RADIATION BY THE NUMBERS: DEVELOPING AN ON-LINE CANADIAN RADIATION DOSE CALCULATOR AS A PUBLIC ENGAGEMENT AND EDUCATION TOOL

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Abstract

Concerns arising from misunderstandings about radiation are often cited as a main reason for public antipathy towards nuclear development and impede decision-making by governments and individuals. A lack of information about everyday sources of radiation exposure that is accessible, relatable and factual contributes to the problem. As part of its efforts to be a fact-based source of information on nuclear issues, the Sylvia Fedoruk Canadian Centre for Nuclear Innovation has developed an on-line Canadian Radiation Dose Calculator as a tool to provide context about common sources of radiation. This paper discusses the development of the calculator and describes how the Fedoruk Centre is using it and other tools to support public engagement on nuclear topics.

Keywords: Radiation awareness, education, engagement, outreach

1. Introduction

Concern and fear of ionizing radiation arising from misunderstanding is frequently cited as one of the main reasons for antinuclear sentiments in the general population, which in turn impedes decision-making by governments. For example, fear of radiation in the aftermath of the tsunami-induced accidents at Fukushima Daiichi has been identified in criticisms of the evacuation effort of surrounding communities, which resulted in fatalities and ongoing deleterious impacts on the health and economic well-being of evacuees. [1]

A lack of information about everyday sources of radiation exposure that is accessible, relatable and factual contributes to public misunderstanding and fear. As part of its mandate to be a fact-based source of information on nuclear issues, the Sylvia Fedoruk Canadian Centre for Nuclear Innovation (Fedoruk Centre) identified a need to address misunderstandings related to radiation as part of its public engagement and outreach activities. Central to this effort is the communication of three main understandings:

- Radiation is a natural part of the environment;
- We are exposed to natural and artificial sources of radiation every day; and
- People are normally exposed to doses of radiation as the result of where and how they live.

1.1 An online annual dose calculator

The Canadian Nuclear Society (CNS), Canadian Nuclear Safety Commission (CNSC), Health Canada and other agencies and organizations feature information on their websites on radiation. While this information is generally accessible and accurate, it was felt that a tool that was more interactive and which could be related to on a personal level by Canadians would be useful. The American Nuclear Society (ANS) maintains a Radiation Dose Chart on its website [2] that identifies common sources of ionizing radiation and then tallies total annual exposure based on an individual's responses and inputs based on a number of geographic, lifestyle and medical factors. However, as it is tailored for a U.S. audience, the ANS chart is not ideal as an outreach tool for Canadians. To address this need, the Fedoruk Centre developed the Canadian Radiation Dose Calculator (Figure 1).

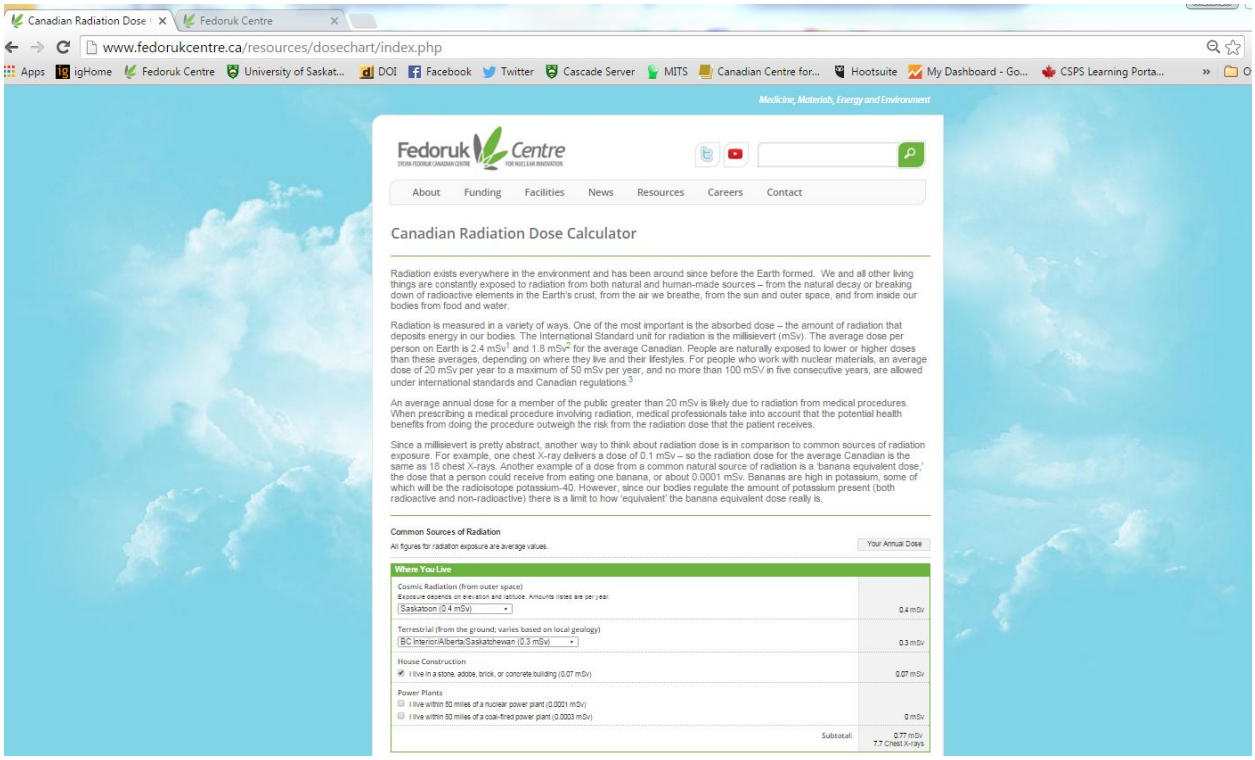

Figure 1. Screen shot of the Canadian Radiation Dose Calculator

2. Canadian Radiation Dose Calculator

The ANS graciously provided the Fedoruk Centre with the code for their dose chart and granted permission for its modification and 'Canadianization.' Like the ANS Dose Chart, the Canadian Radiation Dose Calculator (CRDC) classifies sources of exposure and dose in four categories:

- "Where You Live:" cosmic radiation (as a function of elevation), terrestrial exposure based on geographic location, house construction, and proximity to both coal and nuclear power plants;
- "Food, Water and Air:" ingestion and inhalation exposures;

- "How You Live:" including various lifestyle factors such as hours travelled by airplane and smoking; and
- Medical Procedures.

Initially, modifications were envisioned as being limited to converting the unit used for measuring dose from millirems to millisieverts (mSv, the SI unit of radiation dose used in Canada), and entering terrestrial exposure values for Canadian localities. Since a millisievert is as abstract as a millirem, it was decided to also present the user's final dose in banana equivalents (1 mSv ≈ the dose that would be received from the decay of potassium-40 in 10,000 bananas). Exposure data for Canadian localities were obtained from the Canadian Nuclear Safety Commission's website [3] and supplemented by values published by Grasty and LaMarre (2004) [4]. However, the modifications were not as straight forward as initially assumed, particularly in determining cosmic, terrestrial and inhalation exposures. This was due to several factors that are discussed for each exposure category below, with the greatest single difficulty being the lack of consistent dose values for representative localities across Canada.

2.1 Cosmic radiation exposure

The ANS Dose Chart calculates cosmic radiation dose strictly as a function of elevation above sea level, based on the assumption that dose from cosmic radiation is lower at lower elevations due to atmospheric absorption. [3] While this generalization is a useful rule of thumb and may indeed be an acceptable approximation for the continental United States, it is not completely accurate due to variations caused by latitude, with localities at higher latitudes receiving a slightly higher cosmic radiation dose regardless of elevation. This was addressed by providing the user with the option of selecting the Canadian average annual exposure of 0.3 mSv or selecting from a list of major Canadian cities (Figure 2). This approach also has the advantage of not requiring users to know the elevation of their city.

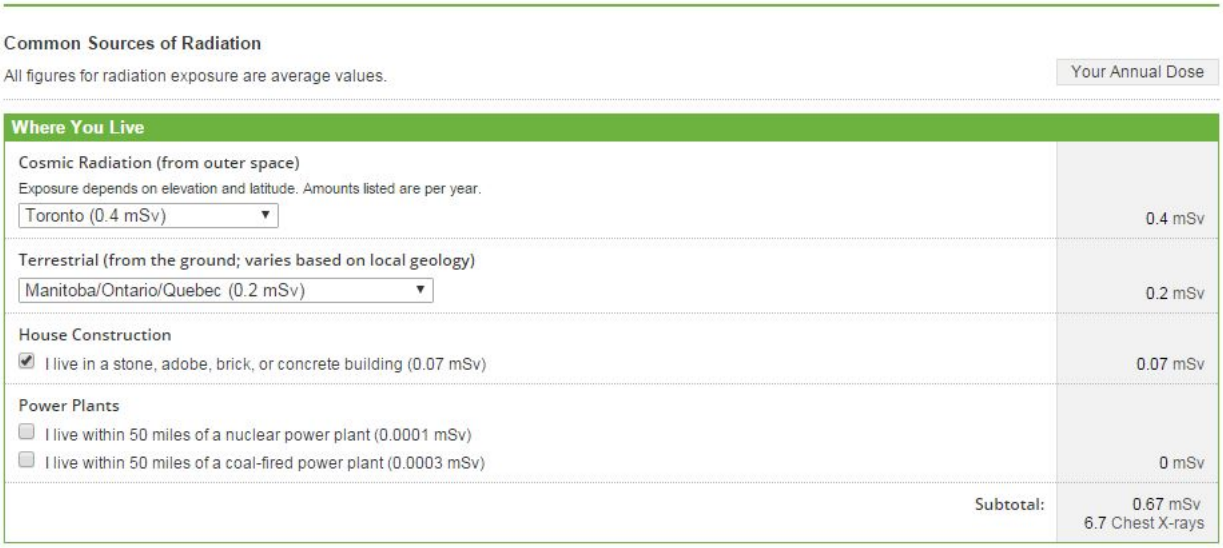

Figure 2. Screen shot displaying the 'Where You Live' field of the CRDC, including cosmic radiation and terrestrial radiation inputs.

2.2 Terrestrial exposure

Natural background radiation from terrestrial sources comes principally from radioisotopes in the soil and in building materials, most notably potassium-40 and products of the uranium-238 and thorium-232 decay series ([4], pg. 215). Values published by the CNSC [3] for selected Canadian communities were used. An inspection of the values combined with observations from the "Radioactivity Map of Canada" [5] compiled by the Geological Survey of Canada showed similarities in terrestrial background radiation in a number of regions, leading to the decision to portray a set of regional values rather than for specific communities. This approach is similar to that taken in the ANS Dose Chart, providing a reasonable approximation of dose while making the tool more accessible to users who do not reside in the listed communities. The Canadian annual average is offered as the default option.

2.3 Inhalation exposure

In the CRDC, inhalation exposure is grouped with internal exposure – the dose received from the decay of radionuclides introduced into the body by eating and drinking (Figure 3). This includes potassium-40, carbon-14 and the aforementioned uranium and thorium decay series, accounting for an annual dose of 0.4 mSv. Inhalation exposure comes primarily from the decay of radon-222 and radon-220 (thoron). The concentration of radon in the environment, both indoors and outdoors, varies across Canada based on geology (from the presence of radiogenic minerals) and precipitation (with more arid regions having higher concentrations of radon) [4,6].

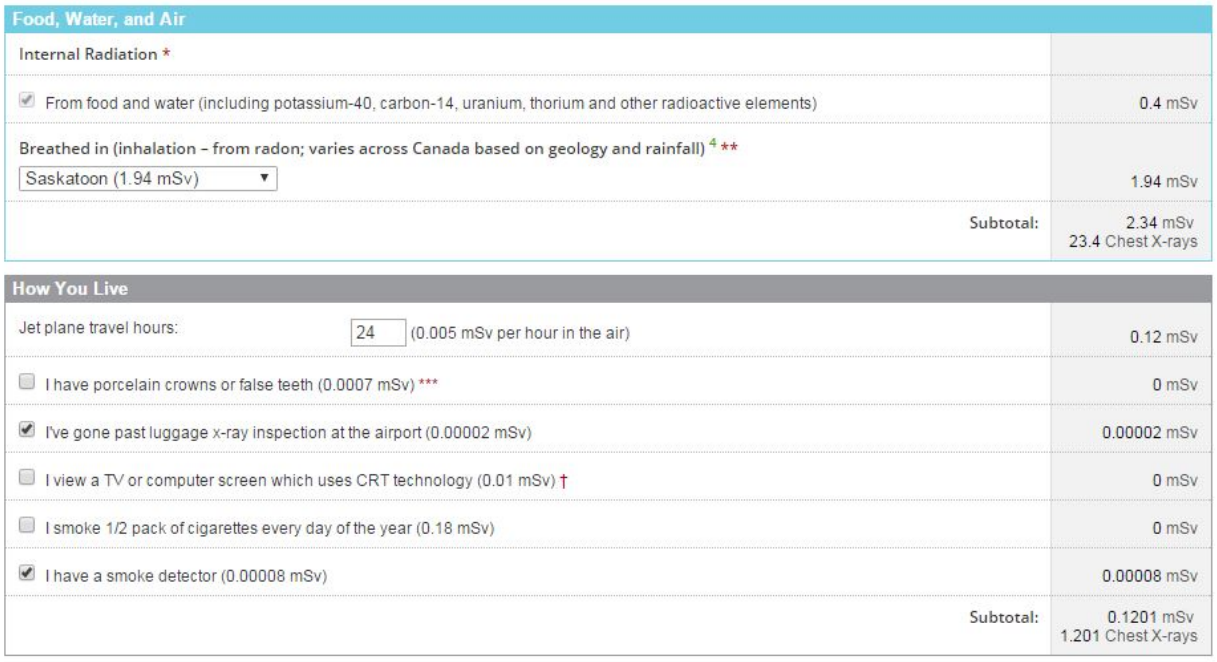

Figure 3. Screen shots of the internal/inhalation exposure fields and the lifestyle exposure fields.

The annual inhalation doses used in the CRDC were taken from Grasty and LaMarre (2004), which were derived from the calculation of inhalation doses of radon-222 from both indoor and outdoor concentrations, measured as part of Health Canada studies using dose conversion factors

recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) ([4], pg. 222). The contribution of radon-220 to total inhalation dose was also calculated by Grasty and LaMarre using the ratio of worldwide annual effective dose from radon-222 to radon-220, published by UNSCEAR (2000) as 1.15 to 0.10 mSv. [7]

The annual outdoor, indoor and total inhalation doses for 16 Canadian cities were published by Grasty and LaMarre as a figure ([4], Figure 7). However, only values for some localities in the figure were published. This resulted in the recalculation of the values following the UNSCEAR equations and radon-222 values given. Discrepancies between calculated and published doses ([4] Table 8) were brought to the attention of Dr. Grasty, who provided corrected values (Grasty, 2015, pers. comm.). Annual inhalation doses for localities for which cosmic ray doses could be obtained were included in the calculator, along with a Canadian average of 0.9 mSv.

2.4 Other categories

Other sources of radiation exposure based on lifestyle factors (e.g. hours of travel by jet, smoking) (Figure 3) and medical diagnostic procedures (Figure 4) were ported from the ANS Radiation Dose Chart and converted to mSv.

Medical Tests		
Medical Diagnostic Tests ‡ Number of millisieverts are per procedure and are average values. Actual numbers may vary. Enter the number of procedures per year.		
X-Ray - Chest	1 (0.10 mSv)	0.1 mSv
X-Ray - Mammography	(0.42 mSv)	0 mSv
X-Ray - Skull	(0.10 mSv)	0 mSv
X-Ray - Cervical Spine	(0.20 mSv)	0 mSv
X-Ray - Lumbar Spine	(6.00 mSv)	0 mSv
X-Ray - Upper GI	(6.00 mSv)	0 mSv
X-Ray - Abdomen (kidney/bladder)	(7.00 mSv)	0 mSv
X-Ray - Barium Enema	(8.00 mSv)	0 mSv
X-Ray - Pelvis	(0.60 mSv)	0 mSv
X-Ray - Hip	(0.70 mSv)	0 mSv
X-Ray - Dental Bitewing/Image	1 (0.005 mSv)	0.005 mSv
X-Ray - Extremity (hand/foot)	1 (0.005 mSv)	0.005 mSv
CT Scans - Head	(2.00 mSv)	0 mSv
CT Scans - Chest	(7.00 mSv)	0 mSv
CT Scans - Abdomen/Pelvis	(10.00 mSv)	0 mSv
CT Scans - Extremity	(0.10 mSv)	0 mSv
CT Scans - Angiography (heart)	(20.00 mSv)	0 mSv
CT Scans - Angiography (head)	(5.00 mSv)	0 mSv
CT Scans - Spine	(10.00 mSv)	0 mSv
CT Scans - Whole Body	(10.00 mSv)	0 mSv
CT Scans - Cardiac	(20.00 mSv)	0 mSv
	Subtotal:	0.11 mSv 1.1 Chest X-rays

Figure 4. Screen shot listing radiation exposures of common nuclear medicine and radiological procedures.

3. Beta testing and feedback

The link to a beta version of the CRDC was sent to a focus of group involved in physics, engineering, medicine, education and science communications. The feedback received was valuable and resulted in a number of improvements to the calculator, including:

- Addition of a dial graphic that displays the user's calculated annual dose in relation to the average dose for a person on Earth (2.4 mSv/yr), Canadian average (1.8 mSv/yr; also the calculator's default value), and an average for a Nuclear Energy Worker (20 mSv/yr; 1/5 of the 5-year regulatory maximum exposure of 100 mSv) (Figure 5);
- The portrayal of dose for each category in mSv and in chest X-ray equivalents (where 1 chest X-ray = 10 mSv); and
- Additional commentary and links to external resources to address concerns that might be expressed by a user whose annual dose comes in substantially higher than the displayed average, which would most likely be due to dose received from medical procedures.

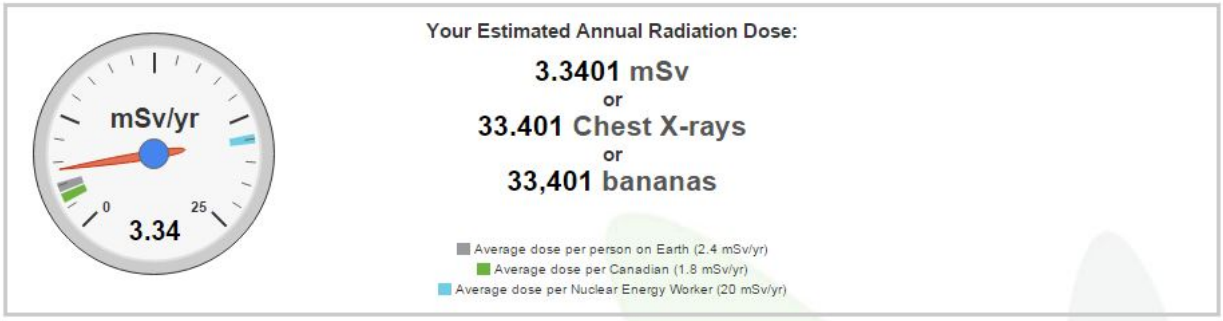

Figure 5. Screen shot of the summary field of the CRDC, showing the estimated annual radiation dose for an individual living in Saskatoon, Saskatchewan, who lives in a brick building, flew 24 hours by jet, owns a smoke detector and underwent chest, dental and extremity medical X-rays.

4. Conclusions

The CRDC is intended to be a tool that demonstrates that radiation is part of the environment that is encountered every day. It is hoped that it, along with other factual resources, can contribute to wider conversations about risk and nuclear technology.

5. Acknowledgements

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