SUBMISSION BY THE CANADIAN ENVIRONMENTAL LAW ASSOCIATION TO THE CANADIAN NUCLEAR SAFETY COMMISSION REGARDING THE REGULATORY OVERSIGHT REPORT FOR NUCLEAR POWER GENERATING SITES IN CANADA: 2019

November 16, 2020

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I. INTRODUCTION

These submissions are filed in response to the Canadian Nuclear Safety Commission's ("CNSC") notice of meeting dated July 8, 2020 in respect of the *Regulatory Oversight Report for Nuclear Power Generating Sites in Canada: 2019* (herein "ROR").[1] A virtual meeting in Ottawa for this matter is scheduled for December 8, 9 and 10, 2020. Our recommendations to the Commission to assist in their review are summarized in **Appendix A** and an expert report from Dr. Ian Fairlie provided in **Appendix B.**

CELA is a non-profit, public interest law organization. For nearly 50 years, CELA has used legal tools to advance the public interest, through advocacy and law reform, in order to increase environmental protection and safeguard communities across Canada. CELA is funded by Legal Aid Ontario as a specialty legal clinic, to provide equitable access to justice to those otherwise unable to afford representation.

CELA has engaged in detailed research and advocacy related to public safety and environmental protection by seeking improvements to nuclear emergency preparedness. We have also appeared before the CNSC on a number of licensing matters, as well as the federal environmental assessment proceedings relating multiple nuclear sites and proposed projects. CELA also has an extensive library of materials related to Canada's nuclear sector which is publicly available on our website.[2]

[1] CNSC, Notice of Participation in a Commission Meeting and Participant Funding, online: https://www.nuclearsafety.gc.ca/eng/the-commission/pdf/NoticeMeetingPFP-ROR-NPGS-2019-e.pdf
[2] Canadian Environmental Law Association, online: www.cela.ca

II. FINDINGS

In response to the 2019 ROR, CELA raises a number of issues relating to the ROR's scope and content and provides the following comments relating to CNSC's review of nuclear power plant sites and activities. Our findings are set out below, accompanied by either requests or recommendations to the Commission and CNSC Staff.

The overarching goal of the comments submitted by CELA is to recommend improvements in the 2019 ROR and make requests to ensure that CNSC Staff provides relevant, additional information when the ROR is before the Commission. CELA furthermore intends these comments to be considered when drafting the upcoming ROR for 2020 and during the drafting and review of the upcoming ROR Discussion Paper which according to the CNSC Staff's presentation for a prior ROR this Fall, is anticipated by end of year 2020.[3] CELA additionally submits that the upcoming ROR Discussion Paper consultation is not a stand in for a response on the matters discussed below, specific to this ROR.

A. Reforming the regulatory oversight reporting process

CELA has reviewed the ROR in detail and finds it necessary to reiterate our ongoing concerns with the ROR process, its utility and use.

First, CELA submits intervenors who provide comments on an ROR should have an opportunity to present orally before the Commission. Currently, intervenors are precluded from presenting and thus the opportunity to engage in dialogue with Commissioners and CNSC Staff does not exist. This maintains the high-level nature of RORs and does not facilitate a public awareness of the interests and considerations weighed by CNSC Staff in reaching the conclusions set out in the report. Should the CNSC retain the existing ROR procedure and not provide oral intervention opportunities to intervenors, CELA suggests the CNSC reframe its ROR as a "Discussion Paper," whereby the Paper provides information but also poses questions and actively seeks public feedback.[4]

Second, we submit 30 days is an insufficient amount of time for members of the public and civil society to review the material of the ROR and provide value-added comments to the Commission. The public's ability to weigh-in during the ROR process can be further constrained due to the time it takes to request and receive references or supporting material, and competing CNSC public comment deadlines. While CELA is not opposed to this ROR being reviewed by the Commission

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[3] CNSC, Directorate of Nuclear Substance Regulation Regulatory Oversight Reports: Part I: Use of Nuclear Substances in Canada: 2019 Part II: Class IB Accelerators in Canada: 2018-2019, CNSC Staff Presentation CMD 20-M23.A, (5 Nov 2020) online: https://www.nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD20/CMD20-M23-A.pdf

[4] *See* for instance, Canada, "Environmental and Regulatory Reviews Discussion Paper" (June 2017), online: https://www.discussionpaper.ca/

in tandem with other RORs (as will occur during the scheduled November 2019 meeting), the length of time granted for review should be extended in light of the other matters also open for public comment. Should the Commission choose to have multiple comment opportunities with the same closing date, at least 60 days should be provided as a recognition of the importance and value of public comments, and to further fairness and respect for adequate procedural rights.

Third, CELA is not aware of a process which sought to define the issues which guided the content of the ROR. To clarify the scope of RORs, CELA recommends the CNSC conduct a pre-meeting conference or discussion, which seeks input on issues to be discussed. Preliminary meetings are a widely used practice in anticipation of tribunal proceedings.[5] Not only would the CNSC, as a quasi-judicial tribunal, benefit from a pre-meeting conference, whereby the scope of the proceeding could be narrowed or expanded, upon input from the regulator, proponent, and intervenors, it would provide demonstrably clearer guidance to intervening parties regarding the acceptability of their submissions.

Issue identification is critically important, not only to ensure the efficient and best use of intervening parties' time, but to ensure matters of critical importance are not deemed out of scope and thus dismissed. While issue identification can require a significant amount of time, a clearer sense of the issues and providing the public an opportunity to comment advances procedural fairness. Therefore, as there has not been a public scoping of issues, whereby the CNSC staff, licensees and intervenors can weigh in on the issues which should frame the report, we submit CELA's comments provided herein are not out of scope.

Fourth, as stated in the introduction of the ROR, "there are no actions requested of the Commission. This CMD [ROR] is for information only."[6] CELA objects to this framing and requests that rather than serving an informational purpose, the aim of the ROR should be to identify gaps and propose action items (even if voluntary or for guidance) which improve licensee compliance within all Safety and Control Areas (SCAs). Until the SCAs for all nuclear generating sites are deemed "fully satisfactory," CELA submits this should be the guiding purpose of the annual ROR.

Recommendations

1. CELA remains of the view that ROR meetings are not a replacement for relicensing hearings and the CNSC must remedy the discrepancy in participation rights among public intervenors and licensees by providing oral presentation opportunities.

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[5] Jerry DeMarco and Paul Muldoon, "Environmental Boards and Tribunals – A Practical Guide, 2nd Ed" (LexisNexis: 2016), p 78.

[6] ROR, p 4

2. The CNSC should extend the amount of time provided to the public for the review of RORs and ensure a minimum 60-day timeframe.

3. The ROR would be more effective if the CNSC canvassed a list of issues and topics to inform the scope of the ROR. Given the trend to longer, ten-year licences, soliciting public comment on the scope of issues addressed in ROR would provide a starting point for public engagement.

B. Release of the Emergency Planning Technical Study

Last year, CELA requested the Commission direct CNSC Staff to obtain the final Provincial Nuclear Emergency Response Plan (PNERP) Technical Study from the Office of the Fire Marshall and Emergency Management (OFMEM).[7] Critically, the PNERP Technical Study may have implications for the adequacy of the planning basis for severe accidents. As the Technical Study has continued to be a matter of public discussion, it is crucial it be made a part of the public record."[8] We are very dismayed that despite President Velshi's inquiry about the timing of the Technical Study's release at last year's ROR meeting,[9] this year's ROR reports that the technical study has not yet been released by the Solicitor General.[10]

As the current ROR states, the technical planning study examines "the planning basis for the Pickering, Darlington, Bruce Power and Fermi 2 areas through robust modelling" and once released, "Ontario licensees plan to revise their training programs for new emergency response staff accordingly."[11] In previous correspondence from OFMEM, it was also indicated that the impact on drinking water supply in the event of a nuclear accident was part of the technical study. [12] We are dismayed by the ROR's cursory review of this outstanding request made by CELA during last year's ROR given its significant value to public health and safety.

Relatedly, during the Bruce Power and Pickering relicensing hearings, CELA sought clarification from the Commission setting out the plans and arrangement made to "protect drinking water

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[7] *See* CELA's Comments to the Submission in 2019, Requested Action, no. 5, online: https://cela.ca/comments-reg-oversight-canadian-nuclear-power-generating-sites/

[8] *Ibid*

[9] CNSC, Transcript November 6, 2019, online: http://www.suretenucleaire.gc.ca/eng/the-commission/pdf/2019-11-06-Meeting-Final-e.pdf at p 137

[10] ROR, p 48

[11] *Ibid*

[12] CNSC, Transcript November 8, 2018, online: http://www.nuclearsafety.gc.ca/eng/the-commission/pdf/2018-11-08-Meeting-e.pdf

supplies" as required in the Provincial Nuclear Emergency Response Master Plan.[13] As we noted, all of Ontario's nuclear reactors are located on the Great Lakes - which supplies the drinking water to 40 million Canadians and Americans. Therefore, we submitted that it was necessary to not only "protect drinking water supplies" but require contingency planning in the event of an accident.

With the Technical Study discussed above outstanding, there remains no study of drinking water and contingency planning in the event of an accident. We again bring forward outstanding recommendations regarding this matter which were not discussed at last year's ROR and remain open since the 2018 relicensing hearings.

Recommendations

4. **PRIORITY RECOMMENDATION As Canada's nuclear safety regulator, it is of paramount importance that OFMEM's technical study be requested and obtained without delay. This matter is critical to the licensing basis for all of Ontario's nuclear generating stations and the health and safety of the millions of people living in and around Ontario's nuclear power plants. CELA again recommends the Commission direct CNSC Staff obtain the final Provincial Nuclear Emergency Response Plan Technical Study from the Office of the Fire Marshall and Emergency Management.**

5. The CNSC should require proof of adequate contingency planning for the protection of drinking water in the event of an emergency as a requirement for licensing. Drinking water monitoring is insufficient in scope to ensure that there are actually sufficient drinking water supplies available in the event of a major radioactive release.

6. The CNSC should require proof of adequate contingency planning for the protection of drinking water in the event of an emergency as a requirement for licensing. The CNSC should ensure that provisions are in place for an alternative source of drinking water for residents whose current drinking water source is Lake Ontario.

C. Radionuclides and the National Pollutant Release Inventory (NPRI)

Last year's ROR for nuclear power plants noted that the CNSC and Canada's National Pollutant Release Inventory (NPRI) were working together to establish active links between the CNSC and NPRI websites. A similar commitment was made by the CNSC's President in their 2020-21 Departmental Plan, noting:

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[13] Ontario, "Provincial Nuclear Emergency Response Plan, Master Plan 2017" online: https://www.emergencymanagementontario.ca/english/emcommunity/response_resources/plans/provincial_nuclear_emergency_response_plan.html at 2.2.5(f)

> Under the joint CNSC and Environment and Climate Change Canada / National Pollution Release Inventory (NPRI) Task Team, efforts are ongoing to increase accessibility to core environmental protection documentation, with an emphasis on radionuclide releases to the environment. In 2019, query links between the CNSC and NPRI websites were established and "beta" tested by a multi-stakeholder working group consisting of representatives of non-governmental organizations, industry and Indigenous groups. In 2020–21 there will be further expansion of digital data sources for radionuclide release transfers and disposal, and improvements to the interoperability of the CNSC and NPRI datasets.[14]

This year's ROR, however, does not provide any review of this matter nor an update. For this reason, we **request** the Commission provide an update on this matter at the ROR meeting. To reiterate, the NPRI is an online data portal and a key resource for identifying pollution prevention priorities, supporting the assessment and risk management of chemicals, and encouraging actions aimed at reducing pollutant releases. Sections 46 – 53 of the *Canadian Environmental Protection Act, 1999* set out the functions of the NPRI. The legislation enables the NPRI to track pollution using a listing approach and categorize substances by threshold.

As radioactive substances **are not** part of the substance list, CELA has continued to advocate for the inclusion of radionuclides on the NPRI substance list especially given the threat radionuclides pose to human health and the environment. We also note that in addition to our participation in this ROR, CELA has been active in advocating for radionuclide data to be accessible on the NPRI[15] and continues to closely monitor how this data is released.

Recommendations

7. Radionuclides should be reportable to Canada's National Pollutant Release Inventory (NPRI), an online data portal and a key resource for identifying pollution prevention priorities, supporting the assessment and risk management of chemicals, and encouraging actions aimed at reducing pollutant releases.

8. The Commission should provide an update on the CNSC-NPRI linked site. As this is directly relevant to all nuclear sites and facilities, it is critical this remain a reportable item in subsequent RORs.

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[14] CNSC, "2020-21 Departmental Plan," online: http://nuclearsafety.gc.ca/eng/resources/publications/reports/rpp/dp-2020-2021/index.cfm

[15] *See for instance*, online: https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/public-consultations/proposal-radionuclides-national-pollutant-release-inventory.html

D. Asbestos Phase Out

CELA **requests** that an update on the CNSC's phase out of asbestos be provided at the upcoming ROR meeting. By way of background, Canada's *Prohibition of Asbestos and Products Containing Asbestos Regulations* entered into force on December 30, 2018 prohibiting the import, sale and use of asbestos, as well as the manufacture, import, sale and use of products containing asbestos, with some exceptions. This regulation was welcomed country wide by workers' health and safety experts, families affected by asbestos related diseases, public health and environmental advocates, after decades of efforts seeking federal action on asbestos. However, nuclear facilities were exempted from the ban until January 1, 2023.

As CELA requested during last year's ROR, we encouraged the ROR to include a review of measures being taken by nuclear facilities to (1) phase out asbestos use in nuclear facilities by December 31, 2022 and (2) pursue technically and economically feasible asbestos-free alternatives. In response to this recommendation, during last year's meeting, CNSC Staff provided it would become "quite onerous" if future RORs covered licensees plans to become compliant by 2023. CELA respectfully disagrees. It is exactly these issues – which are common among all licensees – that we **recommend** be reviewed and discussed in the ROR context especially given their time sensitive nature and impact on human health and safety.

Recommendation:

9. As a standing item, the ROR should review measures being taken by nuclear facilities to (1) phase out asbestos use in nuclear facilities by December 31, 2022 and (2) pursue technically and economically feasible asbestos-free alternatives pursuant to the *Prohibition of Asbestos and Products Containing Asbestos Regulations*.

E. Revised Provincial Policy Statement for Ontario

Last year, CELA requested the Commission direct CNSC Staff to provide comments to the Ministry of Municipal Affairs and Housing during their review of Ontario's Provincial Policy Statement (PPS). Specifically, we recommended the Commission communicate to the Ministry, noting the need to limit the use and occupation of land within 20 km of the Pickering nuclear power plant, to ensure the maintenance of safety margins for the fifth level of Defence in Depth by preventing the intensification and development of residential dwellings.

A response to this recommendation was not provided at last year's ROR meeting in November 2019. As the province of Ontario's revised PPS came into affect on May 1, 2020[16] of this year,

[16] Online: https://files.ontario.ca/mmah-provincial-policy-statement-2020-accessible-final-en-2020-02-14.pdf

we **request** the Commission clarify:

- Whether the Commission conveyed messages regarding land use compatibility in the vicinity of Ontario's nuclear power plants to the province during the call for comments; and if so, are these comments publicly available;

- Has the Commission reviewed the revised PPS to ensure land use computability in the vicinity of major facilities, which includes energy generation facilities. Specific regard should be given to population density and growth around nuclear generating stations and impacts on the implementation of emergency measures and existing plans.

CELA submits that that the PPS is within the purview of the Commission and this was recognized during 2018 Pickering relicensing hearings. As CNSC Staff noted at the time, the Commission does have a role in engaging on updates to the Provincial Policy Statement, however, Staff can only act if given the direction to do so. As the CNSC's Executive Vice President noted:

> [T]he province's policy statement of 2014 now includes the land use compatibility and the definition of major facility. So it's all municipality now, and the Province of Ontario [that] need to demonstrate alignment with the 2014 [PPS]. So, if there is a sense from the Commission that a municipality is not in alignment, the Commission can direct them to do so.[17]

Therefore, CELA **recommends** the following be undertaken at the upcoming ROR meeting.

Recommendation

10. The Commission should direct staff to make their comments on the Provincial Policy Statement (PPS) publicly available, in the event the need to consider land use compatibility in the vicinity of nuclear power plants was conveyed to the Province of Ontario during the 2019 PPS consultation.

11. The Commission should direct staff to review the revised PPS to ensure land use compatibility in the vicinity of major facilities, which includes energy generation facilities. Specific regard should be given to population density and growth around nuclear generating stations and impacts on the implementation of emergency measures and existing plans.

[17] CNSC, "Transcript, Public Hearing, June 29, 2019" online: https://nuclearsafety.gc.ca/eng/the-commission/pdf/FinalTranscript-OPG-Pickering-Hearing-June29-2018.pdf, p 197.

F. ‘New and Emerging Challenges’ and Climate Change

In reviewing the compliance verification program for nuclear power plants, the ROR notes that “additional compliance verification activities for NPPs and WMFs may also be added as necessary during the year in response to new or emerging licensee challenges.”[18]

As the ROR does not elaborate on what these ‘new or emerging challenges’ may be, CELA **recommends** the Commission should direct Staff to expressly consider climate impacts and vulnerabilities within the scope of the ROR. On multiple occasions, CELA has requested the CNSC conduct a climate impact and vulnerability review of licensees.[19] Unfortunately, no ROR nor licensing review to date has taken up our recommendation.

We know that that climate change and nuclear power plants do not mix: indeed, this year’s ROR discussion of the Pickering nuclear powerplants attributed the weighing down of the fish diversion barrier in Lake Ontario to “algae loading” and the “rapid water temperature changes related to lake conditions” as an explanation for increased fish impingement.[20] In prior years, significant amounts of algae have also clogged cooling water intakes causing reactors to go temporarily offline.[21]

As climate impacts become more frequent and pronounced, CELA again **urges** the CNSC to specifically discuss climate change in the context of licensee oversight because of the major safety and environmental issues it poses to operations. CELA submits oversight of potential climate impacts is within the purview of the CNSC’s review because of its responsibility to protect the environment from unintended radioactive releases. Catastrophic weather events are becoming more frequent and CELA **recommends** the CNSC review the climate resiliency of licensees as part of their regulatory oversight reporting.

CELA has previously raised this issue before the Commission, and we again urge the Commission to direct Staff to expressly consider climate impacts and vulnerabilities within the scope of the ROR.

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[18] ROR, p 21

[19] *See for instance,* online: https://cela.ca/wp-content/uploads/2019/07/CELAs-Report-ROR-Nuclear-Substance-and-Uranium-Facilities-2017.pdf; https://cela.ca/submission-by-cela-to-the-cnsc-the-regulatory-oversight-report-for-uranium-mines-and-mills-in-canada-2018/; and http://www.nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD18/CMD19-M24-6.pdf

[20] ROR, p 86

[21] See online: https://environmentaldefence.ca/2018/07/25/algae-caused-climate-change-causing-climate-change/

Recommendation

12. The Commission should direct Staff to expressly consider climate impacts and vulnerabilities within the scope of the ROR. As climate impacts become more frequent and pronounced, CELA urges the CNSC to discuss climate change in the context of licensee oversight because of the major safety and environmental issues it poses to operations, health and safety.

G. COVID-19 Response and Emergency Planning

CELA would also like to note that, while COVID is not strictly speaking a 2019-related issue, CELA finds that the ROR meeting presents an important opportunity to discuss the impact of COVID on the activities covered by this ROR. As such, CELA **recommends** the Commission should use this opportunity to discuss emergency planning and the efficacy of existing emergency plans when emergency response and medical personnel may be at or beyond capacity. Further, offsite emergency plans, including plans for evacuees and evacuation centres, should be reviewed in light of COVID-19 public health guidelines.

While this year's ROR provides preliminary remarks on the CNCS's COVID-19 response, it is silent on emergency planning and the efficacy of existing emergency plans when emergency response and medical personnel are at or beyond capacity. While the CNSC notes it reviewed "licensee adherence to their pandemic response plans and COVID-19 health protocols," it is silent on whether offsite emergency plans, including plans for evacuees and evacuation centres, have been reviewed in line with public health guidelines.

As the CNSC is vested with overseeing and regulating emergency response activities,[22] the Commission should direct CNSC Staff to undertake a review of Ontario's PNERP and the New Brunswick EMO's offsite emergency response plan and publicly report how the pandemic may affect plans in place to safeguard human health and safety, and the environment in the event of an emergency. As over five million Ontarians live within 50km of Ontario's nuclear power plants and 40 million Americans and Canadians rely on the Great Lakes for their drinking water supply, CELA submits it is critical that despite the COVID-19 pandemic, the CNSC ensure the safe operation of nuclear power plants. Compounding an accident with a pandemic could overwhelm existing emergency response capacity and expose already at-risk populations, such as elderly members of the population, to even greater harm.[23]

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[22] PNERP, Annex I

[23] CELA, "Emergency Planning at the Point Lepreau Nuclear Generating Station" (3 April 2017), online: https://cela.ca/emergency-planning-at-the-point-lepreau-nuclear-generating-station-2/

As the CNSC has already discussed this matter in more detail at a recent Commission meeting from June 2020,[24] we **request** the CNSC in future RORs link to meetings where other relevant matters may have been raised, reviewed and discussed by the CNSC.

Recommendation

13. The Commission should direct CNSC Staff to undertake a review of Ontario's PNERP and the New Brunswick EMO's offsite emergency response plan and publicly report how the pandemic may affect plans in place to safeguard human health and safety, and the environment in the event of an emergency.

H. Plans to extend Pickering nuclear power plant licence

The ROR makes repeated reference to the "planned shutdown in 2024" of the Pickering nuclear power plant. However, in light plans announced by the Ontario Power Generation (OPG) and supported by the Ontario government to operate the Pickering station beyond 2024,[25] CELA submits the ROR should have responded to this critical development. While recognizing that the ROR's focus is primarily 2019, CELA **requests** the Commission respond to these statements by OPG and the province, and outline the scope of the existing licence and what would be required should such an extension to be granted. As the Pickering nuclear power plant is already operating beyond its intended design life,[26] a further extension is unquestionably a matter of significant public importance due to health and safety implications.

Additionally, CELA is concerned that by assuming a shutdown date of 2024, the CNSC is overlooking and exempting OPG from requirements which would otherwise apply. For instance, as a result of the planned shutdown in 2024, the CNSC notes that it was "not practical" for Pickering to implement *CSA N285.7, Periodic Inspection and CANDU Nuclear Power Plant Balance of Plant Systems and Components.*[27] CELA **requests** the CNSC confirm whether there are other such CSA standards or updates to RegDocs that have not been applied to the Pickering site for the same reason that it is planning to shutdown in 2024.

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[24] CNSC, "Meeting of the Commission" (3 June 2020) CMD 20-M7 online: http://nuclearsafety.gc.ca/eng/the-commission/pdf/20-M7-Agenda-June17-18-2020-e.pdf
[25] Ontario Newsroom, "Ontario Supports Plan to Safely Extend the Life of the Pickering Nuclear Generating Station" (14 Aug 2020), online: https://news.ontario.ca/en/release/57995/ontario-supports-plan-to-safely-extend-the-life-of-the-pickering-nuclear-generating-station
[26] CELA, "Casework – Pickering Nuclear Generating Station Life Extension," online: https://cela.ca/casework-pickering-nuclear-generating-station-life-extension/
[27] ROR, p 41

Recommendation

14. The Commission provide a statement in response to plans from OPG and the province of Ontario to extend the current operations at Pickering. For public clarity, it would be of much value for the Commission to speak to their role and the licensing process which would be required for this further extension to occur.

I. False alarm text message from Pickering nuclear power plant

On January 12, 2020, thousands of Ontarians were awoken by an alert from the Province of Ontario indicating that an incident was reported at the Pickering nuclear power plant. CELA **requests** that this matter, given the widespread confusion it caused and the ramifications it has on emergency planning and preparedness, be included among the 2020 Updates at the upcoming ROR meeting.

Further, we note that the CNSC webpage for the Pickering site[28] does not reference this event, the official release from the Commission, nor the events independent review by Global Public Affairs and **request** it be updated.[29] Notably, we are concerned by the independent reviews comments that:

- Most staff explained that the January 12 incident tested the CNSC because there was no existing communications protocol for non-nuclear emergencies and that no previous training or exercise had focused on what to do in the event of a false alert[30]
- While the CNSC team expressed a willingness and ability to exercise judgement to step outside of protocol, had they responded first noting the falsity of the message, CNSC staff wouldn't have simply taken an organizational risk, they would have risked the reputation and relationship of the Province and facility[31]
- While staff agreed that January 12 served as an important learning opportunity, serious concerns were raised regarding staff resources, noting that CNSC would be hard-pressed to fully staff a 24/7 emergency communications group for a sustained period[32]

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[28] *See*: https://nuclearsafety.gc.ca/eng/reactors/power-plants/nuclear-facilities/pickering-nuclear-generating-station/index.cfm

[29] "Global Public Affairs Independent Review of the Canadian Nuclear Safety Commission's Response to the January 12, 2020 Pickering False Alarm and CNSC Management Response," (9 June 2020) online: https://www.nuclearsafety.gc.ca/eng/the-commission/meetings/cmd/pdf/CMD20/CMD20-M11-A.pdf [**Global Public Affairs**]

[30] Global Public Affairs, p 12

[31] *Ibid*, p 17

[32] *Ibid*, p 20

In light of these findings, CELA concurs that emergency response planning and preparedness is multi-faceted and requires cooperation between the regulator, provincial authorities and licensee. However, the CNSC is vested with the jurisdiction to exercise a stringent oversight role as to whether emergency planning and preparedness has been sufficiently demonstrated by provinces and licensees.

Not only does the CNSC have authority to require, review and approve emergency plans which are in the purview of its licensees; it also has authority to review emergency plans in place for off-site response and to use its assessment of the adequacy of those plans as part of its determination as to whether a nuclear power plant or other facility may operate, or under what terms and conditions. The CNSC's jurisdiction extends to the portions of plans which have been undertaken by other authorities external to the plant operator. That is, the CNSC must review the gamut of emergency preparedness measures, to make a determination whether the risk to the public is acceptably low per section 24(4) of the *Nuclear Safety and Control Act*.

In response to the Global Public Affairs independent review of the Pickering false alarm, it is fundamental that the CNSC not limit its review of emergency planning to plant boundaries or operator action. Rather, it must specify expectations for emergency planning to the fullest extent of potential impacts on the public and environment. This includes making recommendations on appropriate reforms and revisions necessary, based on the lessons learned from the Pickering false alert.

Recommendation

15. The Pickering false alert text should be among the 2020 updates provided at the ROR meeting. The CNSC should also respond to the findings of the Global Public Affairs independent review. Given the widespread confusion caused by the text message and the ramifications it has on emergency planning and preparedness – specifically the public's willingness to heed future text messages in the event of an actual emergency – this matter should be critically and publicly reviewed by the Commission.

J. Tritium Emissions to the Environment

Appendix D of the ROR sets out the derived release limits and radiological releases to the environment from nuclear power plants.[33] To assist in the review of this chapter, CELA sought the expert advise of Dr. Ian Fairlie.

First, CELA notes that the ROR indicates very high annual tritium emissions to air and discharges to Lake Ontario from the Pickering nuclear power plant. According to Dr. Fairlie,

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[33] ROR, p 189

"these are among the largest from any nuclear facility in the world."[34] This is of immediate concern, as the Pickering nuclear power plant lies within the boundary of Greater Toronto Area, with a population of 6 million people (2.2 million of which live within 30 kilometres of the plant). Accordingly, Dr. Fairlie found "these emissions and releases constitute a serious health hazard to these residents of GTA."[35] As the CNSC has licensed the Pickering station to continue to operate until the end of December 2023, Dr. Fairlie **recommends** the immediate application of the precautionary principle which if applied, would result in the Pickering station being "closed as soon as technically feasible. In other words, steps would be taken to close the 6 remaining Pickering reactors without delay."[36]

Second, CELA **requests** the CNSC explain why the tritium (and other) annual emissions from Point Lepreau NGS, which has one 660 MW reactor, has approximately the same annual emissions as the Bruce NGS with 8 reactors and Pickering NGS with 6 reactors.

Third, CELA **requests** the CNSC explain why Gentilly-2 is still emitting large TBq/a amounts of tritium (and other emissions) in 2019 given it was closed at the end of 2012 and all its fuel removed by the end of 2014.[37] CELA further **requests** CNSC confirm potential reasons for these emissions.

Fourth, CELA has received permission from Dr. Fairlie to append his expert report to this submission which was originally submitted to the CNSC for consideration during the 2018 Pickering relicensing hearings. As this report was not adequately replied to in the context of the hearing, CELA submits the expert report remains valid, and it continues to provide directly relevant information to the Commission for its review of this ROR.

Recommendations

16. CNSC staff should explain the reasons for the very high annual tritium emissions to air and discharges to Lake Ontario from the Pickering nuclear power plant; clarify why the emissions from one reactor at Point Lepreau are nearly equivalent to the Bruce Power and Pickering sites (which have 6 – 8 reactors); and explain why the Gentilly-2 site continues to emit tritium despite the removal of fuel in 2014 and its closure in 2012.

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[34] Personal correspondence, I. Fairlie to K. Blaise (5 Nov 2020)
[35] *Ibid*
[36] *Ibid*
[37] *See* Dr. I. Fairlie, "Continued Radioactive Emissions from Old Closed Nuclear Reactors" (12 Oct 2019), online: https://www.ianfairlie.org/news/continued-radioactive-emissions-from-old-closed-nuclear-reactors/

K. Status Report on Power Reactors

CELA is aware that many of the matters discussed herein (including the COVID-19 response and false alert from the Pickering nuclear power plant) were also discussed that the June 2020 meeting of the Commission for the "Status Report on Power Reactors."[38] However, CELA **recommends** that when matters are raised in other Commission proceedings that are directly relevant to the other, CNSC Staff provide a reference to these other materials, meeting minutes, and transcripts in the ROR.

We also **recommend** the CNSC maintain and continuously update a publicly accessible chart on the CNSC site which lists all issues raised across CNSC meetings. This chart could provide links to the relevant proceeding where the issue was discussed (whether meeting minutes, transcript or CNSC Staff CMD). At the moment, even the most well informed and interested members of the public cannot realistically find and follow these matters of significant public interest.

Further, as there is no public intervention opportunity accompanying the Status Report on Power Reactors, CELA was precluded from providing comments on timely 2020 matters. However, as we remain of the review that the issues raised herein require public review by the CNSC, we raise them in this forum as it remains the only opportunity to do so.

We further submit that the Commission's responses on the matters raised in this submission, but made at other meetings, not be used as a stand in for full and thorough consideration of CELA's requests and recommendations.

Recommendation

17. When matters are raised in other Commission proceedings that are directly relevant to an ROR, CNSC Staff should reference to these proceedings, including materials, meeting minutes, and transcripts directly in the ROR.

18. Comments made by the Commission and CNSC Staff raised herein at previous Commission proceedings – for which there is no public opportunity to provide comments – should not be used as a stand in for full and thorough consideration of requests and recommendations made in this submission.

19. The CNSC should establish and continuously update a publicly accessible chart on the CNSC site which lists all issues raised at all CSNC meetings. This chart could provide

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[38] Online: *http://nuclearsafety.gc.ca/eng/the-commission/pdf/NoticeCommissionMeeting-June17-18-2020-e.pdf*

links to the relevant documents (ie. meeting minutes, transcript or CNSC Staff CMDs) as discussed by the Commission.

III. CONCLUSIONS

We respectfully provide these comments to assist the Commission in its review of the Regulatory Oversight Report for Canadian Nuclear Power Generating Sites: 2019.

CANADIAN ENVIRONMENTAL LAW ASSOCIATION

Kerrie Blaise, Legal Counsel

APPENDIX A
Summary of Recommendations

1. CELA remains of the view that ROR meetings are not a replacement for relicensing hearings and the CNSC must remedy the discrepancy in participation rights among public intervenors and licensees by providing oral presentation opportunities.

2. The CNSC should extend the amount of time provided to the public for the review of RORs and ensure a minimum 60-day timeframe.

3. The ROR would be more effective if the CNSC canvassed a list of issues and topics to inform the scope of the ROR. Given the trend to longer, ten-year licences, soliciting public comment on the scope of issues addressed in ROR would provide a starting point for public engagement.

4. **PRIORITY RECOMMENDATION As Canada's nuclear safety regulator, it is of paramount importance that OFMEM's technical study be requested and obtained without delay. This matter is critical to the licensing basis for all of Ontario's nuclear generating stations and the health and safety of the millions of people living in and around Ontario's nuclear power plants. CELA again recommends the Commission direct CNSC Staff obtain the final Provincial Nuclear Emergency Response Plan Technical Study from the Office of the Fire Marshall and Emergency Management.**

5. The CNSC should require proof of adequate contingency planning for the protection of drinking water in the event of an emergency as a requirement for licensing. Drinking water monitoring is insufficient in scope to ensure that there are actually sufficient drinking water supplies available in the event of a major radioactive release.

6. The CNSC should require proof of adequate contingency planning for the protection of drinking water in the event of an emergency as a requirement for licensing. The CNSC should ensure that provisions are in place for an alternative source of drinking water for residents whose current drinking water source is Lake Ontario.

7. Radionuclides should be reportable to Canada's National Pollutant Release Inventory (NPRI), an online data portal and a key resource for identifying pollution prevention priorities, supporting the assessment and risk management of chemicals, and encouraging actions aimed at reducing pollutant releases.

8. The Commission should provide an update on the CNSC-NPRI linked site. As this is directly relevant to all nuclear sites and facilities, it is critical this remain a reportable item in subsequent RORs.

9. As a standing item, the ROR should review measures being taken by nuclear facilities to (1) phase out asbestos use in nuclear facilities by December 31, 2022 and (2) pursue technically and economically feasible asbestos-free alternatives pursuant to the *Prohibition of Asbestos and Products Containing Asbestos Regulations*.

10. The Commission should direct staff to make their comments on the Provincial Policy Statement (PPS) publicly available, in the event the need to consider land use compatibility in the vicinity of nuclear power plants was conveyed to the Province of Ontario during the 2019 PPS consultation.

11. The Commission should direct staff to review the revised PPS to ensure land use compatibility in the vicinity of major facilities, which includes energy generation facilities. Specific regard should be given to population density and growth around nuclear generating stations and impacts on the implementation of emergency measures and existing plans.

12. The Commission should direct Staff to expressly consider climate impacts and vulnerabilities within the scope of the ROR. As climate impacts become more frequent and pronounced, CELA urges the CNSC to discuss climate change in the context of licensee oversight because of the major safety and environmental issues it poses to operations, health and safety.

13. The Commission should direct CNSC Staff to undertake a review of Ontario's PNERP and the New Brunswick EMO's offsite emergency response plan and publicly report how the pandemic may affect plans in place to safeguard human health and safety, and the environment in the event of an emergency.

14. The Commission provide a statement in response to plans from OPG and the province of Ontario to extend the current operations at Pickering. For public clarity, it would be of much value for the Commission to speak to their role and the licensing process which would be required for this further extension to occur.

15. The Pickering false alert text should be among the 2020 updates provided at the ROR meeting. The CNSC should also respond to the findings of the Global Public Affairs independent review. Given the widespread confusion caused by the text message and the ramifications it has on emergency planning and preparedness – specifically the public's

willingness to heed future text messages in the event of an actual emergency – this matter should be critically and publicly reviewed by the Commission.

16. CNSC staff should explain the reasons for the very high annual tritium emissions to air and discharges to Lake Ontario from the Pickering nuclear power plant; clarify why the emissions from one reactor at Point Lepreau are nearly equivalent to the Bruce Power and Pickering sites (which have 6 – 8 reactors); and explain why the Gentilly-2 site continues to emit tritium despite the removal of fuel in 2014 and its closure in 2012.

17. When matters are raised in other Commission proceedings that are directly relevant to an ROR, CNSC Staff should reference to these proceedings, including materials, meeting minutes, and transcripts directly in the ROR.

18. Comments made by the Commission and CNSC Staff raised herein at previous Commission proceedings – for which there is no public opportunity to provide comments – should not be used as a stand in for full and thorough consideration of requests and recommendations made in this submission.

19. The CNSC should establish and continuously update a publicly accessible chart on the CNSC site which lists all issues raised at all CSNC meetings. This chart could provide links to the relevant documents (ie. meeting minutes, transcript or CNSC Staff CMDs) as discussed by the Commission.

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Submission: Tritium problems at Pickering

Re:Pickering Nuclear Generating Station Licence Renewal

By May 8 2018

Table of Contents

Executive Summary

Ontario Power Generation (OPG) has applied for a 10 year extension of its license at the Pickering NGS near Toronto from 2018 to 2028. Annual tritium emissions to air from Pickering NGS are among the largest, if not the largest, from any nuclear facility in the world. The station lies within the boundary of Greater Toronto with a population of 6 million people with 2.2 million people living within 30 kilometres of the plant.

This written submission concludes that tritium and other emissions and releases constitute a serious health hazard to many residents of Greater Toronto. Current plans are for the Pickering plant to continue to operate until the end of December 2023. If the precautionary principle were to be applied, the application should be declined and the station closed as soon as technically feasible. In other words, steps should be taken to close the 6 remaining Pickering reactors without delay.

Major international agencies recognise that tritium, the radioactive isotope of hydrogen, has unusual properties marking it as an unusually hazardous nuclide. It is extremely mobile in the environment, contaminates all biota in nearby areas including humans and binds with organic matter to form organically bound tritium (OBT) with long residence times in the body making it more radiotoxic than tritiated water.

Environmental measurements of tritium in air, soils, foodstuffs, and water near the Pickering NGS facility indicate pervasive widespread tritium contamination.

This report estimates that annual tritium intakes for local residents amount to about 120,000 Bq. This is mainly from inhalation and skin absorption of tritiated water vapour. This estimate is conservative as it assumes residents neither consume their own garden produce nor drink from their own wells. These amounts are considerably higher than the natural background intake of 6,000 Bq/a. More hazardous OBT intakes will also occur.

These radioactive intakes increase the probability of cancer and other diseases in exposed people. Embryos, fetuses, babies, infants and children are more radiosensitive than adults, and females more than males. Due to long latency periods, these cancers will arise in the future. It is not possible to ascertain in advance who will be affected but these probabilistic effects mean all exposed people in and near Toronto will have each been handed “negative” lottery tickets, and that some of them at random will get cancer in future.

Considerable evidence from cell and animal studies, and radiation biology theory indicates that radiogenic effects will occur. Indicative (‘ecological’) epidemiology studies of Canadian facilities emitting tritium reveal increases in cancer and congenital malformations: This is backed by strong evidence from recent, large scale, statistically powerful epidemiology studies from other countries.

The Canadian studies hese should have been confirmed with case-control or cohort studies. The absence of such studies is a notable lapse in the duties of care of public

health bodies in the Toronto area, especially Toronto's Public Health officials and Board of Health, to protect the health of Toronto citizens. It is concluded that the license for Pickering should not be renewed, and that the station should be phased out as soon as reasonably practical.

A. Overview

1. OPG has applied for a 10 year extension of its license at Pickering NGS, currently the largest source of tritium in the world[1]. Tritium is the radioactive isotope of hydrogen with a half-life of 12.3 years. This independent report summarises current understandings of the biological and health effects of exposures to tritium and comments on the risks faced by local citizens near Pickering NGS.

2. I am a Canadian citizen currently resident in the United Kingdom. I am an independent consultant on radioactivity in the environment with degrees in chemistry and radiation biology. My doctoral studies at Imperial College, UK and Princeton University, US examined nuclear waste technologies. My area of expertise is the dosimetric impacts of nuclear reactor emissions. I have authored many articles in peer-reviewed journals on epidemiology studies of child leukemias near radiation facilities and on the hazards of radionuclides. I have been a consultant to UK Government Departments, the European Parliament, the World Health Organisation, environment NGOs, and UK local authorities. Between 2000 and 2004, he was head of the Secretariat to the UK Government's Committee Examining the Radiation Risks of Internal Emitters (CERRIE).

3. Of particular relevance to the hearing, I have written numerous scientific articles discussing the hazards of tritium emissions, including the following:

- Fairlie I. (2014) A hypothesis to explain childhood cancers near nuclear power plants J Environ Radioact. 133 (2014) pp 10- 17
- Fairlie I. Hypothesis to Explain Childhood Cancer near Nuclear Power Plants. Int J Occup Environ Health 2010;16:341–350.
- Fairlie I. The hazards of tritium – revisited. Medicine, Conflict and Survival. Vol 24:4. October 2008. pp 306 -319. http://www.informaworld.com/smpp/content~content=a904743144~db=all~order=page
- Fairlie I. RBE and w_R values of Auger emitters and low-range beta emitters with particular reference to tritium. Journal of Radiological Protection. 2007; 27:157-168. http://www.iop.org/EJ/abstract/0952-4746/27/2/003/
- Fairlie I. Tritium Hazard Report: Pollution and Radiation Risk from Canadian Nuclear Facilities. Published by Greenpeace Canada. June 2007. http://www.greenpeace.org/raw/content/canada/en/documents-and-links/publications/tritium-hazard-report-pollu.pdf
- Fairlie I. Tritium Hazard Report on Cernavoda 3/4: Environment Impact Analysis: Report for Greenpeace Romania. Published by Greenpeace Central Europe. November 2007. http://www.greenpeace.ro/uploads/articole/Cernavoda%20Report%20for%20GP%20Central%20Europe.pdf
- Fairlie I. Uncertainties in Doses and Risks from Internal Radiation. Medicine, Conflict and Survival, Vol 21:2. pp 111 – 126. (2005) http://www.informaworld.com/smpp/content~content=a714004320~db=all~order=page
- Fairlie I. Tritium: The Overlooked Nuclear Hazard. The Ecologist. 22 No 5. 228-232 (1992)

B. Tritium Releases from Pickering NGS

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[1] Although tritium is created in the upper atmosphere by cosmic ray bombardment, annual tritium releases from Canadian heavy water reactors comfortably exceed the amounts created naturally.

4. For many years, Pickering NGS has been emitting very large quantities of tritium – the radioactive isotope of hydrogen. See Table 1. In recent years these emissions have been increasing. These emissions are of the order of hundreds of terabecquerels per year (TBq/a – see radioactivity units at Annex B). One terabecquerel is 10^{12}, or one trillion Bq, a very large amount of radioactivity. This tritium is released mainly in two forms – tritium gas (HT) and tritiated water vapour (HTO) however for regulatory purposes the two source terms are combined. Both are invisible gases, both are odourless, mainly tasteless and silent. They are not detectable by any of our senses, but they are nevertheless still very hazardous[2].

5.

Table 1 Annual Tritium Emissions to Air and to Lake Ontario from Pickering: TBq per year

Year	HTO emissions to Air	HTO discharges to Lake Ontario	Total
2016	680	320	1,000
2015	540	370	910
2014	530	340	870
2013	430	310	740
2012	530	290	820
2011	550	310	860
averages	543	322	867

Source: OPG: RESULTS OF ENVIRONMENTAL MONITORING PROGRAMS
https://www.opg.com/news-and-media/Reports/2016_EMP_Report.pdf

6. These annual emissions to air are significantly higher than other reactor types, as shown in table 2.

TABLE 2. Annual Tritium air emissions from various sources

Facility	Year	TBq/a
Pickering	2016	680
Dungeness B (AGR) UK	2013	12
Sizewell B (PWR) UK	2013	3
Dungeness A (Magnox) UK	2013	2.6
German NPPs (BWRs, PWRs)	2003	0.5 average

7. In the assessment of risk, aerial emissions are more important than liquid discharges for two reasons. First, the key parameters in estimating radiation doses to local people are nuclide concentrations in environmental materials. Contrary to what many people think, air emissions result in higher environmental concentrations than water discharges. The reason is dilution. A cubic metre of water contains a million grams of water which dilutes radioactive contaminants far more effectively than a cubic metre of air with a mass of ~10 grams: i.e., >100,000 times more effectively. This is not to accept that dilution is the solution to pollution. It isn't: it merely reflects the fact of existing (ill-advised) methods of disposing nuclear wastes. Second, individual and collective doses from air emissions are much larger than from discharges to water. Accordingly this report deals mainly with air emissions.

[2] An analogy here is bacteria. Everyone knows that they exist even though they are invisible to the naked eye, and not detectable to any of our senses.

BOX 1. Molecular Exchange

CNSC reports commonly distinguish between elemental tritium (HT) and tritiated water vapour (HTO) emissions. However in the environment, tritium atoms in HT rapidly exchange with stable H atoms in water through the phenomenon of molecular exchange. Therefore here all tritium releases are treated as HTO. This is common practice in OPG and AECL (Davis et al, 1997).

In more detail, in matter, all atoms engage in exchange reactions with like atoms in other molecules to varying degrees. This means that tritium atoms in HT swap positions with stable H atoms in the environment in the hydrosphere and in biota, including humans. H and T, the smallest atoms (apart from deuterium) are prominent as regards exchange reactions. These exchange reactions are very quick, taking about 10^{-15} seconds on average.

As the most common hydrogenous material in the environment is water in liquid or vapour forms, this means that tritium in HT relatively quickly transfers to HTO. In practical terms, open water surfaces and biota downwind, including food growing in the area, plants, animals and humans, would become contaminated with tritium up to the tritium concentration in the atmosphere. For example, it would include vegetables and fruit in exposed market stalls and shops (Inoue, 1993).

C. CNSC Measurements of tritium levels in environmental samples

8. The CNSC carries out an annual sampling program of environmental materials (air, soil, grass, vegetation, food) near Pickering. Some values for 2017 are noted below-see http://nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/pickering.cfm#table

9. These values for tritium clearly indicate that the areas near Pickering are highly contaminated with tritium. xxx

10. The concentration values for tritium vary considerably from very low levels of a few Bq per litre or kg to hundreds of Bq per litre/kg. The CNSC description of these measurements does not explain what is going on or the reasons for these wide variations. Therefore this report will in an effort to render these measurements meaningful for local people.

11. The source of these high levels of tritium is of course the air emissions from the six remaining reactors at Pickering NGS. These reactors continuously emit both forms of tritium – elemental tritium and tritiated water vapour. As a general rule, the closer the inhabitants live to the station, the higher the HTO concentrations, but this is not a hard and fast rule, as much depends on the strength and direction of the winds during emissions. Sometimes radioactive plumes can travel for dozens of kilometres. After the Chernobyl accident in 1986, the plumes travelled right round the world.

Illustrative values of tritium (HTO) concentrations near Pickering from CNSC measurements in 2017.

Sample	Value	Sample Number
grass/vegetation	178.7 Bq per kg fresh weight	PP01-V01
grass/vegetation	12.2 Bq/kg fresh weight-(OBT)	PP01-V01
grass/vegetation	520.4 Bq/kg	PP07-V05
air	4.9 Bq per cu meter	PP07-A03
Lake Ontario water	30.4 Bq per litre	PP05-W02
Lake Ontario water	14.8 Bq per litre	PP02-W01
Milk		

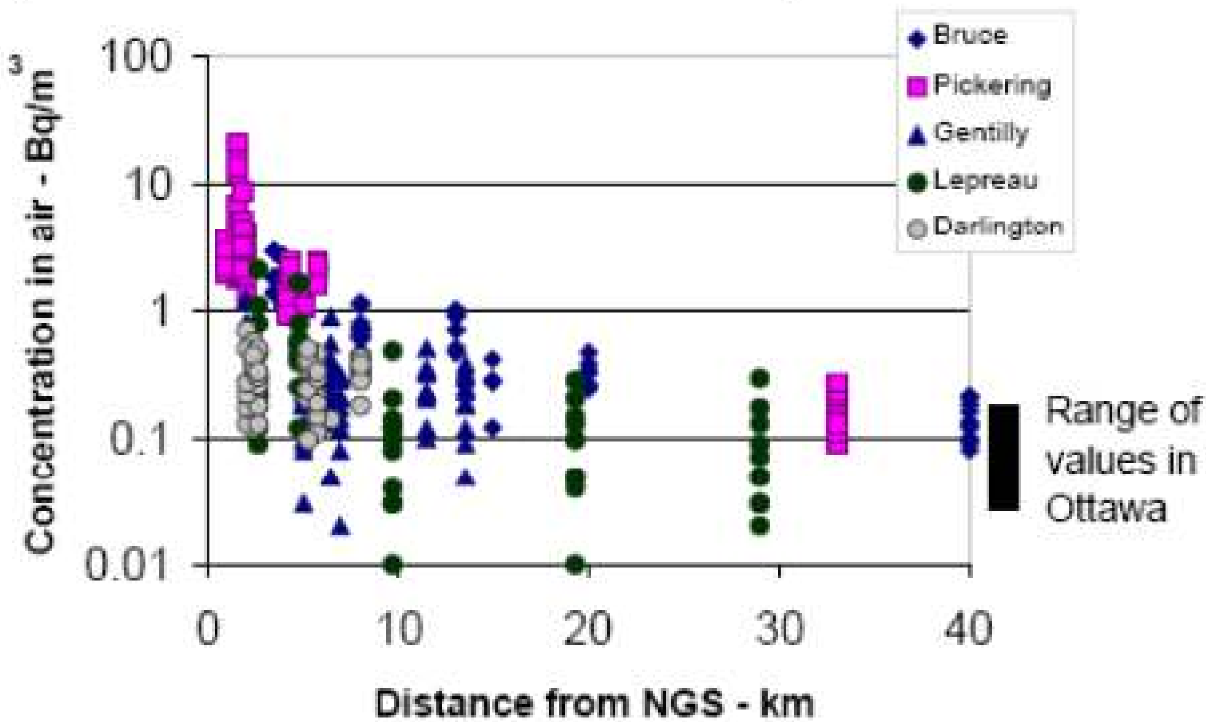
Potatoes		

D. Are these Tritium Levels Safe?

12. To assess risks to local people, the official approach is to estimate tritium's radiation doses in mSv units, but tritium's dosimetry is seriously problematic as major difficulties exist with it (Fairlie, 2007). The result is that that estimates of internal doses and risks from tritium are highly unreliable – as the CERRIE Report (2004) concluded. Instead of radiation doses, this report uses radioactivity: in other words it will estimate tritium's Bq annual intakes and concentrations in local people and the resulting likely levels of risks. This approach has been used by other scientists (Osborne, 2002).It consists of four steps as follows.

13. **STEP 1.** Tritium emissions will result in raised tritium air concentrations near Pickering as indicated in Figure 1 which shows tritium concentrations near Canadian nuclear power stations. We use the following graphs to see what actually occurs and what the trends are.

Figure 1. **Tritium concentrations in air near tritium-emitting facilities**



(Figure reproduced with permission from Tritium in the Canadian Environment: Levels and Health Effects. Report RSP-0153-1. Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne. Data from Health Canada, 2001)

14. The above graph indicates that the closer people live to a NGS, the higher the air concentrations of tritium. The logarithmic scale of the Y-axis compresses the data range: the highest air concentrations (~30 Bq per cubic metre) are 3,000 times greater than the lowest concentration (0.01 Bq per cubic metre).

15. However we need to know tritium concentrations in the air's <u>water vapour</u> rather than the air itself. If we assume a reasonable value of 10 grams of water per cubic metre of air (Davis et al, 1996) then observed tritium water vapour concentrations in air 1 to 2 km from Pickering in the graph vary between 100 to 3,000 Bq per litre.

16. These data are point measurements. Air concentrations vary considerably and large spikes of tritium emissions may occur. Pulsed tritium emissions could result in heavy labelling of cells being formed in the embryos and fetuses of nearby pregnant women at that particular moment. This fear was expressed decades ago by Professor Edward Radford in his 1979 testimony to the Ontario Government's Select Committee on Ontario Hydro Affairs: Hearings on The Safety of Ontario's Nuclear Reactors, July 10 1979. [See http://www.ccnr.org/tritium_2.html#scoha]. This provides the basic mechanism for the hypothesis explaining the large observed increases in leukemias in subsequent children born near nuclear reactors (Fairlie, 2014). Radionuclide spikes are discussed further in Appendix D of this report.

17. **STEP 2**. The second step is that high tritium air concentrations result in raised tritium <u>concentrations in foodstuffs</u>, as seen in figure 2.

Figure 2. **Tritium concentrations in foodstuffs near tritium-emitting facilities**

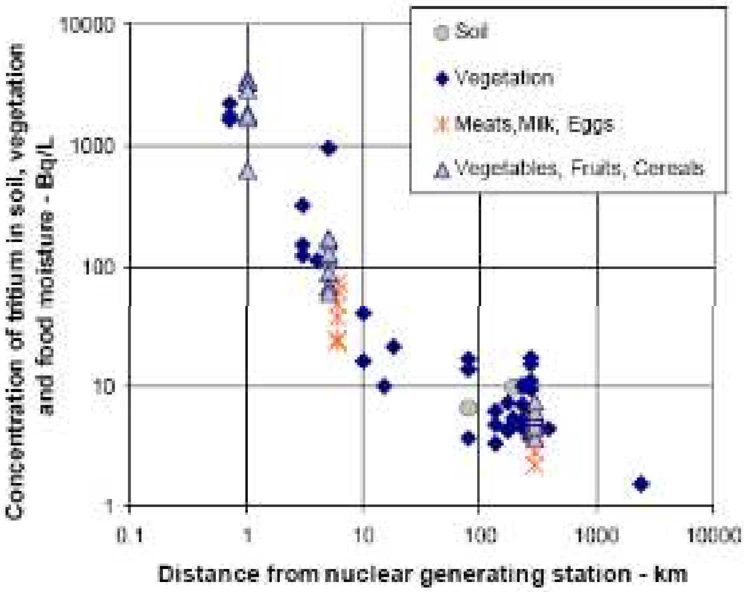


Figure reproduced with permission from *Tritium in the Canadian Environment: Levels and Health Effects. Report* RSP-0153-1. Prepared for the Canadian Nuclear Safety Commission under CNSC contract no. 87055-01-0184 by Ranasara Consultants and Richard Osborne. (Data from Health Canada),

STEP 3. The next step is to estimate tritium intakes in local people living near the Pickering facility. They will be exposed from:

- ingesting foodstuffs contaminated with tritiated water vapour, e.g. from local markets and fruit stalls
- inhaling tritium gas and tritiated water vapour
- drinking tritiated water and milk, and
- skin absorption of tritiated water vapour

BOX 2 – Estimate of Annual HTO Intakes

To calculate annual tritium intakes by residents near Pickering, we multiply together two parameters. First, average annual dietary, breathing and eating rates for adult Canadians. Second, HTO concentrations as measured by CNSC (2017) http://nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/pickering.cfm

Average breathing and eating rates for adult Canadians have been compiled by Health Canada (1994) from a national habit and diet survey. These values, together values for air and drinking water intakes from Health Canada (2001) are shown below.

18. This analysis indicates that local people living near the Pickering plant will have high intakes of tritium. Therefore tritium concentrations in local people should be measured using urine analyses for HTO and non-invasive bioassays such as nail clippings and hair clippings for OBT. As far as is known, this does not occur.

19. Using the approach adopted by Osborne et al (2002), this report estimates annual HTO uptakes in people living close (within 5 km) to Pickering plant to be about 120,000 **Bq/year** to two significant figures**.** The calculations are set out in BOX 2. Note this estimate assumes that people do not consume their own garden produce nor drink water from their own wells. It assumes people obtain one third of their food from locally-sourced foods.

20. Some uncertainty exists about the estimated tritium concentrations in food and water, but these amounts are the smallest of the four intake categories below. Even if incorrect, they would not significantly affect the overall estimate.

Table 3. **Annual food, water and air intakes by adult Canadians**

Water Source	Average Intake
Total foods	490 kg per year
Drinking water and made-up drinks	550 litres per year
Air	8,400 cubic metres per year

Reference: Health Canada (1994). Daily rates are multiplied by 365 days per year [in Health Canada (2001) guide.]

Table II **Estimate of annual HTO intakes in people living near Pickering NGS (<2 km)**

Source of HTO	Intake per year	HTO Concentration	HTO Bq/year
Air Inhalation	8,400 m^3	5.9 Bq/m^3 *	**50,000**
Skin absorpt'n	60% ** of inhalation intake	5.9 Bq/m^3 *	**30,000**
Food	33% of 490 kg = 160 kg	179 Bq/kg **	**29,000**
Water in drinks	550 litres	14.8 Bq/L ***	**8,000**
		TOTAL	**~117,000**

* (Sample code

** Osborne, 1966. (Sample code *** Assumptions: 1/3 of food from local market; no home-grown food. xxx

*** (Sample code

TABLE 3

Source of OBT	Intake per year	**Bq/kg** (See table 4 on p 36 below)	OBT Bq/year
Food	160 kg/a x 20% solid matter in foods	average = 116	4,000

BOX C – Estimation of annual OBT Intake

To calculate annual OBT intake by residents near Pickering NGS, we multiply together three parameters.

First, average annual dietary intake for adult Canadians. Second, the parameter of 20% solid matter in foods. Third, the average OBT concentration in foods as measured by CNSC (2017) xxx

21. Our 120,000 Bq/a estimate is higher than estimates near other tritium-contaminated sites. For example, Osborne et al (2002) estimated an annual HTO uptake of 67,000 Bq in people within 5 - 10 km of nuclear reactors. Trivedi et al (1997) calculated annual HTO uptakes of 20,000 Bq in adults living in Deep River, Ontario (10 km from the AECL Chalk River reactor). Our estimate is also considerably larger than annual intakes of 6,000 Bq of HTO by adults from background (Osborne, 2002), about 30 times higher.

22. For OBT, our calculation in Box C above using tritium in food data from Thompson et al (2015) indicates that people within 2 km of Pickering would also annually ingest approximately 4,000 Bq of OBT in their food. This compares with the Osborne et al (2002) OBT estimate of 7,000 Bq/a in people living within 5 - 10 km from nuclear reactors, and the Trivedi et al (1997) estimate of 800 Bq/a OBT in people living 10 km from the AECL Chalk River

reactor. The 4,000 Bq/a OBT level is also larger than annual intake of 350 Bq OBT from background (Osborne et al, 2002), ie about 10 times higher. Table 2 sets out the comparisons for HTO and OBT annual intakes.

TABLE 2. **Annual Tritium Intakes near various sites- Bq/a**

SOURCE	EXPOSED PEOPLE	HTO	OBT
This report	2 km from Pickering NGS	120,000	4,000
Trivedi et al, 1997	10 km from Chalk River reactor	20,000	800
Osborne et al, 2002	5-10 km of Canadian NPPs	67,000	7,000
Osborne et al, 2002	background level in Canada	6,000	350

23. **STEP 4**. The last step is to address the original question in this section, i.e., are these annual tritium levels hazardous? To answer this we need a yardstick, which we construct in the next paragraph.

24. It is widely accepted that an annual risk of one in a million (10^{-6}) of fatal cancer from an exposure to a toxic agent is acceptable. Using this acceptable risk level, the Ontario Government's Ontario Drinking Water Advisory Council (ODWAC, 2009) http://www.odwac.gov.on.ca/reports/minister_reports.htm recommended a maximum concentration for tritium in drinking water of 20 Bq/L, after an initial period. If we multiply this concentration by Health Canada's average annual water intake (see Box B) of 550 litres for adult Canadians, we get **~10,000 Bq** of tritiated water per year, correct to one significant figure**.** This may be used as rough yardstick for an acceptable annual intake of tritium. It is true the yardstick depends on the value chosen for the drinking water limit, and different views exist on this - table 3 shows the various limits in play. In our view, it is reasonable to use the limit recommended by the Ontario Government's ODWAC –ie 20 Bq/L limit.

Table 3. Tritium Concentration Limits in drinking water - Bq per litre

AGENCY	DATE	TRITIUM LIMIT BQ PER LITRE
Ontario Government's Advisory Committee on Environmental Standards	1994	20*
EC (European Commission,1998)	1998	100
US State of Colorado target	2008	18
US State of California target	2008	15
Ontario Government (ODWAC,2009)	2009	20
CNSC design guide for groundwater (CNSC,2011)	2011	100

* after an initial 100 Bq/L.

25. The 120,000 Bq per year we estimate for nearby people is 12 times higher than our annual yardstick. However even if a drinking water limit of 100 Bq/L were used, the annual intake near Pickering would still exceed the resulting limit by a factor of 2.4.

26. It is concluded from this analysis that people living near Pickering NGS are being exposed annually to hazardous levels of tritium. We estimate that each year they will take up

much more tritium than they would normally take in from background levels. This will result in added radiation exposures which will increase their cancer risks.

D. The Hazards of Tritium

27. In order to appreciate the risks to local people from tritium uptakes and exposures, we need to discuss tritium's properties in some depth. In the past, nuclear scientists had tended to minimise the risks from tritium and to regard it as being only weakly radiotoxic. This is changing: in recent years, 10 major reports on tritium have been published by radiation safety agencies in the UK (AGIR, 2008), and Canada (CNSC, 2010a; 2010b). In France, the French Nuclear Safety Authority (ASN, 2010) has published a comprehensive White Paper on tritium and the French Institute de Radioprotection and Nuclear Safety has published six major reports on tritium (IRSN, 2010a; 2010b; 2010c; 2010d; 2010e; 2010f). In particular, the reports all noted that tritium exposures resulted in internal radiation doses whose estimation contained uncertainties which could render them unreliable.

28. The most comprehensive report on tritium was published by the UK Government's senior Advisory Group on Ionising Radiation (AGIR, 2008). This report strongly recommended that tritium's hazard (ie, its radiation weighting factor) should be doubled from 1 to 2. However other scientists (Fairlie, 2008; Fairlie, 2007a; Fairlie, 2007b; Melintescu et al, 2007; Makhijani et al, 2006) have presented evidence for even larger increases in tritium's radiotoxicity, including the US EPA (2006) which recommended a 2.5 fold increase.

29. These reports draw attention to tritium's properties which mark it out as an unusually hazardous radionuclide. These include

a. its relatively long half life of 12.3 years
b. its mobility and cycling (as H_2O) in the biosphere,
c. its multiple pathways to man,
d. its ability to swap instantaneously with H atoms in adjacent materials,
e. its relatively high relative biological effectiveness (RBE) of 2 to 3,
f. its binding with cell constituents to form organically-bound tritium (OBT) with heterogeneous distribution in humans, and
g. its short-range beta particle, meaning that its damage depends on location within cellular molecules, e.g. DNA

30. For these reasons, tritium presents several challenges to conventional dosimetry and health-risk assessment. Also, in its elemental form, tritium diffuses through most containers, including those made of steel, aluminium, concrete and plastic. In the oxide form, tritium is generally not detected by commonly-used survey instruments (Okada et al, 1993).

31. When tritium is emitted from Pickering (whether as water vapour or elemental tritium), it travels via multiple environmental pathways to reach humans. It cycles in the environment, as tritium atoms exchange quickly with stable hydrogen atoms in the biosphere and hydrosphere. This means that open water surfaces, rivers, streams and all biota, local crops and foods in open-air markets (Inoue, 1993), and humans will become contaminated by tritiated moisture up to ambient levels – that is, up to the air concentrations of the emitted tritium.

32. Humans can become tritiated by skin absorption, by inhalation of contaminated water vapour, and by ingestion of contaminated food and water. When tritium enters the body, it is readily taken up through exchange mechanisms and used in metabolic reactions and in cellular growth: over 60 per cent of the body's atoms are hydrogen atoms and every day about five per cent of these are engaged in metabolic reactions and cell proliferation. The

result is that a proportion of the tritium taken in is fixed to proteins, lipids and carbohydrates, including nucleoproteins such as DNA and RNA.

33. This is termed organically bound tritium (OBT) which is non-uniformly distributed and is retained for longer periods than tritiated water. ICRP dosimetric models assume the opposite – that tritium is homogenously distributed in the body/tissue/ organ of interest and is relatively quickly excreted. Exposures from OBT are therefore higher than from HTO. The longer people are exposed to tritiated water emissions, the higher their levels of OBT become until, in the case of exposures lasting years, equilibria is established between HTO and OBT levels. Again ICRP dosimetric models assume the opposite: only single exposures are considered so that OBT levels remain low.

34. Tritium's unusual properties suggest that it should be regarded as hazardous in radiation protection advice. Unfortunately these properties are not recognised by the ICRP and authorities which take their lead from the ICRP. This is discussed further in Appendix F.

35. The main controversy is over the ICRP's radiation weighting factor (w_R) for tritium of 1. See Fairlie (2007a). The debate has lasted more than fifty years. It should be borne in mind that the ICRP is not an official body, but a voluntary one. It operates rather like a trade association, principally concerned with protecting the interests of its members rather than those of the general public. It appears that non-scientific considerations may have played a part in the ICRP's decisions on tritium, as regards nuclear weapons production plants in the past and proposed fusion facilities more recently.

E. Organically Bound Tritium

36. The form of organically bound tritium (OBT) which is bound to carbon atoms is produced through photosynthesis in plants and by metabolic processes in animals. It is detected in most organic materials such as plants, animals and soils. A second form of OBT which is more loosely bound to P, N and S atoms is called exchangeable OBT.

37. The behaviour of OBT (both forms) in the environment is not well understood, e.g. it is very heterogeneously distributed in natural ecosystems. Nevertheless OBT is increasingly recognized as being more significant than HTO in understanding tritium's behaviour in the environment. (Kim et al, 2013). This is partly because OBT measurements provide a more accurate representation of tritium in the environment due to its longer retention time than HTO. (Kim and Roche, 2012)

38. OBT can be incorporated into all biochemical compounds, including amino acids, sugars, starches, lipids and cell structural materials: it therefore has longer retention times than tritiated water which only has a half life of about 10 days. Some biomolecules are very long-lived, e.g. phospholipids in nerve cells and the DNA and RNA macromolecules. These longer retention times result in OBT's greater radiotoxicity than tritiated water. The ICRP has recommended an OBT ingestion exposure coefficient 2.3 times greater than that for HTO[3]. However much evidence suggests it should be at least 5 times greater (Fairlie, 2008).

39. Following a single HTO intake, the current ICRP model assumes 3% is bound as OBT and may be neglected. But Trivedi et al (1997) estimated that up to 9% is bound as OBT. Animal studies also indicate that OBT levels must be considered – essentially because OBT is cleared from the body more slowly than HTO. Commerford et. al (1982) found, after

[3] ICRP dose coefficients for adults are 1.8×10^{-11} Sv/Bq for tritiated water and 4.2×10^{-11} Sv/Bq for OBT.

a transient HTO exposure, tritium remained bound to DNA and histone 8 weeks later. They concluded that the OBT doses from them would exceed HTO doses overall.

40. The same goes for chronic exposures except more so. Commerford, Carsten and Cronkite (1977) found most of the tritium dose came from OBT 2 to 3 days after stopping chronic HTO administration to mice. Rogers (1992) concluded OBT was the principal determinant in tritium doses to mice following chronic HTO exposure. Recently, Kim et al (2013a) discussed the OBT contribution to tritium exposures from chronic tritium releases to air. They compared 11 studies whose mean OBT contribution to total tritium exposures was 21%. In other words, any estimates of HTO exposures from PICKERING NGS emissions should be multiplied by the factor 5/4.

Longevity of OBT in the environment

41. Eyrolle-Boyer et. al (2014) have suggested that OBT levels can persist in the environment for several decades. They found that terrestrial biomass pools, contaminated by global atmospheric fallout from nuclear weapons testing in the 1950s and 1960s constituted a significant delayed source of OBT, resulting in an apparent enrichment of OBT levels compared to HTO. This finding helps explain OBT/HTO ratios greater than 1 observed in areas not affected by industrial radioactive wastes. This finding supports the findings by Ichimasa (1995) of long-term raised OBT levels near Chalk River following chronic HT releases.

42. A recent study (Thompson et al, 2015) has emphasised the importance of OBT in the environment. It stated that, as soil acts as a repository for decaying organic matter, OBT soil concentrations represents long-term reservoirs of past tritium releases. It added "Our data support the mounting evidence suggesting that some parameters used in environmental transfer models approved for regulatory assessments should be revisited to better account for the behaviour of HTO and OBT in the environment and to ensure that modelled estimates (e.g. plant OBT) are appropriately conservative."

F. Tritium Concentrations in Food and Environment

43. The overall conclusion from the CNSC environmental data is that the local area around Pickering NGS is contaminated with tritium. Tritium levels do not appear to be decreasing. Urine samples for HTO and non-intrusive bioassays (e.g. hair, nail clippings) of OBT levels should be undertaken in order that the risks of radiation exposures from OBT can be estimated.

G. Epidemiological Evidence of Risks

44. Because of methodological limitations, epidemiology studies are often a blunt tool for discovering whether adverse effects result from radiation exposures. These limitations include:

- under-ascertainment, i.e., people move away, or cases are not found or reported.
- strict data requirements: ideally, epidemiology data is required with good case identification, uniform registration, clear diagnostic criteria and uniformity of data collation. These data requirements are often difficult to fulfil and make large demands on time and resources.

- confounding factors: the true causes of morbidity or mortality can be uncertain due to confounding factors such as socio-economic status and competing causes of death.
- bias: smoking and alcohol cause major increases in overall mortality and morbidity, and in cancer and cardiovascular disease. These require careful handling of the raw data to avoid bias.
- poor signal to noise: only large, expensive and lengthy epidemiology studies are able to reveal effects where the signal (added cancers) is weak, and the noise (large numbers of spontaneous cancers) is strong.
- uncertain doses: establishing causality often requires estimating doses in order to show a dose-effect relationship. However, large uncertainties often exist in estimating doses - especially from internal radiation, e.g. from tritium.
- wide confidence intervals: usually findings (e.g. risks or odds ratios) are expressed with 95% confidence intervals- that is, the range of values within which the true value lies within 95% of the time. But often this range can be very wide - simply because of low numbers of cases. This can severely limit what we can conclude from the findings.

45. Many epidemiology studies are ecologic studies, that is, quick studies which look at health or population stats and not individual data. Their findings are usually regarded as indicative not conclusive. If their findings suggest an adverse effect then these should be investigated further by more detailed cohort or case-control studies. The latter match “cases” (i.e., those which have an adverse effect) with randomly-selected similar individuals, in order to minimise under-ascertainment. However fewer of these are carried out because of their expense and long time-spans.

46. We need to be aware of the many factors to be taken into account when considering epidemiology studies, and we need to interpret their findings with care. Readers are advised to lower their expectations when considering the following studies - which are all ecologic.

Leukaemia in children near Candu nuclear facilities

47. Clarke et al. (1989, 1991) studied mortality and incidence of childhood leukaemia near nuclear facilities in Ontario. The first report (Clarke et al. 1989) considered leukaemia deaths and cases at ages 0-4, and the second (Clarke et al. 1991) considered cases and deaths at ages 0-14. Data for areas “nearby” (<25 km) the 16 reactors at Bruce and Pickering over the period 1971-1987 were pooled together to increase statistical significance. The findings were 36 leukemia deaths aged 0-14 vs 25.7 expected (SMR = 1.40, 95% CI 0.98 - 1.9) indicating excess leukemia mortality with borderline statistical significance. However the confidence intervals were wide: the data were consistent with there being no increase and with there being a 90% increase in leukemia.

48. However there were indications which warranted further investigation: higher leukemia death rates after the reactors had started than before; more deaths when counted at place of birth than at place of death; and the size of the higher confidence interval. It is notable that different levels of statistical significance were adopted by the two reports. The first was 10%, and the second 5%. If the 10% level had been used in the second study as it had been in the first, the leukemia increase would have been considered "statistically significant". The authors recommended further case-control research which was not carried out.

Birth defects and infant mortality in the vicinity of the Pickering nuclear facility, Ontario

49. Johnson and Rouleau (1991) studied birth defects, stillbirths, perinatal, neonatal and infant mortality within 25 km of the Pickering nuclear station. They also studied these

endpoints in relation to airborne and waterborne discharges of tritium from Pickering, concentrating on the Pickering and Ajax townships closest to the Pickering plant.

50. The incidence of central nervous system defects was significantly elevated in Pickering township for the highest level of airborne tritium emissions ((odds ratio in highest group = 4.01 (95% CI; 1.25, 14.04), based on 6 cases)) but no statistically significant trends with tritium emissions (p=0.197) or ground monitoring data (p=0.24) were observed.

51. Births with Down Syndrome in Pickering township were significantly increased ((24 observed *vs* 12.9 expected (relative risk = 1.85, 95% CI = 1.19, 2.76)). But 23 other birth defect endpoints did not show such an excess. The raised incidence of Down Syndrome cases was notable, as many Chernobyl studies also indicate excesses in areas exposed to radioactive fallout. However the authors of the study queried why the incidence of Down Syndrome alone should be increased and not other forms of congenital malformation. This does not provide a reason to discount the observed association between tritium exposures and Down Syndrome.

Offspring of Canadian nuclear workers

52. Green et al (1997) assessed cases of congenital abnormalities and matched controls in the offspring of Canadian nuclear workers. (763 case-control pairs of fathers, and 165 case-control pairs of mothers). Tritium doses were assessed for those cases/controls having a recorded tritium dose 60 days before conception vs those with no dose. The study revealed increased chromosomal disorders with tritium exposure, but the number of cases (two) is small and confidence intervals wide.

Offspring of Ontario radiation workers

53. McLaughlin et al (1992, 1993) considered cases of childhood leukaemia in the offspring (aged 0-14) of Ontario radiation workers and matched cases. Tritium workers were those employed at the AECL laboratories at Chalk River, and 5 power stations ((Rolphton, Pickering (A, B), Bruce (A, B);.112 cases and 896 controls)). Preconceptional tritium doses were assessed for this group. There was some evidence of raised risks with internal tritium + external radiation exposures but with wide confidence intervals.

Durham Region Health Department (2007)

54. This study showed statistically significant elevated rates of several radiogenic cancers near the NPPs east of Toronto. Leukemia incidence in males were significantly increased in Ajax-Pickering and Clarington males in 1993-2004. This study was based on municipal borders, about 10 km from the reactors. The authors admitted some findings were of concern and recommended further more accurate studies, but none have been done. However the report was at pains to conclude that the overall findings did not indicate a pattern.

Lane Study (Lane et al, 2013)

55. This study purportedly sought to determine whether radiation doses to members of the public living within 25 km of the Pickering, Darlington and Bruce nuclear power plants (NPPs) were causing an increase in cancer rates from 1990-2008. It reported that some types of cancers were statistically higher than expected but no overall pattern could be seen.

Wanigaratne et al Study (2013)

56. This study examined cancer incidences (1985–2005) among Pickering and north Oshawa residents including all cancers, leukemia, lung, thyroid and childhood cancers (6–19 years). Person-years analysis showed female childhood cancer cases to be significantly higher than expected (SIR = 1.99, 95% CI: 1.08–3.38). It concluded that “multiple comparisons were the most likely explanation for this finding”.

57. The above studies mostly show increased ill effects, some statistically significant and others with borderline statistical significance. Some studies showed no increases for specific illnesses, but as Altman and Bland (1995) stated “absence of evidence is not evidence of absence”. In addition, the methodological limitations and small sizes of some of these studies mean they were simply unable to detect effects with statistical certainty.

58. Despite the positive numerical findings, the published conclusions of these studies were invariably negative, often on the flimsy grounds of inconsistent results, too many comparisons, lack of an overall pattern etc.

59. With this in mind, our conclusion is that the above studies taken together provide suggestive, albeit limited, evidence for increased health effects from exposure to tritium. These could be confirmed with case-control or cohort studies. More important, considerable evidence from cell and animal studies and radiation biology theory indicates that adverse effects will occur. This is backed by evidence from recent, large scale, statistically powerful epidemiology studies – see http://www.ianfairlie.org/news/recent-evidence-on-the-risks-of-very-low-level-radiation/

H. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

60. Annual tritium emissions from Pickering NGS are very large compared to most nuclear power stations in the world.

61. Major international agencies recognise that tritium has unusual properties marking it as a hazardous nuclide. It is extremely mobile in the environment, contaminates all biota in nearby areas including humans to ambient levels, and binds with organic matter to form OBT with long residence times in the body making it more radiotoxic.

62. Environmental measurements of soils, foodstuffs, wells and sewage near the facility indicate pervasive tritium contamination. Tritium levels in environmental samples are erratic but do not appear to be declining.

63. We estimate that annual tritium intakes for local residents (who neither consume their own garden produce nor drink from their own wells) amount to about 120,000 Bq, mainly from inhalation and skin absorption of tritiated water vapour in the vicinity of Pickering . These amounts are higher than the yardstick of 10,000 Bq/a for “acceptable” intakes and higher than the natural background intake of 6,000 Bq/a. OBT exposures will also occur.

64. These intakes increase the probability of cancer and other diseases in exposed people. It is not possible to ascertain in advance who will be affected but embryos, fetuses, babies, infants and children are more radiosensitive than adults, and females more than males. These cancers will arise in the future because they have long latency periods in most cases. Probabilistic effects mean exposed people will have each been handed “negative” lottery tickets, and some tickets will come up in future ie fatal cancers will occur.

65. Epidemiology studies of Canadian facilities emitting tritium suggest increases in cancer and congenital malformations: these could be confirmed with case-control or cohort studies. More important, considerable evidence from cell/animal studies and radiation biology theory indicates that adverse effects will occur. This is backed by evidence from recent, large scale, statistically powerful epidemiology studies – see http://www.ianfairlie.org/news/recent-evidence-on-the-risks-of-very-low-level-radiation/

RECOMMENDATIONS

66. It is recommended that steps be taken to close the Pickering NGS as soon as possible. In the interim period before closure the following should be implemented immediately.

i. CNSC should ensure the Ontario Government's ODWAC recommendation of 20 becquerels per litre (Bq/L) for drinking water is met for all Toronto citizens.
ii. CNSC should implement its own design guide for groundwater for tritium of 100 Bq/L for tritium levels in wells near Pickering NGS.
iii. Urine tests and non-invasive bioassay tests should be carried out on volunteers from the community to ascertain HTO/OBT levels.
iv. Local residents should be advised to avoid consuming locally-grown foods and water from local wells.
v. In view of the discussion in Appendix E, local women intending to have a family, and families with babies and young children should consider moving elsewhere. It is recognised this recommendation may cause concern but it is better to be aware of the risks to babies and young children than be ignorant of them.
vi. OPG employees and their spouses, especially young workers, should be informed about the hazards of tritium.

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APPENDICES

APPENDIX A. NEW INFORMATION ON RADIATION'S EFFECTS

OPG's application and the CNSC's responses fail to discuss the new information of non-targeted (ie., on DNA) effects of radiation. These effects include genomic instability where effects occur many generations later, and bystander effects where adjacent cells not hit by radiation are damaged, and mini-satellite mutations.

The New Effects of Radiation

These "new" effects were in fact discovered about 18 years ago[4], for example, Khadim et al (1992) discovered genomic instability effects in 1992. However they have not been widely discussed in the popular press. Indeed, there is little public awareness of these effects in Canada. This is partly due to their absence in mainstream reviews such as those published by the former NRPB, USEPA, ICRP and BEIR (and only recently by UNSCEAR in 2009). Nevertheless these new effects have resulted in a "paradigm shift" in scientists' views as evidenced by the articles in the Box below, and they continue to be intensively discussed among radiation biologists.

BOX A-1: Untargeted effects: a paradigm shift?

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Importance for risk estimation

Non-targeted effects are important in assessing radiation risks for a number of reasons.

First, they do not rely on structural damage to DNA or genetic structures for their effects, the classic explanation for radiation's effects. This is a vital matter because, up to recently, radiation protection authorities had relied on the classic theory to lend support to their estimates for radiation risks derived from epidemiology. That is, the classic theory of radiation's effects (ionisation-induced DNA strand breaks) buttressed[5] current estimates of radiation risks. The new effects do not do this.

Second, these effects occur at very low doses of radiation. In fact, some effects occur after the passage of a single alpha particle through a cell (resulting in a less than 10 mGy dose to the cell).

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[4] Some scientists (Baverstock, 2000; Baverstock and Belyakov, 2005) consider that non-targeted effects had in fact been observed in cell/animal studies many years previously but had been unrecognised as they fell outside the then accepted "paradigm" of radiation's effects.

[5] For example, in dose terms, radiation's effects were related to the chances of damaging genes: the smaller the target gene, the larger the dose required to cause damage. Thus, effect and dose were related through radiation damage in irradiated DNA.

A third reason is that, as many genome instability effects and bystander effects are present in malignant cells, most scientists now think that genomic instability is a precursor to cancer.

Annex C of the UNSCEAR 2009 report stated (paragraph 158) “it would seem prudent to consider the implications of non-targeted and delayed effects of radiation exposure when considering models of radiation carcinogenesis, particularly at low doses.” And “…models of radiation-induced carcinogenesis should incorporate both direct and indirect effects when evaluating radiation risks.”

When faced with the uncertainties posed by non-targeted effects, it would be wise to apply the Precautionary Principle. One means of doing this would be to recognise publicly that radiation risks are likely to be greater than currently estimated and to add a safety factor – by increasing current official estimates of doses by factor of 10.

APPENDIX B. UNCERTAINTIES IN “DOSE” ESTIMATES

Various CNSC reports contain tables with doses to members of the public: these are invariably very small.[However these reports do not explain that these are estimates not measurements and may contain large uncertainties.

How these dose estimates are derived is not widely understood by scientists, and usually not at all by members of the public. In fact, the method is complicated, as they are derived using many computer models in sequence, with the median value from each model being plugged into the next model. Although there are many smaller sub models, the main models include:

- environmental transport models for radionuclides, including weather models
- human metabolism models for nuclide uptake, retention and excretion
- dose models which estimate doses from internally retained nuclides, and
- risk models

A major source of uncertainty is that we often do not know where radionuclides wind up inside the body after inhalation/ingestion. It is often assumed they are uniformly distributed - but this there is no realistic way of proving this.

Each of the above model results will contain uncertainties which have to be combined to gain an idea of the overall uncertainty in the final dose estimate (Fairlie, 2005). Further uncertainties are introduced by unconservative radiation weighting factors and tissue weighting factors in official models (Fairlie, 2007a). The cumulative uncertainty in dose estimates could be very large as formally accepted by the UK Government’s CERRIE Committee in 2004 (www.cerrie.org) particularly for internal emitters.

APPENDIX C. OTHER PROBLEMS WITH THE CONCEPT OF “DOSE”

Indeed, there are problems with the concept of “dose” itself; including its various definitions and units (Sv and Gy): the sievert (Sv) unit has two different definitions for example. The “dose” concept may give reliable results when **external** radiation (eg X-rays or gamma rays) is physically measured by counting devices such as common Geiger counters, but not with **internal** radiation which cannot be measured except with whole body monitors, that is, very rarely. It is noted that in the parallel field of chemical toxicity, “dose” is not used: concentrations per gram are used instead.

Since almost all of the radioactivity from Pickering emissions results in internal radiation, this report does not rely on radiation “dose” but instead uses concentrations of radionuclides measured in becquerels (Bq) per kg or per litre. When a radionuclide decays inside the body, it gives off radiation (alpha, beta or gamma) which results in body tissues being irradiated. The unit of radioactivity is the becquerel (Bq) defined as one atomic disintegration per second. Bq concentrations have the merit of being measurable: i.e., one can make relatively good measurements of how much radioactivity is inside a person (eg, from bioassays). These measurements are considerably more reliable than “dose” estimates particularly when considering internal emitters.

APPENDIX D. SPIKED NUCLIDE RELEASES

Brief exposures to high concentrations are more hazardous to residents near Pickering NGS than chronic exposures to low concentrations. This is partly due to environmental factors (eg wind direction) and partly to metabolic factors: exposures to high concentrations result in higher internal doses due to the labelling of dividing cells and cell proteins at high levels particularly with radioactive tritium inhaled/ingested from Pickering emissions.

In 2011, the UK National Dose Assessment Working Group published guidance on “Short Term Releases to the Atmosphere” http://www.ndawg.org/documents/NDAWG-2-2011_000.pdf. This states that "...exposures from the assessment of a single realistic short-term release are a factor of about 20 greater than doses from the continuous release assessment." An older German study (Hinrichsen, 2001) indicated that these exposures could amount to a factor of 100 greater.

The potential for increased harm from short-term releases is partly related to the duration of release. Short-term releases produce narrow plumes, whereas longer durations produce wide plumes. Widths vary non-linearly as a fractional power of duration times with the result that individual doses (per Bq emitted) increase with shorter releases. The reason is also partly due to the fact that spikes result in higher concentrations of OBT in environmental materials and in humans.

APPENDIX E: INCREASED INCIDENCES OF CANCER NEAR NPPs

Recent epidemiological studies indicating increases in child leukemias near NPPs in Europe [are] ~~is~~ of relevance to the Pickering situation as it emits large amounts of tritium.(For example, the annual average for tritium to air emissions from German nuclear power stations in 2003 (a representative year) was 0.53 TBq - much lower than the 680 TBq from Pickering in 2016.)

In the late 1980s and early 1990s, several UK studies revealed increased incidences of childhood leukemia near UK nuclear facilities. Recent epidemiological studies have reopened the child leukemia debate, the most important being the KiKK study (*Kinderkrebs in der Umgebung von Kernkraftwerken* -‘Childhood Cancer in the Vicinity of Nuclear Power Plants’]. Spix et al (2007) and Kaatsch et al (2008) found a 60% increase in solid cancer risk in embryos and a 120% increase in leukemia risk among children under 5 years living within 5 km of all German nuclear reactors. The KiKK findings are important because it was a large well-conducted study, because it was scientifically rigorous, because its evidence was very strong and because the German Government, which had commissioned the study, confirmed the researchers’ findings.

The KiKK study has been the subject of much debate in scientific communities. It is too early to provide an explanation for the increased cancers, although there is evidence to implicate radiation exposures with cancer effects. One hypothesis (Fairlie, 2014) proposes that infant leukemias are a teratogenic effect of *in utero* exposures to radiation from intakes of radionuclides during fetal development in pregnancies. The German study suggests that exposures from nuclear plant emissions to embryos/foetuses in pregnant women living nearby may be much larger than currently estimated. For example, haematopoietic (ie blood-forming) tissues are known to be more radiosensitive in embryos and foetuses than in adults. Also, children, particularly in the first six years, undergo rapid development. The combined immaturity of children's nervous systems and blood-forming systems make them particularly vulnerable to radiation exposures.

Official organizations have found it difficult to accept that the large cancer increases near nuclear facilities are due to radioactive emissions. This is mainly because their "dose" estimates from NPP emissions are too small by factors of 100 to 1000 to explain the observed increases in risks. This of course assumes that official dose estimates and risk models are correct and without uncertainties. Importantly, the UK Government CERRIE Committee in 2004 www.cerrie.org concluded the opposite.

APPENDIX F: NEED FOR A HAZARD INDEX OF RADIONUCLIDES

The hazards of tritium raise the question of how radiation protection authorities classify dangerous radionuclides: the short answer is that they do not.

There is no comprehensive hazard index for radionuclides as there is for chemicals. Many scientists consider there should be one as the properties of nuclides would be better recognised thus helping regulators to gauge the harmful impact of nuclides on health. Kirchner (1990) has suggested the following characteristics of nuclides should be included in a hazard index:

- large releases to environment;
- widespread use (i.e., industrial/military/research/medical uses);
- rapid nuclide transport, solubility and cycling in biosphere;
- global distribution and resulting large collective doses;
- diverse pathways of exposure (i.e., soil ingestion);
- rapid molecular exchange rates (that is, fast uptake by humans);
- large percentage uptake to blood following intake;
- organic binding in biota;
- long-biological half-life in humans;
- long radiological half-life;
- long nuclide decay chains with radiotoxic daughters;
- high radiotoxicity - the dose coefficient of the nuclide (i.e., the radiation dose imparted from the disintegration of one atom of the nuclide).

Tritium is unique in that it exhibits so many of these characteristics – in fact, ten of the above twelve. Most other nuclides exhibit only three or four traits. This raises a further question – how do radiation authorities currently gauge the relative hazards of nuclides? The answer is by estimating radiation "dose" from the nuclide to an exposed person from one disintegration of that nuclide. As discussed in Appendices B and C, using 'dose' alone ignores the first six of the above twelve characteristics. In other words, 'dose' is an inadequate indicator of hazard for most radionuclides, and for tritium, it's a very poor one.

SCIENTIFIC ANNEXES

ANNEX A. ACRONYMS AND ABBREVIATIONS

AECB	former Atomic Energy Control Board (now CNSC qv)
Bq	becquerel (SI unit of radioactivity)
CERRIE	UK Committee Examining the Radiation Risks of Internal Emitters
Ci	curie (US unit of radioactivity)
COMARE	UK Committee on the Medical Aspects of Radiation in the Environment
CNSC	Canadian Nuclear Safety Commission
DRL	derived release limit
DNA	deoxyribose nucleic acid
EC	European Commission
EPA	US Environmental Protection Agency
EU	European Union
Gy	gray (unit of absorbed radiation dose)
HTO	tritiated water
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LET	lineal energy transfer, energy transferred per unit length of track
LNT	linear no-threshold (radiation's dose-effect relationship)
NEA	Nuclear Energy Agency of the OECD
NCI	US National Cancer Institute
NPP	nuclear power plant
NRC	US Nuclear Regulatory Commission
NRPB	former UK National Radiological Protection Board
OBT	organically bound tritium
OPG	Ontario Power Generation Ltd
rad	US unit of absorbed radiation dose
rem	US unit of radiation dose
SI	Systeme Internationale
Sv	sievert (SI unit of equivalent or effective radiation dose)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organisation

ANNEX B. SYSTÈME INTERNATIONALE (SI) UNITS

E = exa	= 10^{18}	d = deci (one tenth)	= 10^{-1}
P = peta	= 10^{15}	c = centi (one hundredth)	= 10^{-2}
T = tera (one trillion)	= 10^{12}	m = milli (one thousandth)	= 10^{-3}
G = giga (one billion)	= 10^{9}	µ = micro (one millionth)	= 10^{-6}
M = mega (one million)	= 10^{6}	n = nano (one billionth)	= 10^{-9}
K = kilo (one thousand)	= 10^{3}	p = pico (one trillionth)	= 10^{-12}

Common examples are:

PBq	= petabecquerel (one million billion becquerels)	= 10^{15} Bq
TBq	= terabecquerel (one trillion becquerels)	= 10^{12} Bq
GBq	= gigabecquerel (one billion becquerels)	= 10^{9} Bq
mSv	= millisievert (one thousandth of a sievert)	= 10^{-3} Sv
µSv	= microsievert (one millionth of a sievert)	= 10^{-6} Sv
nSv	= nanosievert (one billionth of a sievert)	= 10^{-9} Sv

CONVERSION BETWEEN SI AND US UNITS

CURIES TO BECQUERELS

1 curie	= 1 Ci	= 37 x 10^9 Becquerels
1 millicurie	= 1 mCi (10^{-3} Ci)	= 37 x 10^6 Becquerels
1 microcurie	= 1 µCi (10^{-6} Ci)	= 37 x 10^3 Becquerels
1 nanocurie	= 1 nCi (10^{-9} Ci)	= 37 x 10^0 Becquerels
1 picocurie	= 1 pCi (10^{-12}Ci)	= 37 x 10^{-3} Becquerels

BECQUERELS TO CURIES

1 petabecquerel	= 1 PBq (10^{15} Bq)	= 27 x 10^3	curies
1 terabecquerel	= 1 TBq (10^{12} Bq)	= 27 x 10^0	curies
1 gigabecquerel	= 1 GBq (10^9 Bq)	= 27 x 10^{-3}	curies
1 megabecquerel	= 1 MBq (10^6 Bq)	= 27 x 10^{-6}	curies
1 kilobecquerel	= 1 kBq (10^3 Bq)	= 27 x 10^{-12}	curies
1 becquerel	= 1 Bq	= 27 x 10^{-15}	curies

REMS TO SIEVERTS

1 rem	= 1 rem	= 10^0 rem	= 10 millisieverts
1 millirem	= 1 mrem	= 10^{-3} rem	= 10 microsieverts
1 microrem	= 1 µrem	= 10^{-6} rem	= 10 nanosieverts

SIEVERTS TO REMS

1 sievert	= 1 Sv	= 1 Sv	= 100 rem
1 millisievert	= 1 mSv	= 10^{-3} Sv	= 100 millirem
1 microsievert	= 1 µSv	= 10-6 Sv	= 100 microrem

ANNEX C. GLOSSARY OF COMMON RADIATION TERMS

Absorbed dose — Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. 1 Gy = 1 joule per kilogram.

Activity — rate at which radioactive substances decay. Unit – the becquerel (Bq).
1 Bq = 1 disintegration per second.

Annual limit of intake (ALI) — The amount of material inhaled or ingested in 1 year that would result in a committed effective dose of 20 mSv.

Beta particle — An electron emitted by the nucleus of a radionuclide.

Decay — The process of spontaneous transformation of a radionuclide. The decrease in the activity of a radioactive substance.

Decay product — A nuclide or radionuclide produced by decay. It may be formed directly from a radionuclide or as a result of a series of successive decays through several radionuclides.

Dose — General term for quantity of radiation. See absorbed dose, effective dose, equivalent dose.

Dose factor — committed effective dose resulting from the inhalation or ingestion of 1 Bq of a given radionuclide. Unit - sievert per becquerel, symbol - Sv/Bq.

Effective dose — The quantity obtained by multiplying the equivalent doses to various tissues and organs by the tissue weighting factor appropriate to each and summing the products. Unit sievert, symbol Sv.

Equivalent dose — The quantity obtained by multiplying the absorbed dose by the appropriate radiation weighting factor to allow for the different effectiveness of the various ionizing radiations in causing harm to tissue. Unit sievert, symbol Sv.

Gamma ray — A discrete quantity of electromagnetic energy, without mass or charge.

Half-life — The time taken for the activity of a radionuclide to lose half its value by decay.

Ionisation — The process by which a neutral atom or molecule acquires or loses an electric charge. The production of ions.

Ionising radiation — Radiation that produces ionisation in matter.

Nuclear fission — The process in which a nucleus splits into two or more nuclei and energy is released.

Radionuclide — An unstable nuclide that emits ionizing radiation when it decays.

Risk factor — The probability of fatal cancer or leukaemia per unit effective dose.

Sievert — See effective dose.