Safety Protocols for Radioactive Sample use at Canadian Light Source

Andrea Albert
Canadian Light Source

The Canadian Light Source (CLS) is Canada's national synchrotron research facility. It currently operates 22 beamlines used for scientific research. Periodically there are research proposals that request the use of radioactive samples at the facility. The CLS has a process for reviewing and approving these experimental proposals to ensure the safe handling of radioactive material and that license requirements can be met. Controls are also put in place for use once the radioactive samples arrive at the facility, and training is provided to those handling these samples. This presentation will cover the process by which radioactive samples are reviewed, imported and shipped, training provided and safety controls implemented for the experiment.

Liquid Moderated Neutron Spectrometer

John Paul Archambault
National Research Council Canada

A novel, water-based, neutron spectroscopy system has been designed, simulated, and tested at the National Research Council of Canada. The active part of the detection system is a proportional counter sensitive to thermal neutrons. The proportional counter is suspended along the symmetry axis of a large, rectangular water bath, and can be positioned remotely anywhere along this axis down to the bottom face. Measured count rates as a function of depth of the counter for both an americium-beryllium (AmBe) and a californium-252 neutron source demonstrate the ability of the system to discriminate between sources with different energy spectra. An MCNP6 simulation of an AmBe source agrees with the data within uncertainties and is used to construct the response functions of the spectrometer system. Unfolded energy spectra are determined using an analysis of the singular value decomposition of the response matrix. Finally, a Monte Carlo study of the system indicates an ability to measure the fluence rate of the radionuclide sources.

Contrasting real-world experience of the response to the terrorist attacks on September 11 2001 with IAEA GSR Part 7 EPR Requirements

Lauren Bergman
Health Canada

The tragic events that occurred in the United States on September 11 2001 shifted the paradigm for emergency preparedness and response (EPR) for terrorist initiated events. The consequence management component of EPR is similar regardless of location or the nature of the initiating event; therefore, the lessons learned from the response that followed in the day and weeks after the events of September 11 can be used to inform EPR plans and arrangements across nations and industries. A record of these lessons learned can be found in the Arlington County After Action Report on the Response to the September 11 Terrorist Attack on the Pentagon. In this work, we will compare the findings of this after action report to the requirements in the current standard for nuclear EPR, the International Atomic Energy Agency (IAEA) General Safety Requirements (GSR) Part 7: Preparedness and Response for a Nuclear or Radiological Emergency. This comparison against observed lessons learned from the consequence management of a significant emergency response allows us to better understand the basis for the GSR Part 7 Requirements, validate them

using real emergency response experience and identify any gaps or areas for improvement in the current nuclear EPR framework.

A review of radon exposure in workplaces and at homes

Jing Chen
Radon Protection Bureau, Health Canada

Radon is a naturally occurring radioactive gas and presents everywhere on the Earth at varying concentrations in workplaces and at homes. Exposure to radon and its short-lived progenies in the air has been identified as the second leading cause of lung cancer after tobacco smoking. Based on community and nationwide radon surveys with long-term radon measurements in a total of 21818 homes, radon distribution characteristics in Canada have been assessed with the population-weighted arithmetic mean radon concentration of 82 Bq/m3. With Canadian labour statistics, time statistics and more than 7600 long-term radon measurements in workplaces, occupational radon exposure is evaluated for all 20 job categories. In indoor workplaces, the employee-weighted arithmetic mean radon concentration is 34 Bq/m3. In outdoor field workplaces, the average radon concentration is 18 Bq/m3. In underground mining operations, the mean radon concentration is 111 Bq/m3 as recorded in National Dose Registry for underground uranium miners (annual effective dose of 0.8 mSv). In workplaces other than mines, occupational radon exposure results in an average annual effective dose of 0.21 mSv, which is lower than the average annual effective dose of 1.8 mSv from radon exposure at home by a factor of about nine. Due to relatively higher radon concentrations in residential homes and longer time spent indoors at home, radon exposure at home contributes 90% of workers' total radon exposure (in workplaces and at homes). Because the biological effect of radon in workplaces can not be distinguished from the biological effect of residential radon, radon-induced lung cancers are attributable to people's total radon exposure accumulated in workplaces and at homes. This review clearly indicates that at local and national level, reduction of radon levels in homes is very important.

Data Visualization: Using Power BI to Track Dose for a Fuel Repatriation Project (Poster)

Jennifer Clarke
Canadian Nuclear Laboratories

Dose management for a fuel repatriation project presented challenges resulting from a condensed project schedule, lower action levels, and a limited number of qualified staff to perform the work while also completing other unrelated tasks.

When a comprehensive method for tracking worker dose was requested, our Health Physics Technologist proposed using Power BI. This data visualization software offers an advanced reporting format which he configured to track all workers against their assigned dose control points (DCP) and CRL's action levels (quarterly and annual) by incorporation of data from at least two different databases.

Power BI reporting provided the area Health Physicist with daily access to project dose data in the form of easy to read graphs with action level thresholds. This enabled quick feedback to the field staff to limit the number of people on the job, to ensure those not directly involved were in low dose waiting areas, and to encourage switching out staff to maintain doses well below action levels.

Even after project completion, use of this reporting tool is ongoing. Many improvements have been added to date that will be presented along with this example.

Facilities Decommissioning at Chalk River

Brittany Cole
Canadian Nuclear Laboratories

Canadian Nuclear Laboratories (CNL) Facilities Decommissioning are currently responsible for 92 buildings that are either undergoing decommissioning or are being maintained under Storage With Surveillance until such time as decommissioning work can begin. This presentation focuses on the decommissioning work performed over 2021-2022 in two of the Chalk River Sites highest hazard buildings. The first building known as the 200 series is made up of 3 sub-buildings B200 A&B, B220, and B204. These buildings are connected to the National Research Experimental (NRX) reactor via a Fuel Rod Trench, they would receive and hold spent fuel before being transferred for dissolution in B220 and B200 and subsequent re-processing for Plutonium and Uranium recovery. The second building is Building 250 which was a large multipurpose laboratory which housed a tritium facility, Class C laboratories, and a Hot Cell Facility used for various experimental processes such as dissolution of fuel samples, various separation and extraction processes as well as waste management solutions such as vitrification trials.

Radiological hazards are identified in each of the buildings with specific controls in place to mitigate or remove these hazards. The 200 series building has implemented different remote tooling techniques to remove contamination and components of a system. One example is the Braun shaver which is being used to remove ¼ inch of contamination off the concrete walls prior to demolishing the building. The second is the Brokk which is a robotic tool to remove components of a system in an area where dose rates are too high for human occupancy. Building 250 has successfully removed a large activity Co-60 source from a loop experiment and an Active Liquid Storage Tank containing Plutonium and the buildings tritium facility using various means to maintain doses ALARA.

A Crushing Experience – Incident Response

Jeff Dovyak
Shared Health, Winnipeg, Manitoba

A Liquid Scintillation Counter (LSC) with an internal source was sent to hospital surplus unknown to the RSOs. Surplus sent it in a load of scrap metal to a local scrapyard. The LSC triggered a portal monitor at the scrapyard once processing began – the load was rejected and sent back to the hospital.

Hospital Warehouse manager notified RSO. RSO attended, checked dose-rates around scrap pile and arranged to come back two days later when calendar was clear and deputy was available.

This oral presentation will address the situation and actions taken by Radiation Safety staff. There are a number of photos.

Reporting tool for the final decommissioning of areas (Poster)

Nathalie Gadbois
Canadian Nuclear Safety Commission

Decontamination is the complete or partial removal of contamination by a deliberate physical, chemical or biological process. Decommissioning refers to the administrative and technical actions taken to remove all or some of the regulatory controls from an authorized facility, location, or site where nuclear substances are managed, used, possessed, or stored. Decommissioning actions are the work activities that are taken to retire a facility, location, or site from service with due regard for the health and safety of people and the environment.
In 2018, the methodology for conducting contamination surveys for the final decommissioning of areas was revised. The Canadian Nuclear Safety Commission (CNSC) licence condition for decommissioning was modified to specify that the surface contamination criteria for Class A, B and C radionuclides pertain to the total surface contamination (non-fixed plus fixed). Prior to 2018, the licence condition referred to non-fixed contamination only and a written approval by the CNSC was required for the release of any area containing fixed contamination.

Records are important to demonstrate that requirements are being met and to provide evidence of the physical state of areas. CNSC staff's review of some Nuclear Substances and Radiation Devices licensees' final decommissioning reports has revealed deficiencies in demonstrating compliance with the revised licence condition for decommissioning, and in adequately documenting the contamination survey results, methods and instruments used.

A tool for the final decommissioning of areas was developed by the CNSC to help licensees demonstrate compliance with the decommissioning criteria and to streamline regulatory reviews. Some important actions to take to properly demonstrate compliance with the decommissioning criteria will be presented along with instructions on how to use the tool.

Using Open Source Software to Convert CT Scans into an MCNP Input File (Poster)

Hannah Graham
Ontario Tech University

When calculating radiation doses to non-human biota, a more accurate model will result in greater dosimetric accuracy. When attempting to calculate doses to organs, voxel models have been used in human modelling for many years. In recent years an attempt has been made to create voxel models for various non-human biota species. Once the voxel models are created, the models are input into a Monte Carlo code. MCNP is an export-controlled Monte Carlo modelling code that is commonly used to model radiation doses using particle transport calculations. Voxel models have previously been imported into MCNP through a variety of methods and software. Much of the current software that is used is export-controlled. In an effort to remove all other export-controlled software from the CT to MCNP pathway, a new method is suggested. An open-source software 3D Slicer was used to segment the different structures that are located within the CT scans into boundaries. The boundaries in 3D slicer are exported in the STL file type. The boundaries are uploaded into an open-source software called Meshlab. Meshlab is used to manipulate the boundaries, and adjust any issues within the boundaries before they can be transformed into MCNP code. Operations include smoothing, simplification, and reorientation. In order to change the STL boundaries into a form that is useable in MCNP, software (VOX-MCNP) was developed using Python. Python was chosen as the programming language to develop the software due to its ability to process large amounts of data quickly. Using many of the available python libraries, the STL mesh can be input into VOX-MCNP which produces an MCNP input file that contains the cell and surface cards for the STL mesh.

Applications of Geostatistics to the Characterization of Nuclear Facilities Prior to Decommissioning

Mike Grey
1004137 Ontario Inc.

The characterization of a nuclear facility is essential perquisite to the planning of the decommissioning of the facility. CSA N294-19 describes the purpose of characterization is to "provide a complete description of the nature, extent, and variability of contamination in each area of the site/facility" and that standard advises following the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) when planning characterization. MARSSIM is currently being revised to place greater emphasis on the use of scan surveys which can be performed using autonomously piloted vehicles. Scan surveys are often performed using gamma detectors which may not detect the low-energy gamma and pure beta emitting radionuclides that often dominate the radionuclide vector post shutdown. Consequently, the scan survey must often be supplemented by the invasive collection of samples which are subjected to laboratory analysis. Then the results of the scan surveys and laboratory analyses must be combined to produce a complete characterization. Geostatistics is a statistical technique that can be used to analyze data that is spatially and/or temporally encoded. This approach is currently being investigated to determine if it can be used to combine the continuous data sets created by scan surveys with the discrete datasets produced by sampling and laboratory analysis to provide a complete characterization of a facility approaching decommissioning. This talk will review the current status of this work.

Experimental validation of simulations confirm that the local environment in a yeast-based impedance biodosimeter strongly influences the measurable dose

Amna Hassan
Ontario Tech University

Recent studies have shown that measuring changes in electrical impedance that follow radiation-induced suppression of metabolic activity in irradiated yeast cells can be used to determine radiation dose. However, the local environment around yeast cells can influence the energy deposition from incident radiation interactions and thereby influence the dose measured in these dosimeters. Previously, Geant4 Monte Carlo simulations were used to explain the differences in the radiation response, by modelling the local environment around yeast cells in a film-badge dosimeter developed by researchers at Purdue University. It was found that when yeast was surrounded by an aluminum-polymer structure, a greater dose to cells was observed. This work describes the benchtop experiments used to verify the simulation results for a novel dosimeter design that directly combined a finely-ground aluminum conversion medium with yeast powder. Two sample groups were irradiated to 3 Gy using a Cs-137 source. The first group contained 10 samples that combined yeast and aluminum powder, while the second group contained only yeast powder. An electrical impedance signal was measured for each dosimeter for 15 minutes. The results of these experiments showed that when irradiated in the presence of aluminum grains, yeast cells yielded a higher impedance signal, thereby indicating greater radiation-induced damage. This is because the increased secondary (and Auger) electrons and soft X-rays caused by absorption in the metal causes additional energy deposition in the yeast cells, and results in a stronger dose response. In conclusion, the local environment significantly influences radiative energy deposition in yeast cells, and hence, the radiation response of yeast cells in a badge assembly must be well characterized if used for biodosimetry applications.

Health Physics Society's Ask the Experts-Common Questions and Concerns from the Public

Daniel Hunton
Canadian Nuclear Laboratories

The Health Physics Society answers questions submitted by members of the public and industry on the subject of radiation protection and radiation safety. So far, over 13,000 detailed answers have been provided by health physics subject matter experts, answering these questions on a volunteer basis. This presentation summarizes some of the more interesting questions received over the last few years, and includes some of the detailed research that has gone into providing appropriate responses, as well as general communication strategies for use with members of the public. Specific issues related to instrumentation and radiation fundamentals are addressed, as well as any follow-up information or conclusions received from the questioners.

Understanding why rural Canadian residential communities contain higher levels of radioactive radon gas relative to urban equivalents, irrespective of region.

Selim Kahn
University of Calgary

Inhalation of radioactive radon gas within the built environment is a leading cause of lung cancer in Canada, with Canadian exposures being amongst the highest globally. No area of Canada has been found to be risk free of long term lung irradiation with cancer-causing doses (100 Bq.m3 or higher) of radon. Differences within the built environment are a primary driver of radon level differences between properties, with newer and larger residential homes with fewer storeys containing even higher levels compared to older, smaller, and multi-storey equivalents. Here, we examined differences in residential radon gas exposure between different community types (city versus large town versus small town versus village-hamlet-isolated properties) across the urban to rural paradigm as classified by Statistics Canada based on population density. We find substantial differences between community types, with people in rural communities in any Canadian province or territory experiencing even greater levels of residential radon exposure relative to urban populations; this was established by unsupervised machine learning multivariate clustering in ArcGIS, as well as a comparative analysis of geometric mean radon. Pairwise and multivariate analysis established that differences in construction years, design type, number of storeys, and ceiling height do not explain urban versus rural differences in radon. However, floorplan size (property square footage) and the usage of groundwater well as a water supply within a community correlated significantly with greater radon in rural community residences. We propose a model in which the proximity of a domestic groundwater well to a residential property operates as a “radon-syphon” enabling greater penetration of surficial soils with radon (from subsurface radon reservoirs in soil gas), generating higher radon levels in rural community homes, especially those that have larger surface areas on the ground. This work highlights a community-based disparity in Canadian residential radon exposure.

CNSC's concern of its ACFD licensees dwindling availability of competent Service Technicians and its present understanding of the situation.

Rick Kosierb
Canadian Nuclear Safety Commission

A few years ago, Accelerators and Class II Facilities Division (ACFD) of the Canadian Nuclear Safety Commission (CNSC) started to recognize that the technicians employed by their licensees to service their Prescribed Equipment (PE) have reached or will soon be reaching retirement age. Although the lack of the ability to repair their PE in a timely manner is not a direct radiation safety issue, the unusual extended repair delays and lack of technicians have an immediate impact on licensees' operations, which could lead to safety issues. This fact is especially true when many of its licensees only have two or three technicians to perform repairs and with most having two, if not all 3, in this age bracket. ACFD was also unfamiliar with the safety training related to the repair of PE beyond the radiation hazard for these technicians. Thus, ACFD conducted a survey of its licensees and their technicians and contracted an experienced individual in 2020 to fully understand both situations. This presentation discusses the findings from both of these actions.

The Development of an ACFD Service Technician's Competency Guidance Document

Rick Kosierb
Canadian Nuclear Safety Commission

With a reasonable understanding of the situation of the dwindling availability of competent Service Technicians of Accelerators and Class II Facilities Division's (ACFD) licensees, one of the actions this Division of the Canadian Nuclear Safety Commission (CNSC) performed was to create a competency guidance document to assist licensees. Written in a general manner, this guidance document outlines objectives, focusing on the application of knowledge and tasks that a service technician will need to accomplish to safely maintain Class II Prescribed Equipment. This presentation discusses this document and how it evolved; what it consists of and CNSC expectations in its use.

Radon in Atlantic Canada

Rabeb Labben
Health Canada

Exposure to high levels of radon in indoor air results in an increased risk of developing lung cancer. It is the leading cause of lung cancer in people who don't smoke. Homes and buildings with high levels of radon exist in all regions of Canada and is a particular concern in Atlantic Canada. The only way to know radon levels in a home or building, is to test for it. Health Canada's national radon program has led and supported many projects and campaigns, worked to create capacity with radon stakeholders, and collaborated with provincial and municipal governments in an effort to increase awareness and to encourage radon testing and mitigation and therefore, reduce the lung cancer risk for people in Atlantic Canada.

Applying Innovative Technology to Radiation Safety Program Management

Michèle Légaré
The Ottawa Hospital
&
Vivien Munoz-Ferrada
Dosel Australasia

Under the innovation program portfolio at The Ottawa Hospital, two continents joined forces and collaborated to customize and automate radiation safety program management to allow for more efficient use of resources.

If you are familiar with using multiple platforms to manage your leak testing, instrument calibration, employee designation and training, dosimetry, annual compliance reports, incidents, inventory sealed and unsealed sources, including managing multiple programs such as nuclear substances, X-Ray, and Laser Safety, you will want to watch this presentation. We will be illustrating how it used to be, ie. how RSOs used to manage their programs manually and how far we have come with digital technology innovation.

Have some fun watching a role play of ´record mania' on how an experienced TOH Corporate RSO working with DOSEL, founded by a brilliant innovative Australian Medical Physicist, created the better, innovative and completely integrated tool for Canadian RSOs to oversee their programs.
You'll see that, when it comes to innovation, two RSO brains are better than one.

Radiation survey of a True Beam linac operating in electron FLASH-RT mode (Poster)

Sheila MacMahon
BC Cancer Agency

Purpose:
There is increased interest in conducting pre-clinical FLASH-RT experiments because FLASH-RT may improve normal tissue sparing. This work compares the radiation levels outside a linac vault for modified FLASH-RT beams (dose rates >40 Gy/s) and unmodified operation.

Materials and methods:
A TrueBeam linac located in a clinical vault was modified to produce FLASH-RT beams. FLASH-RT dose rates were produced by running the linac in photon mode with the target, flattening filter, and MU chamber retracted from the beam and with an electron scattering foil in the beam. During continuous 15 MeV FLASH-RT delivery, a radiation survey was conducted using a Victoreen 451P survey meter and a Berthold 6411 neutron meter. Dose rates were measured at multiple locations outside the vault both with and without scattering material in the field. FLASH-RT survey measurements were compared with results acquired during continuous delivery of the highest energy 15 MV clinical photon beam.

Results:
Maximum observed gamma radiation dose rates during FLASH-RT (clinical beam) delivery were 10 (3.2) µSv/h at the vault door, 7.6 (0.8) µSv/h at the linac console, 5.6 (0.5) µSv/h through primary shielding adjacent to the vault door, 22 (2.5) µSv/h at a physics cable port in the shielding, and 27 (2.8) µSv/h through primary shielding on the building exterior. Background readings were <0.1 µSv/h. Maximum observed neutron dose rates were 0.2 µSv/h

and 0.1 µSv/h at the vault door during FLASH-RT and clinical beam deliveries respectively. The dose rate >25 µSv/h measured outside the building during FLASH-RT resulted in the decision to restrict the gantry angle in FLASH-RT experiments to 0^o.

Conclusions:
While TrueBeam linacs are capable of producing radiation fields suitable for electron FLASH-RT experiments, the ability to operate in FLASH-RT mode while complying with radiation safety regulations may depend on the existing vault shielding design.

The Role of Radioactive Sources in Ionizing Radiation Metrology - Challenges & Opportunities

Malcolm McEwan
National Research Council Canada

Radioactive sources have found numerous applications since the original discovery by Becquerel in 1896 – radiation sterilization, well-logging, cancer therapy, radiography, environmental pathway tracing, to name a few. Radioactive sources are also critical to the field of ionizing radiation metrology, providing reliable calibration fields and reference sources for detector characterization and long-term monitoring of measurement standards.

Over recent years there has been increased pressure to limit the use of radioactive sources in many of these applications, driven primarily by security concerns. For example, the Office of Radiological Security (ORS) has a target to eliminate all Cs-137 blood irradiators in the US by 2027. With Cs-137 fulfilling a critical role in radiation protection - both in calibration laboratories and in normative standards - the loss of this key isotope would have a significant impact. Although metrology uses of radioactive sources are not a primary focus of regulators, there are already challenges in obtaining suitable sources and/or maintaining existing irradiators containing radioactive sources.

In light of this, the Consultative Committee on Ionizing Radiation (CCRI) of the BIPM (Bureau Internatonal des Poids et Mesures) formed a task group to look at the role of radioactive sources in ionizing radiation metrology and the potential options for alternatives. The task group drew representatives from National Metrology Institutes from around the world, as well as experts from the IAEA and the radioactive source manufacturers' community, with the aim of providing a metrology-specific perspective on this topic.

This presentation will describe the work of the CCRI TG, highlighting the current situation, immediate and future challenges, and options for maintaining accurate measurement standards and calibration services. Non-isotopic solutions to specific measurement issues will be discussed, including ultra-stable x-ray systems, accelerator-on-a-chip technologies, and an increasing role for simulations.

Acceptance Criteria for Optimizing Acceptance for Radiation Protection of People from Nuclear Fuel Repository

Chantal Medri
Nuclear Waste Management Organization

The Nuclear Waste Management Organization (NWMO) is responsible for implementing Adaptive Phased Management (APM), the federally approved plan for the safe long-term management of Canada's used nuclear fuel. Under this plan, used nuclear fuel will ultimately be placed within a deep geological repository in a suitable host rock formation. The primary objective of a deep geological repository is the long-term containment and isolation of used nuclear fuel. The long-term safety of the repository is based on a combination of the properties of the waste material, engineered barriers, and geology. As the project moves toward site selection and in preparation for the licensing process, the NWMO is performing preliminary pre-closure and post-closure safety assessments of the potential sites. These assessments help determine the possible effects of the repository on the health and safety of people and the environment during the operation of the facility and in the long term after repository closure. The results of the site-specific safety analyses are judged for acceptability using acceptance criteria. Acceptance criteria form part of a safety goal, ensuring that the protection of people and the environment during all APM project stages is optimized, with social and economic factors considered. This presentation describes the approach to defining acceptance criteria as tools for optimizing the radiological protection of persons and the environment during all phases of the APM project, taking into account national and international guidance, assessment uncertainties, and the iterative nature of the safety assessment and design cycle.

Investigations into the First NRX Reactor Calandria at Chalk River Laboratories

Dale Morris
Canadian Nuclear Laboratories

On December 12th, 1952 a severe accident occurred at the NRX reactor at the CRL site. An experiment resulted in coolant boiling, fuel melting and component failure that severely damaged the NRX Calandria. After the accident the damaged Calandria was removed and has been buried in a CRL Waste Management Area for the past 70 years. Reactor physics calculations used neutron activation analysis and decay correction to estimate the radionuclide activities in the Calandria. Dose and shielding calculations used these activities to estimate the dose rates from the full calandria and samples to be collected.

CRL Reactor Segmentation staff led the project to design and built tooling, and enable access of the buried calandria. Video inspection into the damaged Calandria were competed. Radiation protection instruments were lowered into the Calandria to collect gamma dose rates, beta doses, and gamma spectroscopy. Samples were collected from the Calandria Shell, fuel channel segments, soil debris in the bottom of the Calandria, and loose contamination.

Preliminary results, video, pictures, and dose rates will be presented. Conclusions can be drawn from the preliminary results to determine a safe method for both the environment and workers to package the material for safe long term storage.

High-yield cyclotron production of ^{203}Pb using a sealed ^{205}Tl solid target

Bryce Nelson (Anthony J. Mackay Student Paper Contest Winner)
University of Alberta

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Introduction
Nuclear medicine theranostics involves labeling a biological targeting vector first with a radionuclide for diagnostic imaging, followed by a particle-emitting radionuclide for targeted radionuclide therapy. Lead-212 (^{212}Pb, $t_{1/2}$ = 10.6 h) is a particularly attractive therapeutic radionuclide due to its payload of one α and two $β^-$ particles in its decay chain, and the rapid decay of its progeny to stable ^{208}Pb. A recent clinical trial (*J Nucl Med*. 2022;63(9):1326-1333) using [^{212}Pb]Pb-DOTAMTATE to treat metastatic neuroendocrine tumors resulted in an 80% overall patient response rate, significantly exceeding standard-of-care treatments. However, diagnostic scans to track ^{212}Pb therapy were performed with conventional fluorine-18 and gallium-68 radiotracers. This is suboptimal, as dissimilar chemistries between the diagnostic and therapeutic radionuclides could result in different radiopharmaceutical biodistribution, potentially leading to unintended α-irradiation of healthy tissues.

^{212}Pb is ideally paired with the chemically identical lead-203 (^{203}Pb, $t_{1/2}$ = 51.9 h) to provide diagnostic SPECT imaging using the 279 keV (81%) gamma-photons emitted during ^{203}Pb decay. However, worldwide supply of ^{203}Pb is extremely limited since cyclotron ^{203}Pb production requires irradiating highly toxic thallium (Tl) material.

Our objectives were to develop a high-yield ^{203}Pb cyclotron production route using isotopically enriched ^{205}Tl target material and the $^{205}Tl(p,3n)^{203}Pb$ reaction as an alternative to lower energy production via the $^{203}Tl(p,n)^{203}Pb$ reaction. A robust cyclotron target and efficient chemical purification process must be designed to maximize ^{203}Pb yield and purity for research and clinical applications, while maintaining stringent radiation and chemical safety given the significant hazards presented to the operators and cyclotron facility.

Methods
Our entire process was designed around preserving radiation and chemical safety. To reduce Tl contamination risk, we employed our patent-pending sealed cyclotron target design that is used to produce other radionuclides. ^{205}Tl metal (99.9% isotopic enrichment) was pressed using a hardened stainless-steel die. High purity aluminum (Al) target discs (99.999%) were machined with a central depression and annulus groove. A ^{205}Tl pellet was placed into the central depression of the Al disc, and indium wire was laid in the annulus. An aluminum foil cover was then pressed on, cold welding the cover to the disc via the indium with an airtight bond. Targets were irradiated at 23.3 MeV for up to 516 min on a TR-24 cyclotron at proton currents up to 60 μA to produce ^{203}Pb via the $^{205}Tl(p,3n)^{203}Pb$ nuclear reaction. Following a period of >12 h to allow decay of ^{204m}Pb ($t_{1/2}$ = 67 min, 899 keV (99%)), the target was removed and ^{205}Tl was dissolved in HNO_3. A NEPTIS Mosaic-LC synthesis unit performed automated separation using Eichrom Pb resin, and ^{203}Pb was eluted with HCl or NH_4OAc. The waste solution was diverted to a vial for subsequent ^{205}Tl recovery in an electrolytic cell. ^{203}Pb product radionuclidic and elemental purity were assessed by high-purity germanium (HPGe) gamma spectroscopy and inductively coupled plasma optical emission spectroscopy

(ICP-OES), respectively. Radiolabeling and stability studies were performed with PSC, TCMC, and DOTA chelators, and ^{203}Pb incorporation was verified by radio-TLC analysis.

Results
Cyclotron irradiations were performed at a 60 µA proton beam current and 23.3 MeV energy without any target degradation. Automated purification took <4 h, yielding >85% decay-corrected ^{203}Pb with a radionuclidic purity of >99.9%. Purified ^{203}Pb yields up to 12 GBq were attained, and ^{203}Pb was successfully chelated and exhibited >99% incorporation after 120 h in human serum.

Radiation safety implications: In over 100 production runs, there were no cyclotron target station or processing equipment contamination incidents. Targets were irradiated during the afternoon and removed the following morning to permit decay of short-lived impurities. By allowing >12 hours (>10 ^{204m}Pb half-lives) prior to target removal, operator dose was minimized. Utilizing high purity Al target components nearly eliminated long-lived activation products, minimizing operator extremity dose when performing target recycling. When combined with a target retrieval shielding cart, a custom-designed lead-shielded processing castle, and an efficient automated process, the operator radiation dose per full production run is <10 µSv (measured by electronic personal dosimeter).

Conclusion
Our recently published high-yield ^{203}Pb production process significantly enhances ^{203}Pb production capabilities to meet the rapidly growing worldwide preclinical and clinical demand for ^{203}Pb radiopharmaceuticals alongside ^{212}Pb alpha particle therapy.

Since January 2022, we have successfully shipped over 60 batches of ^{203}Pb to customers and collaborators in 11 locations across 5 countries for research and diagnostic SPECT imaging clinical trials of metastatic melanoma and neuroendocrine tumors. Although we anticipate continually increasing demand, we are confident that our robust process design will maintain operator radiation dose at a small fraction of the permitted annual limit.

Radiologists' ability to identify noise and image quality in pediatric phantoms at one institution

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Introduction
Pediatric patients exposed to radiation due to diagnostic imaging have an increased risk of developing future malignancies. Radiology scanning procedures and technology vary from institution to institution making it difficult to come up with universal strategies for radiation dose reduction. We conducted a single-institution study investigating radiologists' ability to detect changes in imaging noise and diagnostic quality at different radiation doses in pediatric phantom scans.

Methods

One pediatric 'phantom' patient of a simulated head, chest/abdomen/pelvis, and abdomen/pelvis was scanned using computed tomography at four different noise index levels.each image set was scanned four times to create four different series, with each series having a different noise index level. In order to modify the noise index between image sets, the mAs was modified between each series. Radiologists at our institution were surveyed for determining relative noise, identifying scans closest to the current standard of practice, and determining scans of diagnostic quality.

Results
Ten radiologists were surveyed. The included participants were academic staff radiologists at McMaster University with 5 to 28 years of experience practicing radiology. Six of the included radiologists were pediatric subspecialists, whereas the remaining four were adult radiologists. Similarly, the time spent reporting pediatric specific scans was widely variable, ranging from every day to rarely ever. Overall, the included participants were able to correctly rank 104/160 series when asked to order the series from least noise to moist noise. 33/40 responses stated that more than one series were of equal noise, which was not true in any of the phantom scans. 11/40 responses stated that the series with the most noise was of diagnostic quality. 9/40 of responses correctly identified the series most similar to their current standard of practice. There was variability in classification accuracy for relative noise between the abdomen/pelvis, chest/abdomen/pelvis, and head scans. Similarly, there was variability in the classification accuracy between the pediatric and adult radiologists.

Discussion
This quality improvement study found that, in general, there was considerable variability in radiologists' ability to accurately determine the relative noise index of a scan when comparing it to the same scan of a different noise index, as radiologists were only able to correctly rank series from least noise to most noise 60% of the time (104/160). Furthermore, this study showed that many radiologists report series' with a NI higher than the institution standard were of diagnostic quality. This indicates the potential for increasing the noise index in order to reduce radiation dose, without losing diagnostic quality of that image. Our institution-specific findings are consistent with the literature in that the ability for radiologists to accurately discern scans with higher noise from those with lower noise displays interobserver and international variability. Interestingly, classification accuracy for relative noise appeared to vary between the abdomen/pelvis, chest, and head scans. When asked what series was most similar to radiologists' current standard of practice, there appeared to be a tendency to pick the series with the least noise. Additionally, multiple radiologists found scans to be of equal noise index, when in reality none of the scans had the same level of noise. This strengthens the possibility for increasing the noise index for the purpose of reducing pediatric radiation dose without sacrificing diagnostic quality. Further investigation is warranted with regards to reducing radiation doses without sacrificing diagnostic quality. Eventually, conducting a similar study with patients would provide the highest quality evidence. Furthermore, we highlight the importance of conducting institution-specific dose reduction studies to improve radiation exposure practices at the institution level, and beyond.

Radiation Protection in Manitoba - A Collaborative Effort

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&
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Our role as radiation protection officers is to support x-ray facilities to meet their diagnostic imaging needs with low dose management goals and provide radiation safety strategies to protect staff, public and patients from potential hazards of ionizing radiation exposures. We accomplish this goal by working with with Health Physicists, Imaging Physicists, Shared Health Manitoba, Manitoba Dental Association, Manitoba Chiropractic Association, Clinical Engineering, Radiation Safety Officers and Red River College, to provide services, resources, and knowledge in matters associated with ionizing radiation.

Radon Progeny Exposure Incident in Underground Uranium Mine

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In January of 2019 routine monthly dosimeter results indicated an unplanned radon progeny exposure incident stemming from work at an underground Uranium mine. The dosimeter measured 0.855 WL (4.3 mSv) - two orders of magnitude higher than average monthly exposures. A full root cause investigation was initiated and findings will be presented that detail the exposure and its causal factors.

Commissioning a Canadian Light Source Beamline for Radiation Safety

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Canadian Light Source Inc.

The Canadian Light Source is Canada's national synchrotron research facility. It operates a 2.9 GeV electron accelerator that produces high energy photons for experimental use. Each beamline is designed and constructed to meet stringent limits for radiation protection. The CLS has a defined process for the commissioning of the beamline safety systems required for operation. This presentation will discuss the process by which CLS beamlines are designed, built, commissioned and released for normal use. It will specifically touch on the radiation protection aspects of shielding configuration, testing parameters and radiation measurements completed before a beamline is ready for routine operation.

Radiation Protection Program for Large Scale Imaging Systems

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The Canada Border Services Agency (CBSA) is involved in providing integrated border services that support national security, public safety priorities and facilitate the free flow of legitimate persons and goods into Canada. Technology and globalization changed the world economy in the 1990s and the CBSA felt the need to conduct its operations in an expeditious manner to keep up with the changing environment. This led to the procurement of Large Scale Imaging (LSI) systems that were capable of examining goods faster, in a non-intrusive manner.

The first LSI system was a mobile gamma-ray-based system procured and operated by the CBSA in 1999. It was used to scan an entire 40-foot long marine container to provide its transmission image in a matter of minutes and provide a first hand information of its contents. Since then the CBSA has enhanced its capabilities by transitioning to more advanced Linear Accelerator (LINAC)-based LSI systems capable of generating high-energy x-rays that

provide better penetration and a higher quality image. These systems enabled the CBSA to better secure the border.

The CBSA has developed a robust Radiation Protection Program for operation of these systems, which ensures that all activities are carried out in a secure manner and appropriate measures are taken to mitigate any risk of radiation exposure to the operating personnel as well as the general public. This presentation will provide an overview of this program and the measures adopted, which include the policies and procedures laid out for operation of various types of LSI equipment, personnel training, use of Personal Protection Equipment (PPE) as well as monitoring and documentation to ensure adherence to the As Low As Reasonable Achievable (ALARA) principle.

Factors Contributing to Ho-166/PLLA Microsphere Degradation

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Background
Selective internal radiation therapy (SIRT) has been gaining popularity as a treatment for hepatocellular carcinoma. A beta-emitting isotope is encapsulated in microspheres and injected into the liver via the hepatic artery. Initial treatment options used Y-90 encapsulated in aluminosilicate glass (Barros et al., 2014). Y-90 undergoes pure beta-minus decay with a 64.1 hour half-life. This results in concentrated doses of radiation directly at tumor locations and minimal external dose risk to manufacturing staff, administering physicians, and shielding requirements to ship treatments. However, Y-90 microspheres do not allow for any imaging to track the location of microspheres. Due to this major limitation, other isotopes were considered for selective internal therapy treatments.

Holmium-166/PLLA microspheres can be used for SIRT while remaining imageable via MRI or SPECT (Yamazaki et al., 2020). Ho-166 decays 100% via beta-minus decay followed by gamma ray emissions of 80 keV (6.5%) and 1379 keV (0.9%). Due to Ho-166 half-life of only 26.8 hours, higher specific activity is needed at production. The gamma emissions and higher specific activity cause radiation dose risk to production staff. Additionally, PLLA microspheres are staticky and act like a powder, unlike previous glass versions. This presents additional radiation protection challenges.

There are several considerations during the production and suspension of Ho-166/PLLA microspheres to ensure adequate quality for patient treatment. Neutron irradiation causes damage to microspheres leading to decomposition. This damage is theorized to be caused by temperature, gamma photons, fast neutrons, and/or side reactions of thermal neutron capture (Vente et al., 2009).

Methods
Microspheres were exposed to a range of gamma doses (0-800 kGy) using a cobalt-60 source. The microsphere batches were then divided and maintained at temperatures ranging from 20-100 °C for at least 4 hours. This created samples with unique combinations of temperature and gamma radiation exposure.

To assess environmental factors in-core, a rig with detachable Pb shielding was engineered. Shielding of 0.25-1.25 cm were tested for temperature, flux, and sample quality. Microspheres were tested at specific activities ~25 MBq/mg and ~40 MBq/mg.

All samples were suspended in media and imaged at 24-hour intervals. Sample quality was assessed by light microscope imaging with a digital camera attachment. The total number of damaged microspheres was calculated as a percentage of the total.

Results

Temperature showed significant impact on quality. Batches below 55 °C had minimal damage (~1-4%). The 60 and 65 °C samples represented a significant damage threshold, where damage was at least 2x that of a control sample at suspension (6-20%). A damage threshold of 60-65 °C coincides with the glass transition temperature (Tg) of PLLA. The 70+ °C batches had extreme levels of damage in all samples, in the range of 80-100% damage.

Gamma dose in temperatures below Tg did not show any notable impact on quality except for 600 kGy samples. Samples at 600 kGy showed more damage than 800 kGy samples in almost all trials. The effects of gamma radiation seen in these trials may change for increased dose rates, more representative of environments in-core. Notably, batches exposed only to gamma radiation and temperature did not show degradation over time, normally seen in samples irradiated in-core.

Variable shielding in core had prominent impacts on temperature, neutron flux, and sample quality. The temperature in the rig showed a decreasing trend with the increase of Pb shielding. Temperatures exceeded 60 °C in the 0.25 cm shield but dropped to 43 °C by the 1.25 cm attachment. Thermal neutron flux decreased with greater Pb thickness for attachments of 0.25-1.0 cm. The 1.25 cm shield increased thermal neutron flux. Microsphere samples in attachments 0.25, 0.5, and 0.75 were all viable at ~25 MBq/mg. Microsphere samples at ~40 MBq/mg showed unacceptable damage in attachments 0.25-1.0 cm of PB.

Conclusions

Temperature showed the most drastic impact on quality. The 60/65 °C samples represented a significant damage threshold. This temperature coincides with the glass transition temperature (Tg) of PLLA, which falls in the range of 60-65 °C. Ionizing radiation inducing chain scissions reduces Tg and may account for the increasing damage in samples above 200 kGy heated to 65 °C. Gamma dose had minimal impact on low temperature samples. Samples irradiated to 600 kGy had more severe damage than other batches and suggests a damage threshold induced by polymer chain-scissions. Further testing is needed for dose-rate impact. Finally, increased Pb shielding of samples was shown to decrease temperature in the sample chamber and alter the thermal neutron flux. These insights inform the selection and equipment production of new reactor sites for Ho-166/PLLA microsphere production.

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Exploring the Concept of Optimization of Radiation Protection in Emergency Planning

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The International Commission on Radiological Protection's three fundamental principles of radiological protection are justification, optimization, and dose limitation. While justification and dose limitation are readily understandable and quantifiable, the concept of optimization is somewhat more abstract.

Optimization is a straightforward high-level concept for a person to grasp - do more with less, last longer with the same power supply, maximize the benefit obtained from resources, etc. However, for technical problems, such as emergency planning, it is far more obtuse and challenging to quantify. Reduction of radiation exposure to levels below known physical and probabilistic health impacts is understandable, but when it is required to be balanced and optimized with other issues such as limited evacuation routes leading to high probability of traffic accidents, long term psychological impacts of an evacuation, mixed hazard environments from other effects like forest fires and other emergency situations, it is more challenging for the health physicist. The IAEA has encouraged Member States "to ensure that radiation protection strategies are developed, justified and optimized to enable effective protective actions to be taken in a timely manner, during a nuclear or radiological emergency" (https://www-pub.iaea.org/MTCD/Publications/PDF/EPR-Protection_Strategy_web.pdf and specifically from GC(62)/RES/6,). There is a need for the elaboration of general overarching views and specific technical guidance on optimization during an emergency for health physicists to reference when they are required to provide input into this area.

This presentation will explore the issue of optimization of radiation protection in emergency planning. We will discuss the concept of optimization and frame how it applies to different areas of nuclear emergency response planning. I will provide an overview of some of the most recent guidance that is related to this topic and ultimately discuss where short comings can be identified and suggest the type of scientific contributions that are needed in the health physics community to address this issue.

Empowering communities to take on Radon: Grass-roots initiative with expert support

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Canadian Association of Radon Scientists and Technicians
&
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In 2021, Statistics Canada reported that 9% of Canadians who had heard of radon had tested their homes. This low rate is concerning, particularly as only 60% of Canadians reported knowing about radon. To address low testing rates, the Take Action on Radon team created a community-based intervention, the "100 Radon Test Kit Challenge". The intervention aimed to 1) work with communities to raise awareness, 2) provide training and resources to get people testing, and 3) report results back to communities. Starting in 2019, 101 communities across 9 provinces participated- a mix of rural, urban and suburban locations. More than 12,000 test kits were distributed and, on average, 74% of the test kits were returned for analysis.

Results from each community varied- the proportion of homes exceeding Health Canada's guideline of 200 Bq/m3 ranged from 0-79%. Radon measurement in participating homes ranged from <15 to over 5000 Bq/m3. Key takeaways from this intervention include: 1) Providing basic radon education is a key first step due to continued low awareness of radon, 2) Creating a testing community is instrumental for recruitment and completion, 3) Establishing local champions is necessary to ensure the program runs smoothly, and 4) Providing a technical support person who can address testing related questions is necessary. 5) Follow-up work with the communities shows that the intervention has led to sustained programming in some communities such as grants for radon mitigation and sales of test kits by municipalities. Our follow up survey with participants shows levels of mitigation rates are consistent with other paid programs across the country.

Continued interest in the program and the high detector return provide clear evidence that a supportive, grassroots based radon testing program is a good model for increasing the number of homes tested for radon in Canada.