# Communicating Qualitative Risk to a Rural Audience - 8417

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## ABSTRACT

Although many risk assessment involve complex mathematical models and a thorough understanding, communicating the risk to the general public can present a considerable challenge. Comprehending a “one-in-a-million” risk some 10 000 years in the future can be a challenge to the average citizen who is surrounded by more imminent dangers and who has, by virtue of their familiarity, become immune to them.

A number of years ago, the then Japan Atomic Energy Institute (JAERI) signed a multi-year cooperative agreement with Atomic Energy of Canada, Ltd (AECL) that included a number of self-contained radioisotope diffusion and migration experiments to be performed under in situ geochemical conditions in a specially designed radiochemistry laboratory at a depth of 240 metres in AECL’s Underground Research Laboratory (URL) near Lac du Bonnet, Manitoba, Canada. This underground facility has been excavated in a previously undisturbed granite pluton in the Canadian Shield to study various aspects of high-level nuclear waste management. The region has been the home to AECL’s Whiteshell Laboratories since the early 1960s and is surrounded by lakes, forests, some agriculture and mining activity. The economy of town, Lac du Bonnet is based on tourism, forestry, mining and agriculture. The relationship between Lac du Bonnet and AECL has generally been good although there have been attempts by a few local citizens, aided by antinuclear activists from Winnipeg, Manitoba’s capital, to curtail the operation of the URL.

Although the use of radioisotopes was approved by the then-Atomic Energy Control Board, the Canadian regulatory body, maintaining good working relations with the elected officials of the neighbouring communities was essential to the proposed radioisotope migration experiments. One reason for this was that minute quantities of radioisotope solutions needed to be transported over a distance of ~25 km between the URL and the Whiteshell Laboratories over public roads.

As part of the public affairs program, the author, before his retirement from AECL, presented a comparison between the amounts of radioisotopes used in the migration experiments and those present in commonly used consumer products. This comparison proved to be adequate to gain the trust and support of the neighbouring communities. This trust was maintained by a rigorous communication program between the project manager and representatives of the local communities, environmental and law enforcement agencies.

## INTRODUCTION

The lack of understanding by the general public of the concept of risk associated with virtual all aspects of nuclear energy, from mining the uranium ore to the geological disposal of all radioactive wastes has become the Achilles heel of the nuclear industry. Some of the fears expressed by the general public have been created by well published nuclear accidents, including Three Mile Island and Chornobyl and are to, some extent, understandable. Much of the fear, however, remains irrational: the general public readily accepts the transport of highly volatile and flammable materials such as gasoline and propane along public highways in spite of sometimes spectacular accidents. The derailment of a mixed freight train containing propane and chlorine in Mississauga, a community just west of Toronto, ON, in November of 1979, where eleven propane tank cars caught fire, led to the evacuation of more than 200 000 people. [1] A similar derailment of a CSX freight train containing equally hazardous material including tripropylene, hydrochloric acid and di(2-ethylhexyl)phthalate in the Howard Street tunnel in Baltimore, MD, created a fire that lasted five days. [2] But highly flammable and toxic chemicals alone are not prerequisites for disastrous fires: a fire in the Mont Blanc tunnel by a truck carrying flour and margarine claimed at least 39 lives in 1999. [3]

The acceptance by the general public of these risks may be partially due to a familiarity of this type of accident and a realization that transport of hazardous materials is essential to maintaining the overall quality of life. To insist on more stringent requirement would increase the costs of transportation and these costs would be passed on to the consumer. In other words, “familiarity breeds acceptance.”

The general public also accepts the use of radioisotopes in medicine, including the injection of radioisotope-containing compounds for diagnostic applications and treatment of some cancers. However, when it comes to radiation and nuclear material, a general lack of understanding and lack of familiarity create fear in the general public. It is then perhaps understandable that the public reacts adversely to the geological disposal of radioactive waste: both the nature of the radioactive materials and the long time frames used in performance assessment calculations are difficult for the average citizen to comprehend. Understanding a “one-in-a-million” risk some 10 000 years in the future can be a challenge to the average citizen who is surrounded by more imminent dangers and who has, by virtue of their familiarity, to a large extent become immune to these dangers. Proposals to use radioisotopes in an underground experimental facility elicit concerns similar to those raised in the geological disposal of nuclear wastes.

One approach that has had a considerable degree of success is to relate radioisotopes to those present in materials that are in common use by a modern society and that are considered to be of general benefit to the general public. It is more appropriate to relate the use of radioisotopes to $^{131}$I used in thyroid treatment than to $^{222}$Rn that may be present in poorly ventilated basements. The former is seen as generally beneficial; the latter is seen as detrimental to a healthy environment. This approach was used by the author, as an AECL employee at the time, to gain the confidence of a target group in a rural area in Manitoba, Canada, for an experimental program using radioisotopes in self-contained diffusion and migration experiments in an underground facility, AECL’s Underground Research Laboratory (URL). This facility was excavated in 1962 in a previously undisturbed granitic batholith on the eastern edge of the Precambrian Canadian Shield. [4] The URL was excavated to a depth of 440 m with working levels at 240 and 420 m (Figure 1).

A thorough understanding of both the audience and the experimental program were crucial in communicating with the elected officials and essential in obtaining support from these officials.

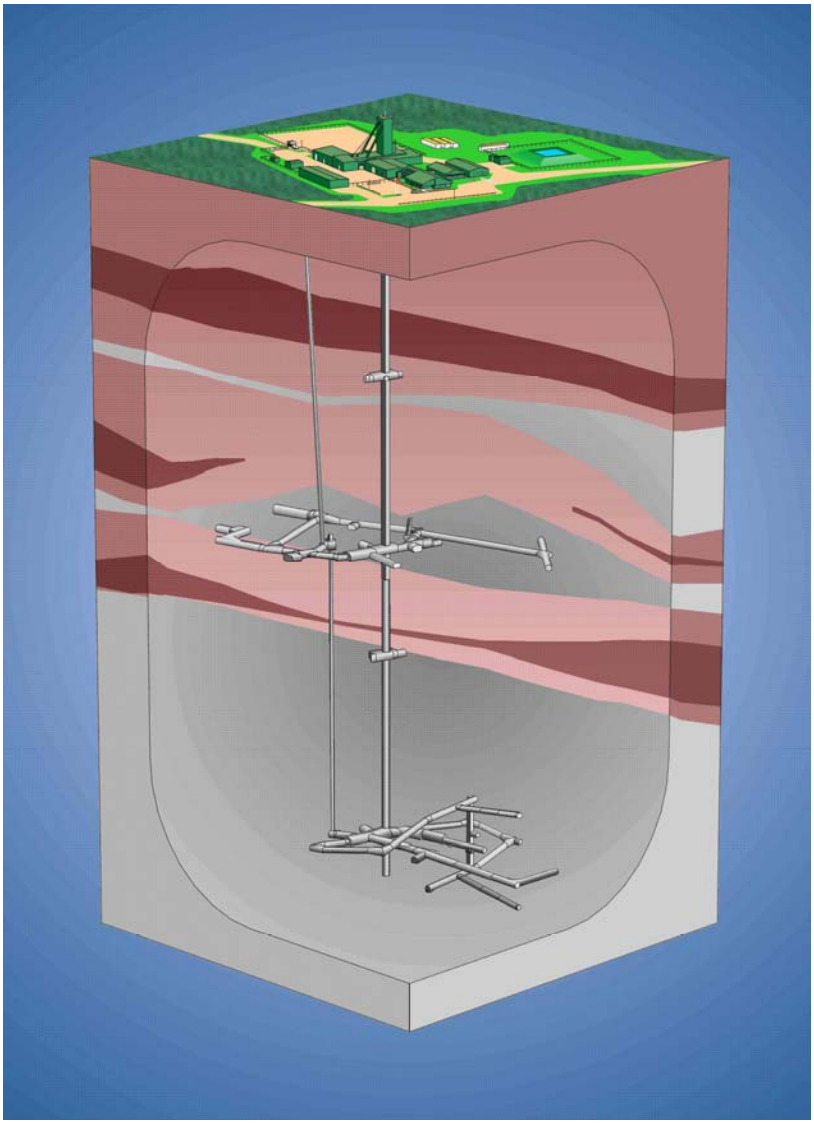

**Fig. 1. Underground Research Laboratory (URL).**

## DEMOGRAPHICS

Pinawa and the URL are located at the edge of the Canadian Shield (Figure 2). The URL is located approximately 15 km north of Pinawa and 15 km east of Lac du Bonnet and lies administratively within the Rural Municipality of Lac du Bonnet. Pinawa was established in 1962 by AECL to house its employees at the Whiteshell Laboratories. It is a “company town” and a planned community located on the Winnipeg River. A close parallel in the United States is Los Alamos, NM, in that both towns were initially populated by non-indigenous people who had little or no historical attachment to the area. The population of Pinawa is currently approximately 1600, down from its historic high of approximately 2000 as a result of AECL’s decision in the late 1990s to move its operations to Chalk River, ON, its main research centre. In contrast to Pinawa, Lac du Bonnet is a well-established rural community with a slightly smaller population but with a well-developed business sector. Its main economic activities are farming, forestry, mining and tourism and the town serves as the main business center for a region with a radius of approximately 50 km. Tourism, especially, is an important industry because of Lac du Bonnet’s proximity to the lakes in the Canadian Shield to the east and to Winnipeg, the capital of Manitoba, 100 km to the west-southwest. Any real or perceived negative impact on the environment would be seen as detrimental to the tourism industry in the area.

The relationship between the residents of Lac du Bonnet and Pinawa are generally good, especially considering the different backgrounds of the two communities. A number of Lac du Bonnet residents have been employed by AECL over the years, primarily in support services. The economic impact of the Whiteshell Laboratories to Eastern Manitoba has been considerable over the years. Pinawa residents support stores and businesses in Lac du Bonnet. Area sports teams, especially hockey, are made up with players from both communities. There is, however, a small, but vocal, opposition to AECL and to the operations of the URL. The reasons for the opposition range from perceived slights by some of the residents in Lac du Bonnet and to the fact that the town is located downstream from the Whiteshell Laboratories. Since a considerable amount of commercial activity in Lac du Bonnet is geared to seasonal residents who own cottages in the area, any potential risk to the environment is often, and quite understandably, seen as a risk to the economic wellbeing of the community. The opposition to all things nuclear has also been aided by special interest groups outside the community, in particular the Winnipeg-based Concerned Citizens of Manitoba.

**Fig. 2. Location of Pinawa, Lac du Bonnet, Whiteshell Laboratories and the Underground Research Laboratory [source: Google Earth]**

## EXPERIMENTAL PROGRAM

A number of years ago, the Japan Atomic Energy Research Institute (JAERI) signed a multi-year cooperative agreement with AECL that included a series of radioisotope diffusion and migration experiment that were to be preformed under *in situ* conditions in the URL. Until then, most radioisotope migration experiments had been performed in laboratories and under standard laboratory conditions under oxidizing conditions. Since the conditions in the near and far field associated with a high-level disposal site below the water table are generally chemically reducing, it is scientifically not warranted to use surface laboratory-obtained radioisotope sorption and migration data in performance assessment. For example, the chemistry and, hence, transport behaviour of key radioisotopes of interest to the nuclear waste management, including the multivalent isotopes of technetium, uranium, neptunium and plutonium, is strongly determined by their oxidation state. Under standard laboratory, or oxic conditions, these radioisotopes exist in a higher oxidation state while under anoxic groundwater conditions at depth, they exist in lower oxidation states.

Although it would, in principle, be feasible to duplicate the in situ conditions in a laboratory environment by using controlled atmosphere chambers, excluding all oxygen from these chambers is exceedingly difficult and maintaining the chemically reducing nature of groundwater during its collection from a water-bearing fracture at depth and subsequent transfer to a laboratory could not be guaranteed.

A submission to the Canadian regulatory agency, the Atomic Energy control Board (AECB, now the Canadian Nuclear Safety Commission (CNCS)) for a radioisotope licence for a specially constructed and dedicated radioisotope laboratory at a depth of 240 m in the URL for these migration experiments and transport of the radioactive solutions and material between the URL and the WL was approved. The radioisotopes and the maximum allowable amounts are listed in Table I.

Table I. Approved Radioisotopes for Use in Contained Diffusion and Migration Experiments in a Radioisotope Laboratory at the URL

| Isotope | Half Life | Maximum Allowed Amount | |
|---|---|---|---|
| | | Bq | Ci |
| $^{3}H$ | 12.3 a | $1.0 \times 10^{9}$ | 27 mCi |
| $^{95m}Tc$ | 61 d | $3.7 \times 10^{8}$ | 10 mCi |
| $^{99}Tc$ | $2.1 \times 10^{5}$ a | $3.7 \times 10^{8}$ | 10 mCi |
| $^{125}I$ | 60 d | $3.7 \times 10^{7}$ | 1 mCi |
| $^{131}I$ | 8 d | $3.7 \times 10^{7}$ | 1 mCi |
| $^{237}Np$ | $2.\ 1 \times 10^{6}$ a | $3.7 \times 10^{6}$ | 100 μCi |
| $^{238}Pu$ | 87.7 a | $3.7 \times 10^{6}$ | 100 μCi |
| $^{241}Am$ | 432 a | $3.7 \times 10^{6}$ | 100 μCi |

It should be pointed out that the maximum amounts listed in Table I were never used. Generally, the amounts that could be used were determined by the solubility of some of the radioisotopes under the chemical conditions of the experiment and the maximum volume of groundwater used in the experiments. Typically <500 mL volumes of solution containing 100 – 3000 Bq/mL were used.

The experiments were designed to be performed in a controlled atmosphere chamber in an atmosphere of <10 ppm (volume) $O_2$ in a $N_2/8\%H_2$ atmosphere [5]. The experimental facility and a schematic of the experimental arrangement are shown in Figures 3 and 4, respectively. A slanted borehole was drilled approximately 70 metres downwards into a subhorizontal water-bearing fracture at a depth of approximately 250 metres. Stainless steel packers, used to isolate the borehole at the fracture, and lines leading from the fracture to the controlled atmosphere chamber were Teflon™-coated to prevent any chemical reaction between the groundwater and the stainless steel. Crushed and sieved geological material was loaded into Teflon-coated stainless steel tubes and inserted in lines leading from the borehole in the controlled atmosphere chamber.

**Fig. 3. Controlled Atmosphere Chamber located at a Depth of 240 m at the Underground Research Laboratory. The distorted image is due to the use of a short focal length lens**

Radioisotope solutions were prepared at WL in another controlled atmosphere chamber using groundwater obtained from the fracture zone and loaded into Teflon-coated stainless steel accumulators. Accumulators are, basically, cylinders with two chambers separated by a piston. Groundwater is drawn into one chamber until the piston is at the end of its travel. A volume of radioisotope-containing groundwater is then drawn into the other end of the cylinder by pumping groundwater from the other end. The piston acts as a barrier and prevents mixing of the two solutions. These accumulators were then shipped over public roads to the URL and inserted in-line. Eluted solutions were collected in sample vials and returned to WL for radiometric analysis. A very stringent protocol was followed in transporting radioactive material between WL and the URL. Liquid samples were packed in 22-L metal containers, surrounded by vermiculite. This material is an excellent absorber of water and has a high capacity to sorb radioisotopes from solution in the unlikely event that the integrity of the container would be compromised. The material was shipped by truck or car over public highways. The offices of the local governments and the detachments of the Royal Canadian Mounted Police (RCMP) were notified in writing prior to any shipment.

To prevent release of radioisotopes from the controlled atmosphere chamber to the groundwater in the URL, a “defence in depth” approach was used. Fraction collectors used to collect the samples were equipped with detectors to detect any spilled liquids. A positive signal from any detector would actuate a shut-off valve leading to that particular column and collector. In case the shut-off valve malfunctioned, radioisotope-containing water would flow to the bottom of the controlled atmosphere chamber where another detector was located. If this detector would be actuated, the entire water supply to the system would be shut off and an alarm sent to the hoist operator and the security office. A final line of defence consisted of a welded steel tray on the floor or the entire laboratory to catch water from the borehole. The capacity of this tray was sufficient to contain water from the experimental facility even if the malfunction were to occur at the start of a weekend.

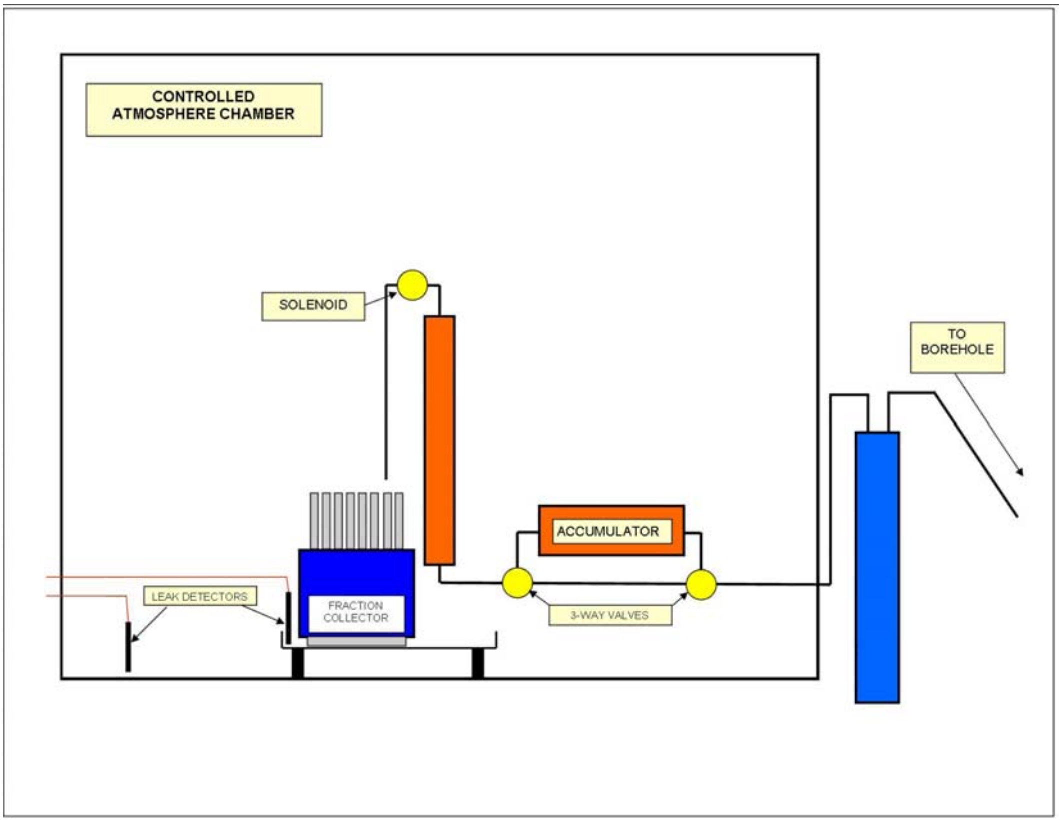

**Fig. 4. Schematic of Experiment to Study Radionuclide Transport through Columns of Crushed Granite under In Situ Conditions**

## COMMUNICATION WITH THE PUBLIC

### Communication with Elected Officials

The main concern of the general public was the potential contamination of surface waters and groundwater, either by a malfunction of the equipment in the laboratory or by a road accident. To address these concerns, a meeting was held with the elected officials of the Town of Lac du Bonnet and of the Rural Municipality of Lac du Bonnet.

To put the amount and the nature of the radioisotopes in perspective, three categories of materials containing radioisotopes were presented.

- Consumer items that function on the basis of the radioisotopes they contain
- Radioisotopes used in medical diagnostics and medical treatment
- Consumer items that contain measurable amounts of radioisotopes but that are not labelled as such

Smoke detectors and Coleman™ lantern mantles fit in the first category. Smoke detectors are ubiquitous in modern society. They typically contain ~1 μCi or 3.7 x $10^4$ Bq $^{241}$Am. This radioisotope decays by alpha emission to $^{237}$Np. These detectors are sold in a variety of stores without any restrictions and are clearly labelled as containing radioactive material. The $^{241}$Am is mixed with gold and incorporated into a composite gold and silver foil sandwich. The source is 3 to 5 mm in diameter, and either crimped or welded into place inside the chamber. [6] There are no restrictions on disposing smoke detectors and common practice is to dispose of them with household waste. The general public handles these detectors and any risk of their use in residential homes is seen to be insignificant compared to the protection they offer. The main point to note here is that it is acceptable to dispose of small quantities of an alpha-emitting actinide with a half life of 432 years in landfill sites.

Mantles used in Coleman lanterns are an excellent example to relate the use of radioisotopes to consumer items to the general public: campers and outdoors people have relied on these lanterns for generations. Until replaced with yttrium, the mantles used in Coleman lantern contained thorium, an alpha-emitting radioisotope. However, mantles containing appreciable quantities of thorium continue to be available. [7] Mantles contain typically 250 – 400 mg thorium and have an activity of 1000 – 1600 Bq. The main isotope in thorium is $^{232}$Th with a half life of 1.4 x $10^{10}$ years. This isotope decays by a series of alpha and beta decay steps that are associated with the emission of a range of γ rays. Most of the members in the $^{232}$Th decay scheme, $^{228}$Ra, $^{228}$Ac, $^{228}$Th, $^{224}$Ra, and $^{220}$Rn, have short half lives and the radiation emitted by a sealed Coleman mantle can readily be detected by Geiger-Müller counters. Some of the $^{224}$Ra and $^{228}$Ra and more than half the $^{212}$Pb and $^{212}$Bi are released to the atmosphere during the first hour of a burn. [8] However, over time, these daughters will grow back into the mantle. The public is generally not aware of the radioactivity of these mantles and there are, again, no restrictions on disposing used mantles. It is common practice to discard them at camp sites without any concern about the leaching of $^{232}$Th and its daughter products into surface waters.

Iodine and technetium isotopes are widely used in medical diagnostics and treatment. The interesting part, from a public affairs perspective, is that patients willingly allow these radioisotopes to be injected because they presumably consider the benefits of these procedures to outweigh any risk. The amounts of radioisotopes are not trivial: 200 -800 MBq of $^{131}$I is commonly inject to treat thyroid problems [9, 10] and 37 MBq $^{95m}$Tc is injected as $^{95m}$Tc-ECD (N,N'-11,2-ethylenediylbis-L-cysteine diethylester). [11] These quantities are higher than, or equal to the amounts allowed by the AECB for use in the experimental program in the URL. It should also be pointed out that patients are generally not quarantined until the radioisotopes have decayed to insignificant levels.

Consumer items that contain measurable amounts of radioisotopes but that are not labelled as such include fertilizer and other materials with appreciably high potassium concentrations. Naturally occurring potassium contains 0.012% $^{40}$K. This isotope decays primarily by β-emission followed by a 1.4 Mev gamma ray. Potassium is essential to biological activity and occurs in most foods (Table II). [12] The most often used example is that of $^{40}$K in bananas. A typical banana contains 240 mg K and has an activity of 7.4 Bq. This is an insignificant amount of activity but mentioning the connection between a naturally occurring radioisotope and a popular fruit places radioisotopes in a context that, just because something as common as beneficial as a banana, it should not be avoided because it contains an insignificant, but measurable amount of radioactive material. A consumer product that does contain an approvable amount of $^{40}$K is a table salt substitute, *Nu-salt*. A 2.5-ounce container of *Nu-salt* contains 1100 Bq $^{40}$K. This example was not used in the presentation to the local elected officials but should be considered for inclusion in future presentations to the general public.

Interestingly, the CNSC stipulates that the exemption quantity for licencing a radioactive source is "10 kBq, where the atomic number of the substance is equal to or less than 81" in respect of a radioactive nuclear substance that is not set out in column 1 of the schedule." [13] Another commercially available dietary table salt substitute, *No-salt*, is available in 11-ounce containers [14], each containing 5 x $10^3$ Bq $^{40}$K, just below the CNSC-imposed limit for use as a radioactive source. Yet, packages of these salt substitutes carry no warning and consumers who have been put on a low salt diet, are apparently unaware that they place a radiation source on their table or that they ingest appreciable amounts of radioactive material.

Another widely used consumer item is lawn fertilizer. A 6.21-kg bag of Scotts Canada 22-2-14 WinterCare® fall lawn fertilizer contains 2.2 x $10^4$ Bq $^{40}$K. Consumers routinely buy this material and spread it on their lawn, with little regard to contaminating their lawn or groundwater. In fact, citing the use of lawn fertilizers as an example of uncontrolled distribution of a radioisotope-containing material can provide an important comparison with the care taken in handling and containing radioactive material. Other examples, not cited in the presentation, could include phosphate-based fertilizers that are known to contain trace amounts of uranium and its daughter products including $^{226}$Ra.

Table II. K Contents and $^{40}$K Activities in Selected Foods

| Food | Portion | K [mg] | $^{40}$K [mg] | Activity [Bq] |
|---|---|---|---|---|
| Hot Dogs | 2 regular | 200 | 0.024 | 6.2 |
| Hamburger | 4 ounces | 960 | 0.1152 | 30.0 |
| Fried Chicken | ¼ chicken | 240 | 0.0288 | 7.4 |
| French Fries | 3.5 ounces | 650 | 0.078 | 20.2 |
| Broccoli | 1 stalk | 270 | 0.0324 | 8.4 |
| Corn | 1 ear | 200 | 0.024 | 6.2 |
| Banana | 1 small | 240 | 0.0288 | 7.4 |
| Orange | 1 medium | 300 | 0.036 | 9.3 |
| 2% Milk | 1 cup | 380 | 0.0456 | 11.8 |
| Ice Cream | 4 ounces | 50 | 0.006 | 1.2 |
| Pepsi Cola | 12 ounces | 13 | 0.00156 | 0.4 |
| Coca Cola | 12 ounces | 4 | 0.00047 | 0.1 |
| Bran Flakes | 1 ounce | 140 | 0.0168 | 4.3 |
| Corn Flakes | 1 ounce | 14 | 0.00168 | 0.4 |
| Whole Wheat Bread | 1 slice/1 ounce | 70 | 0.0084 | 2.2 |
| White Bread | 1 slice/1 ounce | 30 | 0.0036 | 0.9 |
| Sunflower Seeds | 3.5 ounces | 920 | 0.1104 | 28.5 |
| Peanut Butter | 1 ounce | 110 | 0.396 | 3.64 |
| Egg | 1 large | 65 | 0.0078 | 2.0 |

Tritium was the radioisotope with the highest allowable level, 1.0 x $10^9$ Bq. Tritium ($^3$H or T) is a radioactive isotope of hydrogen. It has a 12.6 year half life and decays by β-emission. It has a biological half life of ~10 days which can be decreased to ~ 3 days by increasing water intake. It is used in consumer items such as watches and some gun sights. Modern $^3$H concentrations in precipitation and in surface waters are in the range of 1 – 2.2 Bq/L. [15] The maximum allowable $^3$H concentration for drinking water is 20 pCi/mL or 740Bq/L. [16] The Annual Limit of Intake (ALI) for $^3$H is 3 x $10^9$ Bq. In the unlikely event that a single individual would ingest the maximum allowable amount of $^3$H, he or she would still only reach one third of the ALI. Any release of $^3$H as tritiated water from the experiment, however, would be diluted by water collected in the sump of the URL and subsequently discharged to a retention pond. The water collected in the retention pond would periodically be discharged to the environment if it met discharge criteria. Any release of $^3$H as a result of a road accident would be diluted by groundwater.

One stipulation imposed by the Government of the Province of Manitoba, passed as the *High-Level Radioactive Waste Act* in 1987, is that the URL may not be used to store or dispose of nuclear waste “not produced on-site as a result of research in Manitoba.” [17] This law had been cited by some opponents to the proposed experimental program that would have prohibited the use of neptunium and plutonium since these two elements are produced in nuclear fuel during the fissioning process. This raised an interesting question as to the definition of waste. A close parallel, successfully used in the presentation to the elected officials, is molasses, a by-product of the refining of sugar from sugar cane. Since molasses can be purchased in grocery stores, it has an intrinsic value that distinguishes it from waste. Similarly, it was shown convincingly that the neptunium and plutonium were purchased and could therefore not be classified as waste.

### Communication during the Experimental Program

Prior to each shipment of radioisotope materials between the URL and WL, letters were sent to the offices of the governments of the Village of Lac du Bonnet, the Rural Municipality of Lac du Bonnet, the Local Government District of Pinawa, and to the RCMP detachments in Lac du Bonnet and Pinawa announcing the date of the transfer.

Periodic updates on the program were given to the elected officials as part of an ongoing communications program at the URL.

## LESSONS LEARNED

The lessons learned from the presentations of this program can be summarized as follows

- know your audience and understand their background, value systems and concerns
- identify with your audience by finding areas of common interest, such as sports, entertainment, religion, hobbies
- be fully versed in the details of the experimental program
- explain complex scientific concepts in terms that a layperson can understand

As a result of communication with the elected officials, a considerable amount of trust was established.

## SUMMARY AND CONCLUSION

The need to present an experimental program to non-scientists presented a golden opportunity to relate the qualitative risk of using radioisotopes in a non-traditional environment to that associated with widely used consumer items and medical therapeutic and diagnostic materials. Although the amounts of radioisotopes used in these experiments are orders of magnitude lower than those in the disposal of nuclear wastes, the approach presented here may have merit in bridging the gap between the scientific community and the general public. The success of the approach used became clear when, towards the end of the experimental program, some of the elected officials expressed satisfaction with the extension of the program for new, a five-year, period.

## ACKNOWLEDGEMENTS

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