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International workshop
Radiation Safety & the Mine Worker
An introduction
African nations
ICEM Sub-Sahara n Region
Radiation Safety
Institute of Canada
Institut de radioprotection du Canada
Presented by
Fergal Nolan, President
Johannesburg, South Africa May 27, 2009
RADIATION SAFETY INSTITUTE OF CANADA
GOOD SCIENCE IN PLAIN LANGUAGE®

Radiation Safety Institute of Canada

We begin with a painful lesson . . .

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For unions and workers in the world's mining industries, worker exposure to radiation is a serious issue. The major concern is the presence of a radioactive gas (called "radon") in underground mines. Many hundreds of miners have died from excessive exposure to radon and its radioactive products in the world's uranium mining industry. That fact is well known and documented.

A fact not so well known is that exposure to radioactive radon gas is not limited to uranium mines. Radiation from radon is a continuing concern in the gold mining industry, especially in South Africa. It is a significant concern also for coal miners in China and for underground miners in a number of countries in Africa and elsewhere.

One of the world's worst mining disasters from radiation exposure occurred in Canada. The miners' union (United Steelworkers) estimates that up to 400 healthy uranium miners suffered long and painful lung cancer deaths from excessive radon exposure in the old Elliot Lake uranium mines of central Canada (now closed). Radiation exposure from radon has been documented as the cause of at least 221 of these deaths. Workers compensation is now approaching $100 million.

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A painful lesson . . . (continued)

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Some years after this disaster, new, high grade uranium mines were proposed for western Canada. But Canadians had learned from experience.

Before the new mines were permitted, the independent Radiation Safety Institute of Canada took the initiative of working with Canadian federal and provincial governments, with the uranium mining companies and with labour unions in a combined effort to make certain that these new mines would be designed, operated and regulated to protect workers from exposure to radiation. The purpose of these efforts was to ensure that never again in Canada would a uranium worker suffer and die from radiation exposure in a uranium mine.

Dr Fergal Nolan, President of the Radiation Safety Institute of Canada, led the effort to promote and implement a new approach to radiation safety in Canadian uranium mining. In this workshop, he will discuss in plain language what it takes to make sure that uranium, gold and other mine workers are protected from radiation exposure. This is an introductory, non-technical workshop aimed at union leaders and worker representatives. Open and frank dialogue on the issues will be encouraged and welcomed.

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Acknowledgements

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Appreciation

This international workshop was prepared by the *Radiation Safety Institute of Canada* and presented in Johannesburg at the invitation of the *International Federation of Chemical, Energy and Mineworkers (ICEM)* and with the encouragement and assistance of the *National Union of Mineworkers of South Africa (NUM).*

The *Radiation Safety Institute* wishes to express its appreciation most particularly to *Joe Drexler and his staff* (ICEM) and to *President Zokwana Senzeni and his staff* (NUM) for their support and cooperation, and to *President Leo Gerard, John Perquin and Steve Hunt* (United Steelworkers, USA and Canada) and *Dave Shier* (Power Workers Union) for their support.

Financial Sponsors

International Federation of Chemical, Energy and Mineworkers (ICEM Geneva)
National Union of Mineworkers (NUM, South Africa)
United Steelworkers (USA-Canada)
and
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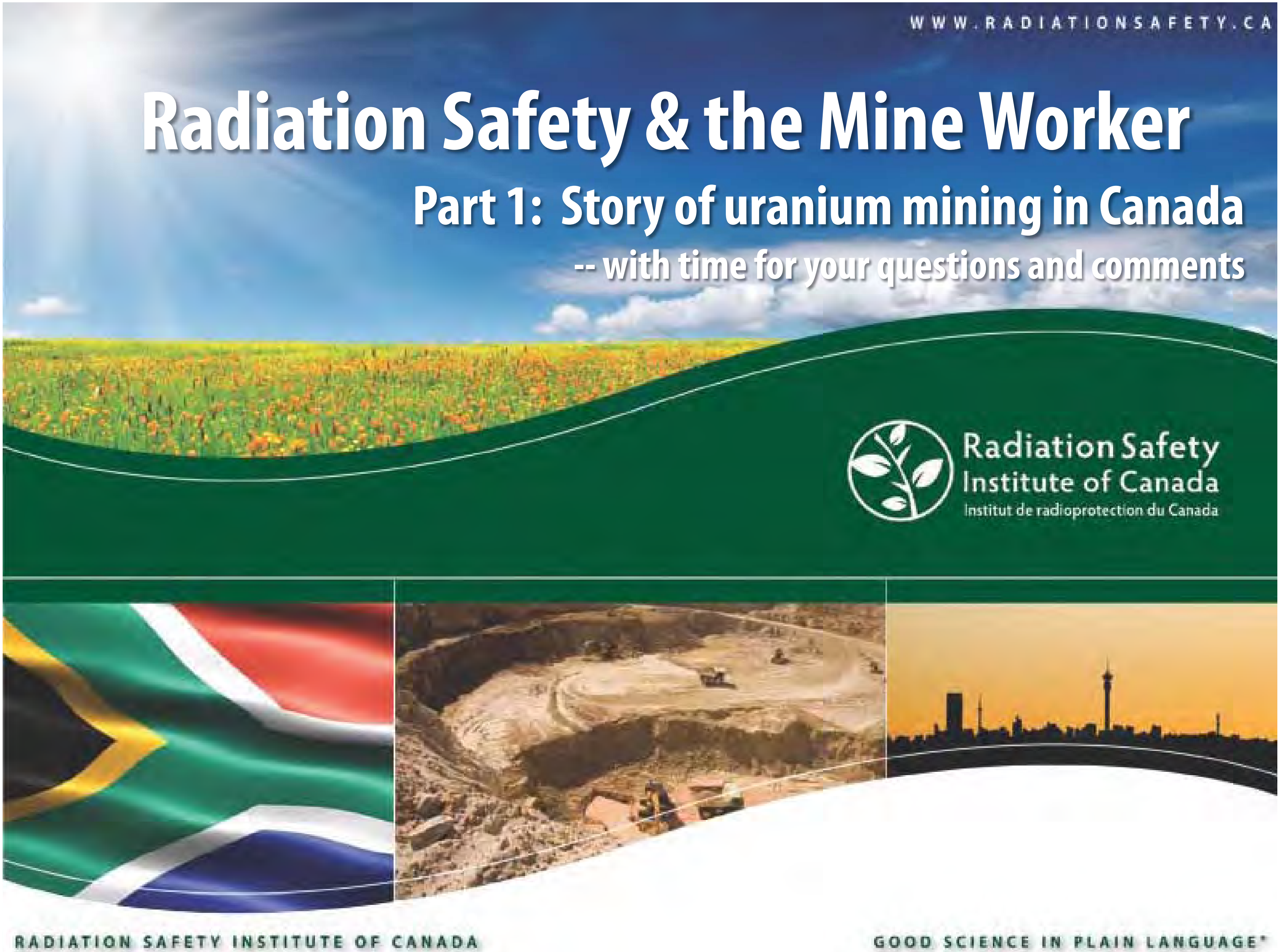
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Part 1: Story of uranium mining in Canada
-- with time for your questions and comments
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Canada – geography of a mining country

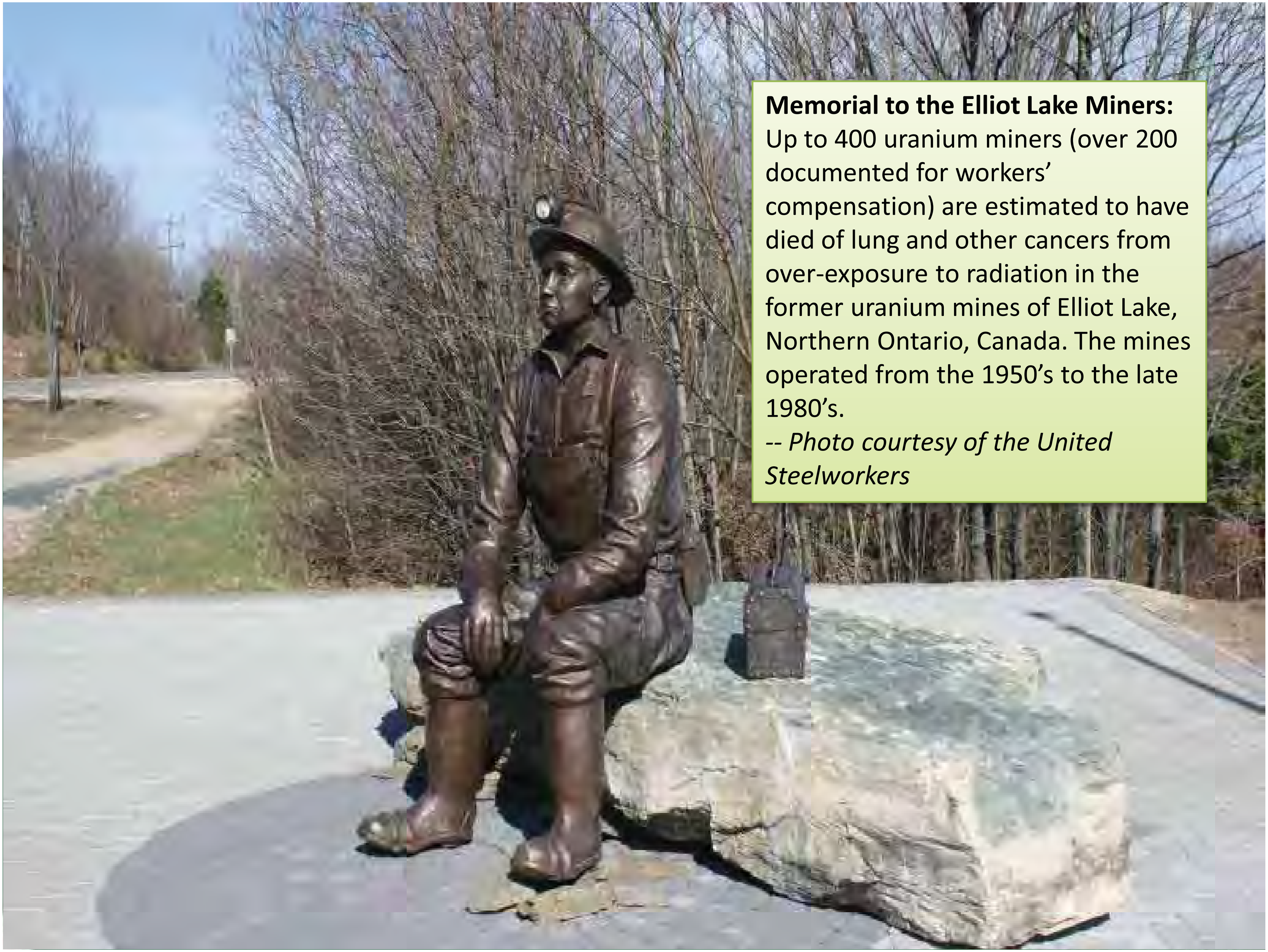
Canadian Jurisdictions: National Federal government plus 10 Provinces in the South and 3 Territories in the North, each with their own governments. Population: 32 million spread across 5 time zones.

The present high-grade uranium mining industry is located in the northern part of the western Province of Saskatchewan. The old uranium mining industry was located in the northern part of the eastern Province of Ontario. New mines are now expected in other provinces and territories.

Challenge of winter in Canada's Far North - aerial view of a diamond mine

– Photo courtesy of the Kivalik Diamond Mine

Challenge of winter in Canada's Far North - Photo courtesy of the Kivalik Diamond Mine



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

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Memorial to the Elliot Lake uranium miners

- Photo courtesy of the United Steelworkers

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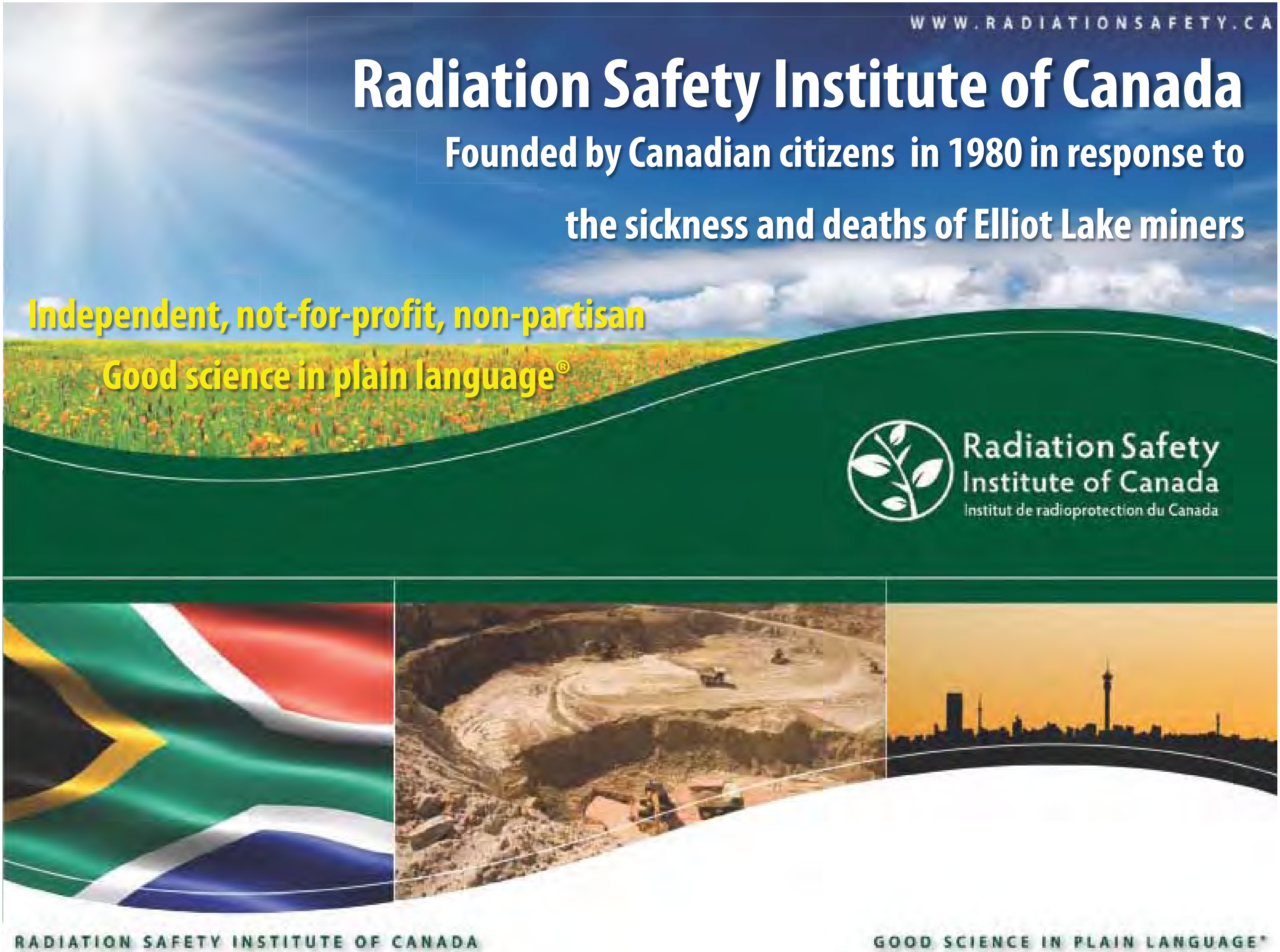
Memorial to the Elliot Lake uranium miners

- Photo courtesy of the United Steelworkers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Founded by Canadian citizens in 1980 in response to
the sickness and deaths of Elliot Lake miners
Independent, not-for-profit, non-partisan
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A word about the Radiation Safety Institute …

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"Good science in plain language"®

The Radiation Safety Institute of Canada is a federally incorporated, not-for-profit organization and registered charity that is independent of industry, government and labour. The Institute's sole concern is radiation safety. It does not take sides in the debate over nuclear energy, but cooperates with all parties to promote radiation safety in workplaces of every kind, in homes and schools and in the environment.

Our aim is to protect people from undue radiation exposure wherever it occurs. We assist those who are concerned about radiation exposure by providing "good science in plain language."® We also provide a range of scientific, technical and educational services for workers, industry, government and the public. Our radiation dosimetry service for industry and workers is licensed, regulated and audited by the federal Canadian Nuclear Safety Commission (CNSC).

Board of Governors and Staff

Governors are chosen for good sense, practiced judgment and broad experience and are elected independently from the business, academic, legal, health care and other communities and from labour, industry and government. A highly educated and professionally qualified staff of radiation scientists, educators and other professionals conduct Institute programs and services.

Facilities

National Education Centre in Toronto, Ontario (Eastern Canada)
National Laboratories in Saskatoon, Saskatchewan (Western Canada)
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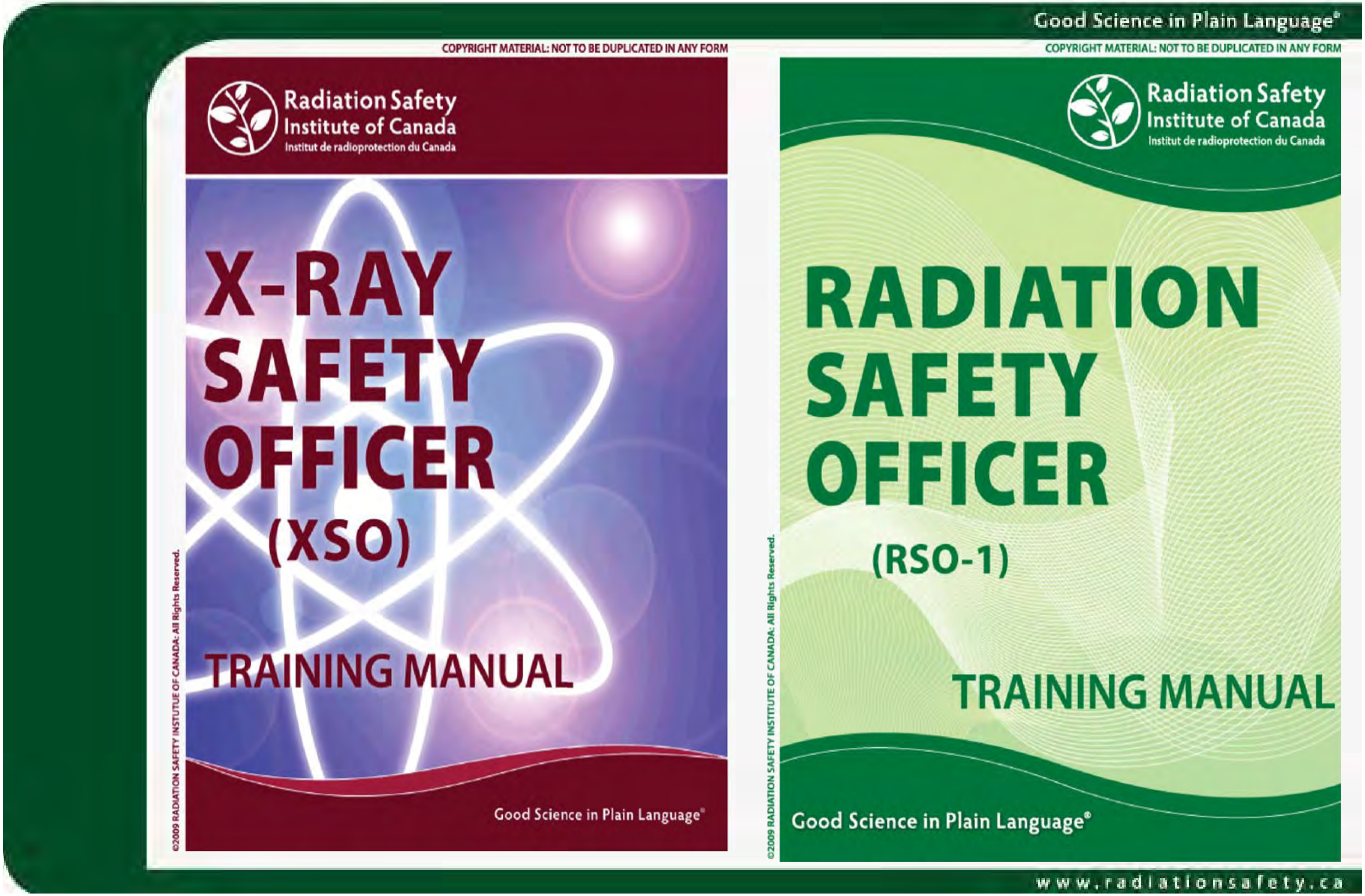
Example: Manuals of two of the most popular training courses National Education Centre, Toronto



Staff at work National Laboratories , Saskatoon

Radon progeny and LLRD dosimetry service:
Preparation of PAD dosimeters for Canadian uranium mines National Laboratories, Saskatoon

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Image of actual radiation impact of radioactive radon progeny

Alpha track image from PAD dosimeter

National Laboratories, Saskatoon

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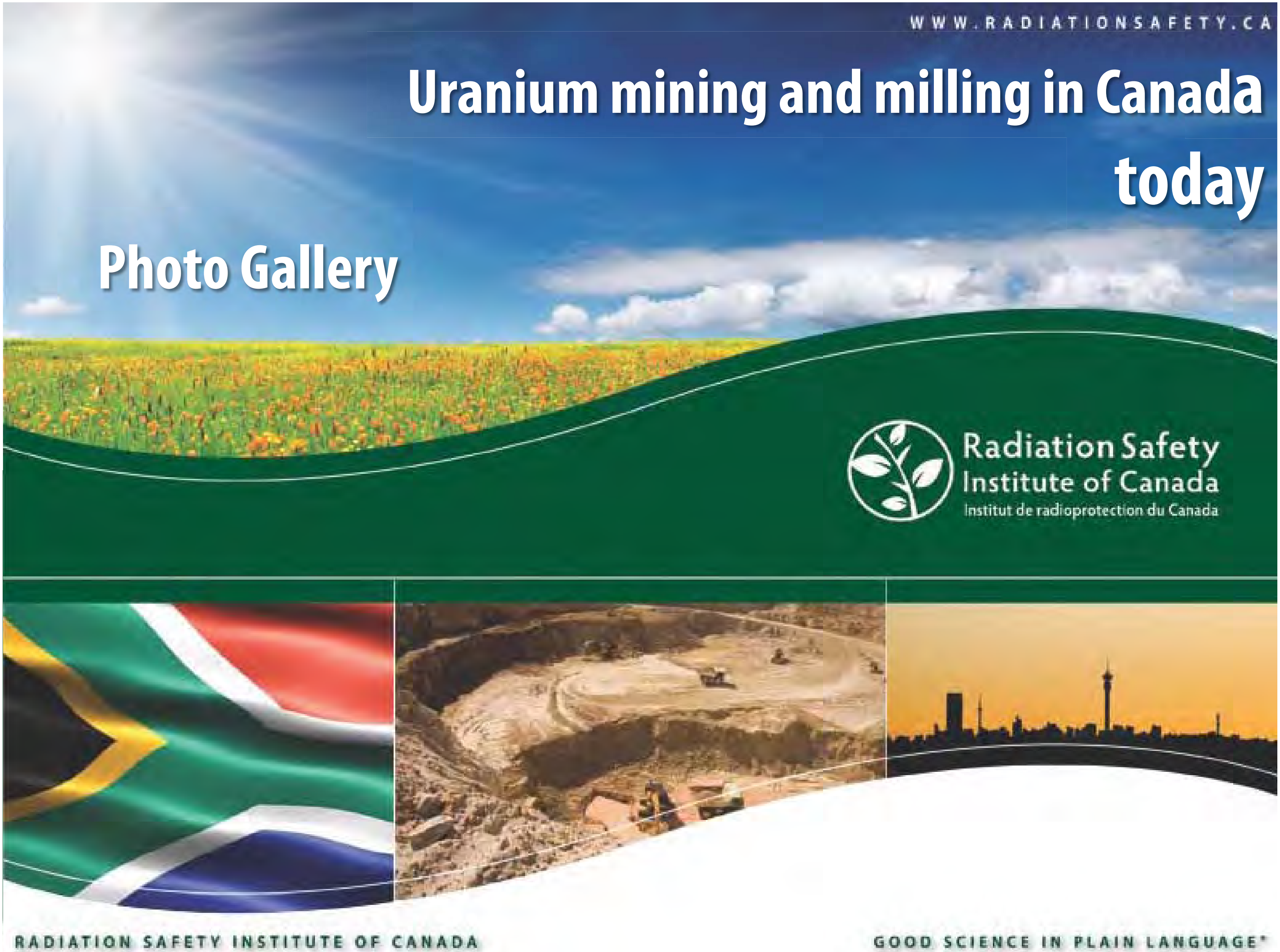
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Uranium mining and milling in Canada today
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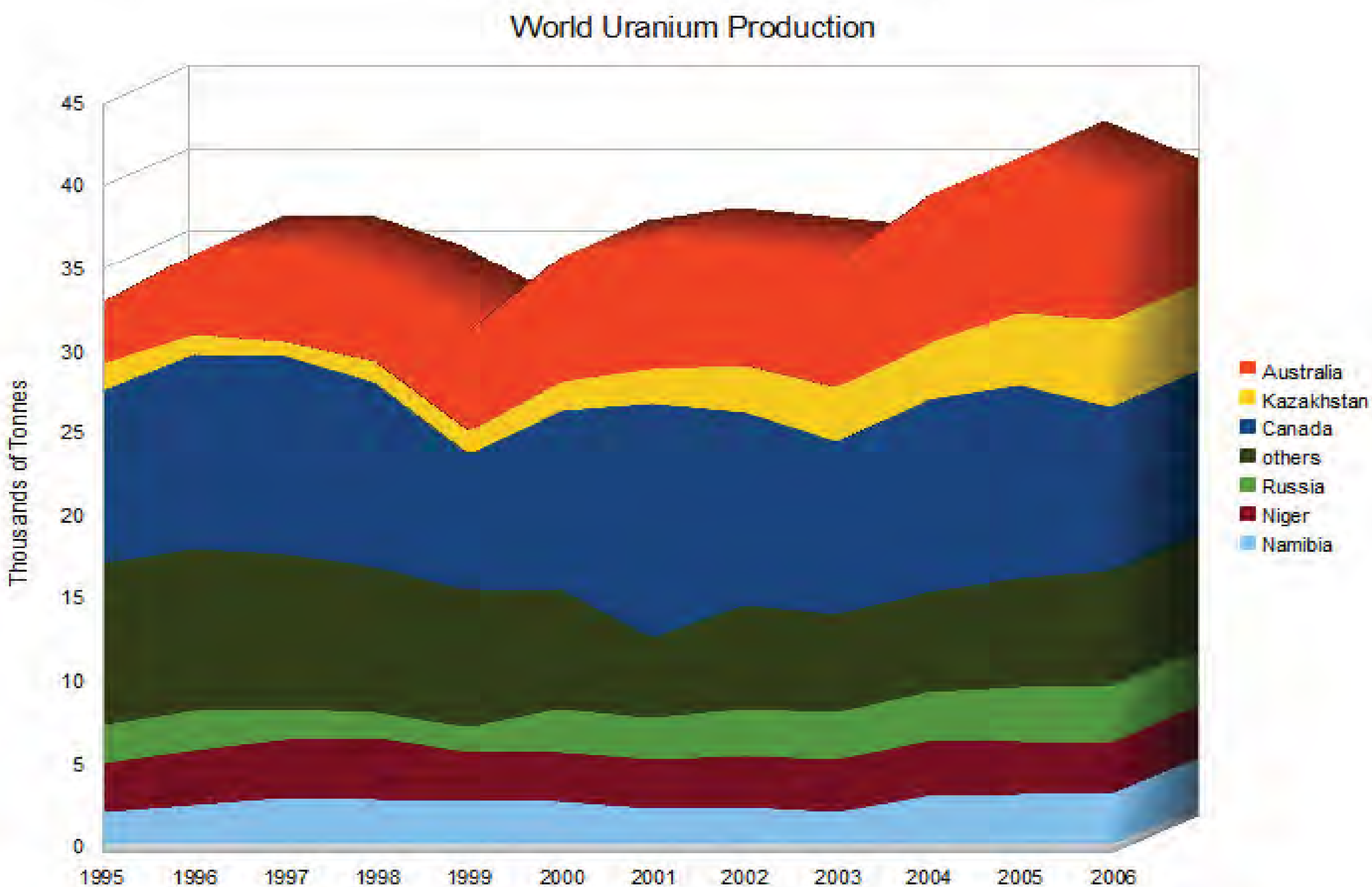
Major Producing Countries 1995-2006



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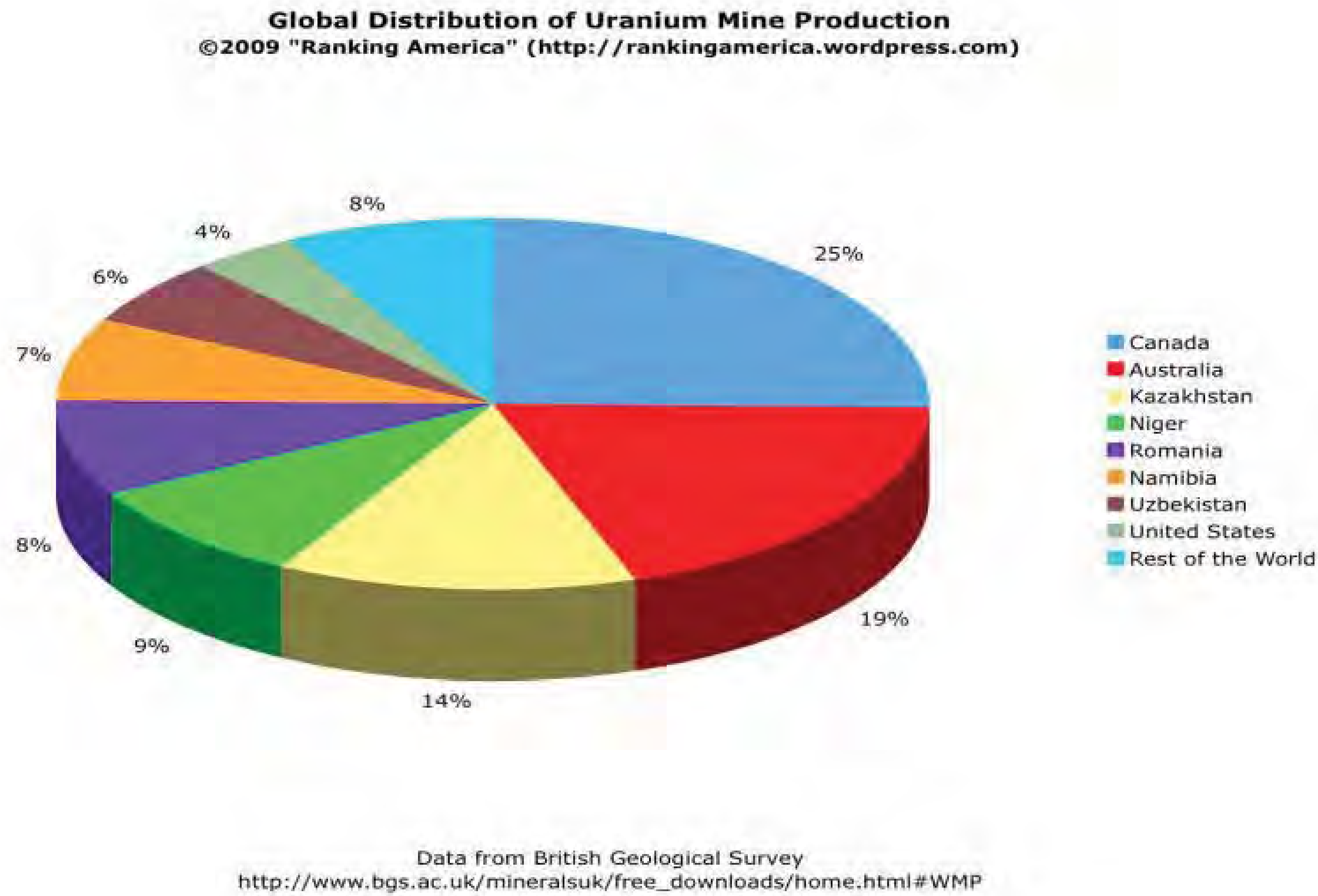
2009 Major Producing Countries



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Example of local wildlife in the uranium mining areas of northern Saskatchewan -- Photo Credits: AREVA Resources Canada

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Another example: Local wildlife in the uranium mining areas of northern Saskatchewan

Photo Credits: AREVA Resources Canada

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- - Photo courtesy of Cameco Corporation

Rabbit Lake
Located in northern Saskatchewan, Rabbit Lake is the longest producing uranium operation in Saskatchewan.

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McArthur River Mine - one of the world's richest uranium ore bodies
-- Photo courtesy of Cameco Corporation

Raisebore Drilling at McArthur River
From the 530 metre level a pilot hole is drilled down through the orezone into the tunnel on the 640 metre level.

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Cigar Lake Mine – another of the world's richest uranium ore bodies

-- Photo courtesy of Cameco Corporation

Cigar Lake
Underground tunnels at Cigar Lake are reinforced with concrete to ensure a safe working environment.

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Miner wearing PAD radon progeny dosimeter (yellow instrument on belt)

-- Photo courtesy of Cameco Corporation

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Rabbit Lake
Remote control scoop tram at the Rabbit Lake mine.

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Environment: McClean Lake Mill - JEB Tailings Management controls the release of radioactive emissions and dust from mill tailings. --Photo credits: AREVA Resources Canada

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Environment: Uranium tailings management

-- Photo credits: AREVA Resources Canada

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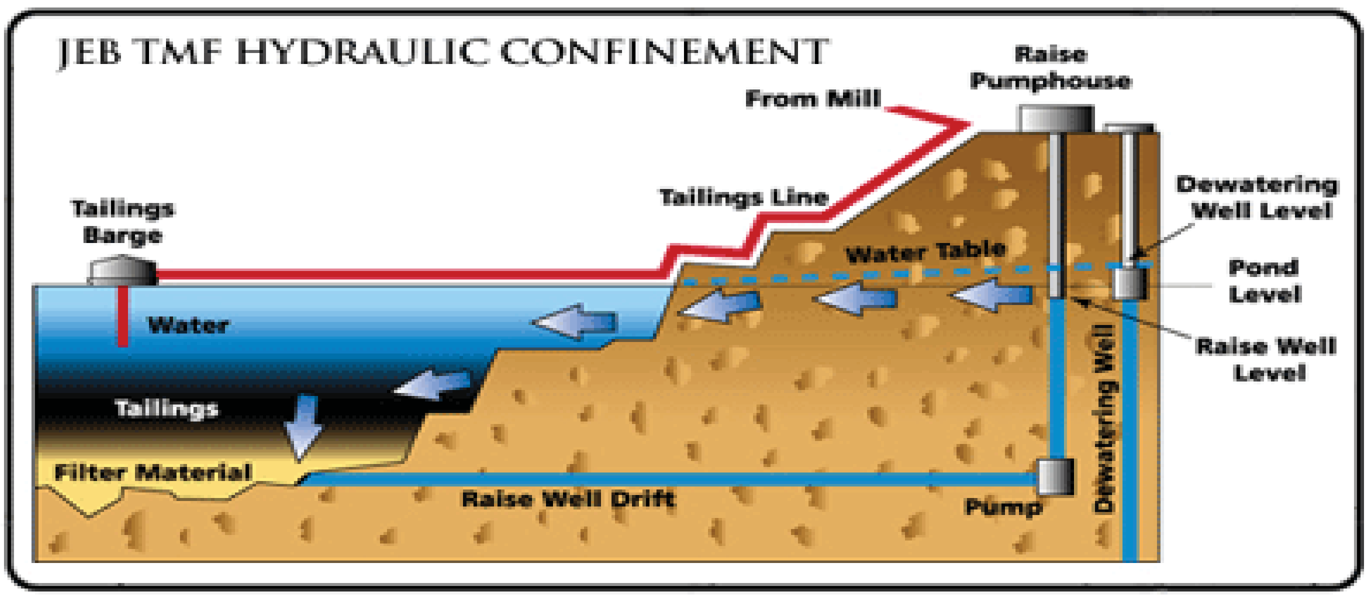

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Environment: Key Lake uranium mine and mill site

-- Photo courtesy of Cameco Corporation

Key Lake
Water samples are collected at Key Lake as part of the environmental management system.

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Yellowcake - the final product of uranium mining and milling
-- Photo courtesy of Cameco Corporation

Rabbit Lake
Prior to shipping, the yellowcake is packaged into special steel drums.

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Preparing yellowcake for shipment to the refinery

Photo courtesy of Areva Resources Canada

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<u>NOTE</u>: The worker is wearing a mask and air pack, headgear, protective clothing, gloves and shoe coverings

-- Photo courtesy of AREVA Resources Canada

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Uranium refinery, Port Hope, Ontario

-- Photo courtesy of Cameco Corporation

Port Hope
Inside UF_6 plant.

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Shipping the refined fuel in secure transportation cylinders

-- Photo courtesy of Cameco Corporation

Port Hope
At the Port Hope conversion facility, a UF_6 cylinder is being loaded for shipping.

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Manufacturing tubes for fuel bundles for nuclear reactors

-- Photo courtesy of Cameco Corporation

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Cameco Fuel Manufacturing Inc.
Zirconium tubes are manufactured at the Cobourg facility.

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Finished nuclear reactor fuel bundle

-- Photo courtesy of Cameco Corporation

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Cameco Fuel Manufacturing Inc.
Fuel bundles manufactured at Fuel Manufacturing are used to generate electricity in Candu reactors.

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Final destination – a Canadian nuclear generating station

-- Photo courtesy of Cameco Corporation

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Bruce Power - A Reactor
Located in Ontario, Bruce Power's six operating nuclear power plants produce enough clean electricity for a city the size of Toronto. Cameco, as partner provides all fuel requirements.

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End of Part 1
Let's take a break!
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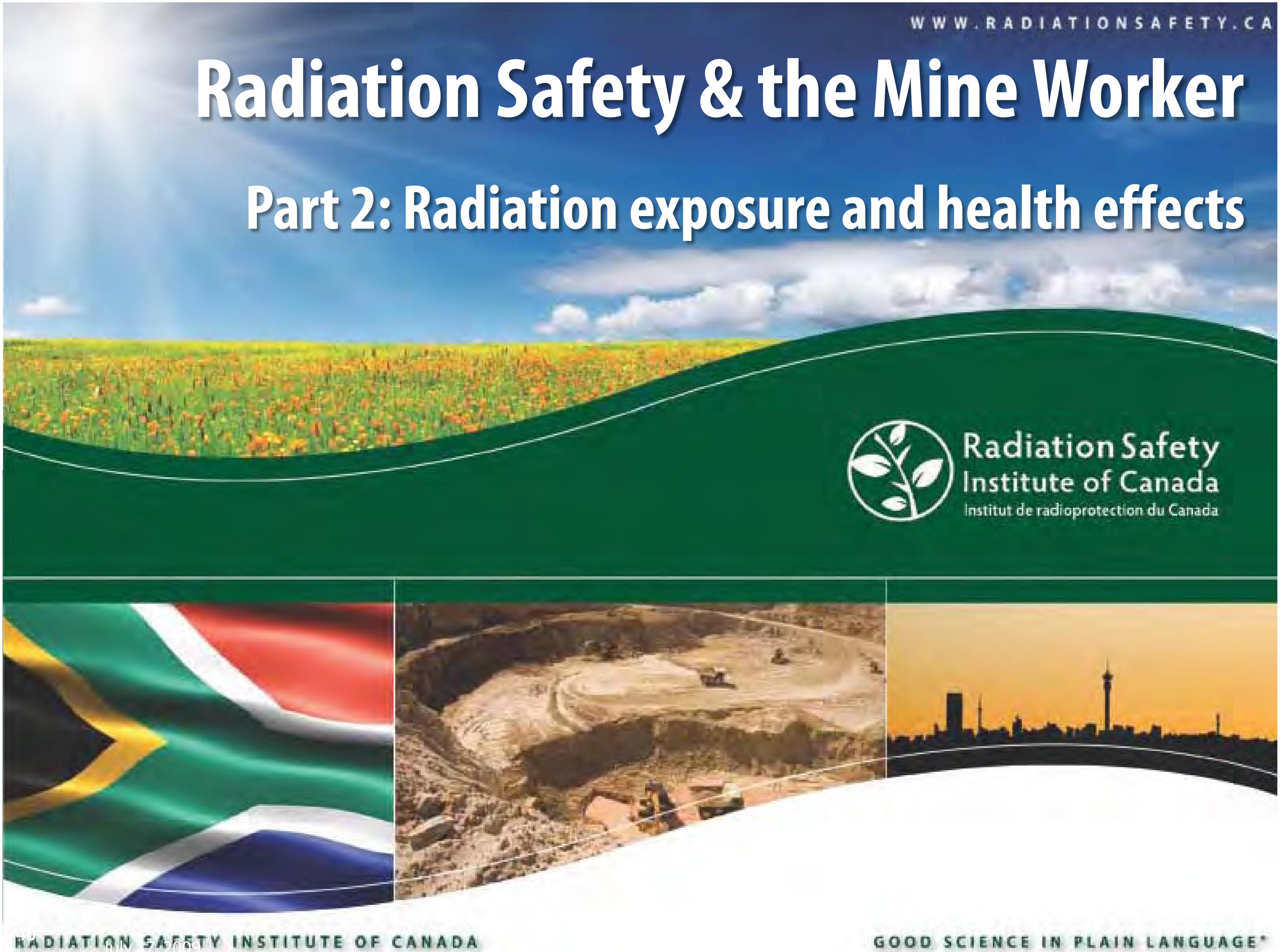
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Part 2: Radiation exposure and health effects
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Session 1

WHAT IS RADIATION?

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What is Radiation?

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Atoms!

All matter is made of atoms.

- We cannot see them, but they are the tiny particles that are the building blocks of our world.

Atoms are made of even smaller particles called protons, neutrons and electrons.

- Protons have a positive electric charge
- Electrons have a negative electric charge
- Neutrons have no charge at all.

The centre of the atom is called the nucleus.

- Protons and neutrons are found in the nucleus.

Electrons are not at the centre of the atom.

- They orbit the nucleus, much like the planets orbit the sun.
- They are very tiny particles, but their negative electric charge is as strong as the proton's positive charge.

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What is Radiation?

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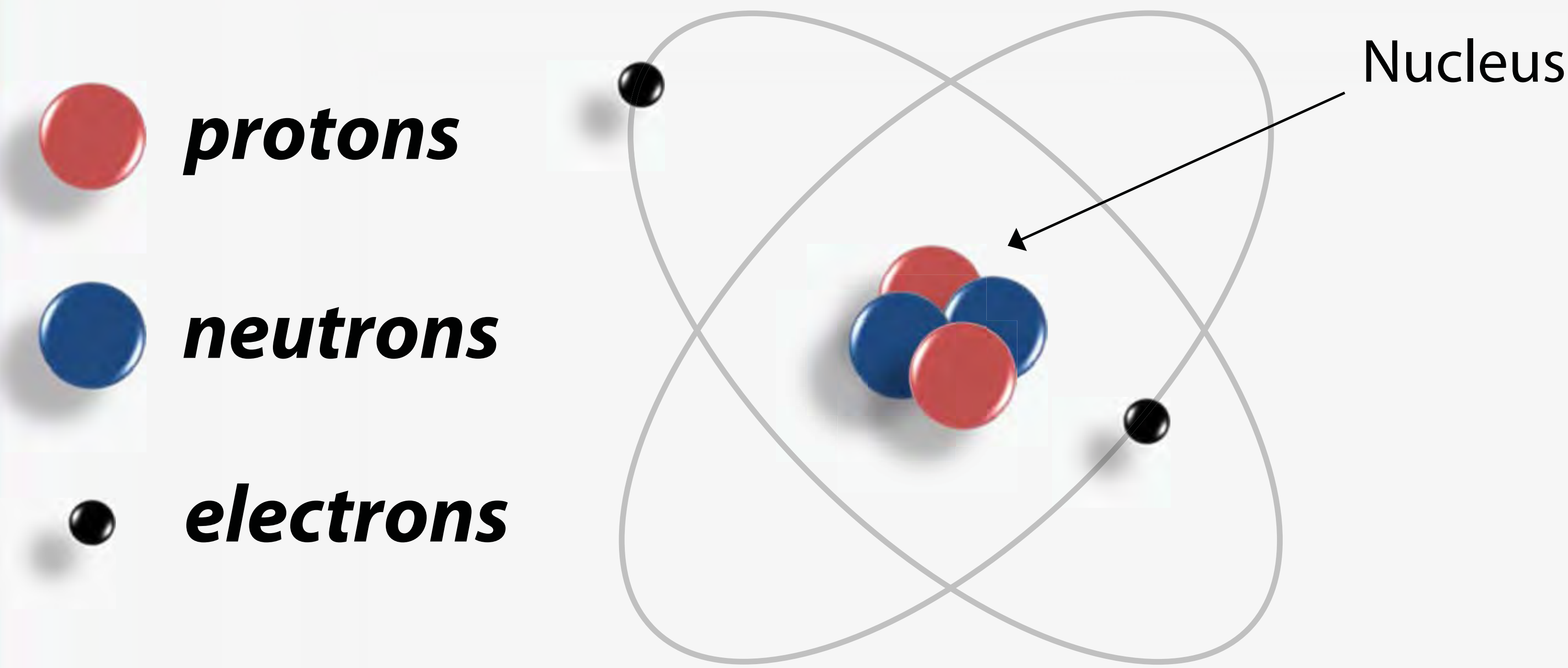
Example: Helium atom



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What is Radiation?

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Radiation

- Radiation is "stuff" that flies out of an atom
- "Stuff"? What "stuff"?
  - A particle from the nucleus (*proton, neutron)*
  - An electromagnetic *wave* of pure energy
- High speed, high energy
  - Radiation from an atom travels at a very high speed
  - Because it is travelling so fast, it has a lot of energy

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What is Radiation?

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"Radioactive"

The atoms of most elements are stable:

- Stable atoms do not suddenly change into some other kind of atom– *for example*:
  - Stable gold atoms do not suddenly turn into silver atoms - they are always gold atoms
  - Stable iron atoms do not suddenly turn into copper atoms – they are always iron atoms

However - some elements are *not* stable:

- *In an instant*, their atoms change – into other kinds of atoms to make an entirely different element!
  - Not all of them at once – but change is happening constantly
  - It's called "decay"
- When an unstable atom changes, *it gives off a tiny burst of radiation*.
  - That is why it is called *"radio"* – *"active"*

Uranium is radioactive - an element with unstable atoms

- Uranium atoms are at the beginning of a radioactive decay chain of billions of years
- Chain ends eventually in common *lead*, a non-radioactive element made of stable atoms

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What is Radiation?

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"Radioactivity"

Some radioactive materials are more *active* than others

- It is important to know how *active* they are
- How much *radioactivity*?

How do we find out?

- We measure the activity with special instruments

Unit of measurement:

- *Becquerel (Bq)* - in honor of French scientist, *Henri Becquerel*

Examples:

- 1 Bq = 1 radioactive decay/change *per second*
- 100 Bq = 100 radioactive decays/changes *per second*
- 1,000 Bq = 1,000 radioactive decays/changes *per second*

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What is Radiation?

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Remember...

Radioactive material:

- *Always* radioactive - radiation from it cannot be slowed down, speeded up or stopped
- Radiation from the material continues until it completely decays and ceases to exist

Example:

- Uranium is *always* radioactive
  - *In four and a half billion years* – half will have changed
  - *In another four and a half billion* – half of the remainder – and so on *by halves*
  - Called *"half-life"* of a radioactive material
  - Some half-lives take only seconds in highly radioactive elements

Radiation machines (X-ray, CT Scans):

- Machines are *not* radioactive
  - Emit radiation only when switched on
  - Radiation stops when machine is switched off
  - Machine requires electricity to produce radiation

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What is Radiation?

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Four kinds of radiation

1. Alpha radiation:

Very serious radiation hazard for miners

- Hundreds have died of lung cancer from alpha radiation in Canada, USA and other countries
- Source: radon and its radioactive products

Present everywhere because uranium and its decay product, radon gas are everywhere

- Can be a high risk in underground in mines – confined spaces
- Also in homes, schools, buildings, service vaults, service tunnels, warehouses, etc

Gets into the body only through breathing

- Heavy *particle* from the nucleus of a very heavy radioactive atom (e.g. uranium, radon)
- Loses energy very quickly - stops after a few centimetres in air
- ***Can be stopped by paper ! - or the dead outer layer of human skin!***

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What is Radiation?

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2. Beta radiation

- Very small, very light *particle* from the nucleus – can travel about two metres in air
- Can penetrate through the dead layer of skin on our bodies and reach the live skin underneath.
- ***Can be stopped by plywood !– or even a sheet of plastic!***

3. Gamma radiation (gamma rays):

- Very high energy electromagnetic *waves* from the nucleus of the atom
- Gamma rays are *very penetrating*:
  - *If thick enough, lead* can stop most of it, but not completely
- ***Can easily travel through our bodies***
- ***Some will hit tissue and can cause damage***

4. X-ray radiation:

- High energy electromagnetic waves produced by *special machines*
- Like gamma rays, x-rays are *very penetrating* - we can never completely stop them
  - *Dense materials, like lead, reduce the number of x-rays that will reach our bodies.*
- ***Can easily travel through our bodies***
- ***Some will hit tissue and can cause damage***

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Session 2

EXPOSURE TO RADIATION

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Exposure to Radiation

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Internal exposure

Source of radiation is ***inside*** your body

- Example: banana
  - Contains small amount of a radioactive form of Potassium (Potassium 40) Emits radiation internally while it is *inside your body*
- Example: medical diagnosis
  - Radioactive material is injected *into your body* to assist in diagnosis – radioactive iodine into your thyroid gland
- Example: radon gas in a mine
  - Radioactive particles from the decay of radon gas are breathed into your lungs *inside your body*. They are called "radon progeny" ("children of radon")
  - Radon progeny atoms: short half-lives – decay quickly with bursts of radiation
  - The cells of your lungs are exposed to this internal radiation

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External exposure

Source of radiation is ***outside*** your body

- Example: Medical or dental X-ray
  - exposure from a medical machine
- Example: Industry:
  - non-destructive testing of materials – exposure from industrial X-ray machines
- Example: Underground mine
  - exposure to gamma radiation from radioactive ores
- Example: Radioactive wastes
  - exposure to gamma radiation from wastes

Exposure to radiation does not mean you become radioactive!

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Exposure to Radiation

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Radiation in nature
("background radiation")

Cosmic radiation:

- Space is a vast ocean of radiation - many kinds, including gamma rays
- Most stopped by Earth's atmosphere - protective shield
- Some radiation does get through - sunburn, skin cancers (UVA, UVB)
- Major concern for astronauts, airline crews, frequent business fliers

Radiation from planet Earth:

- Planet Earth: many kinds of natural radioactive materials
  - underground and on the surface in soil and water
  - Potassium-40, carbon-14 , uranium, thorium, radon, radon progeny
- We are exposed to some radiation every day emitted by these materials

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Exposure to Radiation

Good Science in Plain Language

Radiation in nature
("background radiation")

Our food:

- Radioactive materials in the soil are absorbed in the nutrients and minerals taken up by the plants and animals we use for food.
- When we eat the food, we consume the radioactive atoms which become an *internal* source of radiation.
- Potassium-40, which is contained in bananas, and carbon-14, which is contained in all plant and animal matter, are two examples of radioactive atoms found in foods.

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Exposure to Radiation

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Radiation in nature
("background radiation")

Will it harm me?

- All radiation exposure carries *risk* of harm
- We can't eliminate background radiation
- Radiation exposure from nature is so low – not usually a concern
- Scientific consensus:
  - "There is no evidence of increased cancer risk at natural background levels" (Health Canada, *Safety Code 29)*

Exceptions: workplace exposure

- Radon: underground workers (mines, tunnels), enclosed spaces in homes, buildings, warehouses
- Cosmic radiation: aircrews, frequent fliers, astronauts, outdoor workers

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Session 3

HEALTH EFFECTS OF EXPOSURE TO RADIATION

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Effects on my health

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Ionizing radiation

- Enough energy to change the structure of atoms in my body
  - Alpha radiation
  - Beta radiation
  - Gamma radiation
  - X-ray radiation

Non-ionizing radiation

- Not enough energy to change the structure of atoms in my body
  - Radio waves
  - Microwaves
  - Infrared (e.g., the heat from a fire)
  - Visible light

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Effects on my health

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How can radiation change my body?

Role of DNA:

- DNA is the "blueprint" of the body: it contains all the genetic information.
- My DNA dictates
  - What each cell in my body is for (lung, heart, brain, hand, foot, finger, finger nail, etc),
  - What each cell is to do: when it is to start growing and stop growing; when it is to reproduce and how often, etc.

Damage to DNA:

- High energy **ionizing** radiation can damage my DNA
- If the DNA molecule is damaged in my body, the effect could be that before it reaches a mature state, the damaged cell reproduces many similar cells.
- The result is a growth of cells with no beneficial function in the body.
- This kind of growth is a called a tumour.
- If the tumour invades other tissues in the body, it is called a **cancer**.

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Effects on my health

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Chronic exposure to low radiation levels

Cancer

Example: Canadian uranium miners

- 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

Acute exposure to high radiation levels

Sickness, visible injuries, death

Examples:

- + 250 mSv radiation dose: lethargy, nausea, vomiting, diarrhea
- + 2000 mSv radiation dose: death

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Effects on my health

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Scientific studies

- Based on Atomic bomb survivors and others - ongoing international studies
- Example: Canadian uranium miners
  - Ontario Ministry of Labour: Dr Jan Mueller, *et al*
  - Most significant study for Canada

International Commission on Radiological Protection (ICRP)

- Foremost scientific authority on health effects of ionizing radiation.
- Independent advisory group of scientific experts in radiation science and protection.
- Reviews existing and new scientific information on the health effects of radiation exposure
- Makes recommendations to national authorities on radiation dose limits.
- Most countries adopt the recommendations of the ICRP in national regulations

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Session 4

PROTECTING MINE WORKERS FROM RADIATION

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Protecting Mine Workers from Radiation

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Employer's obligations

Obligation 1: Obey the law and the regulations

- Government legal dose limits for workers
  - Annual maximum radiation dose limit and five-year maximum dose limit
  - Based on ICRP recommendations for worker dose limits
  - Note: Governments are sometimes slow to act on ICRP advice

Obligation 2: Implement and maintain the ALARA principle

- International standard of practice:
  - Employers must keep worker radiation doses ***as low as reasonably achievable*** (ALARA)
  - **Real goal**: radiation doses must be kept as far below the legal limit as is reasonable for the workplace

Unacceptable goal: to be at (or just below) the legal dose limit

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Instance: South Africa

National Nuclear Regulator (NNR):

"Over the past few years, there has been a continuous downward trend in the number of workers exposed to [radiation] doses higher than regulatory limits as a result of mining operations.

During the previous financial year, over-exposure stood at 8 workers. The number of over-exposed individuals for the year under review is 2. The facility in question was directed by the Regulator to discontinue operations until corrective actions were taken.

While there was a decrease in over-exposures, it is not acceptable that there are still workers exposed to radiation above the regulatory limits.

The NNR will continue enforcing standards and regulations to ensure that no over-exposures occur in facilities under authorization."

-- Annual Report 2006-7, Dept of Minerals and Energy.

Also reported for the same year:

- NNR ordered two mines to halt operations for non-compliance with regulations
- REASON: high radiation exposure of mine workers to radon
- Mines allowed to re-start in same year once in compliance with NNR regulations

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Protecting Mine Workers from Radiation

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Some questions that come to mind

- Where is the ALARA principle in this report?
- What are the regulations?
- Are they adequate for worker protection?
- What was the source of radiation exposure in the cases above? Radon? Something else?
- What changes were made by the companies to allow them to re-open ?
- Are company safety personnel professionally trained in radiation safety?
- How much radiation exposure are miners getting? Are the statistics reliable?
- Are miners individually monitored for exposure?
- Are miners given their exposure results?
- Are the results explained to them?
- Is there a national dose registry for recording the radiation doses of all exposed workers in South Africa in all workplaces?
- Are workers trained in radiation safety?
- Do they know how to protect themselves from unnecessary exposure?
- Is worker training required by law?

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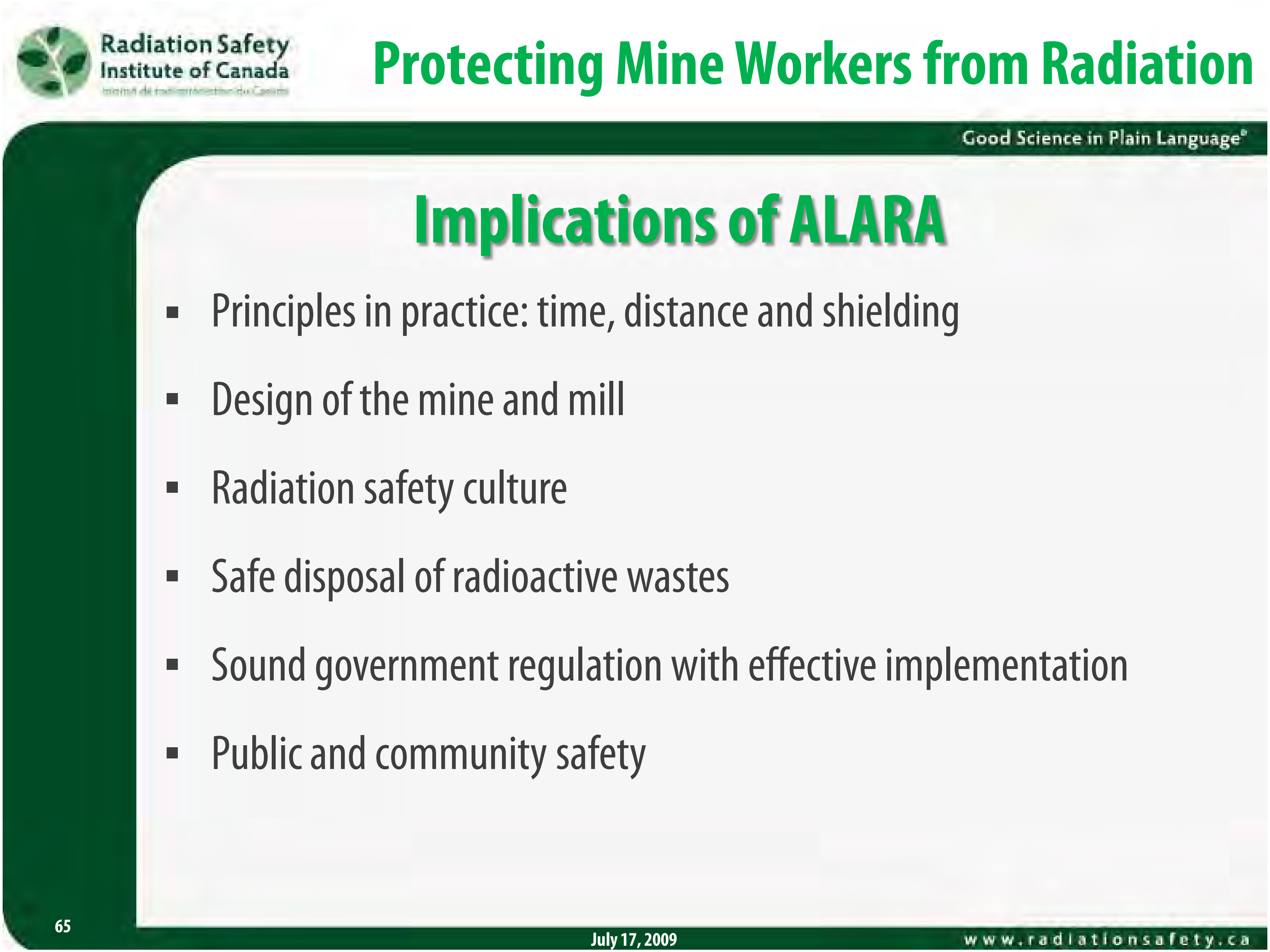
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Protecting Mine Workers from Radiation
Good Science in Plain Language
Implications of ALARA
Principles in practice: time, distance and shielding
Design of the mine and mill
Radiation safety culture
Safe disposal of radioactive wastes
Sound government regulation with effective implementation
Public and community safety
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Protecting Mine Workers from Radiation

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Three principles

1. **Time:**
   - To lessen amount of energy absorbed by your body, limit the time you spend near a radiation source
2. **Distance:**
   - Keep your distance from the radiation – you don't have to move far!
   - The closer you are, the more exposure you get
   - The further away you are, the less exposure
   - Example: heat from a fire
3. **Shielding:**
   - Shield yourself from the radiation
   - Use the appropriate material for the kind of radiation present

Three Principles apply to:

- Employers:
  - in radiation protection systems and practices for workers
- Workers
  - in protecting themselves and their co-workers

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Protecting Mine Workers from Radiation

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MINE AND MILL:

Incorporate radiation safety *into the design*

Don't leave it until later! It may be too late!

For example:

- Systems and procedures to control radioactive dust
- Ventilation systems to lower amount of radon gas
- Continuous workplace monitoring system for radon
- Alarm system to warn workers of high radon gas levels
- Etc.

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Culture of radiation safety means -

An informed company management and staff:

- Awareness education; RSO training – managers, supervisors, technical staff

Informed mine workers:

- Awareness education for workers and RSO training for labour representatives

Radiation safety hygiene

- Protective clothing, gloves, hard hats, boots, "booties"
- Respirators (special conditions)
- Good housekeeping (radiation hygiene) practices in the workplace

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)

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Session 5

RADIATION SAFETY STANDARDS AND REGULATIONS

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Regulations

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Radiation dose limits

ICRP Recommendations

Effective dose:

Radiation worker	Public
20 mSv per year (average over 5 years)	1 mSv per year

Equivalent dose:

Lens of the eye	150 mSv per year	15 mSv per year
Skin	500 mSv per year	50 mSv per year
Hands and feet	500 mSv per year	

International agreement:

ICRP recommended dose limits are the legislated standard in most countries, including Canada (*Nuclear Safety and Control Act 1997*)and South Africa (*National Nuclear Regulator Act 1999*).

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National regulations
(Example: Canada)

- Nuclear energy worker, including a pregnant nuclear energy worker

(a) One-year dosimetry period	*Maximum*	*50 mSv*
(b) Five-year dosimetry period	*Maximum*	*100 mSv*

- Pregnant nuclear energy worker

Balance of the pregnancy (months)	*Maximum*	*4 mSv*

- A person who is not a nuclear energy worker

One calendar year	*Maximum*	*1mSv*

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Regulations

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Why is the dose limit so much higher for radiation/nuclear energy workers?

ICRP radiation protection philosophy:

- All occupations carry some risk to a worker's health
- Compare occupations with similar health risks
- Goal: risk faced by radiation workers should be no greater than risk faced by other workers.
- Set radiation dose accordingly
- Result: major revision of radiation dose limits published in ICRP Bulletin 60 in 1990 (drop from 50 mSv annually to 20 mSv annually)
- Major effect on uranium mining regulations and practice in Canada

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Regulations

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Names

"Radiation worker" and "Nuclear energy worker" ("NEW")

- Legally required designation when a worker is likely to receive a radiation dose of more than 1 mSv in one year
- *Employer required by law* to inform these workers of the risks of working with radiation and to outline radiation risks for the workers
- *Worker required by law* to acknowledge and to accept those risks as a condition of employment as a "radiation worker" or "NEW"
- Employers and workers: regulatory controls over work practices and radiation safety procedures more strict than for public
- Purpose: to ensure that the radiation dose the radiation worker receives is kept below the regulated limits.

Radiation Protection Regulations
Subject areas
(Example: Canada)

Obligations of Licensees [Employers] and Nuclear Energy Workers

- Administration of Nuclear Substance for Medical Purposes
- Radiation Protection Program
- Ascertainment and Recording of Doses
- Action Levels
- Provision of Information
- Requirement to Use Licensed Dosimetry Service
- Collection of Personal Information
- Nuclear Energy Workers
- Pregnant Nuclear Energy Workers

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Regulations

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Radiation Protection Regulations

(Example: Canada - continued)

Radiation Dose Limits

- Interpretation
- Effective Dose Limits
- Equivalent Dose Limits
- Emergencies
- When Dose Limit Exceeded
- Authorization of Return to Work

Dosimetry Services

- Application for Licence to Operate
- Obligations of Licensees

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Regulations

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Radiation Protection Regulations

(Example: Canada - continued)

Labeling And Signs

- Labeling of Containers and Devices
- Posting of Signs at Boundaries and Points of Access
- Use of Radiation Warning Symbol
- Frivolous Posting of Signs

Records to be kept by licensees

Transitional provision

Coming into force

Schedule 1 : Organ or Tissue Weighting Factors

Schedule 2 : Radiation Weighting Factors

Schedule 3 : Radiation Warning Symbol

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Session 6

REGULATIONS FOR URANIUM MINES AND MILLS

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Uranium Mine Regulations

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Uranium Mines and Mills Regulations
(Example: Canada)

Licence Applications

- General Requirements
- Requirement for Code of Practice
- Licence to Prepare Site and Construct
- Licence to Operate
- Licence to Decommission
- Licence to Abandon

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Uranium Mine Regulations

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Uranium Mines and Mills Regulations

(Example: Canada - continued)

Obligations of Licensees [Employers]

- Posting of Code of Practice
- Operating Procedures
- Ventilation Systems
- Malfunction of Ventilation System
- Use of Respirators
- Gamma Radiation
- Training Program

Records to be kept and made available

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Uranium Mine Regulations

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ALARA again!

Code of Practice

Action levels on worker exposure

REQUIREMENT FOR CODE OF PRACTICE

4. (1) In this section, "action level" means a specific dose of radiation or other parameter that, if reached, *may indicate a loss of control of part of a licensee's radiation protection program or environmental protection program*, **and triggers a requirement for specific action to be taken.**

POSTING OF CODE OF PRACTICE

9. Every licensee shall post a copy of the code of practice referred to in the licence at a location within the uranium mine or mill ***that is accessible to all workers and where it is most likely to come to their attention.***

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Session 7

REGULATIONS IN PRACTICE

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Example: Regulations in practice – Action Plans

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2. ACTION LEVELS

2.1 WEEKLY INDICATOR - The first action level is an unplanned weekly estimated effective dose greater than 1.0 mSv. This will be assessed with engineering monitoring data because the reporting periods for official dosimetry are monthly or quarterly.

2.2 QUARTERLY INDICATOR - The second action level is an unplanned quarterly radiation dose greater than 5.0 mSv effective dose. Estimates of the quarterly radiation dose will be based on the official dosimetry results.

2.3 ACTIONS REQUIRED - The following actions will be taken if an action level has been reached:

a) an investigation will be conducted into the cause of the worker reaching the action level;

b) take corrective action when reasonably practicable, to restore the effectiveness of the radiation safety program; and

c) notify the CNSC and Saskatchewan Labour on the first working day after becoming aware of the occurence.

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Example: Regulations in practice – Action Plans

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3.2 Gamma Radiation

No.	Gamma Range	Protective Actions
1.	≤ 15 µ Sv/h	1. Continue normal operations
2.	16 to 24 µSv/h	1. If higher than normal level for the area, investigate to determine cause and take corrective action when reasonably practicable 2. If higher than normal level for the area, notify area Foreman and Radiation Specialist or designates.
3.	25 to 100 µSv/h	1. Monitor prior to working in area, daily if a routine work area. 2. Post radiation warning signs. 3. Radiation work permit required for areas greater than 50 µSv/h if the worker will be in the area greater than 15 minutes (Confined work locations must have at RWP no matter the time duration). 4. If higher than normal level for the area, investigate to determine cause and take corrective action when reasonably practicable 5. Notify as per 2.2 and Mine General Foreman and Sr Coordinator, Radiation Safety or designates.
4.	> 100 µSv/h	1. As per 3.1 to 3.4 2. Use of DRD is mandatory. 3. Notify as per 3.5 and the General and Mill Manager, and the Manager Regulatory Compliance or designates, immediately with follow-up in writing. 4. Notify the Senior Health Physicist (Corporate), CNSC, and Sask. Labour of the occurrence within 72 hours and in the monthly monitoring report.

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Example: Regulations in practice – Action Plans

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3.3 Direct Reading Dosimeters (DRD)

No.	Gamma Range	Protective Actions
1.	≥ 50 μSv/d	1. Worker signs supervisor's log book indicating worker's name, DRD result, where exposure occurred, and work that was performed. 2. The results from the logbook are reported at the daily site management meeting by the department representative.
2.	≥ 200 μSv/d	1. Leave the area. 2. Notify department General Foreman and the Sr. Coordinator, Radiation Safety or designates with a written report to describe work being performed.
3.	≥ 200 μSv during the week	1. Worker's supervisor to submit work plan to the Radiation Specialist, or designate, how the worker's total gamma dose will be kept under 400μSv for the remainder of the work week. 2. Notify department superintendent and the Coordinator, Environment and Radiation or designates with a written report to describe work being performed.
4.	≥ 400 μSv/wk	1. Notify the General and Mine Manager, and the Manager of Regulatory Compliance or designates, immediately, with follow-up in writing. 2. Notify the Senior Health Physicist (Corporate), CNSC and Sask. Labour of the occurrence within 72 hours and in the monthly monitoring report.

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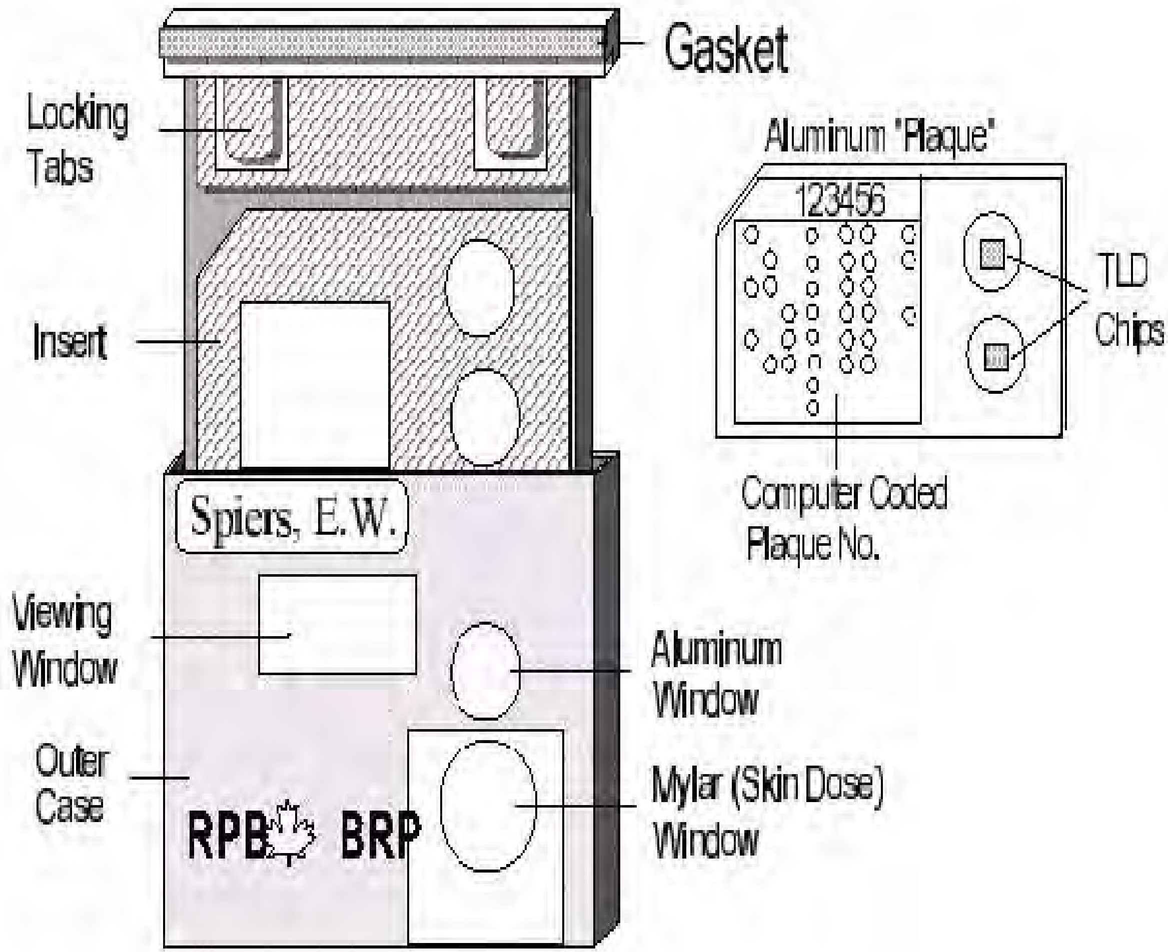

Gamma radiation dosimeter (TLD)

Courtesy of National Dosimetry Service, Radiation Protection Bureau (RPB), Health Canada, Ottawa, Ontario

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Gamma radiation dosimeter (TLD)

Courtesy of Global Dosimetry Solutions, USA

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Gamma radiation dosimeter (TLD) Courtesy of Landauer Corp, USA

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Example: Regulations in practice – Action Plans

3. ADMINISTRATIVE LEVELS:

3.1 Radon Progeny

No.	WL Range	Prism Light Indicator	Protective Actions
1.	≤ 0.1	Green	1. Continue normal operations.
2.	0.11 to 0.25	Green/ Amber	1. Investigate cause and take corrective action when reasonably practicable. 2. If condition persists > 4 h, Rad Tech & Vent Tech investigate and take corrective action when reasonably practicable. 3. If condition persists > 24 h, rope off area, post airborne radiation warning sign, and radiation work permit required. 4. Notify Mine Foreman and Radiation Specialist or designates (after 24 h problem).
3.	0.26 to 0.50	Amber	1. Investigate cause and take corrective action when reasonably practicable. 2. If condition persists > 2 h, Rad Tech & Vent Tech investigate and take corrective action when reasonably practicable. 3. If condition persists > 6 h, normal operations cease, rope off area, post airborne radiation sign and radiation work permit required. 4. Notify as per 2.4 and Mine General Foreman and Senior Coordinator, Radiation Safety or designates (after 6 h problem).
4.	0.51 to 1.0	Amber/ Red	1. Investigate cause and take corrective action when reasonably practicable. 2. If condition persists > 1 h, Rad Tech & Vent Tech investigate and take corrective action when reasonably practicable. 3. If condition persists > 2 h, normal operations cease, rope off area, post airborne radiation sign and radiation work permit required. 4. Notify as per 3.4 and Mine Manager and the Manager of Regulatory Compliance, or designates, immediately with follow-up in writing (after 2 h problem).
5.	1.01 to 2.0	Red or Red with Strobing White	1. Leave area immediately. 2. Rope off area and post airborne radiation warning. 3. Radiation work permit required. 4. Rad Tech and Vent Tech are called immediately to investigate and correct. 5. Notify as per 4.4 and General Manager, or designate, immediately with follow-up in writing.
6.	> 2.0	Red or Red with Strobing White	1. As per 5.1 to 5.4. 2. Notify as per 5.5, and Senior Health Physicist (Corporate), CNSC, and Sask. Labour of the occurrence within 72 hours and in the monthly monitoring report.

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Example: Regulations in practice – Action plans

3.4 Long-Lived Radioactive Dust

No.	LLRD Range	Protective Actions
1.	≤ 0.25 DAC*	1. Continue routine monitoring.
2.	> 0.25 to 0.50 DAC*	1. Investigate to determine cause and take corrective action when reasonably practicable. 2. On second occurrence in the quarter for the same job group, reassess adequacy of sampling frequency for the affected job group. 3. Notify Area Foreman and Radiation Specialist or designates.
3.	> 0.50 to 1.0 DAC*	1. Investigate as soon as possible to determine cause and take corrective action when reasonably practicable. 2. Take engineering sample(s) to assess effectiveness of corrective actions. 3. Reassess adequacy of sampling frequency for the affected job group. 4. Notify as per 2.3 and area General Foreman and Sr. Coordinator, Radiation Safety or designate.
4.	> 1.0 to 2.0 DAC*	1. Investigate as soon as possible to determine cause and take corrective action when reasonably practicable. 2. Take engineering sample(s) to assess effectiveness of corrective actions. 3. Control access and post signs, if applicable, and require respiratory protection until the problem has been corrected. 4. Radiation work permit required. 5. Reassess adequacy o' sampling frequency for the affected job group. 6. Notify as per 3.4 and Mine Manager and the Manager, Regulatory Compliance, or designates, immediately with follow-up in writing.
5.	> 2.0 DAC*	1. As per 4.1 to 4.4 2. Increase the sampling frequency for the affected job group. 3. Notify as per 4.6, and the General Manager, or designate, immediately, with follow-up in writing. 4. Notify the Senior Health Physicist (Corporate), CNSC, and Sask. Labour of the occurrence within 72 hours and in the monthly monitoring report.

***DAC - Derived Air Concentration**
Exposure to a concentration of 1 DAC for 2000 hours (one full working year) results in a dose of 20 mSv. Using DAC enables a consistent approach to be taken for different dust types (e.g. Calcined yellowcake, non-calcined yellowcake, and ore dust) without having to convert different measuring units.

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Miner with PAD dosimeter on belt: for legal dosimetry of exposure to radon progeny and long-lived radioactive dust (LLRD) -- Photo courtesy of Cameco Corporation

Rabbit Lake
Remote control scoop tram at the Rabbit Lake mine.

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Radiation impact of radon progeny: Alpha track image from PAD dosimeter Radiation Safety Institute of Canada, National Laboratories, Saskatoon

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Radon progeny and LLRD dosimetry service: Preparation of PAD dosimeters for Canadian uranium mines Radiation Safety Institute of Canada, National Laboratories, Saskatoon

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Radon progeny and LLRD dosimetry service: preparing to count LLRD also collected by PAD dosimeters - Radiation Safety Institute of Canada, National Laboratories, Saskatoon

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Example: Regulations in practice – Action plans

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3.5 Radon Gas

No.	Radon Gas Range	Protective Actions
1.	< 3,000 Bq/m³	1. Routine monitoring.
2.	3,000 to < 20,000 Bq/m³	1. Investigate cause and take corrective action when reasonably practicable. 2. Rope off area and post airborne radiation warning. 3. Radiation work permit required. 4. Notify Mine Foreman and Radiation Specialist or designates.
3.	20,000 to < 60,000 Bq/m³	1. As per 3.1 and 3.3. 2. Limit time in the area to two working days/wk. 3. Notify Mine General Foreman and Senior Coordinator, Radiation Safety or designates.
4.	> 60,000 Bq/m³	1. As per 3.1 and 3.3. 2. Supplied Air or Self-Contained Breathing Apparatus required to carry out corrective action. 3. Notify the General and Mine Manager and the Manager, Regulatory Compliance or designates, immediately, with follow-up in writing. 4. Notify the Senior Health Physicist (Corporate), CNSC, and Sask. Labour of the occurrence within 72 hours and in the monthly monitoring report.

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Session 8 Contamination Controls

PROTECTING THE MINE WORKER - AND HIS OR HER FAMILY - FROM CONTAMINATION BY RADIOACTIVE MATERIALS

EXAMPLE OF PRACTICAL CONTROL MEASURES

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Contamination Controls

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Purpose of Controls

- **To prevent possible harm from radioactive materials to:**
  - Yourself
  - Your fellow workers
  - Your family
  - Your community and the public
- **How can harm be caused?**
  - To yourself: by accidental eating of radioactive materials with your food and drink or while smoking
  - To your fellow workers: by accidental contamination of their food, clothing, living quarters
  - To your family: by accidental contamination of your living quarters and your home
  - To your community and the public: by accidental contamination of homes , buildings and public spaces

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Contamination Controls

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"ALARA" Principle again!

- Internationally accepted principle for practical control of exposure to radiation
- Applies to workplace radiation safety
- "ALARA" means:
  - Workplace exposure is to be "as low as reasonably achievable"
  - Other factors
- Intention is to **minimize** exposure in practical way
- Not intended to remove all possible radiation exposure from the workplace

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Primary focus of Mine Controls

Prevent contamination of Clean Areas

- by radioactive materials from *Radiation Areas*

Clean Areas of mine site

- Offices
- Living quarters and eating areas
- Coffee rooms

Radiation Areas

- Mine workings
- Mill workings
- Machinery and mechanical
- Etc.

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Preventing Contamination

Radiation Areas of uranium mine:

1. Protective clothing must be worn
   - Supplied by company, including coveralls, hard hats, rubber gloves, tyvecs, booties
2. Smoking, chewing tobacco, eating:
   - In designated areas only
   - Advice: always wash hands thoroughly to avoid ingesting radioactive ore and dust
3. Dust control measures:
   - Water hoses, atomizers, scrubbers: use is required

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Moving to *Clean Areas* from *Dirty Areas*

"Dirty" facility:

- Changing clothes, storage of dirty work clothes, hard hats and boots
- Removal of rubber gloves, tyvecs and booties
- Showers required before leaving "dirty" facility

Clean facility:

- Storage of and change into street clothes

Laundry:

- All protective clothing washed daily by company staff
- Dirty work clothes not permitted in mining camp
- Radiation monitoring of protective clothing for removable and fixed radioactive contamination
- If contaminated clothing cannot be cleaned, it is removed as radioactive waste

Radiation safety monitoring:

- Periodic radiation scans of *Clean Areas* to ensure they are free of contamination

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Contamination of a Clean Area !

Action!

Supervisor take charge!

Identify the source:

- Where is the radioactive contamination coming from?

Prevent:

- Further entry of radioactive materials into the Clean Area (e.g. barricade).

Stop :

- Stop traffic of people and equipment through contaminated area to prevent spread of contamination in the area and beyond.

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Clean-up

Wash: Wash radioactive material (if possible) into nearby sumps using water hoses, scrub brushes, brooms or rags, as necessary.

Wipe: Wipe outer surfaces of contaminated articles with rags to remove surface contamination.

Clean interiors: Disassemble contaminated articles to remove any and all radioactive material inside.

Solvents: Use solvents, as necessary, to dissolve contaminated materials.

Vacuum cleaner: Use vacuum cleaner to collect dry materials.

Disposal of cleaning materials: Decontaminate and scan cleaning materials; where decontamination is not possible, dispose of rags, brushes, etc as radioactive waste.

Confirmation: On completion of clean-up, contact Radiation Protection staff to confirm that all contamination has been removed.

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Mine Contamination Control Zones

Level 1 control zone:

- Designated work place areas where the use and storage of radioactive material is ***not permitted***, and where radioactive contamination (if any) shall be the lowest.

Level 2 control zone:

- Designated work place areas where radioactive material is used and stored, and where ***moderate radioactive contamination*** is anticipated and controlled accordingly.

Level 3 control zone:

- Designated work place areas ***where radioactive material is used and stored***, where radioactive contamination controls are subject to the operational ambient radiation backgrounds, and where ***Nuclear Energy Workers (NEW) can access*** **without a special authorization**.

Level 4 control zone:

- Designated work place areas where radioactive material is used and stored, where radioactive contamination controls are subject to the operational ambient radiation backgrounds, and where ***NEW access may be subject to the "Work Stay Permit"***

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Contamination Controls

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Protecting workers from radioactive dusts

Respirators

- Used to keep the radiation doses of mineworkers "as low as reasonably achievable" (ALARA).
- Primarily to protect workers from breathing in radioactive dusts in areas of the mine and mill where the potential for dust contamination is significant.
- Airborne and surface dust sampling by mine Radiation Protection staff determines when respirators will be used.
- For example:
  - Respirators are routinely used in the calcining and packaging enclosures.
  - Respirators may also be required for specific tasks, e.g. changing filters in the HVAC system (heating, ventilation, air conditioning system).

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Example of use of a respirator

Photo courtesy of AREVA Canada

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Tag System

Responsibility:

- Radiation Protection staff of the mining company must check all known and suspected contaminated materials before they are taken off the mine site

Green Tag:

- Articles and equipment that are checked for contamination and cleared for removal from the mine site

Yellow Tag – special conditions:

- Articles and equipment that do not meet Green Tag criteria, but that must be sent off-site to another company mine site or for repairs
- **Required**: Signed approvals and recorded conditions for removal

No Green Tag:

- Items which have no suspicion of being contaminated do not require Green Tags.
- Radiation Protection staff will exclude articles from the off-site requirement for Green Tags based on their knowledge of where the article came from and what it was used for.

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Failure to Control

Canadian uranium mines must ensure that articles and equipment of any kind contaminated by radioactive material are *not removed from mine sites*. Failure has consequences.

For the Company

- Severe fines and financial penalties
- Suspension by the national regulator (Canadian Nuclear Safety Commission) of the mine's operating license
- Difficulties in the company's relationship with federal and provincial regulators
- Public and political difficulties

For the public

- Potential harm to public health and the environment
- Renewed concern about uranium mining industry

For workers

- Disciplinary action.
- Potential harm to family and community

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Session 9 General discussion

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What should the next step be
for African nations
to protect
mine workers from radiation exposure?

And the next step after that?

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– it was an honour and a pleasure to be with you!
Fergal Nolan
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