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Written Submission from the Canadian Coalition for Nuclear Responsibility

Mémoire du Regroupement pour la surveillance du nucléaire

In the matter of the

À l'égard du

Regulatory Oversight Report for Canadian Nuclear Power Generating Sites for 2024

Rapport de surveillance réglementaire des sites de centrales nucléaires au Canada : 2024

Commission Meeting

Réunion de la Commission

March 2026

Mars 2026

Overlooking Offsite Impacts

an intervention by the

Canadian Coalition for Nuclear Responsibility (CCNR)

submitted to the

Canadian Nuclear Safety Commission (CNSC)

regarding the CNSC's

Regulatory Oversight Report (ROR)
on
Nuclear Power Generating Sites for 2024

submitted by email
on January 28, 2026

Recommendations

Recommendation 1. CCNR recommends that CNSC, as an agency legally bound to disseminate objective scientific information to the public, publicly set the record straight by saying quite simply that nuclear power is not altogether clean. Alternatively, CNSC should either cease describing itself as a science-based organization, or disseminate a clear science-based explanation of how one may logically reconcile large routine emissions of radioactive poisons into the environment with the notion of nuclear power as "clean energy".

Recommendation 2. CCNR recommends that CNSC require its nuclear generating station licensees to post on the internet real-time data on radioactive emissions from the plant as they occur, and to give advance warning when elevated emissions are likely to result from planned outages or other planned activities such as overnight tritium purges.

Recommendation 3. CCNR recommends that CNSC require its nuclear generating station licensees to calculate the collective dose to the population within five miles of the plant, based on annual emissions.

Recommendation 4. CCNR recommends that CNSC require its nuclear generating station licensees to work to reduce their annual environmental emissions of tritium, carbon-14, iodine-131, and particulates of alpha-emitting and beta-emitting radionuclides by several orders of magnitude.

Recommendation 5. CCNR recommends that CNSC immediately adopt a provisional Relative Biological Effectiveness (RBE) of "2" for tritium exposures, with the expectation that the RBE for tritium may be revised upwards as new evidence becomes available.

Recommendation 6. CCNR recommends that CNSC publish a science-based explanation and justification of the existing Canadian standard for the maximum permissible concentration of tritium in drinking water, 7000 becquerels per litre.

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Background on CCNR

The Canadian Coalition for Nuclear Responsibility (CCNR) was created in Montreal in 1976 by a group of thirty individuals, all of them knowledgeable about the dangers of nuclear weapons and nuclear power. The meeting was called by Fred Knelman, Head of the Department of Science and Public Policy at Sir George Williams University (since named Concordia), in response to two shocking events: the detonation of a nuclear bomb by India in 1974 using plutonium created in a Canadian research reactor, and the revelation one year later of extensive radioactive contamination of homes, schools, ravines, and many public areas in Port Hope through the careless dissemination of voluminous radioactive wastes left over from the chemical processing of radioactive ores. Two years later CCNR was federally incorporated as a not-for profit organization.

CCNR is dedicated to education and research on all issues related to nuclear energy, whether civilian or military – including non-nuclear alternatives – especially those pertaining to Canada and Canadians. This mandate grew out of a realization that Canadians have not been well-informed about nuclear hazards. Necessary facts were either hidden from view entirely, or obscured by blanket reassurances that everything nuclear is perfectly safe, or simply not communicated in plain enough language that can be adequately understood by non-experts.

CCNR believes that an essential aspect of protecting the health and safety of Canadians and the environment, and of ensuring that Canada fulfills its international obligations, is education. Providing the necessary scientific information in a forthright manner is built into the legal mandate of the CNSC. CCNR believes that CNSC should more fully accept this challenge and oblige all of its licensees to do likewise. When education is seen to be lacking, CCNR does what it can to fill the gap for politicians, academics, journalists, communities, Indigenous people and environmental activists.

For example, in the early years of nuclear power in Canada, most Canadians were told repeatedly that "atoms for peace" had nothing to do with nuclear weapons. That is not education, it is public relations. Naturally, Canadians were shocked to learn through the Indian nuclear explosion that a human-made material – plutonium – created as an inevitable byproduct in a peaceful research reactor, can be used as a nuclear explosive. At that time, this important piece of information was missing, leading to a gap in understanding that extended to parliamentarians and a great many otherwise well-educated Canadians, including many that worked in the nuclear industry in Canada. It was not then common knowledge that Canada had played a significant role in the World War II Atomic Bomb Project nor that Canada had sold plutonium, produced in nuclear reactors at Chalk River, to the USA for use in nuclear weapons during the Cold War era.

Likewise, the people of Port Hope did not know the basic scientific facts about radium-bearing wastes from uranium processing and the associated health risks. Accordingly, the voluminous and seemingly innocuous sandy residues from the Eldorado plant, located in downtown Port Hope, were used in the construction of hundreds of homes and other properties. These wastes were also widely dispersed in public areas.

The townsfolk and most workers at the plant were unaware that the sand itself was radioactive (radium-bearing) and was constantly giving off an odorless, colourless, highly carcinogenic radioactive gas – radon – due to the relentless radioactive disintegration of radium atoms. Radium had in turn been created deep underground in the ore by the slow disintegration of uranium atoms over periods of many millennia.

Ignorance of basic scientific facts contributed to widespread radioactive contamination in Port Hope that is still being remediated to this day by the federal government through the auspices of the private contractor Canadian Nuclear Laboratories (CNL). The Port Hope "cleanup" has been going on since 1975 and will cost over $2.5 billion in public funds. The result is two gigantic earthen mounds, intended to last for 500 years, containing more than 1.5 million tonnes of waste that will remain radiotoxic for millennia.

Almost all of the radioactive wastes destined for the Port Hope and Port Granby mounds are naturally occurring disintegration byproducts of uranium and thorium, including radioactive isotopes of bismuth and lead along with isotopes of radium, polonium and radon.

While the citizens of Port Hope were ignorant of the essential facts when the processing of radioactive ores began in Port Hope, the government of Canada was not. As early as 1931, 44 years before the extent of the town's radioactive contamination became evident in 1975, the Canadian Department of Mines reported as follows:

> **Precautions for workers in the treating of radium ores.**
> Recent investigations in the field of radium poisoning have led to the conclusion that precautions are necessary even in the handling of substances of low radioactivity. The ingestion of small amounts of radioactive dust or emanation over a long period of time will cause a building up of radioactive material in the body, which eventually may have serious consequences. Lung cancer, bone necrosis, and rapid anemia are possible diseases due to the deposition of radioactive substances in the cell tissue or bone structure of the body.
> *W.R. McClelland, Canada, Department of Mines, 1931*
> *Investigations in ore dressing and metallurgy. See Annex A.*

These cautionary notes were intended to protect the workers in the Department of Mines who were tasked with assaying samples of the radium-rich ore from a site on the eastern shore of Great Bear Lake, later called Port Radium. Unfortunately, this information (which was gleaned from the sensational deaths of radium dial painters and others in the late 1920s due to radium poisoning, and the scientific evidence published in the 1930s on the cancer-causing nature of radon gas) was not communicated to the residents of Port Hope or to the miners and ore carriers in the far North, many of whom died of preventable radiation-induced cancers. Radon was, at that time, referred to as "radium emanation".

While public awareness of the serious health risks of radon is now widespread, many Canadians are still unaware that radon infiltration in homes is invariably the result of radium in the soil, bedrock, or building materials. There can be no chronic radon problem without the presence of radium, and there can be no radium contamination without chronic radon gas emissions. In this way radon and radium are bound together to make an indissoluble pairing.

As recently as January 26, 2026, CBC National News reported that up to 10 million homes in Canada have dangerous levels of radon. It is estimated that over 3000 Canadians die each year from radiation-induced lung cancer as a result of radon exposures in their homes. Many houses in such towns as Port Hope, Elliot Lake, Oka and Varennes, have have high levels of indoor radon due to the unwitting use of radioactively contaminated building materials or landfill derived from nearby mining or ore-handling facilities.

CCNR Comments on ROR

As a non-governmental education and research organization, CCNR is less concerned with the day-to-day operations of nuclear facilities than with the possible adverse repercussions on members of the public, including Indigenous communities, due to routine emissions and accidents. CCNR is particularly concerned about the radioactive legacy of the nuclear age – radioactive wastes that will remain problematic for decades or for millions of years, depending on the radionuclide content.

CCNR believes that the Canadian public would like to see the CNSC as a regulator whose primary job is to protect the health and safety of Canadians and the environment. CCNR thinks that part of that job is to provide accurate unbiased information about the risks, and to clarify the overall context of nuclear operations (such as the movement and storage of radioactive materials) so that ordinary citizens and Indigenous peoples can better understand how they may be affected by industrial actions authorized through decisions made by the CNSC.

Indeed, article 9(b) of the Nuclear Safety and Control Act states that the CNSC has an obligation “ to disseminate objective scientific, technical and regulatory information to the public". This language implies an active educational outreach by CNSC; information is not only to be made available, it should be actively "disseminated".

An example of context: cobalt-60

In the ROR Report for NGS we read that CNSC granted an amendment to Darlington's Power Reactor Operating Licence (PROL) in 2024 to authorize production of cobalt-60 (Co-60) in each of the four reactors at Darlington. Cobalt-60 is a human-made highly radioactive element created inside a nuclear reactor by bombarding non-radioactive cobalt-59 with neutrons. The newly created cobalt-60 emits extremely powerful gamma rays, much more penetrating than x-rays. Once produced, cobalt-60 can then be packaged and sold for use in medicine or industry, typically in batches of tens of trillions of becquerels (disintegrations per second).

Radioactive atoms are unstable. They all sooner or later disintegrate. The number of disintegrations per second is the number of becquerels. Each disintegration of a cobalt-60 atom emits a gamma ray. But as time goes by the intensity of the gamma radiation diminishes. Cobalt-60 has a half-life of 5.27 years, meaning that half of the atoms will have disintegrated in that time period, after which there will be half as many cobalt-60 atoms left, half as many becquerels, and half as many gamma rays given off.

Eventually the cobalt-60 comes to be regarded as unwanted radioactive waste. There is no way to stop the gamma emissions, because radioactivity cannot be "turned off", so the residual cobalt-60 remains highly dangerous to humans and other living things, but at the same time the intensity of gamma radiation has greatly diminished and is no longer able to "do the job" it was meant for. Since the purchaser does not accept the expense and the danger of looking after the waste, the remaining cobalt-60 is returned to the vendor, and – lo and behold – it is sent to the Chalk River site, managed by CNL, where it becomes a public liability, added to the extensive radiotoxic legacy already stored there, on unceded Algonquin lands adjacent to the Kichi-Sibi – the Ottawa River.

At Chalk River, CNL (owned and operated by a consortium of private multinational corporations, but funded by billions of dollars from the Canadian Treasury through the crown corporation Atomic Energy of Canada Limited) is proposing to bury 90,600 trillion becquerels of this unwanted (disused) cobalt-60 in a giant earthen mound called the Near Surface Disposal Facility – an engineered landfill-type operation. Inspired by the Port Hope mound for naturally-occurring radioactive leftovers, the NSDF is intended to be a permanent repository for about a million tonnes of mainly human-made post-fission "low-level radioactive waste" and other toxic materials. This is the first time that Canada has ever been asked to approve a permanent facility for the storage of post-fission radionuclides, many of which have half-lives in excess of 5000 years. Indeed, about one third of the radionuclides in the NSDF radioactive inventory have half-lives in excess of 100,000 years. According to CNL documents, cobalt-60 (with a half-life of only 5.7 years) will account for 99% of the initial radioactivity to be placed in the NSDF. See Annex B for a complete list of radionuclides in the radioactive inventory of the NSDF,

In response to a question posed at a 2022 CNSC hearing, CCNR was informed that the mass of cobalt-60 – despite the fact that it totally dominates the initial radioactivity of the proposed "megadump" – was only a few kilograms, in the well-packaged and shielded form of "sealed sources". Such a small mass of material could easily be stored in Shielded Modular Above-Ground Vaults (SMAGs, already existing at the Chalk River site) until the radioactivity of the cobalt-60 diminishes to an extremely small amount. These few kilograms of material do not have to be stored in a gigantic million-tonne landfill-type "near surface" facility – a type of facility which, by the way, according to the International Atomic Energy Agency (IAEA), is suitable only for VERY low level waste (VLLW) consisting mainly of "soil and rubble with low levels of activity." [IAEA 2009)]

To pretend that these cobalt-60 sources are "very low level waste", when they are in fact very radioactive commercial wastes that have to be heavily shielded in order to protect the workers from over-exposure to gamma radiation, is patently absurd. A single unshielded cobalt-60 pellet would be extremely dangerous and could cause a severe radiation exposure of up to 25 rads per hour. Many sealed sources contain hundreds or even thousands of such pellets.

“Darlington is now authorized to produce cobalt-60 in all four reactors.” A person reading this one little detail in the ROR document, would not likely realize that all cobalt-60 produced in Canada becomes radioactive waste, and that those who use cobalt-60 do not accept responsibility for their waste, and so it is returned to Canada. Historically, most of it ends up at Chalk River, on Algonquin lands, without notification, consultation, or consent of the Algonquins. This, despite UNDRIP article 29(2): “ States shall take effective measures to ensure that no storage or disposal of hazardous materials shall take place in the lands or territories of indigenous peoples without their free, prior and informed consent.” Who would have thought that a decision about the Darlington NGS would end up impacting the lands of the Algonquins of the Kichi Sibi (Ottawa River)?

CCNR believes that CNSC, as a responsible regulator, should take a “ cradle to grave” approach to all licensed nuclear activities, and should insist that its staff and licensees take a similar approach and address the chain of implications from beginning to end. In particular, that approach should be reflected in the CNSC’s Regulatory Review Reports.

Radioactive releases

One of the most striking things about the 2024 ROR on NGS is how little discussion there is of the public or of the environment – things that CNSC is mandated to protect, according to article 9(a) of the Nuclear Safety and Control Act. The focus of the ROR report seldom extends beyond the plant boundary. When radiation doses are discussed, when the ALARA principle is invoked, when the collective dose concept is employed, it is inevitably in the context of in-plant exposures of workers rather than out-of-plant exposures to members of the public.

When it comes to public radiation exposures, the only comment made in the ROR is that such exposures are “below regulatory limits”. What happened to the ALARA principle? Are public radiation exposures truly “As Low As Reasonably Achievable”? Has either the regulator or the licensee ever challenged the status quo? Large routine radioactive releases of tritium, carbon-14, iodine-131 and a host of other alpha and beta emitters to the water and air are not discussed in any detail in the ROR and are not even reported, though they all contribute to radiation exposures of members of the public.

CCNR took the liberty of consulting the Radionuclide Release Datasets available on the Open Canada web site, which specifies radionuclide releases from all of Canada's nuclear generating stations for the last 15 years (from 2011 to 2025). From the downloaded spread sheet it is clear that, every year, each operating CANDU reactor releases over 100 trillion becquerels of tritium, more than 100 billion becquerels of carbon-14, and several hundred thousand becquerels of iodine-131 to the outside environment, along with a goodly smattering of alpha-emitting and beta-emitting particulates of many varieties. Given the magnitude and persistence of these routine radioactive releases, it is evident that describing nuclear power as a "clean" emery source is simply a falsehood.

Recommendation 1. CCNR recommends that CNSC, as an agency legally bound to disseminate objective scientific information to the public, publicly set the record straight by saying quite simply that nuclear power is not altogether clean. Alternatively, CNSC should either cease describing itself as a science-based organization, or disseminate a clear science-based explanation of how one may logically reconcile large routine emissions of radioactive poisons into the environment with the notion of nuclear power as "clean energy".

The largest radioactive releases from CANDU reactors, bar none, are tritium and carbon-14. Because they are both relatively long-lived, they accumulate in the environment from one year to the next, each year's emissions adding to the total.

Using the dataset from Open Canada, the total amount of carbon-14 released from CANDU reactors over the fifteen year period from 2011 to 2024 (using simple addition) is 96.4 trillion becquerels. Because carbon-14 has a very long half-life of 5,700 years, there is no significant reduction in the carbon-14 inventory over this fifteen year period.

Because tritium has a 12.3 year half-life, only about 94% of last year's tritium will still be around this year. Using the half-life of tritium to adjust for radioactive decay, we can use the same dataset to find the total amount of tritium remaining in the environment today as a result of just the last fifteen year's worth of emissions: it is 39,387 trillion becquerels. In other words, 39.4 quadrillion becquerels of tritium. Evidently, if we included all the previous years' emissions as well, the totals for both carbon-14 and tritium would be correspondingly larger.

These are very large totals of radionuclides loose in the environment, and some of those totals are growing year by year. Iodine-131 has such a short half-life (8 days) that the emissions from one year do not carry forward to the next year; in that case, next year's emissions simply replace this year's emissions without adding to them.

At present, in Canada, the maximum permissible level of tritium in drinking water is 7,000 becquerels per litre. Thus the 39,387 trillion becquerels of tritium that have accumulated in the environment over the last 15 years from CANDU emissions during that time period would be enough, in principle, to render (39,387 trillion)/7000 = 5.6 trillion litres of water unfit for human consumption. That volume of water is about equal to the total amount of water used by the City of Toronto during the entire 15 year period in question. This calculation is simply to make the point that these tritium emissions are quite formidable when looked at as a totality.

The ALARA principle

According to the ALARA principle, espoused by CNSC, it is not enough to keep radiation exposures "below regulatory limits". The exposures should also be kept "As Low As Reasonably Achievable". In cases of worker exposures, the ALARA principle is often invoked (it is mentioned numerous times in the ROR, using the repeated phrase "Appropriate measures were used to control occupational exposures and to keep doses

ALARA”), but in terms of public exposures the ALARA principle is almost never mentioned. Is this indicative of a double standard? Are members of the public to be regarded as “second class citizens”?

In addition, we read in the ROR-NGS document:

> The safety performance indicator for the Application of ALARA is the “collective radiation exposure” also known as collective dose. In 2024, the total collective dose for monitored individuals at all Canadian NPPs and WMFs was 34.2 person-Sieverts (p-Sv), which is an increase from the industry-wide collective dose reported for 2023 (30.7 p-Sv) and 2022 (30.0 p-Sv), and in-line with the industry-wide collective dose reported for 2021 (35.5 p-Sv).
>
> *ROR for NGS, p.191*

Indeed, the collective dose (the sum of all the individual doses) is the appropriate measurement needed in utilizing the linear no-threshold (LNT) model of radiation carcinogenesis, which is still the official policy of the CNSC in terms of radiation protection. LNT states that the excess collective dose of radiation exposure to a given population is proportional to the excess number of radiation-induced cancers expected in that exposed population.

However, there is no effort to calculate the collective dose for the public surrounding each nuclear generating station. The same individual radiation dose, if applied to a ten times larger population, will result in a ten-fold increase in the collective dose, which in turn will lead to a ten-fold increase in the expected excess cancer incidence (i.e. the number of radiation-induced cancer cases). Is the CNSC’s failure to calculate the collective dose for the public another indication of a double standard at work? Although CNSC almost always refrains from using the word “cancer”, it is a well-known fact that cancers of various kinds are the main stochastic health effect expected from a given dose of ionizing radiation, whether that is due to external exposure (gamma rays and neutrons) or though internalized emitters (such as tritium, carbon-14, iodine-131, and almost all activation products as well as fission products and actinides that may escape from the used nuclear fuel).

So when the CNSC is given a legal mandate “to prevent unreasonable risk, to the environment and to the health and safety of persons”, it is in large part a mandate to prevent unreasonable risk of radiation-induced cancers, and therefore to prevent or limit exposures of people to radioactive carcinogens. Generally speaking, the best policy is to eliminate exposures to such carcinogens as asbestos, second hand smoke, etc.

Here is what the International Agency on Research on Cancer (IARC) has to say :

- β-Particles emitted by radionuclides, irrespective of their source, produce similar patterns of secondary ionizations and the same type of localized damage to biological molecules, including to DNA. These effects include DNA double strand breaks, chromosomal aberrations, gene mutations and cell transformation.
- All radionuclides that emit β-particles and that have been adequately studied, have been shown to cause cancer in humans and in experimental animals. This includes hydrogen-3, which produces β-particles of very low energy, but for which there is nonetheless *sufficient evidence* of carcinogenicity in experimental animals.
- β-Particles emitted by radionuclides, irrespective of their source, have been shown to cause chromosomal aberrations in circulating lymphocytes and gene mutations in humans in vivo.
- The evidence from studies in humans and experimental animals suggests that similar doses to the same tissues — for example lung cells or bone surfaces — from β -particles emitted during the decay of different radionuclides produce the same types of non-neoplastic effects and cancers.

All types of ionizing radiation are *carcinogenic to humans (Group 1).*

Screen shot from p.298 of IARC 2012 monograph 100D,
“Internalized beta-particle emitting radionuclides”

And, as the Canadian Cancer Society states on its web page, “Carcinogens should be removed or replaced with safer options. If it’s not possible to get rid of a carcinogen or find something safer, it’s important to reduce the amount of exposure to as low as reasonably achievable or reduce the time you spend around it as much as possible.”

In order for those who are especially vulnerable to radiation damage, such as pregnant women, to distance themselves from elevated radioactive emissions, they need to be notified immediately when emissions are particularly elevated or when that is expected.

Recommendation 2. CCNR recommends that CNSC require its nuclear generating station licensees to post on the internet real-time data on radioactive emissions from the plant as they occur, and to give advance warning when elevated emissions are likely to result from planned outages or other planned activities such as overnight tritium purges.

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Recommendation 4. CCNR recommends that CNSC require its nuclear generating station licensees to work to reduce their annual environmental emissions of tritium, carbon-14, iodine-131, and particulates of alpha-emitting and beta-emitting radionuclides by several orders of magnitude.

The nuclear industry claims that it can safely keep radioactive poisons out of the environment of living things for millions of years. Is it too much to ask that they demonstrate their skill by keeping radioactive poisons out of the environment on an ongoing basis? The public is sometimes skeptical. Perhaps they can be proven wrong.

Health Hazards

For genotoxic carcinogens, including ionizing radiation, the consensus in the biomedical community is that there is not likely to be any “safe threshold” of exposure below which cancer induction cannot occur. Because of the monoclonal nature of most malignancies, it is more than likely that a single damaged cell was the precursor of the cancer. Reducing the collective exposure to a given population will reduce the number of damaged precursor cells, and hence the number of cancers in the population, but the resulting cancers will be no different in kind from those caused by a much larger exposure. Thus the “dose-response” relationship has nothing to do with the severity of the outcome, but only with the frequency of the outcome. Hence the term: “stochastic”.

There is a lot of uncertainty about the degree of harm posed by chronic exposure to slightly elevated levels of tritium. The very fact that different jurisdictions have a hodge-podge of regulations regarding the maximum permissible concentration of tritium in drinking water is a testament to the lingering scientific uncertainties. How can all these diverse standards be science-based?

Two separate toxicological investigations into the carcinogenicity of tritium were commissioned by the Ontario Government some years apart – the Advisory Committee on Environmental Standards (ACES, 1994) and the Ontario Drinking Water Advisory Council (ODWAC, 2009). Both independently concluded that Canada’s existing standard for the maximum allowable concentration of tritium in drinking water is about 350 times too lenient. Instead of 7000 becquerels per litre, both groups recommended 20 becquerels per litre. This conclusion, while plagued with uncertainties, was based on a comparison between tritium with chemical carcinogens that are tightly regulated.

Earlier in this paper the amount of tritium in the environment today as a result of the last 15 years of CANDU emissions was calculated as 39,387 trillion becquerels, and the amount of drinking water that could theoretically be rendered undrinkable was calculated as 5.63 trillion litres. However that was based on the 7000 becquerels per litre standard. If we were to use the 20 becquerels per litre standard, recommended by ACES and ODWAC, the amount of water that could be rendered unusable would be 350 times greater: 1,970 trillion litres, which is about 2 quadrillion litres of water. That’s four times larger than the volume of water in Lake Erie.

Despite the uncertainties, there is a widespread agreement in the scientific community that the “relative biological effectiveness” (RBE) of tritium is greater than that of x-rays and gamma-rays. What that means is that – per unit of ionizing energy delivered to living tissue – tritium is more damaging than gamma radiation or x-irradiation.

Although this fact has been known for many decades – more than 50 years – the CNSC does not take it into consideration when calculating tritium doses in millisieverts. CNSC assigns tritium exposures an RBE of "1" – exactly the same as the RBE for gamma exposures – resulting in a consistently incorrect calculation of the doses received by workers and members of the public from tritium. The actual doses are higher than reported.

In 2010, following scandalously high tritium releases in Peterborough and Pembroke from two manufacturers of tritium-illuminated "glow-in-the-dark" signs, CNSC held a number of workshops on tritium toxicity in Ottawa. Some of those tritium workshops were attended by Dr. Gordon Edwards (Ph.D.) of CCNR along with his colleague Dr. Eric Notebaert (M.D.) of CAPE (Canadian Association of Physicians for the Environment).

Several reports were published by the CNSC, including one entitled Health Effects, Dosimetry and Radiological Protection of Tritium (INFO 0799).

Here is an excerpt from that report:

> There are more than 50 different estimates of the RBE for tritium. However, considerable variation and uncertainty in the radiobiological data exists making it difficult to choose a single RBE value. The RBE data largely differs because its reference radiation also has variations: that is, the two types of radiation (x-rays and gamma rays) usually used as the reference radiation have different RBE values of their own.
>
> Studies to determine a single value for tritium radiation's RBE indicate that:
> • where x-rays are chosen as the reference radiation, an RBE value of about 1.4 would be appropriate.
> • if gamma radiation is chosen as the reference, an RBE value closer to 2.2 would be indicated.
>
> https://api.cnsc-ccsn.gc.ca/dms/digital-medias/CNSC_Health_Effects_Eng-web.pdf/object

There is indeed a wide variation in the RBE estimates for tritium, but they are calculated to be greater than 1. A workshop conducted in Britain by the Committee Examining the Radiological Risks of Internal Emitters (CERRIE) goes into much greater detail, and concludes that the RBE for tritium should be set at 2 or more, possibly 3. That would imply that the ODWAC recommendation of 20 becquerels per lite would have to be reduced by a factor of 2 or 3, and even the present Canadian standard would have to be reduced by a factor of 2 or 3. Meanwhile, calculated tritium doses (in millisieverts) would have to be revised upwards by a factor of 2 or 3 (depending on the RBE).

Recommendation 5. CCNR recommends that CNSC immediately adopt a provisional Relative Biological Effectiveness (RBE) of “2” for tritium exposures, with the expectation that the RBE for tritium may be revised upwards as new evidence becomes available.

Recommendation 6. CCNR recommends that CNSC publish a science-based explanation and justification of the existing Canadian standard for the maximum permissible concentration of tritium in drinking water, 7000 becquerels per litre.

Technical Addendum

In CANDU reactors, carbon-14 and tritium are mainly activation products. They are created in the heavy water moderator, and in the coolant, by neutron activation. There are other mechanisms as well, but this is the most important.

Tritium (aka hydrogen-3) is created when “heavy hydrogen” (hydrogen-2, commonly known as deuterium) – is activated (hydrogen-2 + neutron = hydrogen-3).

Carbon-14 is created when “heavy oxygen” (oxygen-17) is activated (oxygen-17 + neutron = carbon-14 + alpha). Because these radionuclides are created outside the solid fuel bundles, they are more likely to escape from the plant’s containment.
It so happens that carbon and hydrogen are the basic building blocks of all organic molecules, including DNA molecules. Accordingly, radioactive hydrogen (i.e. tritium) and radioactive carbon (i.e. carbon-14), when disseminated into the environment, have ready access to all living things. Moreover, when radioactive varieties of these two organic building blocks enter into the body through inhalation, ingestion, or absorption through the skin, a certain fraction will become “organically bound”. In other words, these two radionuclides are incorporated into organic molecules through a free exchange of radioactive and non-radioactive hydrogen and carbon atoms.

Tritium is usually released in the form of tritiated heavy water, DTO. There is no municipal or household water treatment technology available that can remove tritium from drinking water. That's because tritiated water molecules are chemically identical to ordinary water molecules. You cannot filter radioactive water from non-radioactive water. It is known from animal studies that tritiated water ingested by a pregnant mother readily crosses the placenta and enters into the foetus. It is also known that women are more vulnerable to radiation-induced damage than men in general, and, in particular, women store more tritium in their body than men do. But unborn children are the most vulnerable of all to the deleterious effects of radiation exposures, including tritium.

Conclusion

While the ROR report in question is an impressive document, summarizing an enormous amount of valuable regulatory work that is mostly concerned with activities taking place within the plant boundaries, there is very little discussion of real or potential impacts on the population or the environment outside the plant. Since CNSC is expected by many to provide a valuable public service in protecting the Canadian public and the environment from harmful impacts, CCNR recommends that in future such reports pay much greater attention to what happens, or what might happen, beyond the plant's perimeter. Radioactive emissions, environmental uptake of radionuclides, and clear evidence of CNSC's efforts to greatly reduce all offsite impacts would be welcome.

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ANNEX A

1931 Radium warning from the Department of Mines

The hazards of handling radioactive radium and uranium ore concentrates were well known early on by the Canadian government, as can be seen in this excerpt from a 1931 Department of Mines report:

CANADA
DEPARTMENT OF MINES

INVESTIGATIONS IN ORE DRESSING AND METALLURGY

1931

OTTAWA

PRECAUTIONS FOR WORKERS IN THE TREATING OF RADIUM ORE

W.R. McClelland

The hazards involved in the handling of high-grade radioactive materials make necessary the adoption of certain precautions. Recent investigations in the field of radium poisoning have led to the conclusion that precautions are necessary even in the handling of substances of low radioactivity. The ingestion of small amounts of radioactive dust or emanation over a long period of time will cause a building up of radioactive material in the body, which eventually may have serious consequences.
Lung cancer,bone necrosis, and rapid anaemia are possible diseases due to the deposition of radioactive substances in the cell tissue or bone struc-ture of the body.

ANNEX B

Radioactive inventory for

the Chalk River NSDF

(Near Surface Disposal Facility)

Radioactive Inventory – from Table 3.3.1-2 of the Final EIS for NSDF

radionuclide (common name)	initial activity (becquerels)	half-life (years)
americium-241	60.4 billion	433
americium-243	52.6 million	7.36 thousand
carbon-14	1.71 trillion	5.7 thousand
chlorine-36	3.97 billion	301 thousand
cobalt-60	90.6 quadrillion	4.25
cesium-135	519 million	2.3 million
cesium-137	5.59 trillion	30
hydrogen-3 (tritium)	891 trillion	12.3
iodine-129	30.3 billion	15.7 million
molybdenum-93	147 thousand	4 thousand
niobium-94	23.4 billion	20.3 thousand
nickel-59	1.21 billion	76 thousand
nickel-63	311 billion	101
neptunium-237	17.4 million	2.14 million
plutonium-239 plutonium-240	87.7 billion	24.1 thousand 6.65 thousand
plutonium-241	1.67 trillion	14
plutonium-242	63.2 million	375 thousand
radium-226	38.5 billion	1.8 thousand
selenium-79	92.6 million	327 thousand
silver-108m	27.3 billion	438
strontium-90	6.05 trillion	29
technetium-99	316 billion	211 thousand
thorium-230	5.3 billion	75.4 thousand
thorium-232	27 billion	14 billion
tin-126	124 million	230 thousand
uranium-233	274 million	159 thousand
uranium-234	68.8 billion	246 thousand
uranium-235	2.96 billion	704 million
uranium-236	75.7 billion	4.47 billion
zirconium-93	492 billion	1.61 million

22 of these 31 radionuclides have half-lives of over 5,000 years.
In the year 7000 and beyond, trillions of becquerels will remain

14 of these 31 radionuclides have half-lives of over 100,000 years
In the year 102,000 there will be more than a trillion becquerels