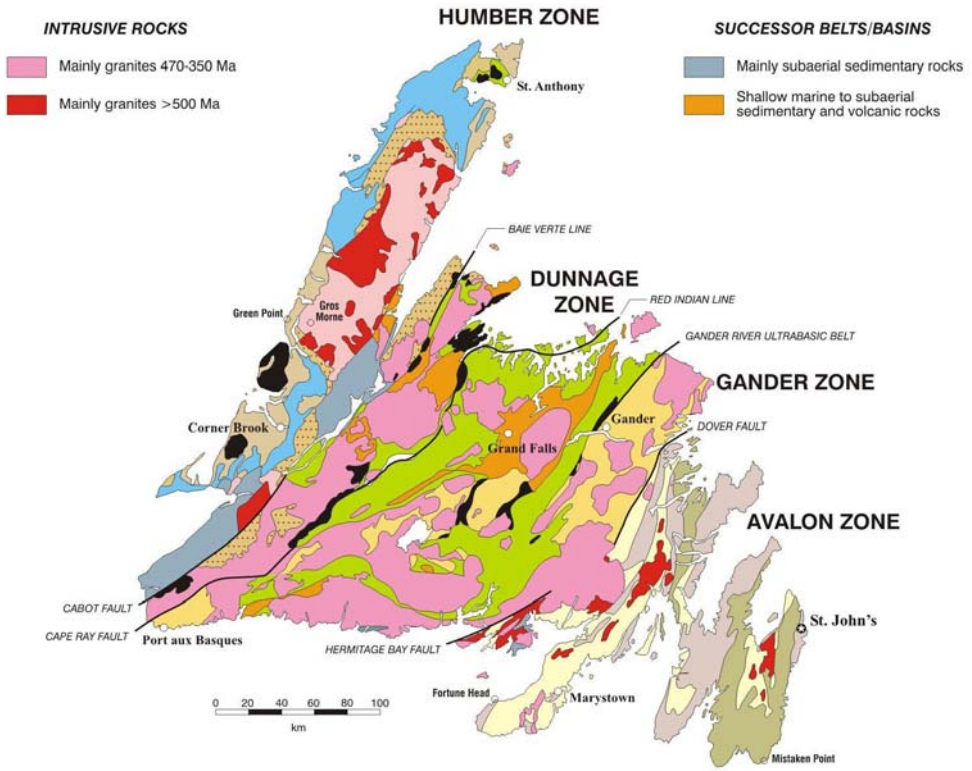
Arsenic in Soil and Bedrock

- Soil:
  - Average concentrations in Canada range from 4.8 to 13.6 mg/kg
  - Higher in industrialized areas, mining operations, smelters
  - Higher in areas based on bedrock type
  - Soil quality guideline for any land use type is 12 mg/kg (based on soil ingestion)

- Bedrock:
  - Typical bedrock includes volcanic and sedimentary rocks
  - In NL, this includes Baie Verte area, Lewisporte and Port aux Basques

Geological Survey
Department of
Natural Resources

GENERALIZED INTERPRETIVE MAP-
NEWFOUNDLAND APPALACHIANS



INTRUSIVE ROCKS

- Mainly granites 470-350 Ma
- Mainly granites >500 Ma

SUCCESSOR BELTS/BASINS

- Mainly subaerial sedimentary rocks
- Shallow marine to subaerial sedimentary and volcanic rocks

HUMBER ZONE
North American Iapetus Margin

- Transported slope/rise rocks
- Shelf, passive margin
- Rift rocks
- Basement rocks

DUNNAGE ZONE
Vestiges of Iapetus

- Volcanic and sedimentary rocks
- Oceanic crust/mantle

GANDER ZONE
Eastern Iapetus Margin

- Sandstones and metamorphic rocks

AVALON ZONE
African Suspect Terrane

- Mainly subaerial sedimentary rocks
- Marine sedimentary rocks
- Volcanic rocks

Map compiled by J. P. Hayes, 1987
Modified by H. Williams, 2004

Arsenic in Groundwater

- Mobility largely controlled by redox conditions, pH, biological activities, and adsorption/desorption reactions
- Aquifers act as a “vessel” enabling the migration of arsenic
- Tasteless and odourless
- In Canadian drinking water, generally less than 0.005 mg/L, but is dependant on many factors!

Arsenic Mobility Profile

- Arsenates - As(V)
  - Usually occurs in aqueous environments that are oxygenated (DO>1ppm) - i.e., $HnAsO_4^{n-3}$
  - predominantly in aerobic soils or well-oxygenated surface waters
- Arsenites – As(III)
  - Usually occurs in aqueous environments that are high in sulphides or methane (DO<1ppm) - i.e., $HnAsO_3^{n-3}$
  - Exists in slightly reduced soils
  - More of a concern with respect to human exposure due to its toxicity and mobility
  - predominantly in reducing conditions (deep lake sediments and groundwater
  - 4 to 10 times more soluble in water than As(V)

Arsenic in Groundwater

- The occurrence and variability of arsenic in groundwater could be related to the following factors:
  - Distribution of arsenic in soil and rocks that are part of the groundwater flow system
  - Characteristics that influence the solubility and transport of arsenic in groundwater
  - Associations between land use, geology and groundwater flow patterns

Guidelines

- Health Canada drinking water guideline of 0.010 mg/L
- Based on municipal and residential scale treatment achievability
- Guideline is based on lifetime exposure (70 years)
- Takes into consideration the ability to measure and remove arsenic from drinking water supplies

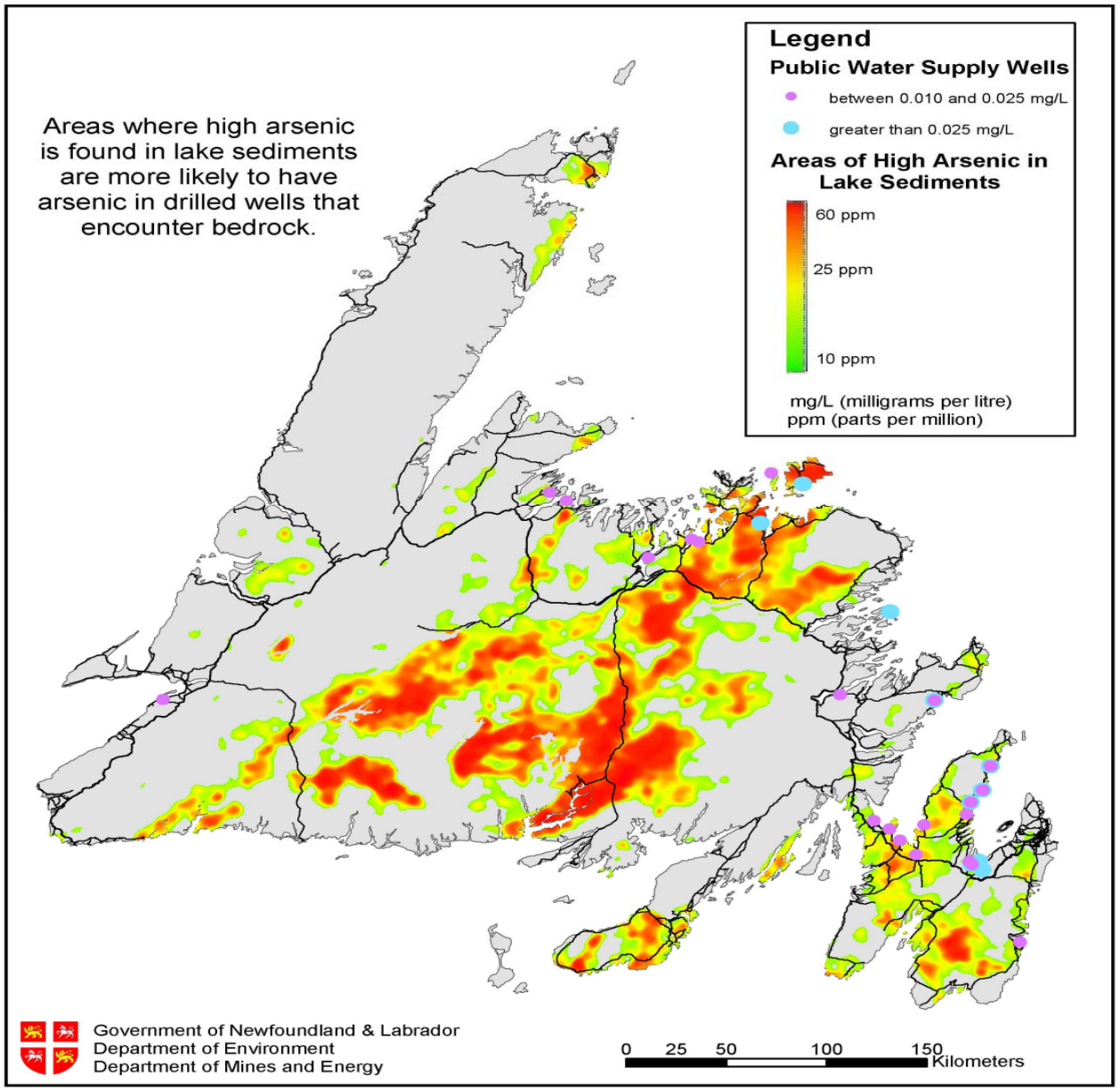
As Levels in Canadian Water

- PEI
  - Groundwater levels ranged from 0.0001 to 0.026 mg/L between 1986 and 2002
- Alberta
  - Groundwater levels ranged from 0.0001 to 1 mg/L in treated groundwater and surface water supplies between 1980 and 2002
- NL
  - Groundwater levels ranged from 0.006 to 0.288 mg/L in public water supplies in 2002
  - Groundwater levels ranged from 0.001 to 0.368 mg/L in public schools in 2002.
  - 19% schools exceeded guideline of 0.010 mg/L

Arsenic in Groundwater in NL

- NL data strongly based on lake-sediment geochemistry
- Well defined pattern in groundwater chemistry and underlying bedrock compared to wells installed in soil or dug wells
- Related to fracture zones

Areas of Potential Arsenic Concentration in Well Water



Arsenic in Groundwater in NL

- Approximately 27 % of Newfoundland obtain their drinking water from groundwater
- Public supplies routinely tested by government officials
- Conducting sampling since 2001
- Sampling conducted in NL communities since 2006 ranged from 0.011 mg/L to 0.027 mg/L
- Detected in school water supplies in St. Brendan's and Wings Point
- Detected in public water supplies including the northwest Avalon Peninsula and Fogo Island

Arsenic in Groundwater in NL

- Some communities have been on a “non-consumption order” by the Dept. of Environment
- Some communities have installed treatment systems or has turned to alternate sources
- No arsenic exceedances reported for Labrador
- Approximately 20,000 privately drilled wells have not been tested (as of 2002)
- Approximately 500 newly drilled wells installed each year

Arsenic Exposure

- Arsenic is a human cancer-causing agent
- For most Canadians, primary source is food, followed by drinking water, soil and air
- Absorbed by the body when ingested and distributed by the blood stream
- Exposure by dermal contact or inhalation it not considered to be significant
- Studies do not indicate greater risks to children or pregnant women in comparison to adults

Arsenic Exposure

- Food sources:
  - Adult 42 ug
  - Child 14.9 ug
  - Vegetation < Fish < Shellfish
- Inhalation:
  - Mean ambient level for 11 Canadian cities 0.001 ug/m^3
  - Higher concentrations near smelters or industrial activities
- Drinking water:
  - Adult < 7.5 ug (based on an intake of 1.5 L)
  - Child < 3.5 ug (based on an intake of 0.7 L)

Effects due to Exposure

- Long term effects due to As in drinking water include:
  - Skin changes: pigmentation changes and thickening
  - Nausea and diarrhea
  - Decreased production of blood cells
  - Abnormal heart beat
  - Numbness in the hands and feet
- Short term effects include:
  - Abdominal pain, muscular pain
  - Flush skin or rash
  - Vomiting and diarrhea
  - Numbness in hands and feet

Effects due to Long Term Exposure

- Other Long term effects due to As exposure via other sources include:
  - Cancer of the skin, lungs, urinary bladder, kidneys

Treatment Options

- Typical concentration of arsenic in groundwater is 0.005 mg/L
- Treatment required to obtain a level of <0.010 mg/L
- Treatment based upon scale of drinking water supply (residential vs. municipal)
- Short term vs. long term exceedances

Treatment Options

- Treatment type based on characteristics of water supply (pH, iron etc.)
- pH = 4 to 10
  - As (V) has –ve charge and is easier to remove
  - As(III) is neutral
- Need to convert As(III) to As(V) by oxidation
- May need to adjust pH (remove TDS and competing ions), often referred to as a “pre-treatment step”

Treatment Options

- Key Considerations when choosing a treatment option:
  - System maintenance
  - Cost effectiveness
  - Difficulty of use
  - Multi-use system?

- Before any treatment system is considered, must understand the water chemistry (pH, competing ions, organic content).

Municipal Scale

- Coagulation/filtration combined with “pre-treatment”
  - Can reduce As to 0.003 -0.005 mg/L
  - Also removes suspended and dissolved solids
- Lime softening
  - Can reduce As to 0.001-0.003 mg/L
  - Good for addressing hard water
  - More expensive
- Activated alumina adsorption with microfiltration
  - Can reduce As to <0.01mg/L (95% effective)
  - Involves chemical handling

Municipal Scale

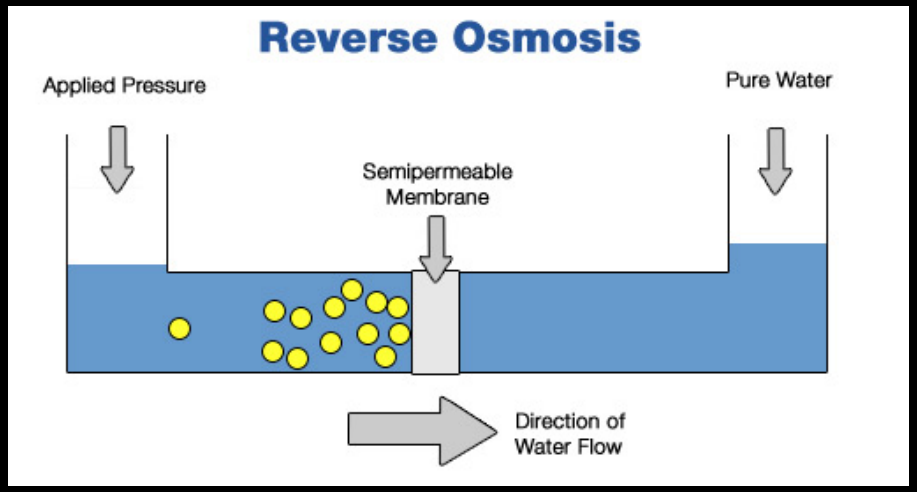
- Treatment types discussed are best suited for larger scale systems
- Can create backwash, contaminated filters for disposal etc.
- Other options include:
  - Reverse osmosis
    - can remove up to 85%
    - requires a lot of water
    - results in a lot of wastewater and arsenic rich brine
    - Not recommended where water resources are scarce
  - Manganese greensand filtration (not a high removal rate, requires iron)

Residential Scale

- Applies to private potable wells
- Have well tested
  - Collect sample at point of entry or point of source
  - Prior to any treatment system or filters
- Arsenic is not removed by boiling the water!

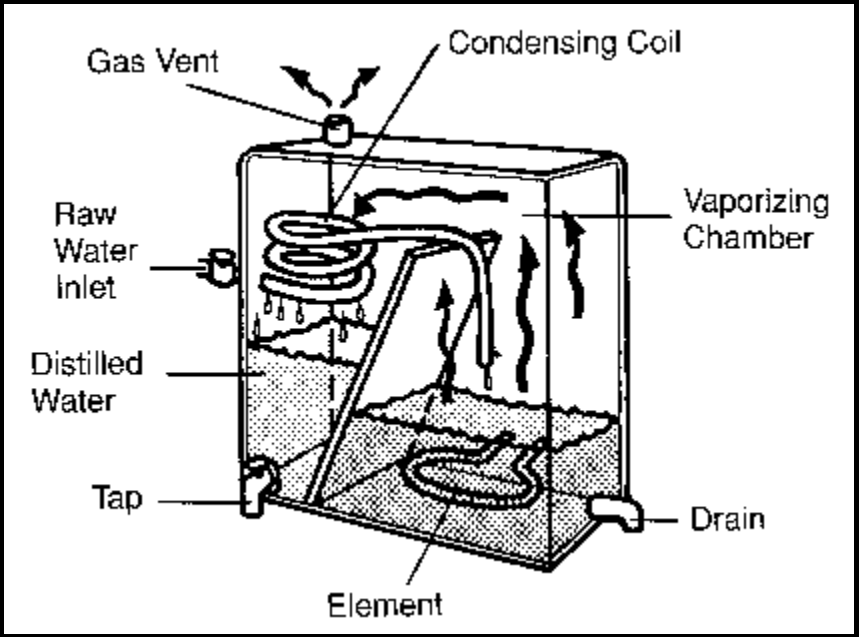
Residential Scale

- Reverse osmosis
  - Requires large quantity of influent water
  - 5 gallons or treated water = 40 to 90 gallons of wastewater
  - Removes other dissolved minerals (98%)
  - Can be installed at point of use or point of entry



Residential Scale

- Steam distillation
  - Heat also kills bacteria that may exist, as well as all other minerals
  - Installed at point of use, but can be noisy!
  - Low maintenance



Residential Scale

- Adsorption
  - Adsorbent filter (carbon or charcoal)
  - in place within the water line prior to point of use
  - Remove other metals, but not bacteria

Prevention and Control

- Inquire about your potable water supply
- Implementation of a monitoring plan in the interim
- Installation of a Treatment System

- Alternate water sources:
  - Connect to public distribution system
  - Look for new Groundwater source

- Education:
  - Sample your residential well
  - Communication with general public

Questions?????