Management of NORM – A Canadian perspective

John M. Takala

ICRP Workshop on Surface Disposal of Radioactive Waste

November 6, 2017 – Fukushima, Japan

DISCLAIMER

- Views and opinions are mine and I am not representing ICRP Committee 4 nor my employer Cameco Corporation

Outline

- Introduction
- Industries impacted by Naturally Occurring Radioactive Materials (NORM)
- Canadian Regulatory Approach
- Practical Implementation Issues

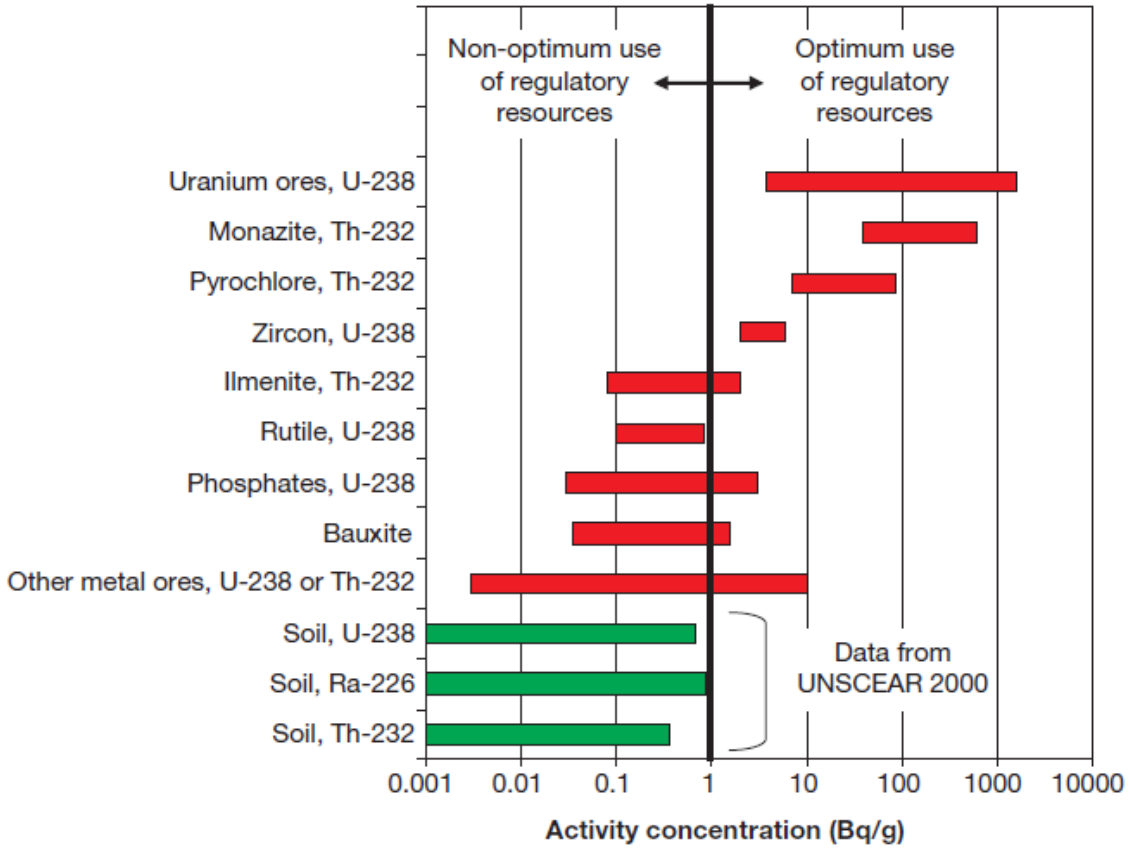
Introduction

- Naturally Occurring Radioactive Material
  - Present in varying concentrations in most materials
- Primordial radionuclides
  - Uranium 238 (and decay series)
  - Thorium 232 (and decay series)
  - Potassium 40
  - Very low concentrations of others (e.g., U 235 decay series)

Introduction

- Concentration of NORM in most substances low
- Human activities can lead to higher concentrations
- In some situations necessitates the need safety measures
- Can occur at different stages
  - Handling
  - Processing
  - Transport
  - Disposal

Introduction



From Wymer 2008. NORM V IAEA

Industries Impacted by NORM

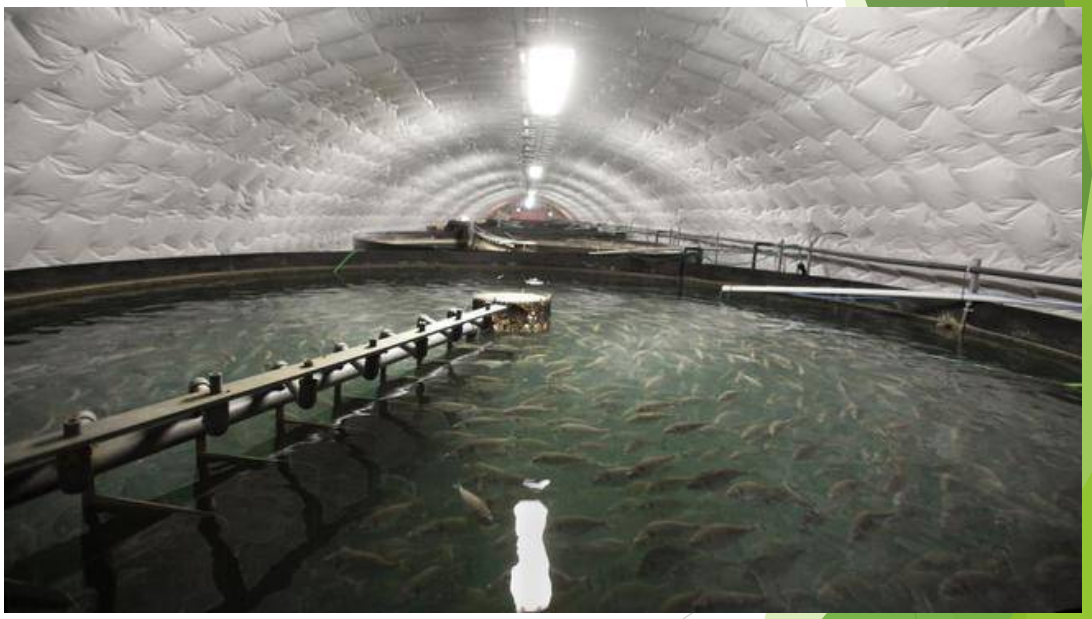
- Mineral Extraction and Processing
  - NORM may be released or concentrated in a process stream during the processing of ore
  - K-40, U-238, and Th-232 decay series in variety of ore formations

Industries Impacted by NORM

- Oil and Gas Production
  - trace quantities of NORM may be found in hydrocarbon bearing geological formations
  - Oil production – Ra-226 can precipitate on process equipment
  - Gas production – Rn-222 in natural gas and can Pb-210 accumulate inside gas processing equipment

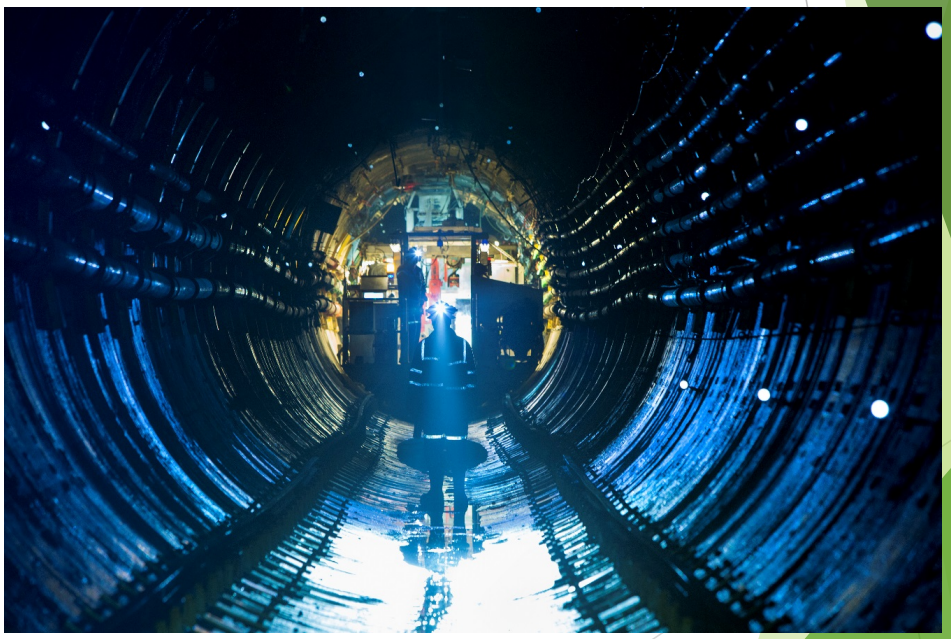
Industries Impacted by NORM

- Water Treatment Facilities
  - Water (fresh or waste) treated through sorptive media or ion-exchange resins to remove impurities may concentrate NORM and may release radon
  - Fish hatcheries



Industries Impacted by NORM

- Tunnelling and Underground Workings
  - Release of radon in underground mines



Industries Impacted by NORM

- Thermal-Electric Production and Forest Products
  - Mineral ashes from combustion may concentrate NORM present in coal and plants

Industries Impacted by NORM

- Metal recycling
  - NORM contaminated can be redistributed

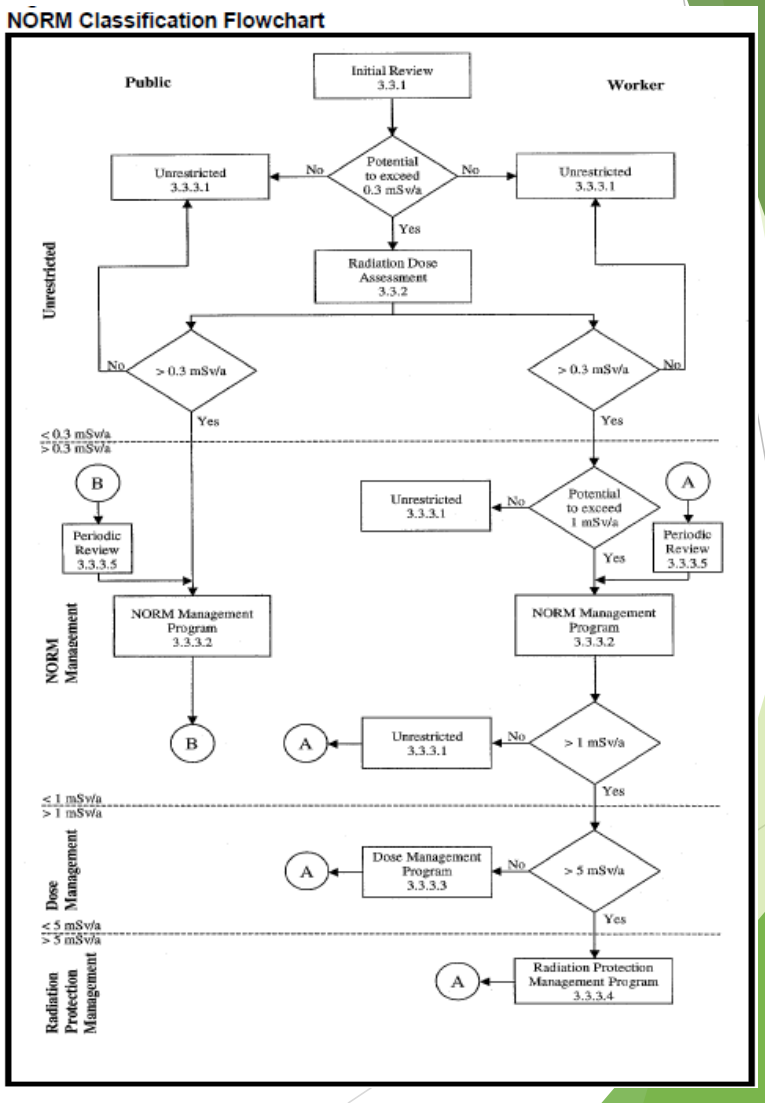
Canadian Regulatory Approach

- Canadian federal regulator (Canadian Nuclear Safety Commission - CNSC) mandate covers nuclear fuel cycle from uranium mining to nuclear power plants and transport of radioactive materials
- Most other industries impacted by NORM are under provincial legislation
- Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM) 2011
  - Jointly developed by federal, provincial, and territorial regulators
  - High-level guidance and basis for specific regulations

Canadian Guidelines for the Management of NORM

- Incorporates guidance from International Commission on Radiological Protection (ICRP) and CNSC regulations
  - ICRP principles of Justification, Optimization, Limitation
  - The emphasis is on optimization and limitation for occupational (and public) exposures
  - Recommended occupational dose limit for NORM workers
    - 50 mSv/y, 100 mSv/5y - practical limit of 20 mSv/y
    - Only applies to workers who are exposed to NORM as part of routine duties
    - Incidentally exposed workers treated as member of public with 1 mSv/y limit

- **NORM Program Classifications**
  - A dose constraint of 0.3 mSv/y is recommended
  - If < 0.3 mSv/y no further actions required
  - If > 0.3 mSv/y develop NORM management program
  - If workers doses > 1 mSv/y need Dose Management Program
    - Consider PPE, training
    - Estimate doses to workers
  - If worker doses > 5 mSv/y need formal Radiation Protection Management Program
    - PPE, training, procedures
    - Individual dosimetry



NORM Material Management

- NORM Derived Release Limits (DRLs)
  - 0.3 mSv/y used as dose constraint in calculation
  - Used to set criteria for unconditional release
  - Still may need to consider non-radiological properties and other criteria
  - Distinction between DIFFUSE NORM and DISCRETE NORM
    - Diffuse NORM – high volume, low radioactive concentration, uniformly distributed throughout the material
    - Discrete NORM – exceed concentration limit for diffuse NORM
  - DRL's calculated on pathways analysis

Diffuse NORM Sources

Unconditional Derived Release Limits- Diffuse NORM Sources

NORM Radionuclide	Derived Release Limit[a]		
	Aqueous[b] (Bq/L)	Solid (Bq/kg)	Air (Bq/m^3)
Uranium-238 Series (all progeny)	1	300	0.003
Uranium-238 (U-238, Th-234, Pa-234m, U-234)	10	10,000	0.05
Thorium-230	5	10,000	0.01
Radium-226 (in equilibrium with its progeny)	5	300	0.05
Lead-210 (in equilibrium with bismuth-210 and polonium-210)	1	300	0.05
Thorium-232 Series (all progeny)	1	300	0.002
Thorium-232	1	10,000	0.006
Radium-228 (in equilibrium with Ac-228)	5	300	0.005
Thorium-228 (in equilibrium with all its progeny)	1	300	0.003
Potassium-40	n/a[d]	17,000[c]	n/a

Discrete NORM Sources

Unconditional Derived Release Limits

NORM Radionuclide	Unconditional Derived Release Limit[(a)] (Bq)
Uranium Ore (in equilibrium with all progeny)	1,000
Uranium-238 (partitioned) (in equilibrium with thorium-234 and protactinium-234)	10,000
Thorium-230 (no progeny)	10,000
Radium-226 (in equilibrium with its progeny)	10,000
Lead-210 (in equilibrium with bismuth-210 and polonium-210)	10,000
Thorium-232 (in equilibrium with all progeny)	1,000
Radium-228 (in equilibrium with actinium-228)	100,000
Thorium-228 (in equilibrium with its short-lived progeny)	10,000
Potassium-40	1,000,000

Discrete NORM Sources

- Discrete NORM sources must also meet surface contamination limits
  - 0.5 µSv/h at 50 cm
  - 1 Bq/cm^2 averaged over 100 cm^2
  - Applies to fixed surface contamination; loose surface contamination completely removed
  - Recommended to use thin-window beta/gamma detector

Practical Implications – Rn in Workplaces

- Radon released from water impacting work environment in fish hatcheries

Practical Implications – Rn in Workplaces

- Application of Canadian NORM Guideline – province of Ontario

Program classifications for radon and NORM

Average annual concentration of radon [Bq/m^3] [1]	NORM program classification [2]
800 – 3,000	Radiation Protection Management
200 – 800	NORM Management
Background – less than 200	Unrestricted

From https://www.labour.gov.on.ca/english/hs/pubs/gl_radon.php

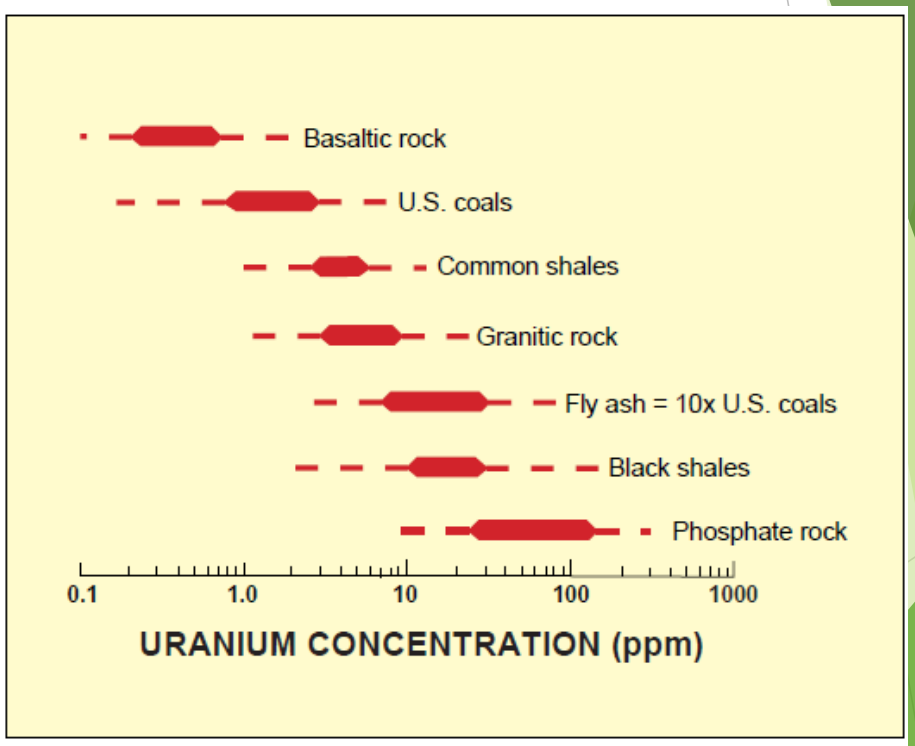
Practical Implications – Rn in Workplaces

Radon in Cody Caves Form

Monitor Number	Start Date MM-DD-YY	End Date MM-DD-YY	Location	Site Identification	Radon in pCi/l	Radon in Bq/m^3
4655692	9-19-06	10-26-06	Entrance	Cody C.1	86.1	3185.7
4655654	9-19-06	10-26-06	Entrance	Cody C.1	83.9	3104.3
4655664	9-19-06	10-26-06	Porcupine Passage	Cody C.2	85.2	3152.4
4655608	9-19-06	10-26-06	Porcupine Passage	Cody C.2	75.0	2775.0
4655697	9-19-06	10-26-06	Twilight A	Cody C.3	83.9	3104.3
4655683	9-19-06	10-26-06	Twilight A	Cody C.3	82.8	3063.6
4655651	9-19-06	10-26-06	Twilight B	Cody C.4	83.3	3082.1
4655710	9-19-06	10-26-06	Upper Rm	Cody C.5	91.8	3396.6
4655642	9-19-06	10-26-06	Upper Rm	Cody C.5	90.5	3348.5
4655652	9-19-06	10-26-06	Balcony Rm	Cody C.6	102.8	3803.6
4655633	9-19-06	10-26-06	Balcony Rm	Cody C.6	94.5	3496.5

Practical Implementation Issues

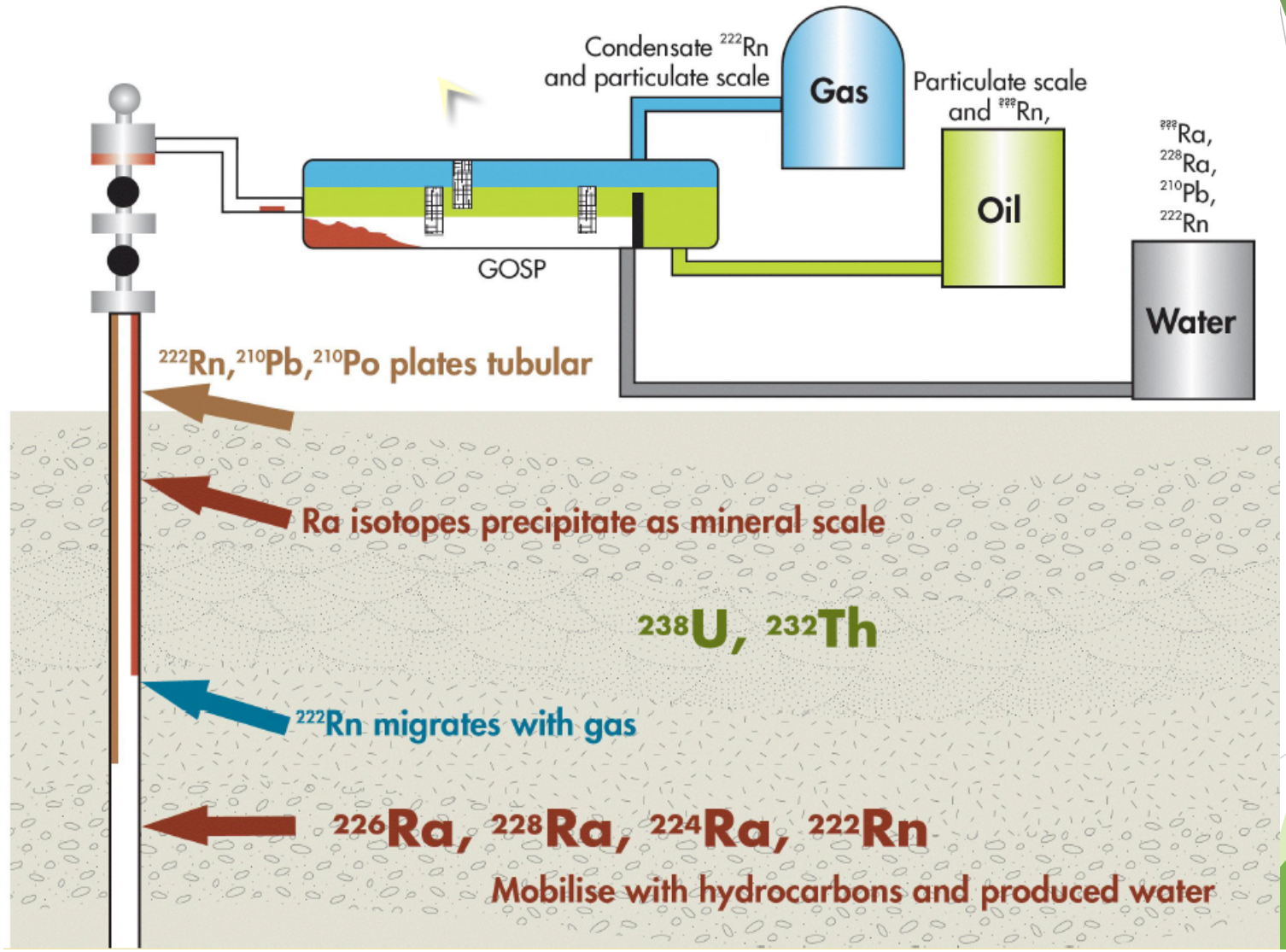
- Coal ash – about 10% by weight and radionuclides can be concentrated by a factor of ~10x
- Fly ash long-term use and disposal



From US Geological Survey Fact Sheet FS-163-97

Practical Implementation Issues

- Oil and gas industries have to deal with NORM
- Occupational issues
  - Radon exposures
  - Inhalation hazard from long-lived alpha activity
  - External gamma radiation

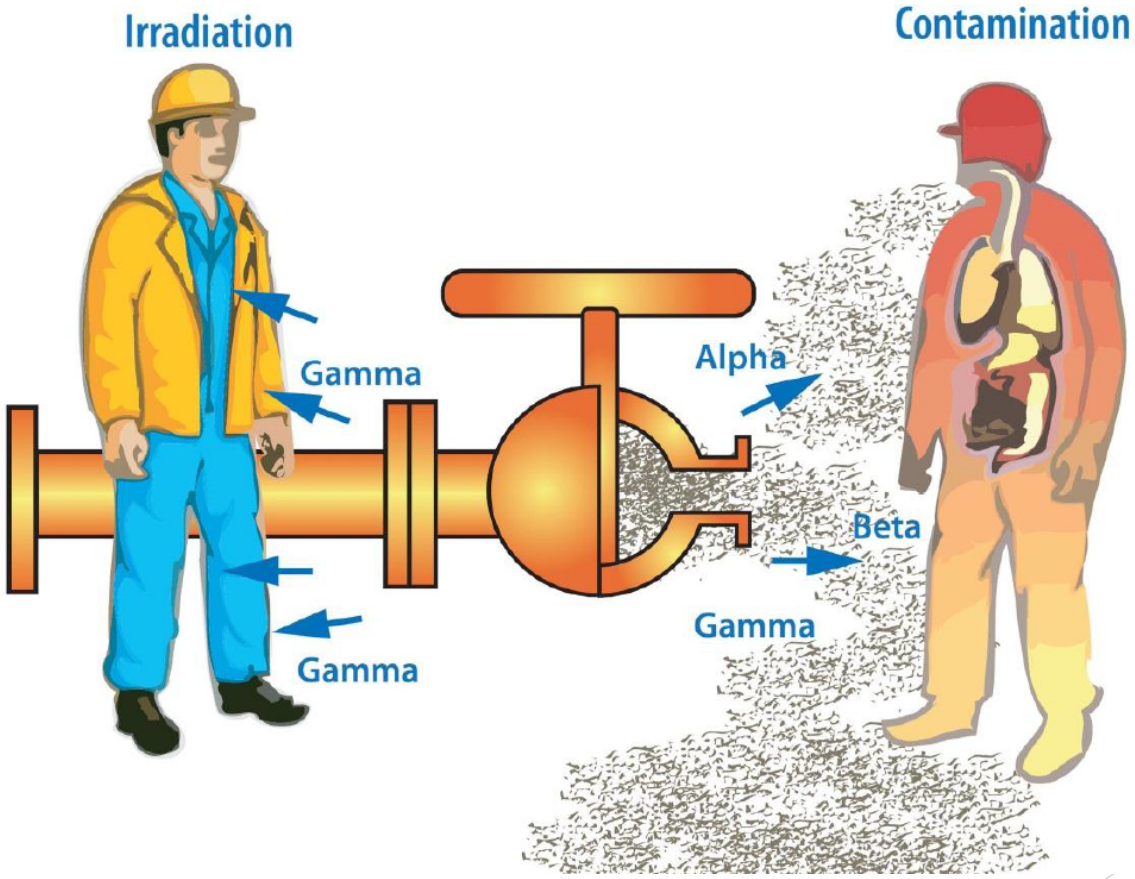

Condensate ^{222}Rn and particulate scale
Gas
Particulate scale and ^{222}Rn,
Oil
^{226}Ra, ^{228}Ra, ^{210}Pb, ^{222}Rn
Water
GOSP
^{222}Rn,^{210}Pb,^{210}Po plates tubular
Ra isotopes precipitate as mineral scale
^{238}U, ^{232}Th
^{222}Rn migrates with gas
^{226}Ra, ^{228}Ra, ^{224}Ra, ^{222}Rn
Mobilise with hydrocarbons and produced water

Practical Implementation Issues

Radionuclide	Natural gas Bq/m^3	Produced water Bq/L	Hard scale Bq/kg	Sludge Bq/kg
U-238		trace	1 - 500	5 - 10
Ra-226		0.002 - 1200	100 - 15 million	50 - 800,000
Po-210	0.002 - 0.08		20 - 1500	4 - 160,000
Pb-210	0.005 - 0.02	0.05 - 190	20 - 75,000	10 - 1.3 million
Rn-222	5 - 200,000			
Th-232		trace	1 - 2	2 - 10
Ra-228		0.3 - 180	50 - 2.8 million	500 - 50,000
Ra-224		0.05 - 40		

Source: IAEA 2003, Safety Report Series 34.

Practical Implementation Issues



Practical Implementation Issues

- Occupational safety measures
  - PPE
  - contamination control
  - work practices to minimize generation of airborne dust
  - Signage for radiation areas
  - Radiation surveys
    - Process area and equipment
    - Po-21, Bi-210, Pb-210 in pipes have no discernable gamma signal
    - Scrap metal being shipped off site
    - Airborne radioactivity sampling

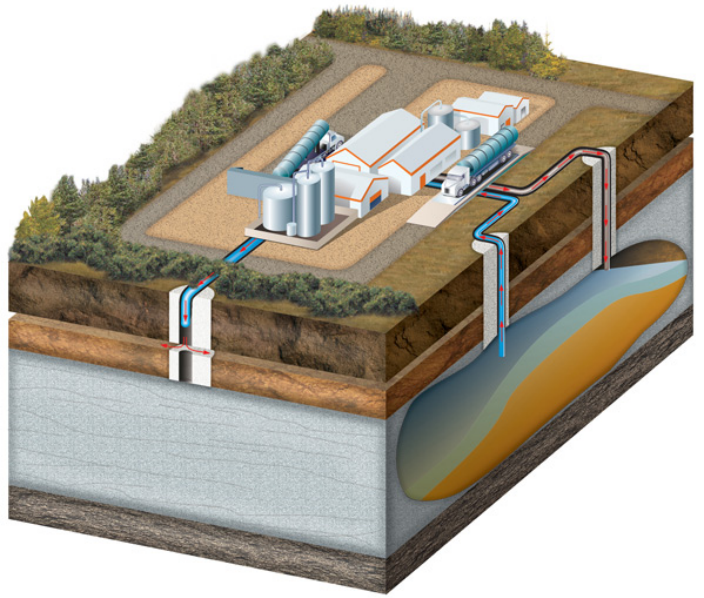
Practical Implementation Issues

- Transport of NORM governed by CNSC (federal) Transport and Packaging of Radioactive Materials Regulations and Transportation of Dangerous Goods Regulations
  - NORM contaminated equipment

A SECURE NORM technician is conducting a NORM screening survey on down-hole tubing and equipment prior to release from location.

Practical Implementation Issues

- NORM Waste Disposal
  - Underground salt cavern
  - 300 Bq/g per radionuclide
- Accepts other types of waste
  - Solvents, greases, lubricants, paint wastes, metal contaminated sludges, non-chlorinated organic wastes



Practical Implementation Issues

- Landfill Disposal of NORM
  - 70 Bq/g (except 55 Bq/g for Ra-226, 2 Bq/g for U-Nat, Th-232 – 6 Bq/g)
  - Some hazardous substances also accepted

SECURE's Pembina Landfill is located north of Drayton Valley at SE-18-050-11W5M. NORM disposal

Conclusions

- NORM issues impact many industries
- Doses to workers and public are generally low
- Standard occupational radiation protection practices work well to control occupational exposures
- Disposal of NORM aligned with other hazardous wastes
- Growing awareness of NORM issues

Questions???

Primary References

- Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM). Prepared by the Canadian NORM Working Group of the Federal Provincial Territorial Radiation Protection Committee. Health Canada 2011
- Doug Chambers 2013. Radiological Protection in North American naturally occurring radioactive mineral industries. Proceedings of the Second International Symposium on the System of Radiological Protection
- G. Hughes and C. Cuthill 2017. Management of Naturally Occurring Radioactive Materials (NORM) in Western Canada. Presentation at CRPA Conference Saskatoon 2017
- Suncor Energy Naturally Occurring Radioactive Material Standard. Revision date 2017/07/31
- World Nuclear Association. Naturally Occurring Radioactive Materials (NORM). http://www.world-nuclear.org/information-library/safety-and-security/radiation-and-health/naturally-occurring-radioactive-materials-norm.aspx