



Canadian Nuclear
Safety Commission

Commission canadienne
de sûreté nucléaire

Canada



Nuclear Substances in Canada: Technical Briefing

Commission Meeting
October 3, 2018
CMD 18-M49



CNSC Staff Presentation



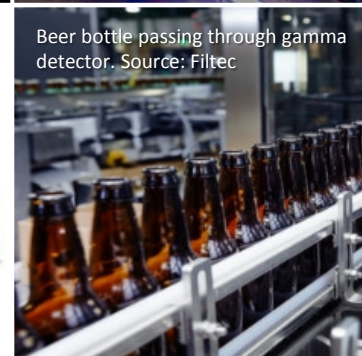
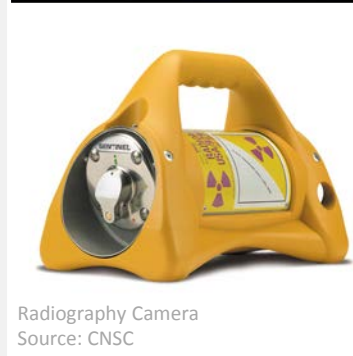
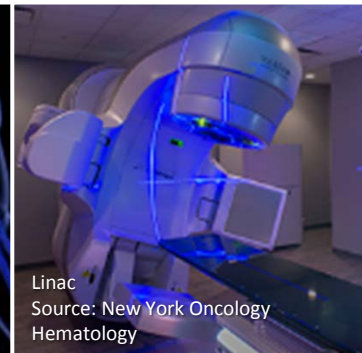
Scope

- Introduction to ionizing radiation
- Diverse applications of nuclear substances, radiation devices and prescribed equipment used in Canada
- Interesting and novel applications



Why is radiation used in Canada?

- Penetrating power
- Detectability
- Reliability
- Non destructive





Sources of Radiation

Sealed source:

- Nuclear substance emitting ionizing radiation, that is encapsulated or bonded to a cover to prevent the radioactive material from escaping or being released

Unsealed source:

- Nuclear substance which is not encapsulated or otherwise contained that emits ionizing radiation

Accelerator:

- Equipment that accelerates charged particles using electromagnetic fields to generate ionizing radiation

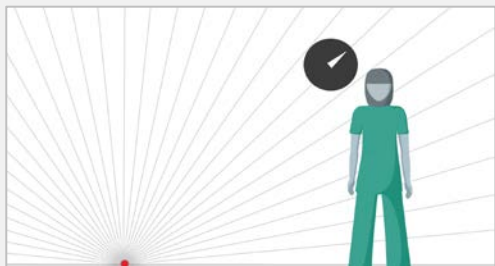


Using Radiation Safely

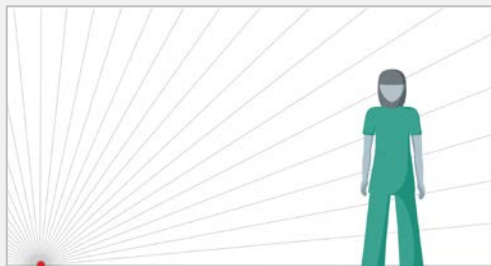
Risk:

- Potential exposure to ionizing radiation

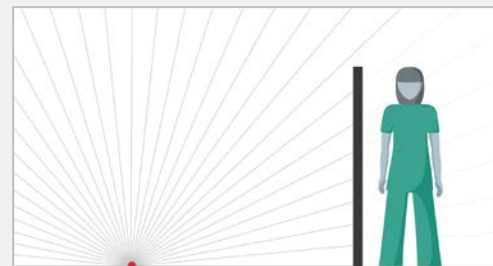
Can be used safely through:



Decreasing **time**



Maximizing **distance**



Making use of **shielding**



Using Unsealed Sources Safely

Risk:

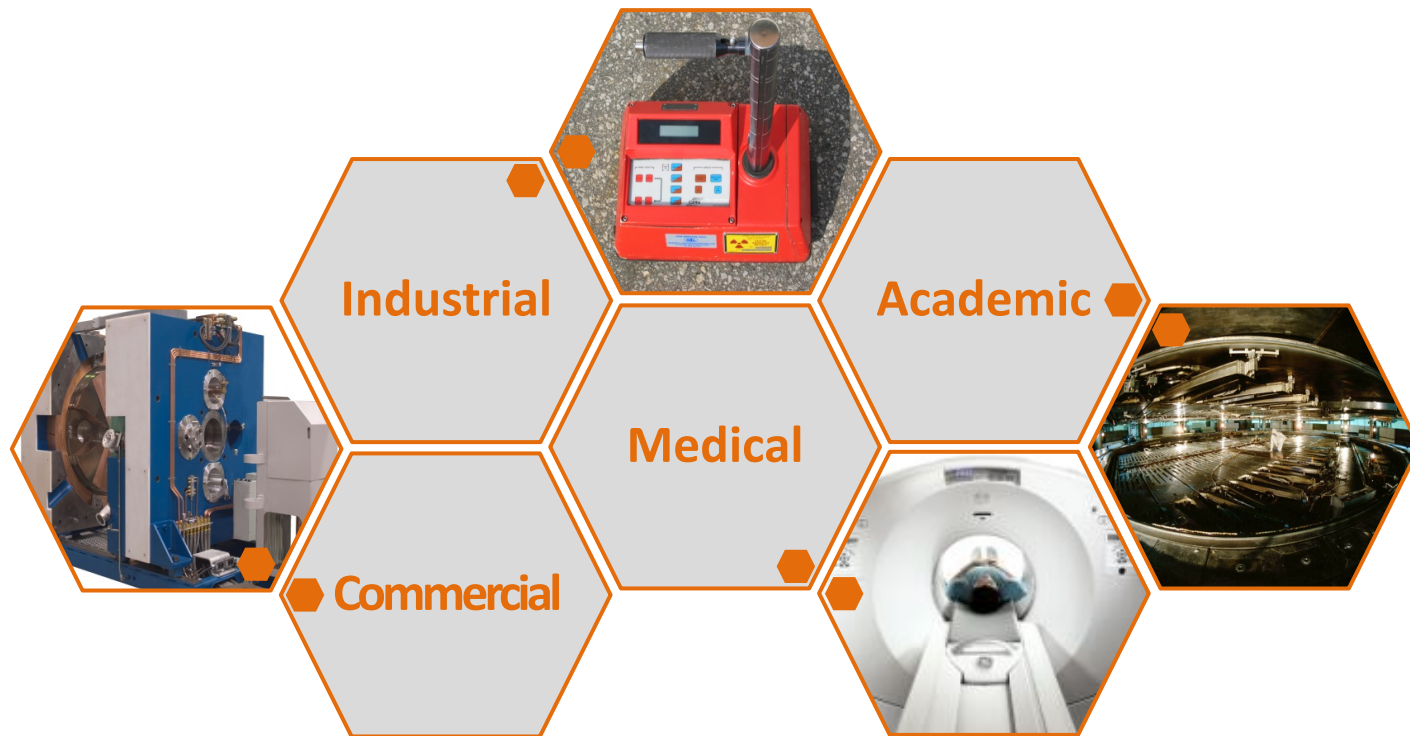
- Potential contamination from unsealed nuclear substances

Can be used safely through:

- Personal Protective Equipment (e.g. lab coat/gowns, gloves, goggles)
- Contamination monitoring
- Radiation protection procedures



Applications of Radiation by Sectors





MEDICAL SECTOR (HUMAN AND VETERINARY)



Outline

Nuclear Medicine

- Diagnostic Imaging: Scintigraphy, SPECT, PET
- Therapeutic Treatment

Radiotherapy

- Linear Accelerators
- Brachytherapy
- Stereotactic Radiosurgery

Interesting and Novel Applications



Nuclear Medicine How does it work?

Physiology (function) based diagnostic imaging and therapy

- Radioactive isotopes are attached to a drug compound to form radiopharmaceuticals
- Radiopharmaceuticals are injected/inhaled/ingested and deliver the radiopharmaceutical to the target location(s) for diagnostic imaging, therapy or palliative care using ionizing radiation.

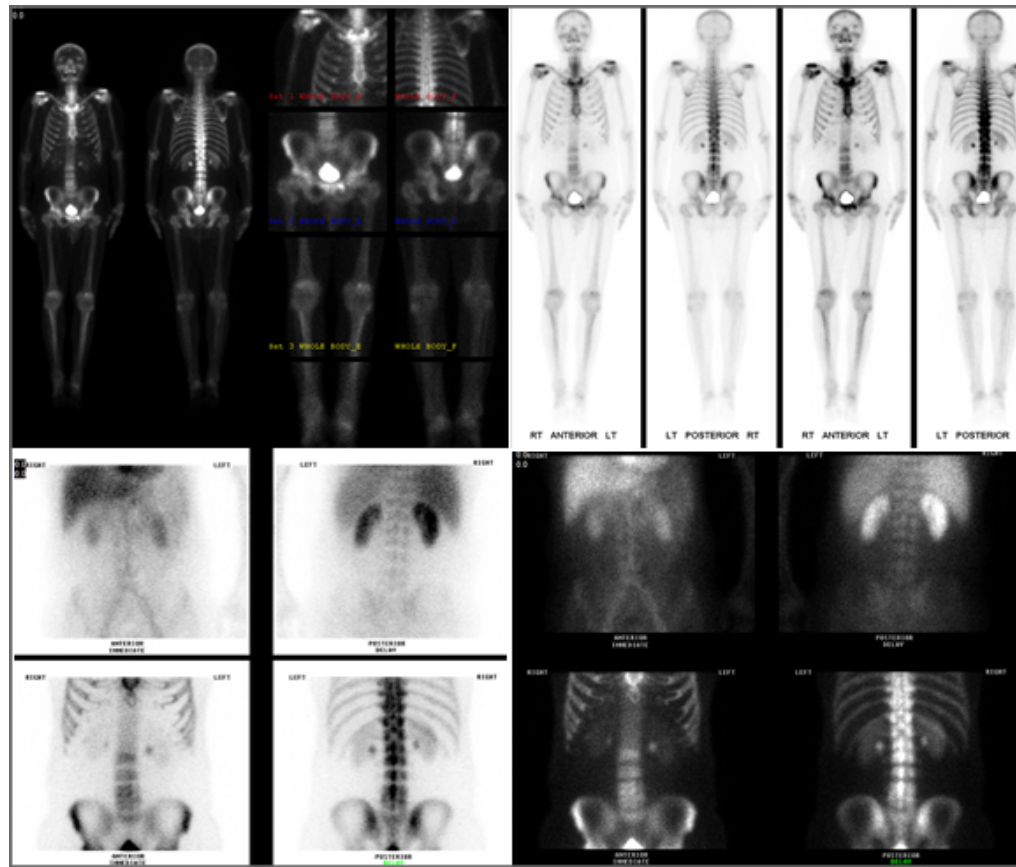




Diagnostic Imaging What is it used for?

- Nuclear medicine diagnostic imaging is used to evaluate a variety of pathologies including bone diseases/pain, renal function, gastrointestinal and endocrine conditions.
- Diagnostic Imaging Techniques:
 - Scintigraphy
 - Single Photon Emission Computed Tomography (SPECT)
 - Positron Emission Tomography (PET)

Bone Scan
Source: Courtesy of
Radiology Associates of
Venice and Englewood



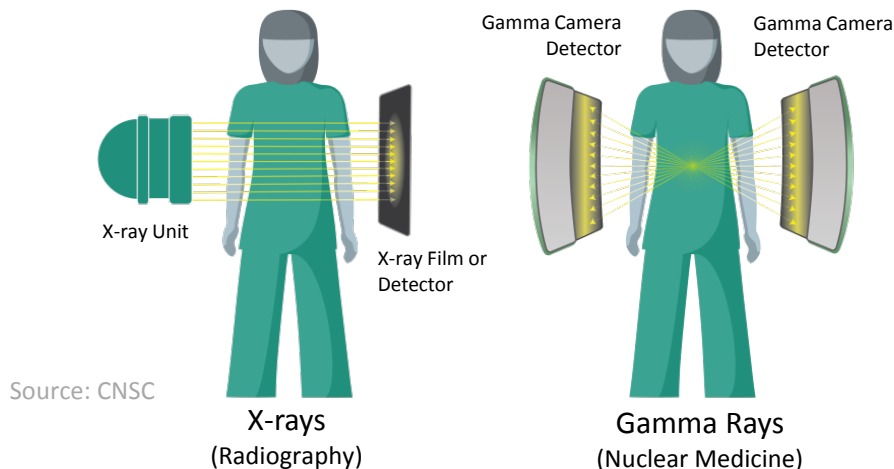


Diagnostic Imaging

What is it used for?

Scintigraphy (planar 2D imaging)

- Detector camera captures gamma rays emitted from radiopharmaceuticals injected/inhaled/ingested into the patient



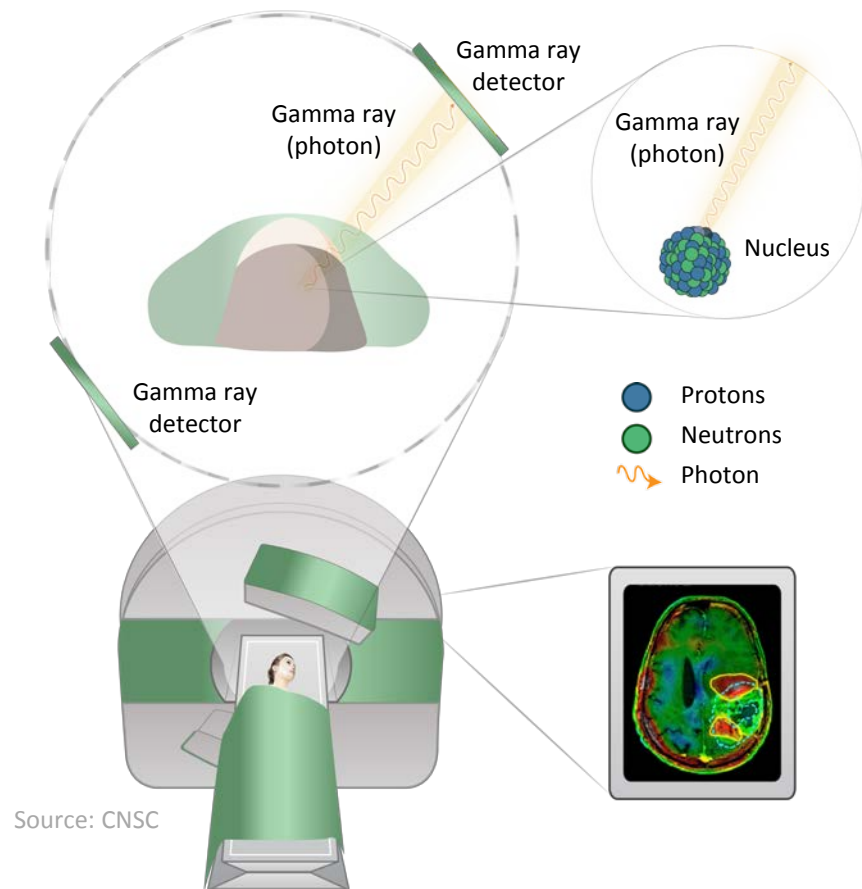


Diagnostic imaging

What is it used for?

Single Photon Emission Computed Tomography (SPECT)

- Like Scintigraphy, SPECT imaging also uses a detector camera to capture the gamma rays emitted however the camera rotates around the patient for **3D imaging**



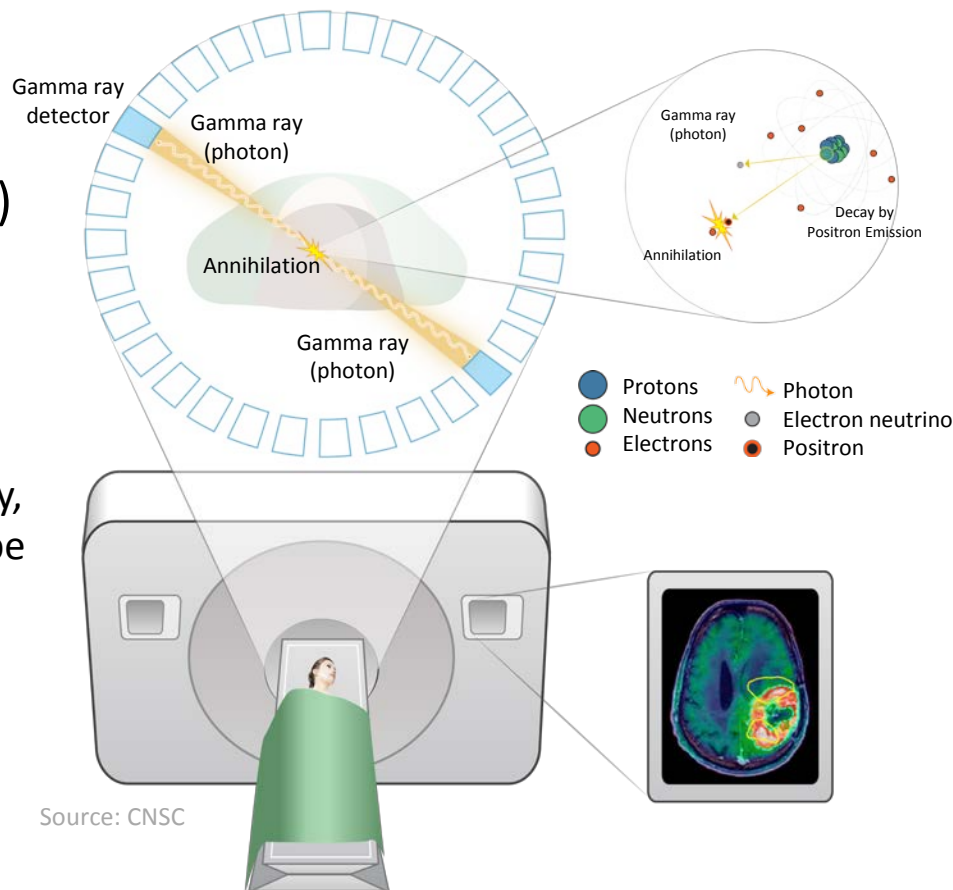
Source: CNSC



Diagnostic imaging What is it used for?

Positron Emission Tomography (PET)

- PET scans are commonly performed for diagnosing/staging cancer, nervous system disorders and cardiovascular diseases.
- PET tracers **emit positrons** that annihilate with electrons up to a few millimeters away, causing **two identical gamma photons** to be emitted in opposite directions which are detected by PET detector cameras
- PET provides more radiation event localization information and gives a **higher spatial resolution** vs SPECT



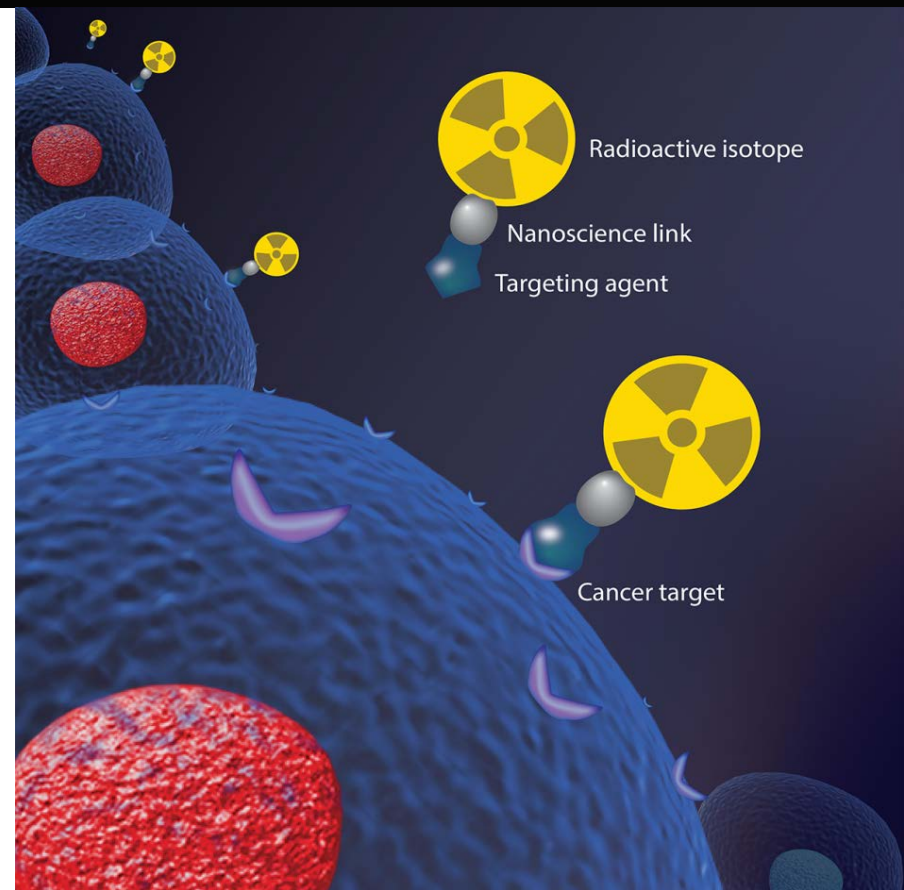
Source: CNSC



Therapeutic Treatment What is it used for?

- Treatment of cancers and other diseases
(e.g. Grave's Disease and Arthritis)
- Palliative Care
(e.g. Pain management for bone metastasis)

Source: CNSC





Diagnostic and Therapeutic Radionuclides

Various gamma, beta and alpha emitting radioisotopes in Nuclear Medicine

Examples of Conventional Nuclear Medicine Isotopes

- Tc-99m, I-123, Ga-67, In-111, Tl-201, C-14
- Examples of PET Isotopes
 - F-18, Rb-82, Ga-68, N-13, O-15, C-11
- Examples of Therapy Isotopes
 - I-131, Lu-177, Y-90, Sr-89, Ra-223, P-32



Nuclear Medicine (Human and Veterinary) Summary

Risks:

- Contamination
- Unplanned exposure

Controlled by:

- Worker Personal Protective Equipment and radiation protection procedures
- Radiation monitoring and contamination controls

Number of Licences:

- Diagnostic Nuclear Medicine – 207
- Therapeutic Nuclear Medicine – 122
- Human Research – 23
- Veterinary Nuclear Medicine – 17



Source: CNSC



Radiotherapy: Linear Accelerators What is it used for?



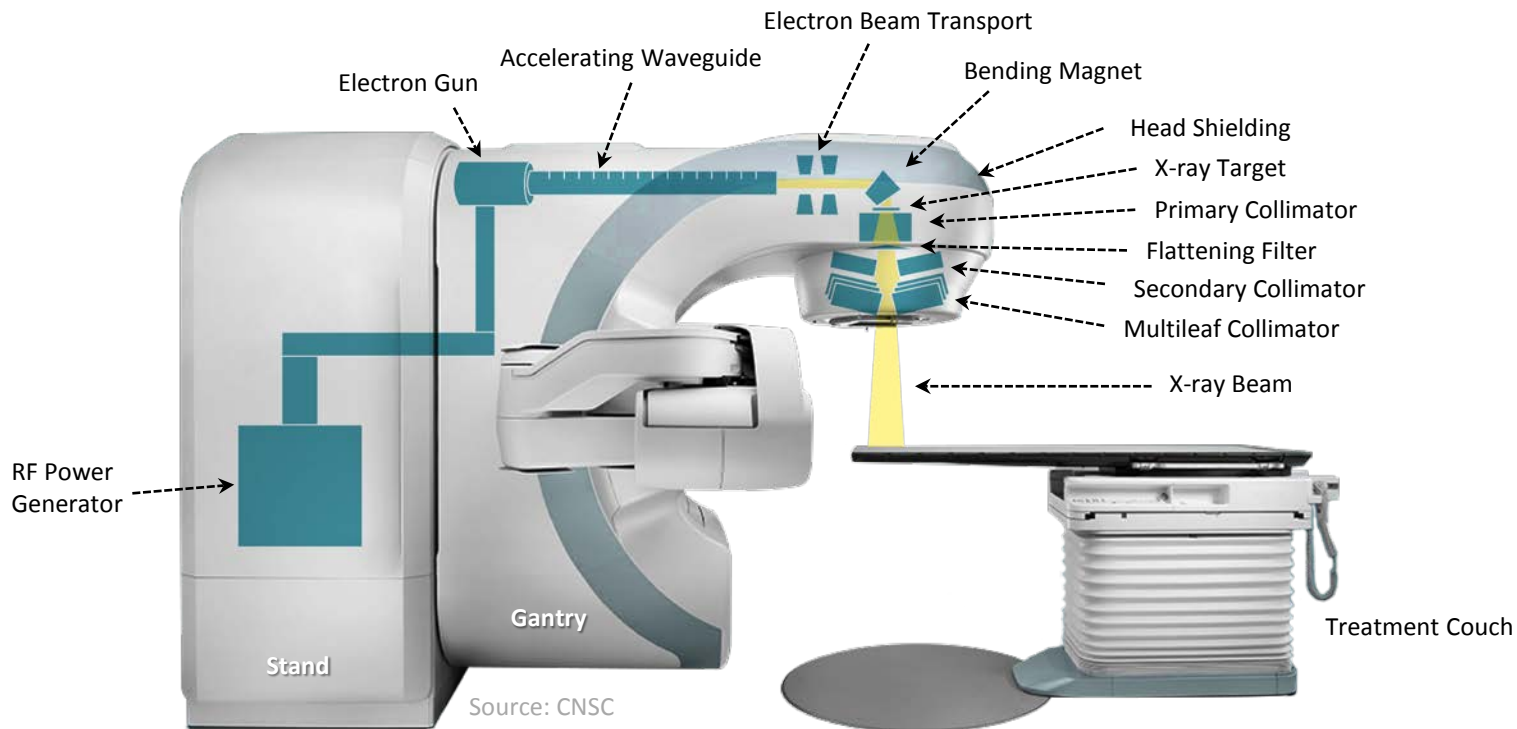
Medical linear accelerators
target and irradiate tumour cells
in cancer patients

Varian Clinac iX medical linear accelerator.
Source: Courtesy of Varian Medical Systems.



Radiotherapy: Linear Accelerators

How does it work?





Radiotherapy: Linear Accelerators

How does it work?





Radiotherapy: Linear Accelerators Summary

Radiation:

- No radioactive sources used but creates X-rays or electron beams

Risks:

- Unplanned exposure
- Mild activation of components

Controlled by:

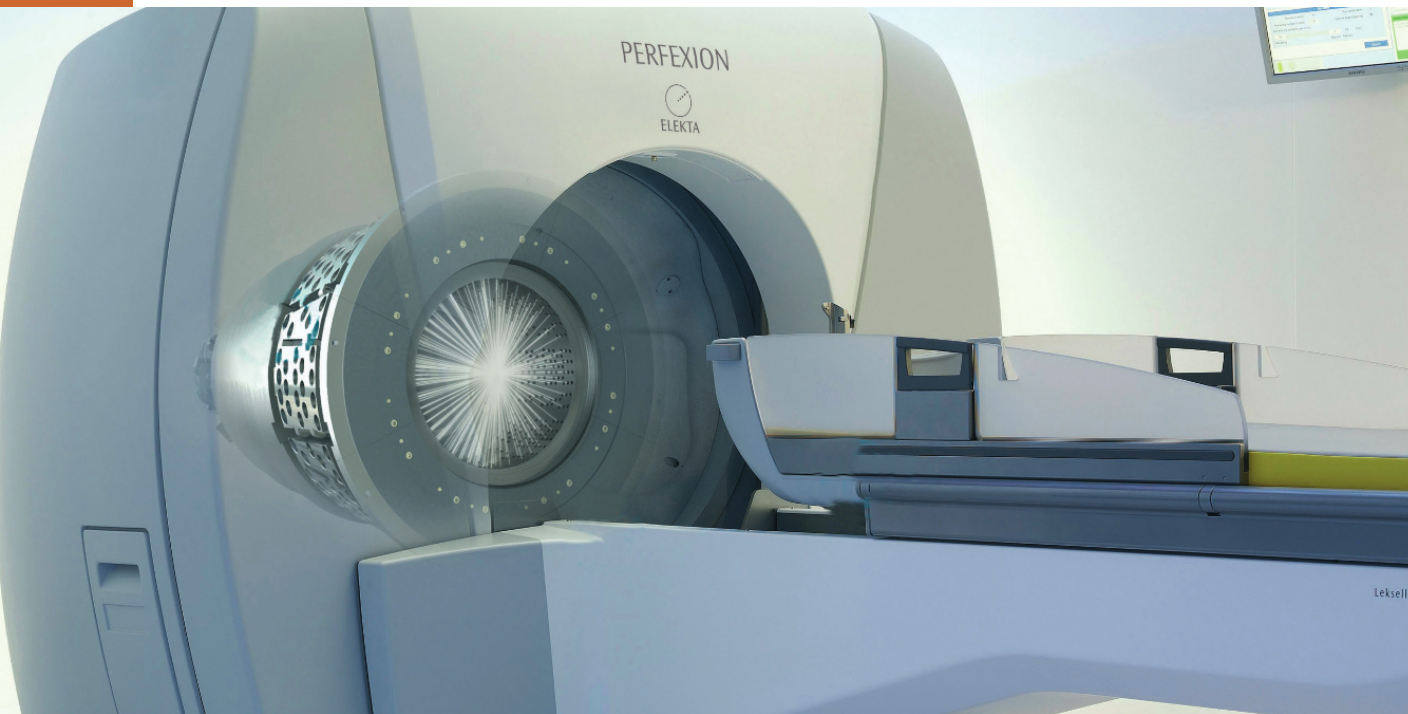
- Shielding
- Access control/interlocks

Number of Units:

- 264 medical linear accelerators in use across Canada



Radiotherapy: Stereotactic Radiosurgery What is it used for?



Stereotactic radiosurgery is used to treat brain tumours, lesions and other neurological conditions.

Leksell Gamma Knife Perfexion machine
Source: Courtesy of Elekta



Radiotherapy: Stereotactic Radiosurgery (Gamma Knife)

How does it work?



Radiotherapy: Stereotactic Radiosurgery Summary

Radioisotope:

- Co-60 (approximately 200 sealed sources)

Risks:

- Unplanned Exposure

Controlled by:

- Shielding
- Access control / interlocks

Number of Units: 6



Radiotherapy: Brachytherapy

What is it used for?



Commonly used as an effective treatment for cervical, prostate, breast, and skin cancer.

Brachytherapy seeds are used to deliver localized dose to diseased or affected tissue.

It can be categorized as:

- Manual
- Remote Afterloading

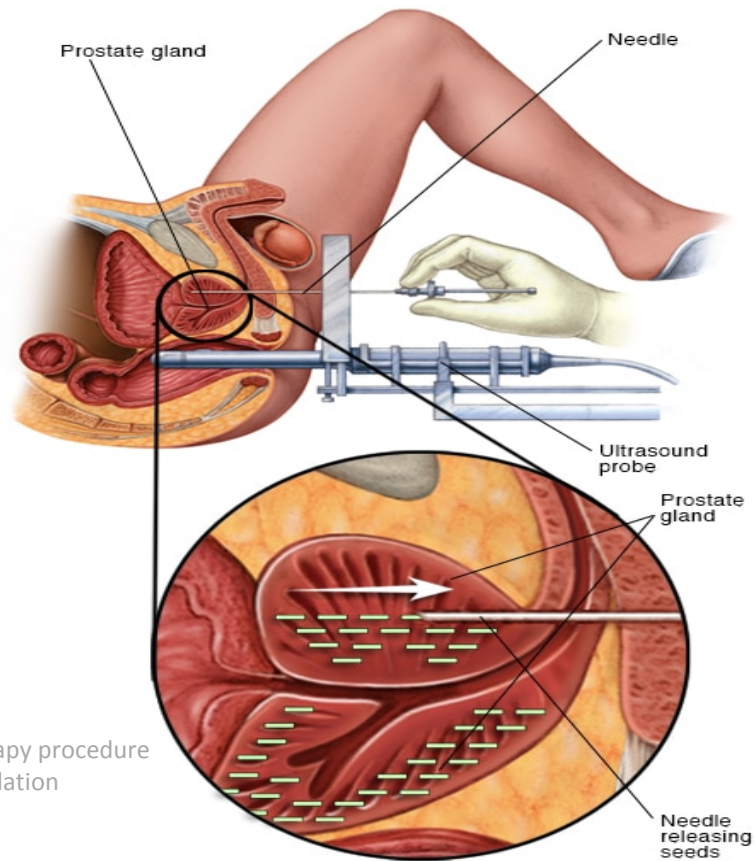


Radiotherapy: Brachytherapy

How does it work?

Manual Brachytherapy

- Source surgically implanted in direct contact with tumour, commonly used to treat prostate and breast cancer
- Examples of Isotopes used: Pd-103 (Breast), I-125 (Prostate)



Permanent prostate brachytherapy procedure
Source: Courtesy of Mayo Foundation

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Radiotherapy: Remote Afterloading High Dose Rate Brachytherapy How does it work?





Radiotherapy: Brachytherapy Summary

Risks

- Unplanned exposure
- Loss of control of seeds
- Stuck source

Controlled by

- Shielding
- Access control/interlocks
- Inventory control

Number of Units

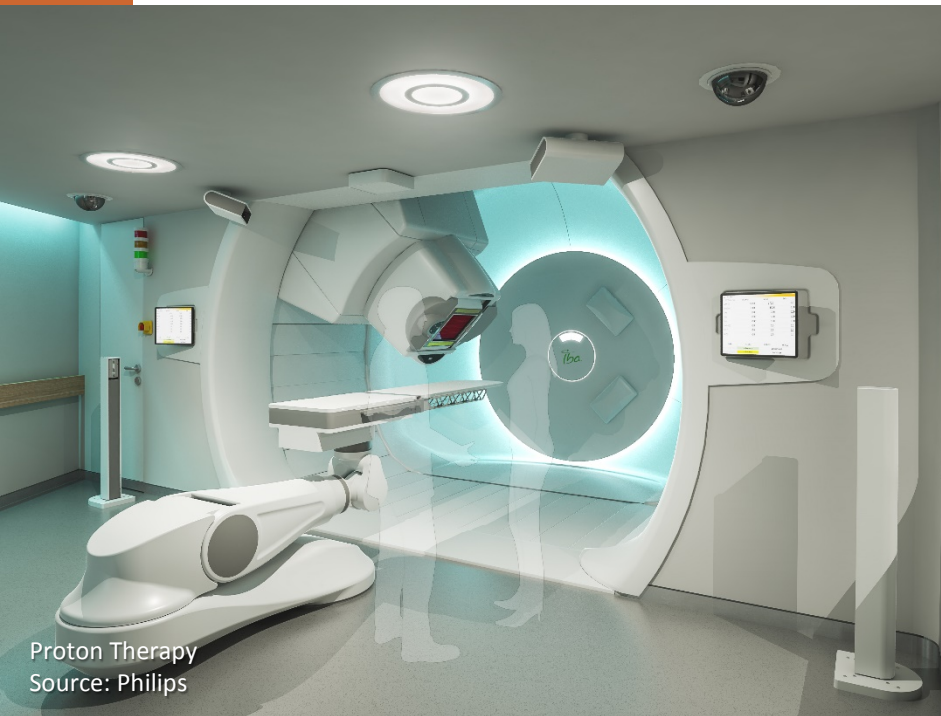
- 49 units of remote afterloaders



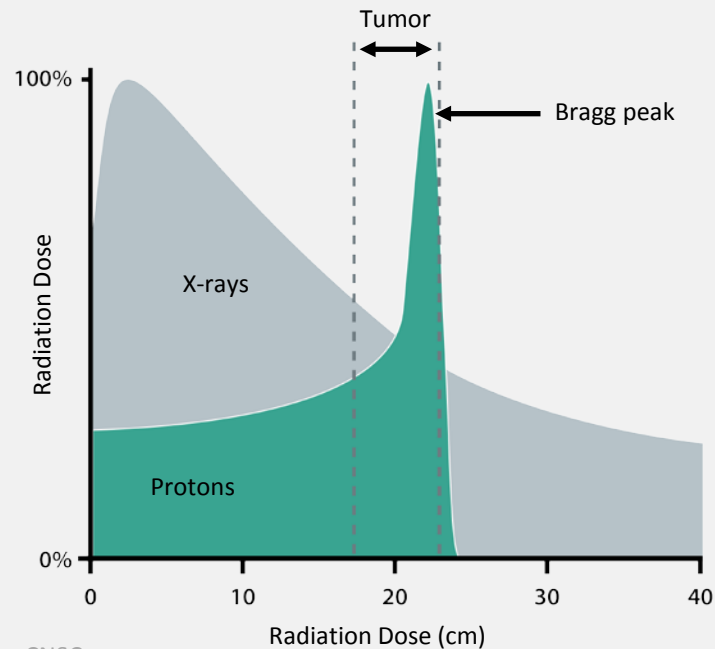
Examples of afterloaders, Left photo courtesy of Nucletron, Right photo courtesy of Varian Medical Systems



Interesting and Novel Applications Proton Therapy



Proton Therapy
Source: Philips



Source: CNSC



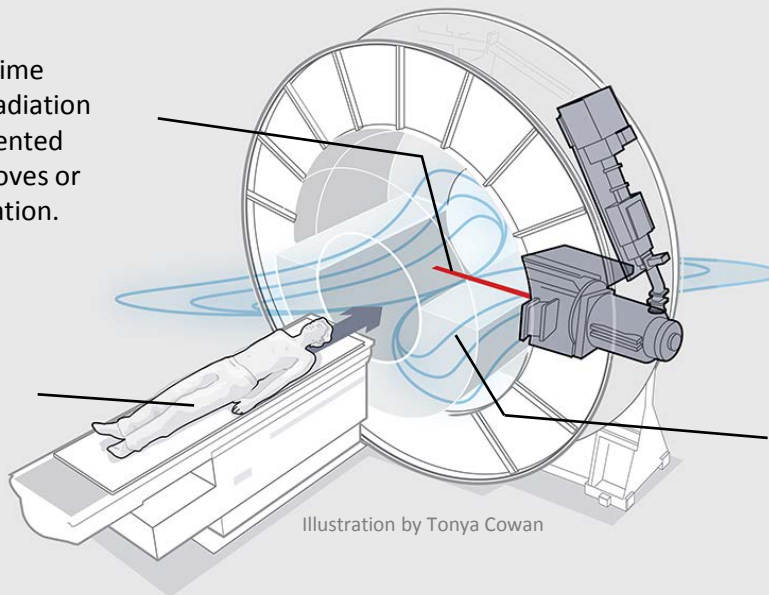
Interesting and Novel Applications MR-Linac

Radiation beam

Because the MR-Linac uses real time imaging, doctors can direct the radiation beam at tumours with unprecedented precision, even as the tumour moves or changes as it is damaged by radiation.

Treatment Bed

As with standard MRI machines, MR-Linac patients lie on a bed that moves into the imaging/treatment chamber.

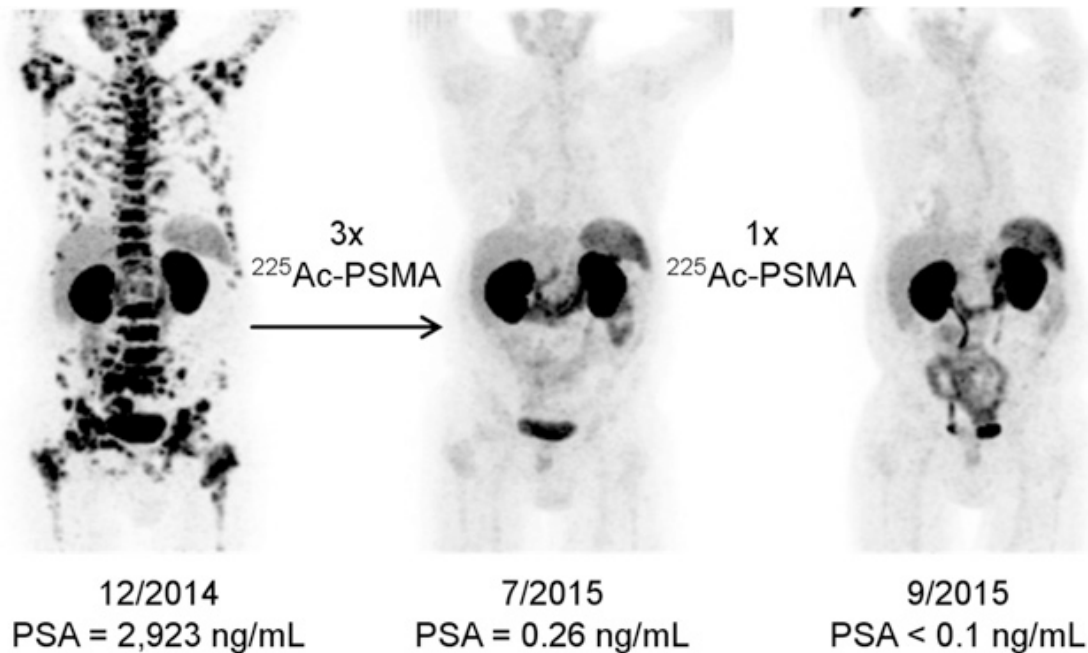


Magnetic field

The MR-Linac's developers overcame a major engineering hurdle by creating a machine that can simultaneously visualize tumours with high-resolution magnetic resonance and treat with radiation.



Interesting and Novel Applications Targeted Alpha-Particle Therapy



*PET images acquired using Ga-68-PSMA

This type of therapy uses targeting biomolecules to deliver alpha-particles to specific sites.

Alpha-particles are cytotoxic and deposit higher doses of radiation per unit distance.

This type of therapy is promising because it produces less damage to nearby healthy tissue.

Alpha-Particle Therapies

Source: Kratochwil et al. *J Nucl Med* 2016



INDUSTRIAL SECTOR



Outline

- Pool Type Irradiator
- Mobile Accelerator
- Industrial Radiography
- Oil Well Logging
- Portable Gauge
- Fixed Gauge
- Interesting and Novel Applications



Pool Type Irradiator What is it used for?



Cobalt-60 Sources in Wet Storage Production Irradiator
Source: Nordion

Used for irradiating products such as:

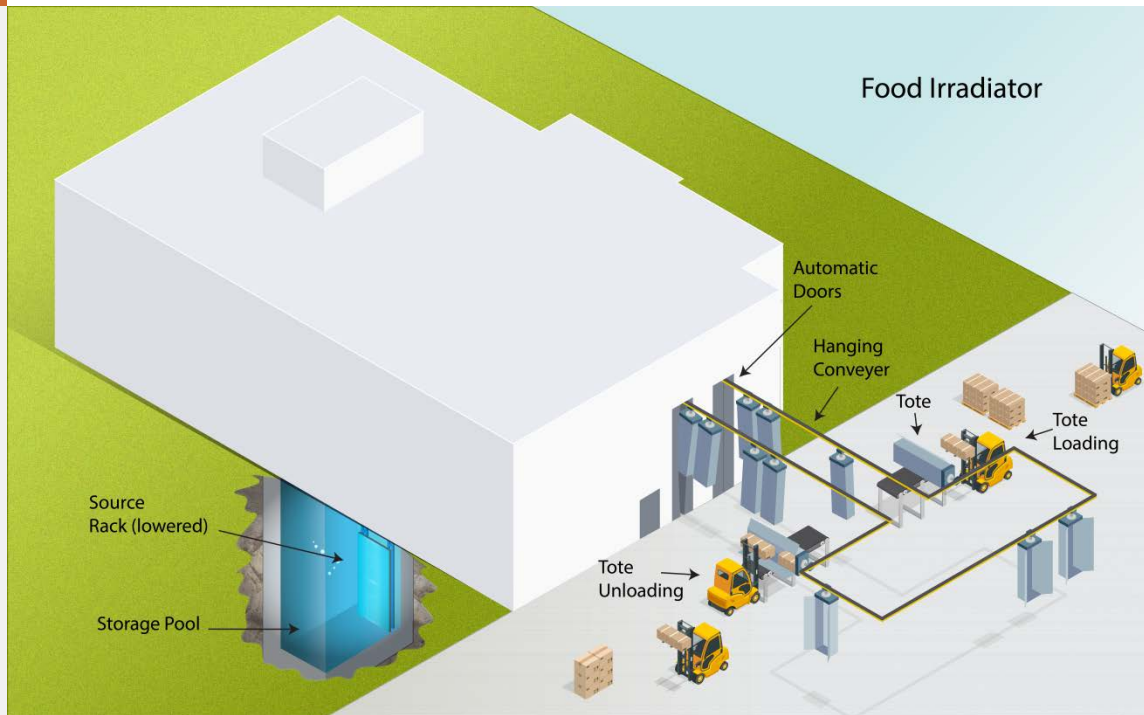
- Medical supplies
- Dog Treats
- Medical Marijuana
- Flour
- Spices
- Potatoes*
- Ground Beef*
- Onions*

Two facilities operating in Canada

* Approved by Health Canada for irradiation but not currently being irradiated



Pool Type Irradiator How does it work?



Radioisotope: Co-60

Source: CNSC



Pool Type Irradiator Summary

Risks:

- High dose rates of gamma radiation in irradiation room
- Theft or sabotage of Co-60 sealed sources

Controlled by:

- Shielding
- Redundant safety systems in place to prevent personnel from occupying the room during irradiation
- Security access controls, intrusion detection system and physical barriers



Mobile Accelerator What is it used for?



Mobile accelerator used by Canadian Border Services Agency
Source: CNSC

Used at the Canadian Border to find illicit materials concealed in vehicles and transports.

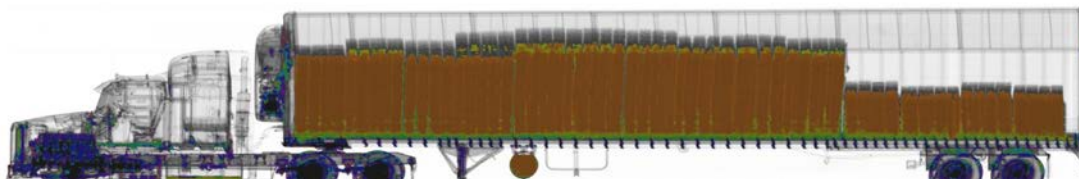


X-ray of concealed weapon
Source: Varian, Industrial and Security Products



Mobile Accelerator How does it work?

Diagram of barrier configuration during operation
Source: CNSC



X-ray of a transport truck
Source: Varian, Industrial & Security Products, 2018



Mobile Accelerator Summary

Radiation:

- Photon beam

Risk:

- Unplanned exposure to personnel in the vicinity

Controlled by:

- Barriers
- Safety systems





Industrial Radiography What is it used for?



A non-destructive method to examine the structures of castings, welds, and other building structures for internal defects and/or inclusions. This testing method utilizes radiation from nuclear sealed sources to capture images.

- Cable-operated exposure devices
- Pipeline exposure devices

Top, cable-operated exposure device. Bottom, pipeline crawler
Source: Welding and NDT Institute

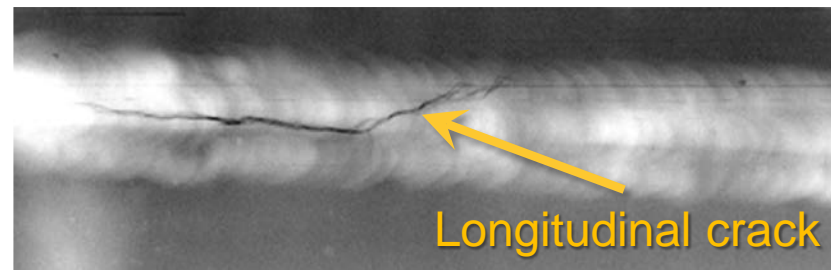
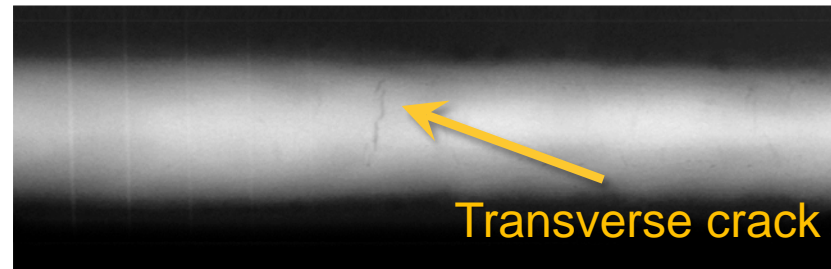


Industrial Radiography How does it work?

The radiation is used to expose radiographic film to produce radiographic images which are interpreted and evaluated against specifications or codes.

Radioisotopes:

Co-60, Ir-192, and Se-75



Radiography image of a crack in a weld.
Source: shutterstock



Industrial Radiography Summary

Risks:

- Unplanned exposure

Controlled by:

- Shielding
- Barriers
- Radiation surveys

Number of Licences: 118

Number of Locations: 239

Number of Devices per Location: between 1 – 48

Worker setting up a shot to perform radiography on a pipe
Source: CNSC





Oil Well Logging What is it used for?



The purpose of logging is to produce a chart recording of exploratory oil well parameters at depths.

Worker at well logging site handling logging tool
Source: shutterstock



Oil Well Logging How does it work?

A radioactive logging tool which is comprised of a sealed source and a detector is lowered into a borehole.

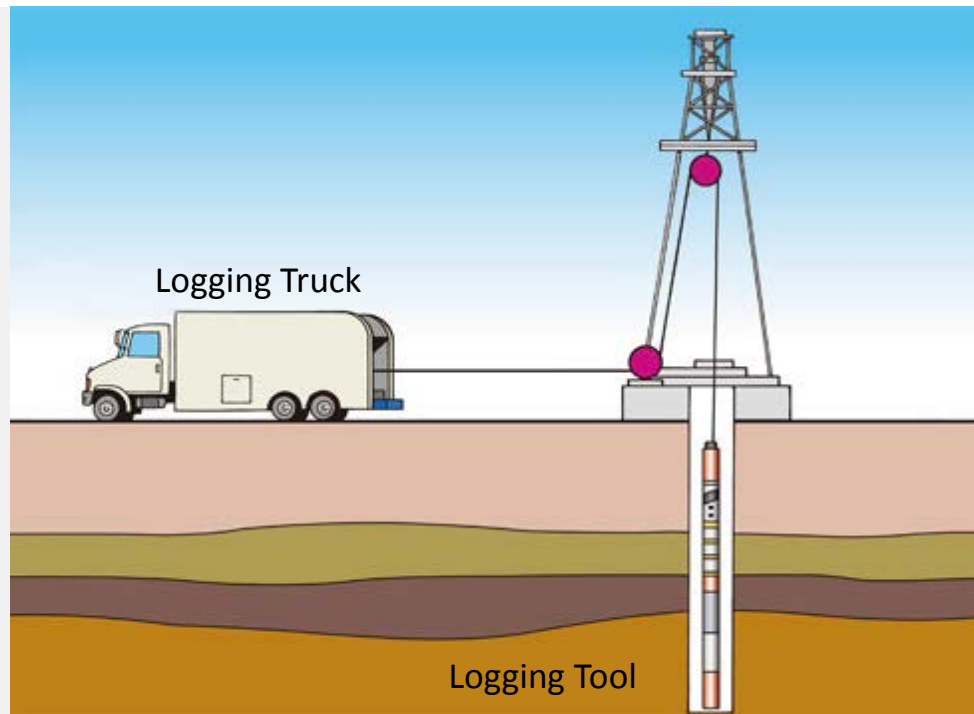
The data gathered is transmitted via an electrical cable to a computer system.

- Neutron porosity well logging
- Density well logging

Radioisotopes:

Cs-137, Cf-252, and Am-241/Be

Basic set-up for wireline logging
Source: Saltworks Consulting





Oil Well Logging Summary

Risks:

- Unplanned exposure
- Environmental contamination if a source is damaged underground

Controlled by:

- Safe handling techniques
- Sealed source is contained inside of a logging tool

Number of Licences: 36



Portable Gauges What is it used for?



Portable gauges
Source: Unknown

Portable nuclear gauges are used as quality control and measurement tools in various construction sites.

Radioisotopes: A typical moisture/density gauge contains Cs-137 and/or Am-241/Be.



Portable Gauges How does it work?

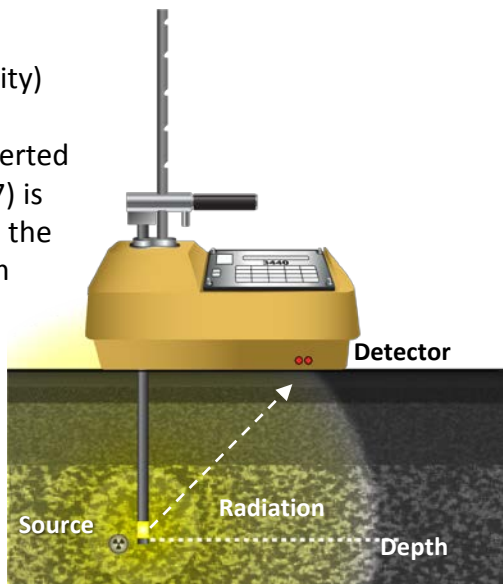
Direct Transmission Method

What is measured:

Compaction (Soil density)

How it works:

Radiation from the inserted gamma source (Cs-137) is transmitted directly to the detector at the bottom of the portable gauge



Source: CNSC

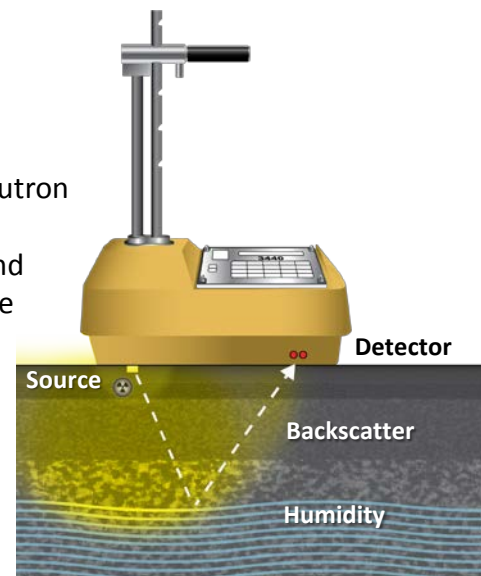
Backscatter Method

What is measured:

Moisture content or density of a material

How it works:

Radiation from the neutron source (Am-241/Be) is emitted into the ground from above the surface and scattered back to the detector



Source: CNSC



Portable Gauges Summary

Risks:

- Unplanned exposure
- Loss or theft of device

Controlled by:

- Safe handling techniques
- Shielding
- Radiation surveys

Number of Locations: 885

Number of Devices per Location: between 1 – 37

Number of devices in Canada: 4280



Safe Use of Portable Gauges



Canada's Nuclear Regulator

**Stay safe working with
portable nuclear gauges**



Fixed Gauges

What is it used for?



Fixed nuclear gauges are most often used in mines, mills and production facilities for quality control and monitoring the production process.

Radioisotopes: Depending on the application, common nuclear substances include Am-241, Co-60, Cs-137, Kr-85 and Sr-90

Figure: Radiometric Measurement in application

Source: Endress + Hauser



Fixed Gauges

How does it work?

Example 1

Flow or Density Measurement System

The gamma source holder emits energy through the walls of the pipe that reaches the detector mounted on the opposite side.

The gamma ray signal reaching the detector is converted into a proportional signal.

The density and flow measurement gauges are often used in the oil and the food industry.

Gamma: Co-60, Cs-137 or Am-241

Fixed Gauge Mounted on a Pipe

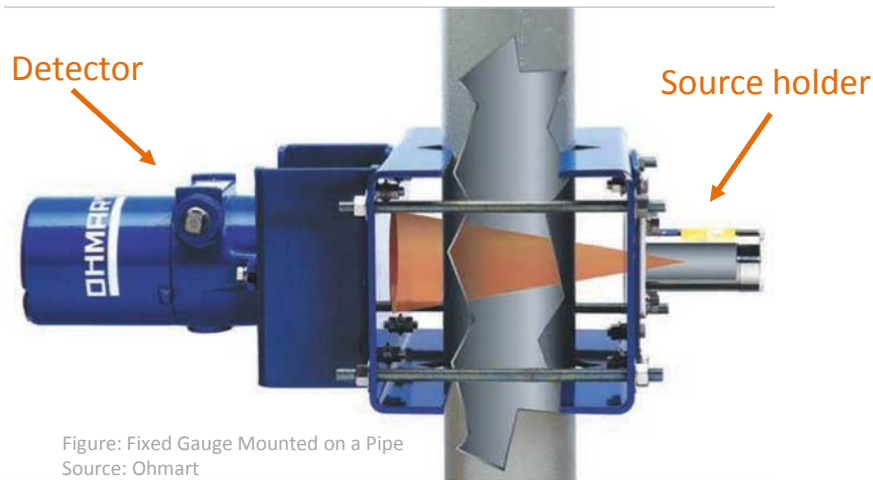


Figure: Fixed Gauge Mounted on a Pipe
Source: Ohmart



Fixed Gauges

How does it work?

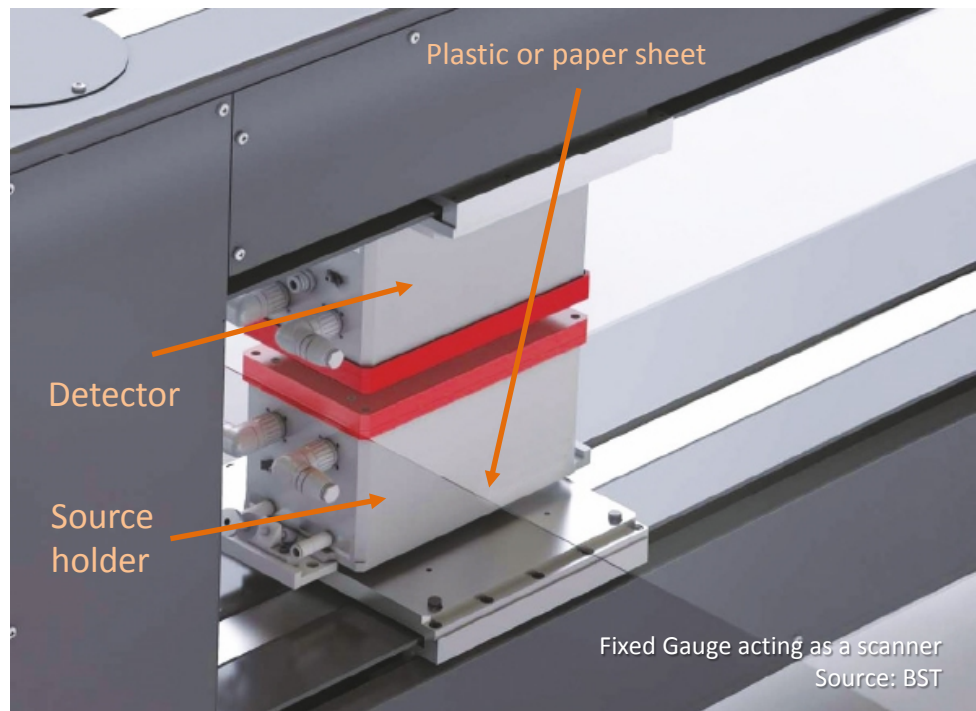
Example 2

Thickness monitoring

The detector analyzes the amount of beta or gamma radiation reaching the detector. This type of gauge is often used for quality control in plastic, pulp and paper industries, and other manufacturing industries.

Beta: Pm-147, Kr-85 or Sr-90

Gamma: Am-241





Fixed Gauges Summary

Risks:

- Unplanned exposure

Controlled by:

- Safe handling techniques
- Shielding
- Radiation surveys

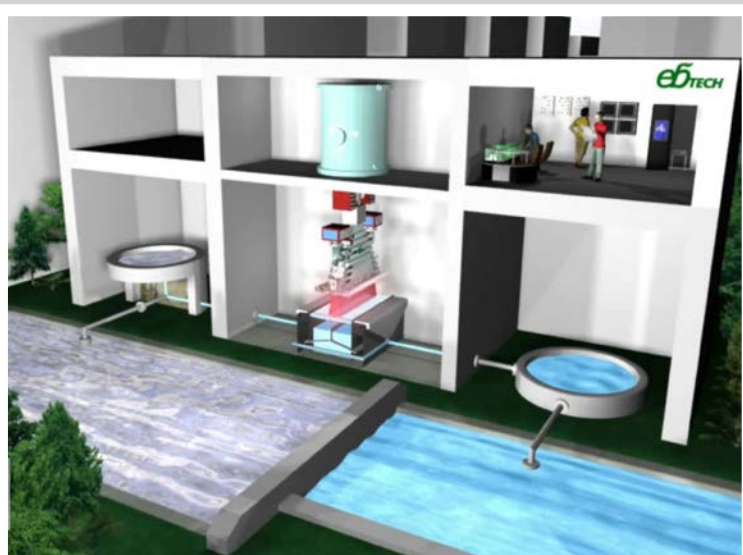
Number of Locations: 713

Number of Devices per Location: between 1 – 303

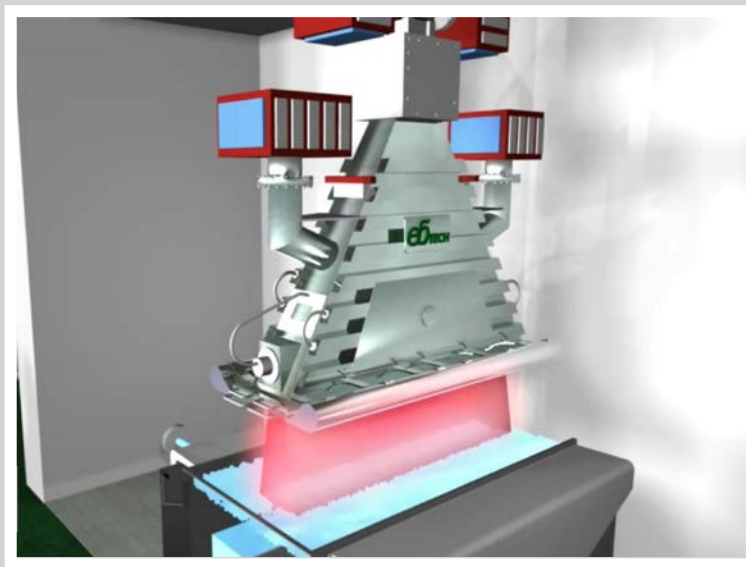
Number of Devices: 7300



Interesting and Novel Applications Electron Beam Accelerators

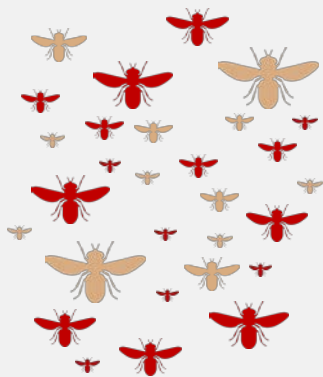


Concept, Treatment of Wastewater for Reuse with Electron Beam
Source: Texas A&M





Interesting and Novel Applications Sterile Insect Technique (SIT)



Mass-rearing of insects takes place in special facilities

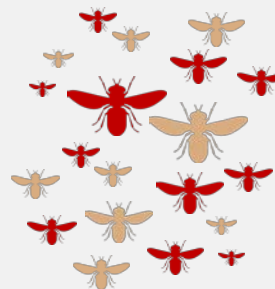
Source: CNSC



Male and female insects are separated. Ionizing radiation is used to sterilize the male insects.



The sterile male insects are released over town or cities...



...where they compete with wild males to mate with females.



These females lay eggs that are infertile and bear no offspring, reducing the insect population.



Interesting and Novel Applications Beehive Frames Sterilization



Linac used to eradicate
pesticides, fungicides and
parasites on beehives
and beehive equipment

Source: shutterstock



ACADEMIC AND RESEARCH SECTOR



Outline

- Academic and Research
- Interesting and Novel Applications



Academic and Research



This sector uses nuclear substances, radiation devices and prescribed equipment as a tool for laboratory studies, research, teaching, and calibration.

- Unsealed sources for the labelling of DNA or plants
- Sealed sources in self-shielded irradiators
- Accelerators and Class II Prescribed equipment for research in Physics and Medicine

Photo: Unsealed nuclear substance used in research laboratory, Source: CNSC
Insert: Self-shielded irradiator, Source: University of Toronto



Academic and Research Summary

Radioisotopes:

- Unsealed sources examples: C-14, Co-57, H-3, I-125, P-32, S-35
- Sealed sources examples: Co-57, Ba-133, Cs-137

Risks:

- Unplanned exposure
- Contamination

Controlled by:

- Radiation protection protocols
- Personal protective equipment

Number of Licences: 194



Interesting and Novel Applications Neutron Radiography

Visible light



X-ray



Neutron Radiography



Neutron Radiography compared to X-ray and Visible light
Source: Paul Scherrer Institut



Interesting and Novel Applications Isotopic Techniques



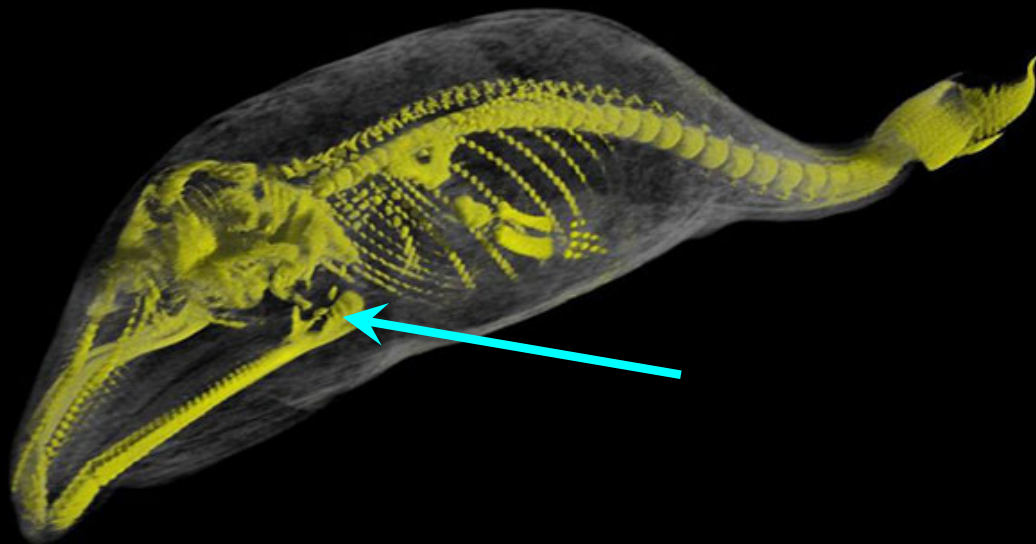
Livestock
Source: comstock



Plants being irrigated using drip irrigation technique at IAEA laboratory
Source: IAEA



Interesting and Novel Applications Novel Linac applications



Linac used as a high-energy CT scanner to scan a Minke whale
Source: FP Innovations



COMMERCIAL SECTOR



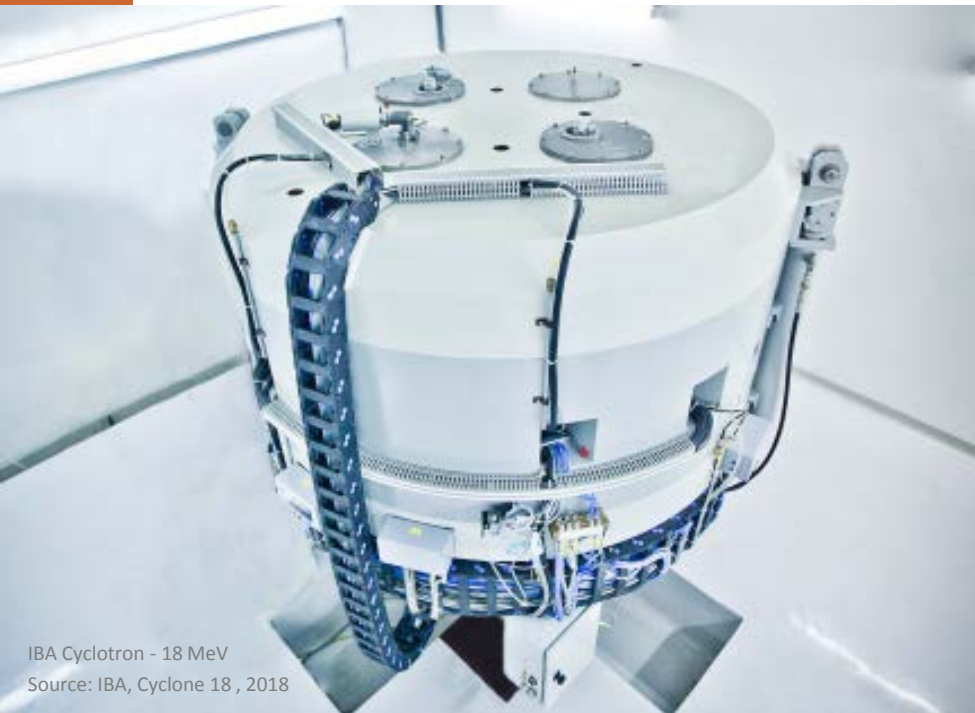
Outline: Commercial Sector

- Cyclotron
- Nuclear Substances Processing
- Calibration
- Other Applications



Cyclotron

What is it used for?



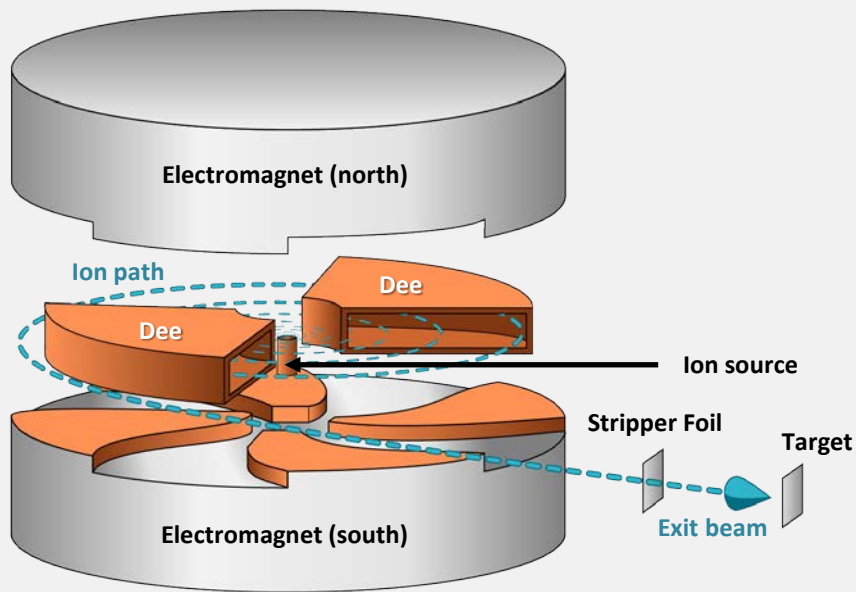
IBA Cyclotron - 18 MeV
Source: IBA, Cyclone 18 , 2018

Produce radioisotopes used
in PET and SPECT
radiopharmaceuticals
Research in production of
new radioisotopes
25 cyclotrons operating
across Canada



Cyclotron

How does it work?



Source: CNSC



Cyclotron

How does it work?





Cyclotron Summary

Risks:

- Exposure to gamma and neutron radiation
- Contamination from radioactive targets, stripper foil materials
- Radioactive gas releases

Controlled by:

- Shielding and safety systems
- Radiation monitoring and contamination controls
- Monitoring and controlling gas releases





Nuclear Substances Processing

What is it used for?:

Processes nuclear substances for use

- e.g. Nuclear medicine radiopharmaceuticals

How does it work?:

Uses various processing methods and equipment

- e.g. Mo-99/Tc-99m generators

Radioisotopes: Various

Risks: Large quantities of unsealed sources, environmental releases

Controlled by: Personal protective equipment, contamination monitoring and environmental release control

Number of Locations: 29



FDG Carousel
Source: CNSC



Calibration

What is it used for?:

- Use of nuclear substances, radiation devices or Class II irradiators to determine the response of radiation detection instruments

Radioisotopes:

- Check sources (Am-241, Pu-229, I-125, Co-60, etc.)
- Calibration sources (Cs-137 or Co-60) in a calibration irradiator

Risk:

- Unplanned exposure

Controlled by:

- Safety systems, radiation monitoring, safe handling techniques, shielding

Number of Radiation Devices: 46

Number of Class II Irradiators: 9



Figure: Exposure device
Source: J.L. Shepherd & Associate

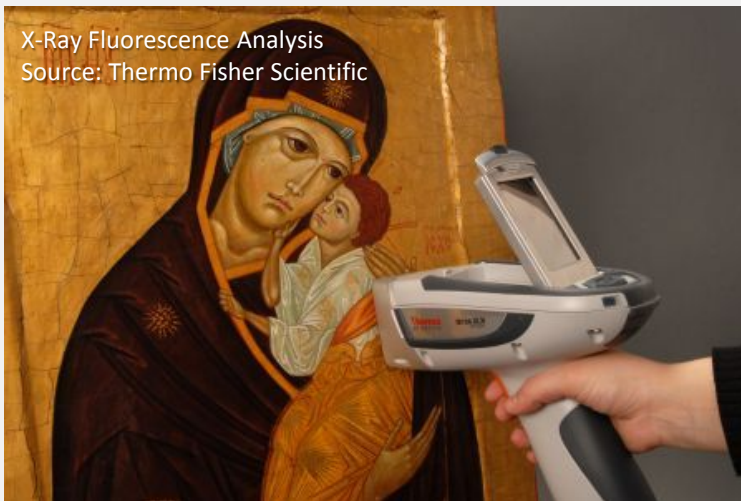


Automatic irradiator
Source: Pacific-Tec Scientific Pte Ltd



Licensed Low Risk Applications

X-Ray Fluorescence



- Am-241
- Determines materials composition

Electron Capture Detection



- Ni-63
- Explosives and narcotics trace detection
- Lab analysis



Devices Exempt From Licensing To:

Possess, transfer, use or abandon:

Tritium Safety Signs

Tritium safety sign
Source: fierceceo.com



Possess, transfer, use or abandon:

Am-241 smoke detectors exempt

Where: Private, Commercial

Smoke detector
Source: Ocean Lighting



Possess, transfer, use or abandon:

Some check sources are exempted

Where: Calibration, Nuclear
Medicine, Academics

Check sources
Source: Alara Consultants

Possess, transfer or use:

Luminous compounds devices
containing radium (Ra-226)

Where: Aircraft instruments, watches

Luminous compound devices containing radium
Source: reaa.ru





CLOSING REMARKS



Conclusion

- Radiation is used in a variety of technologies and applications within Canada across many sectors
- Changing technologies will provide future challenges
- CNSC's regulatory oversight and risk-informed approach ensures that all Canadians benefit from using such technologies, and can effectively control and mitigate risks

Continued Safe Use of Radiation in Canada

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Canadian Nuclear
Safety Commission

Commission canadienne
de sûreté nucléaire

Canada 