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Canadian Nuclear Association

INDEPENDENT PEER-REVIEW

March 2018 Report: “A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effect”

2018 May 20TH

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March 2018 Report: "A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effects"

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EXECUTIVE SUMMARY

In March 2018, Dr. Ian Fairlie published a report titled "*A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effects*" on behalf of the Ontario Clean Air Alliance.

In our view, Dr Fairlie's report provides incomplete and, in some cases, incorrect information concerning the Fukushima incident. As a result, Dr Fairlie's report has the potential to create false perceptions about the safety of nuclear power in Ontario.

Perception is important. In our opinion, nuclear power is well suited to provide a low carbon baseload energy source and is sorely needed to support Canadian, and indeed global initiatives, for greenhouse gas reduction. Poor or misguided science can falsely inform public opinion and as a consequence, has the potential to adversely affect the future role of nuclear power In Ontario.

In view of our concerns over the potential impact of Dr Fairlie's report on the public's perception of nuclear power, we have tried to provide an independent review of Dr Fairlie's report in the hope of clarifying what we consider to be incomplete or false science. Time has not permitted a full critique of Dr Fairlie's report, but nonetheless, we hope that the following brief comments help to provide some balance to the discussion.

A few key observations include the following:

- Dr. Fairlie incorrectly reports that the OPG PNGS does not have the ability to provide cooling; however, there is in fact adequate cooling available in the highly unlikely event of a severe accident via emergency mitigation equipment generators and pumps with multiple hookup locations, the effectiveness of which has been evaluated by the CNSC post-Fukushima.
- Dr. Fairlie lists some common features between the Pickering and Fukushima Daiichi reactors, but fails to mention that the reactors used are fundamentally different (i.e., CANDU vs Boiling Water reactor (BWR)) and the underlying source term, namely natural uranium fuel (0.7% U-235) at PNGS compared to low enriched uranium (3-5% U-235) and Mixed Oxide fuel for the TEPCO Fukushima Daiichi nuclear power plant.
- The maximum dose received by members of the public in Japan were low and below the level at which ICRP recommends evacuation. Japans decision to use a dose of 1 mSv as the initial threshold for evacuation resulted in additional fatalities and much of the social, economic and psychological impacts arising from the Fukuishima Daiichi accident.

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Douglas Chambers, PhD

Dr. Chambers is a member of numerous professional societies. He was a founding member of the Canadian Radiation Protection Association and has been a member of the Canadian Standards Association N288 Committee on Environmental Radiation Protection since 1977, the second chair and continues to support the activities of CSA N288. He became a member of the Canadian Atomic Energy Control Board's (former) Advisory Committee on Radiological Protection in 1993 and was vice-chairman in 2001. He was a member of the US NCRP Committee 85 on radon. Dr. Chambers was a member of the Canadian delegation to UNSCEAR from 1998 through 2011 during which period he prepared two UNSCEAR Annexes (2006 Annex E on radon; 2008 Annex E on effects of radiation on non-human biota) and has contributed to the preparation of two recent UNSCEAR Annexes on tritium and uranium. He is a member of an ICRP Task Group evaluating RBE for non-human biota and was a member of ICRP Committee 2 (dosimetry). In addition, he has been a member of the US EPA's Radiation Advisory Committee (RAC) and past President of the Environment and Radon Section of the US Health Physics Society. Dr. Chambers was the recipient of the 1997 W.B. Lewis award of the Canadian Nuclear Society for his achievements in environmental radioactivity. In February 2002, Dr. Chambers was the Morgan lecturer for the Health Physics mid-year symposium in Orlando.

Adrienne Ethier, PhD

Adrienne has extensive experience in the areas of contaminated sites modeling (radiological, metal, organics), environmental risk and safety assessments, contaminant toxicology, remedial options assessment, emergency preparedness, emergency exercise coordination and planning, risk communication, stakeholder engagement, radiation protection, quality management systems, quality assurance, and risk management. She has developed innovative monitoring equipment (Patent# 62/180,325) to assist with the detection of contaminants (e.g., Hg, I-131, Xe-133, Xe-135) in air in isolated locations, and has improved air, water and soil sampling methodologies (routine and emergency response) and monitoring program designs. Dr. Ethier has also served on technical sub-committees for international (e.g., ISO TC82/SC2) and Canadian (e.g., CSA N288.1) radiological standards, provided expert reviews for regulatory documents (e.g., CNSC REGDOC-2.9.1, CCME EcoRA) and scientific journals (e.g., Environ Pollution, STOTEN), and participated on teams aimed at bridging the gap between science and stakeholder perceptions (e.g., ISSP @Risk).

1 INTRODUCTION

In March 2018, a report was published by Dr. Ian Fairlie titled "*A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effects*" on behalf of the Ontario Clean Air Alliance, but to our knowledge, no independent peer reviews were conducted prior to the publication of this report (Fairlie, 2018). The intention here is to provide the independent scientific peer review that unfortunately did not occur prior to publication.

Scientific publications require rigorous independent peer reviews to mitigate the introduction of "false science". This seems to be especially true where radiation or radioactivity is concerned and where it is very easy to raise false perceptions by the incomplete or improper presentation of data. Scientists are better equipped to identify and address concerns arising from such false or incomplete data, but the general public is not so well equipped.

The Fukushima incident triggered by a very large tidal wave arising from a major earthquake off the coast of Japan was indeed a disaster; however, the simplistic and, in our opinion, incomplete and improper transfer of information from the Fukushima incident to the Pickering reactors is improper, is not good science, and has the potential to create false perceptions about the safety of nuclear power in Ontario.

Perception is important. Nuclear power is well suited to provide a low carbon baseload energy source, which in our opinion, is sorely needed to support the Canadian and indeed global initiatives for greenhouse gas reduction. Poor or misguided science can falsely inform public opinion and adversely affect the future role of nuclear power In Ontario. In view of our concerns over the potential impact of Dr Fairlie's report on the public's perception of nuclear power and the potential consequences arising from that, we have tried to provide an independent review of Dr Fairlie's report in the hope of clarifying what we consider to be incomplete or false science.

The CNSC has raised similar concerns as evidenced by comments made by Commissioner Rumina Velshi during the Commission hearing of April 4th (2018) as documented in the Public Meeting transcript, in reference to Dr Fairlie's report prepared for the "Clean Air Alliance Report" (CNSC, 2018b):

> *"I haven't seen anyone respond in a scientific, factual, technical manner.*
>
> *Is that something the province does, the CNSC with its mandate of disseminating scientific knowledge, is it Health Canada, I mean, or is it a joint responsibility? And I'm just thinking of it from a perspective of a member of the public, where do I get information that tells me, here's a different perspective to this issue?"*

Time has not permitted a full critique of Dr Fairlie's report, but nonetheless, we hope that the following comments help to provide some balance to the discussion.

1.1 The Fukushima Incident

On 2011 March 11th, a massive earthquake shook Japan followed by a tsunami which struck a wide area of coastal Japan (i.e., waves reaching upwards of some 15 metres). The tsunami resulted in widespread damage along the coast and the death of over 15,000 people. The nuclear reactors at the Fukushima Daiichi nuclear power plant proved seismically robust but were vulnerable to the flooding from the tsunami which resulted in the loss of electrical supply from both the grid and onsite backup generators, as well as resulting in substantial destruction to the operational and safety infrastructure from the tsunami (IAEA, 2014).

Other nuclear power plants along the coast were also affected to different degrees from this event, but Fukushima Daiichi was the only one unable to safely shutdown due to the loss of both off-site and on-site electrical power and the resulting loss of cooling function at the then three operating reactor units and spent fuel pools.

The loss of cooling function for the Fukushima reactors resulted in overheating within the reactor cores of Units 1-3, and the subsequent melting of nuclear fuel and breaching of the containment vessel. This process forms hydrogen gas[1] which accumulated and triggered explosions in the reactor building after it was released from the reactor pressure vessels. Radionuclides were discharged to the atmosphere, deposited on land and ocean, along with direct releases into the sea (IAEA, 2014). Dr. Fairlie states in his report that the precise nature of these hydrogen explosions at Fukushima is a matter of debate, which should be removed since there is no evidence to support this from peer-reviewed publications.

Residents within 20 km radius of the Fukushima Daiichi site were evacuated, and residents within 20-30 km radius were instructed to shelter and then advised to voluntarily evacuate. Restrictions were also placed on distribution and consumption of locally grown food and water to minimize exposure.

Dr. Fairlie states in his report that “TEPCO is still spraying cooling water on the destroyed reactor to avert further explosions” but has not identified a source for this information. In the Fukushima Daiichi Status Updates on the IAEA website (IAEA, 2018), it is acknowledged that Japan has taken multiple initiatives to reduce the rate of groundwater inflow into the buildings and the subsequent need to pump groundwater out, such as installation of a by-pass, sub-drains and / or impermeable walls to minimize groundwater intrusion which began operation between April 2014 and March 2016 (TEPCO, 2017). However, to our knowledge, there is no recent indication that TEPCO should or does continue to provide cooling water to the reactor since the above measures were installed.

According to Leppold et. al. (2016), over 80 000 people in the Fukushima prefecture were forced to evacuate their homes following the nuclear accident. These authors (and many others in the open literature) comment that the evacuation resulted in widespread social stigma attached to being from Fukushima and suggest the stigma is largely due to incorrect assumptions about radiation exposure and consequent health risks.

In 2011, clean-up efforts were initiated towards the recovery of the areas affected by the earthquake, tsunami and reactor accident, including the remediation and revitalization of communities and infrastructure (IAEA, 2014).

1.2 Author

The author, Dr. Ian Fairlie, has a long history of promoting fear of exposure to low level radiation. Radiation experts and researchers have openly rebuffed his work for using unscientific methods,

[1] Oxidation of the zirconium cladding at high temperatures in the presence of steam produces hydrogen exothermically, with this exacerbating the fuel decay heat problem

speculations and exaggerations (e.g., Corrice, 2015; Socol, 2015). It seems unethical for a scientist to deliberately ignore important fact(s) which does not support their ideology or motivations.

2 LESSONS LEARNED

The Fukushima Daiichi reactor accidents triggered comprehensive reviews of the incident and subsequent intensive follow-up safety assessments at both the International (e.g., IAEA) and Canadian Federal (CNSC) level.

2.1 IAEA

The International Atomic Energy Agency (IAEA) Director General's report on the Fukushima Daiichi accident (IAEA, 2015), which includes five technical volumes written by a collaborative team of international experts (i.e., 180 experts from 42 IAEA Member States), assesses the causes and consequences of the accident. The report considers human, organizational and technical factors to provide an understanding of what happened and why, so that lessons learned can be acted upon by governments, regulators and nuclear facilities. The technical volumes provide context and description of the accident, safety assessment, emergency preparedness and response, radiological consequences, and post-accident recovery.

One of the key lessons learned from the accident stemming from progress on the IAEA Action Plan on Nuclear Safety is the crucial importance of preparation in protecting vital safety systems – cooling, emergency power, emergency communications and control systems – against extreme events such as tsunamis, floods, hurricanes and earthquakes (Henriques, 2015). In light of the events surrounding the Fukushima Daiichi accident, regulators and operators from around the world have been reassessing the vulnerabilities of their nuclear power plants to potential external events and making improvements to strengthen resiliency where needed.

2.2 CNSC

The CNSC's Fukushima Task Force re-examined the safety cases of their nuclear facilities in response the events that unfolded during Fukushima Daiichi accident. The results of this review (CNSC, 2011), and the subsequent comments received from the IAEA and external peer-reviewers, confirmed that nuclear facilities in Canada were safe and pose a very small risk to the health and safety of Canadians and the environment. The Task Force was also able to identify areas where the licensees and CNSC staff could further strengthen reactor defence in depth, enhance emergency response, improve regulatory oversight and crisis communication capabilities, and enhance international collaboration.

The CNSC's Integrated Action Plan (August 2013), which is based on the above-mentioned review, contains specific and attainable actions for licensees and the CNSC to further strengthen nuclear reactor safety in Canada.

The Ontario Power Generation (OPG) Pickering Nuclear Generating Station (PGNS) has successfully addressed the 101 specific Fukushima action items assigned to their facility by the CNSC (see Section 2.3 for further details). OPG PNGS went beyond these Fukushima Action Item requirements by implementing Phase II Emergency Mitigating Equipment (all in place) and are now implementing further safety modifications as part of their Periodic Safety Review actions.

2.3 OPG Pickering Station

The Ontario Power Generation (OPG) Pickering Nuclear Generating Station (PNGS) is located on the shore of Lake Ontario in the city of Pickering and lies 32 km northeast of downtown Toronto and 21 km southwest of Oshawa. The PNGS consists of eight CANDU pressurized heavy water reactors and their associated equipment, which have been producing electrical power since the early 1970's. Two of these units (2 and 3) are in a permanent safe storage state and will remain so until the eventual decommissioning of the station (CNSC, 2018a). Currently, the PNGS has a total output of 3,100 MW, which is enough to fulfill 14% of Ontario's electricity needs and/or a city of one and a half million people.

During normal operation, the releases of radioactivity from the Pickering site is of no consequence. The OPG PNGS Environmental Risk Assessment, which is compliant with CSA N288.6 (ecological) and CSA N288.1 (human), found no potential for adverse effects from the facility to either human or ecological receptors (OPG, 2017). The annual dose to the closest human critical group (i.e., urban resident adult with potential for highest dose) from 2011 -2015 was 0.1% of the regulatory public dose limit of 1 mSv/y and approximately 0.1% of the dose due to natural background radiation in Canada.

The OPG PNGS is committed to uphold nuclear safety, assure fitness for service, maintain an engaged workforce and low impacts of operation, support transparency and public engagement, and to continue to invest in activities that will improve protection for the public, workers and the environment. In 2016, the CNSC's Regulatory Oversight Report even gave PNGS a very strong and commendable rating of "Fully Satisfactory".

Dr. Fairlie incorrectly assumes in his report that no actions have been taken by OPG PNGS since Fukushima (e.g., hydrogen not addressed). From 2013 – 2017, the OPG PNGS has invested in significant improvements to enhance emergency preventative and response measures for the facility. These investments included passive autocatalytic recombiners for enhanced hydrogen mitigation in containment (i.e., hydrogen triggered explosion at Fukushima), installation of flood barrier, procedural updates to enhance containment filtered venting capability in situations without electrical power (i.e., minimizing airborne release during an accident), and real-time perimeter radiation detectors (i.e., track plume progression outside facility boundaries) (CNSC, 2018a). Probabilistic safety assessments confirmed that these facility improvements provided an additional hazard reduction of about a factor of 10 for PNGS A and PNGS B (CNSC, 2018b).

3 WHAT ABOUT FUKUSHIMA AT PICKERING?

Dr. Fairlie listed some common features between the Pickering and Fukushima Daiichi reactors, and one difference (i.e., total MW), but there are several other notable and significant differences that the author did not mention. Both the type of reactor used (i.e., CANDU vs Boiling Water reactor (BWR)) and the underlying source term, namely natural uranium fuel (0.7% U-235) at PNGS compared to low enriched uranium (3-5% U-235) and Mixed Oxide fuel for the TEPCO Fukushima Daiichi nuclear power plant. The bottom line is from top to bottom, the OPG PNGS reactors are substantially different from those at the Fukushima Daiichi nuclear power plant.

Dr. Fairlie reports that 'many experts' have noted that the positive void coefficient in the OPG PNGS CANDU reactors is a fundamental design flaw, but then only provides one biased reference to the Ontario Clean Air Alliance. In addition to this, although the CANDU reactors do have a small positive void coefficient, it is not the only contributor to total reactivity feedback. The power coefficient, which is also quite small in CANDU reactors, is more important to operational stability. In the Fukushima BWRs, the large negative void coefficient must be handled by safety systems capable of mitigating a massive void collapse since magnitude is far more important than sign (i.e., positive or negative) (Meneley and Muzumbar, 2009; Whitlock et al., 1995).

3.1 Potential for such an Incident

Dr. Fairlie incorrectly reports that the OPG PNGS does not have the ability to provide cooling; however, there is in fact adequate cooling available via emergency mitigation equipment pumps and generators with multiple hookup locations, the effectiveness of which were evaluated by the CNSC post-Fukushima.

In addition to this, CANDU reactor units 5 to 8 in operation at OPG PNGS each have two separate (both physically and logically) systems capable of a quick and safe shutdown under extreme conditions (i.e., spring-assisted rods and high-pressure liquid injection), along with triple redundancy logic from two separate detection networks distributed throughout the core (Meneley and Muzumdar, 2009). The OPG PNGS CANDU reactor units 1 and 4 are similar but use a second logically independent trigger for shutoff rods instead of liquid injection.

The CNSC required, post-Fukushima, that all nuclear power plant operators in Canada acquire portable emergency power generators to complement their existing standby power generators, on-site emergency power generators and emergency batteries. The availability of portable generators combined with multiple hook-up locations, and additional water pumps to provide fuel cooling (heat sink), provide another means to bring reactors to a safe shutdown state in the unlikely event of a severe accident. Such an option, if it had been available, could have prevented the Fukushima accident (CNSC, 2015a).

Health Canada, on behalf of the Office of the Fire Marshal and Emergency Management (OFMEM), conducted a dose assessment based on the CNSC (2015b) report "Severe Accident Progression without Operator Action (Darlington)", which has a frequency in the range of once in every 100 million years. The first radioactive emissions, which occur 11 hours after the initiating event and the only credible one prior to operator intervention, were used to model doses and to establish the nuclear emergency planning zones (PNERP, 2017). Incidentally, the Health Canada analysis intentionally did not take EME into account since it was decided to assume no operator action as a conservative assumption.

In the event of an accident, OPG PNGS has also invested in and implemented several post-Fukushima improvements to enhance emergency preventative and response measures to mitigate potential consequences (as discussed in Section 2.3), but none of these station improvements were considered in the accident progression modelling (PNERP, 2017). OPG also evaluated a potential worst-case scenario (i.e., engineered defenses and power supply overwhelmed) more extreme than an earthquake with a probability of recurrence of less than one in 10,000 years (i.e., Fukushima was one in 1,000 years). It concluded that the above measures, along with procedures, drills and exercises, would ensure prevention of fuel failure and radiological release even under extreme conditions.

Dr. Fairlie refers to several potential accident scenarios at Pickering. There is reference to a potential plane crash and lack of a no-fly zone, which OPG had assessed, but found that the level of risk and frequency too low to be considered further. Dr. Fairlie has written the paragraph in such a manner, that it may insinuate to a reader that OPG could be hiding something (i.e., unnecessary creation of distrust).

For seismic risks, Dr. Fairlie doesn't define what 'minor damage' was experienced at PNGS owing to the earthquake. This statement needs more context since the magnitude of 'minor' can be open to interpretation, and in the case of the Pickering station, there has been no significant earthquake damage, including from those that occurred in 1974 and 1983. The pressure tube rupture events had nothing to do with earthquakes. Dr. Fairlie also mentions that OPG and CNSC 'claim' that emergency plans exist but seems to have ignored the fact that these probabilistic assessments are freely available on-line. The author simply had to do a quick search to provide confirmation.

3.2 Magnitude of Potential Event at Pickering

In Ontario, evacuation would only be considered in areas that continue to have doses greater than 20 mSv/yr following the initial period after the accident (PNERP, 2017). This means that only 5% (i.e., 146,000 / 2,854,000) of the residential areas listed in Appendix B of Dr. Fairlie's report would be potentially evacuated based on his calculation and mapping of dose rates. But if some of the other sources of error in his report are accounted for (see examples in Section 3.1), when the potential doses from severe accidents at PNGS are considered, it is unlikely that any evacuations would be required (as was recommended by the ICRP for Fukushima Daiichi accident (ICRP, 2011), see Section 5.2.2).

3.3 Predicted Fatalities

If an accident were to occur at PGNS, no fatalities are expected unless an evacuation is ordered (Section 4 and 5). Evacuations could trigger fatalities, but radiation exposure from a severe accident at PNGS poses only a negligible risk of cancer which wouldn't be distinguishable from background cancer risks.

Nuclear energy production has a very strong safety record, despite the ongoing misperceptions of risk. The actual number of fatalities due to radiation exposure at nuclear power plants since 1969 is in the range of 30 to 45 (i.e., Chernobyl accident), depending on whether potential stochastic effects from thyroid cancer (15 fatalities) are accounted for (UNSCEAR, 2017), which is at least an order of magnitude (> 35 times) less than any other long-term source of energy production (Hirschberg et al., 1998).

In short, nuclear electricity production has an exceptional long-term safety record given that the Chernobyl accident is the only event in history with fatalities attributable to radiation exposure.

3.4 Predicted Non-Fatal Risk

Dr. Fairlie speculates about "other radiation effects'" (bottom of Page 27), such as long-term genetic, teratogenic, eye cataracts, and cardiovascular disease plus stroke. The author then provides no reference to corroborate this statement and goes on to state that the main reason for these exclusions from his analysis is that there are" few internationally agreed risk factors for these effects". This is because the only stochastic (i.e., long-term) risk that has been identified was an increased risk of thyroid cancer after the Chernobyl accident, which was a direct result of a failure at the time to mitigate exposure to food and milk in the weeks that followed (e.g., children were drinking contaminated milk).

From 1991 to 2015, there were about 20,000 cases of thyroid cancer registered in people under 18 years of age living in the area at the time of the Chernobyl accident (1986). Of these reported cases, there were only 15 fatalities. It has also been estimated that only about 5,000 of the cases are attributable to radiation exposure (UNSCEAR, 2017). Since then, measures have been taken to reduce exposure to I-131 (i.e., the radionuclide linked to increased risk of thyroid cancer) post-accident and to further reduce potential risk through the distribution of iodine tablets to residents living near nuclear power plants (i.e., if thyroid is saturated with stable iodine, it will not accumulate I-131).

UNSCEAR (2017) suggests that there is no increased risk of thyroid cancers in the public expected post-Fukushima (UNSCEAR, 2017). Dr. Fairlie speculates that a low percentage of the population will use the iodine tablets, but exposure from food and milk sources will be controlled and residents will be able to choose to take this further preventative action. It is not something that should be forced upon them.

If an accident were to occur at PNGS, it is expected that the residents living in the area would experience no health effects associated with radiation exposure but may incur some from potential evacuation measures and/or the stress arising from undue fear of radiation (PNERP, 2017).

On the other hand, medical scientists have found an improvement to life expectancy of patients due to the immune boosting and cancer preventative effects of low-dose radiation. There is also evidence that low-dose radiation may be effective in the control of neurodegenerative diseases, such as Alzheimer's and Parkinson's. If these and other benefits from low-dose radiation could be realized, and the undue fear of radiation mitigated, the disruption to health that occurred with the Fukushima evacuation could have been avoided (i.e., radiation levels were also below ICRP recommended limits for evacuation) (Doss et al., 2015; Sotou, 2016). Irrespective of arguments over the beneficial effects of exposure to low-dose radiation, it is patently true that the risks from exposure to low doses of radiation are small.

In addition to this, post-Chernobyl the conifers in about 10 km^2 of forest closest to the nuclear power plant were killed by thermal heat and/or high radiation levels, but regeneration started the following year. The net environmental effect of the accident has been much greater biodiversity and abundance of species. The exclusion zone has become a unique sanctuary for wildlife (UNSCEAR, 2017).

4 HEALTH IMPACTS

Natural background radiation is highly variable, and people have lived for generations without adverse health effects in high background areas, such as Kerala (35 mSv/y), India and Ramsar (260 mSv/y), Iran. In addition to this, the Atomic bomb survivors were used to derive the LNT, but the lifespan study of this population has identified beneficial effects (lessened cancer incidence) for doses ranging from 400 to 600 mSv that were not accounted for in the derivation of the LNT model (Sutou, 2016).

Previously, Fairlie and Sumner (2006) claimed that the direct health consequences of the radiation exposure from the Chernobyl accident are much more severe. He supported his statements by arguing that the medical data were, and still are, filtered by the governments to draw attention away from the misconduct and reduce their responsibilities. Second, he argues that the data are analyzed by agencies connected to nuclear energy and are therefore pro-nuclear biased and interested in diminishing consequences from the Chernobyl accident (Socol, 2015).

We dispute Fairlie's conclusion about pro-nuclear bias in government and agency reports. There has been considerable interest worldwide in the wake of the Fukushima incident, in addition to the reports of government and national and international agencies – in particular, the World Health Organization and the United Nations Scientific Committee on the Effects of Atomic Radiation. There are also numerous peer reviewed documents in the open literature which have been reporting on the various aspects of the Fukushima incident (e.g., Socol, 2015; Sutou, 2016).

In developing its 2013 report on the health risks arising from the Fukushima incident, the WHO implemented its mandate to assess and respond to public health risks. The WHO's 2013 report builds on an earlier preliminary estimate of radiation doses provided in a 2011 WHO report. In developing its health risk assessment, the WHO assembled a team of international experts with experience in relevant disciplines including risk modelling, dosimetry, and radiation health effects. The 2013 WHO report provides dose estimates for several areas both within and outside of the Fukushima prefecture and report, including the following:

- All doses were estimated to be well below the level at which deterministic effects would be expected to occur
- Estimated doses in the first year following the incident in the most affected areas of the Fukushima Prefecture are in the range of 12 to 25 mSv
- Dose estimates for the next most exposed group are in the range of 3-5 mSv, and
- Continued monitoring of food and the environment will provide valuable information to revise dose calculations and associated potential health effects

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR was established by the General Assembly of the United Nations in 1955 with the mandate to assess and report levels and effects of exposure to ionizing radiation. Governments and organizations throughout the world rely on UNSCEARs work to provide the scientific basis for evaluating the risks from ionizing radiation. At the moment, scientists from 27 countries are members of UNSCEAR. The scientific work of the Committee is supported not only by the scientists who are members of UNSCEAR but also by international organizations and non-governmental organizations, and in addition, engages specialists to analyze peer reviewed scientific reports and produce scientific evaluations which are available free of charge at www.unscear.org. During the development of a report, all documents are reviewed by the Committee and external specialist, often involving review by more than 100 scientists from around the world. It is simply not credible to presume a conspiracy of amongst this number of scientists to agree to produce a biased report.

UNSCEAR 2013 reports on the radiation doses and potential health effects to members of the public arising from external exposure to radioactive plumes, internal exposure from inhalation of radioactive materials during plume passage and that from radioactive materials deposited on the ground during plume passage. In brief, in respect to potential health effects arising from the Fukushima incident UNSCEAR 2013 concluded that the potential health risks resulting from the Fukushima incident "to be far lower than those for the Chernobyl accident, owing to the substantially lower doses received by the public and workers"; and further concluded that:

- no deterministic effects from radiation exposure had been observed among the public and none were expected;
- no discernible increase in heritable disease among the descendants of those exposed from the accident was expected
- no discernible radiation-related increases in rates of leukaemia or breast cancer (two of the most radiogenic cancer types), nor in other types of solid cancer besides possibly thyroid cancer, were expected; and
- no large excess of thyroid cancer due to radiation exposure, such as occurred after the Chernobyl accident, was expected[2].

UNSCEAR has done three follow-ups in the form of Whitepapers incorporating developments since their original assessment of doses and health effects in 2013, in 2015, 2016 and most recently in 2017. The most recent UNSCEAR 2017 Whitepaper notes [at para 89] that "*doses to the general public in Japan continue to decrease and that updated dose estimates based on personal dose measurement and shielding factors are in general agreement with original estimates*".

In the case of Fukushima emergency workers, UNSCEAR (2013,2015,2016,2017) concluded that deterministic effects in the emergency workers are unlikely. Moreover, UNSCEAR concluded that an increased incidence of cancer would be likely not be discernible among natural background cancer incidence and that its findings regarding health effects of radiation exposure from the Fukushima incident in their 2013 report "*remain valid and are largely unaffected by new information that has since been published*" [para 122, UNSCEAR 2017).

Finally, UNSCEAR noted that the major health impacts that had been observed among the general public and among workers were mental health problems and impaired social well- being.

5 ECONOMIC AND SOCIETAL IMPACTS

In 2018, the Ontario Chamber of Commerce published an independent review (OCC, 2018) of the economic contribution that the OPG PNGS could make to Ontario to 2024 which included an analysis of the OPG operational and capital expenses. The study concluded that Pickering's continued operation to 2024 would be a benefit to Ontario's economy, its climate change goals, and the stability of its energy system. The benefits include $1.54 billion to Ontario's GDP, 7,590 full-time equivalent jobs, and $290 million in government taxation revenues. If PNGS were to cease operation, the cost of energy in Ontario would increase as the province turns to more expensive alternative options.

The current total cost of energy for nuclear in Ontario is $0.069 / kWh, which may be slightly higher than hydro ($0.058 / kWh) but is appreciably less than wind ($0.173 / kWh) or solar ($0.480 / kWh). In 2016, Ontario received 60% of its electrical power from nuclear energy production and there is no substantial capacity for hydro production. Wind and solar are not only expensive alternatives, but they are not

[2] This is because the estimated thyroid doses due to the Fukushima incident are much lower than those seen at Chernobyl. Moreover, UNSCEAR notes that "the sensitive ultrasound-based thyroid screening of those aged 18 years or younger at the *time of the accident had been expected to detect a large number of thyroid cysts and solid nodules, including a number of thyroid cancers "that would not normally have been detected without such intensive screening*" (paragraph 225 of UNSCEAR 2013).

without their own environmental and operational considerations and are unable to meet Ontario's base load demands (i.e., provision of a steady and reliable source of electricity) (OCC, 2018).

Dr. Fairlie stated the "Hydro Quebec had offered Ontario power for 20 years at a cost of five cents a kilowatt hour (kWh)". The reference cited, Pierre Couture, reported last month (Couture, 2018) that Hydro Quebec clients pay 5.9 cents per kWh for the first 36 kWh used each day, followed by 9.12 cents per kWh thereafter. There is also reference to the 5 cents per kWh cost, but with 25 cents per kWh cost in the morning and evening (can assume peak times). Residents of Quebec would certainly not be pleased if Ontario was paying less per kWh for electricity produced in their province. In addition to this, for Ontario to purchase electricity from Quebec, it would cost $1 – 1.4 billion with a lead time of 10 years to carry out the planning, design, local and indigenous consultations, and environmental studies to build the capability to deliver this energy to the GTA load centre (OCC, 2018).

There is mention in Dr. Fairlie's report that the demand for electricity in Ontario is dropping. This is true due to some recent advances in technology (e.g., LEDs), but the cost of energy has still been steadily going up and the alternatives (i.e., wind and solar) are not capable of meeting base load demands (i.e., the provision of a steady uninterrupted baseload supply of electricity). Dr. Fairlie also makes reference to the 668 deaths estimated each year from air pollution if coal-fired power stations continued to operate, a threat which was eliminated in Ontario through the operation of nuclear power stations.

5.1 Evacuation

Evacuation poses social and health consequences that often far exceed those associated with the radiological exposure (e.g., Chernobyl - Section 5.2.1, Fukushima – Section 5.2.2). Dr. Fairlie states that 10 mSv/y is the Ontario recommended "lower level" above which evacuations "should be applied unless valid reasons exist for deferring actions", and that these are not defined in the emergency response plan (with reference to PNERP 2017). The PNERP (2017) states that the protective action for a projected dose of 10 mSv is sheltering in the first two days, not for the entire year, and that evacuations should only be considered for a projected dose of 100 mSv in the first seven days (or 500 μSv / hr) with recognition that the relocation of the population also causes significant psychosocial and economic disruptions. PNERP (2017) therefore suggests deferring actions, even if projected dose is above 100 mSv, if the risk associated with an evacuation exceeds the risk associated with radiological exposure (i.e., negative net benefit). In short, PNERP has clearly defined criteria for evacuation as well as valid reasons for deferring actions and will only consider an evacuation if the projected dose is much higher than what is shown in Dr. Fairlie's report (i.e., 10 mSv in two days equates to a dose rate of 1825 mSv/y, not 10 mSv/y). If there was a need to evacuate, the PNERP infrastructure and process is in place to help ensure that it takes place in a safe and timely manner, and not several months as Dr. Fairlie suggests in his report.

Following a postulated accident, PNERP would then conduct a medical follow-up (health screening) as a protective action for population monitoring if projected dose is above 100 mSv in one month. For longer-term planning following a postulated accident, 20 mSv/y is the target population dose to enable transition to the existing situation (i.e., return to normal) (PNERP, 2017).

Dr. Fairlie states that the evacuees near Fukushima were forced to return to their homes. Do these residents still have a functional home after damage received from earthquake and tsunami? If they do, it is better for their own health and well-being that life return to normal for them. If these residents are afraid to return home due to fears associated with Fukushima Daiichi accident, we have Dr. Fairlie and other anti-nuclear activists to thank for continuing to instill and perpetuate an undue fear of radiation.

5.2 Consequences of Misperception

The dissemination of scientific information should not be misconstrued or falsified. To intentionally introduce erroneous or exaggerated work into the scientific literature with no concern for consequence, is unacceptable. Science must be free from excessive direction for non-scientific purposes, in this case, so that society can make well-informed decisions on their safety and the future of energy production.

It appears that the CNSC shares our concerns over the effect of incorrect and misleading science on public perception. At a CNSC Public Meeting on 2018 April 4th, Mr Gerry Frappier (CNSC Directorate of Power Reactor Operation) stated, with reference to the "Clean Air Alliance Report" (CNSC, 2018b):

> "…as far as issues of fake science, if you like, or at least exaggerated science and that, that has been very, very difficult to put in a bottle. There are things that are clearly not true, but still end up getting talked about over and over again and that generates a lot of fear and what exactly can be done of that is a little bit more challenging."

> "…what level of importance would be put on trying to nullify some of the clearly erroneous assumptions that they made and science that they've used."

As the examples below demonstrate, there are potentially dire consequences that can be directly attributed to an undue fear of radiation. If Dr. Fairlie truly believes "it is time to stop risking lives", he should reconsider where he focuses his efforts.

5.2.1 Chernobyl Accident

The Chernobyl accident resulted in major human suffering caused by the evacuation and other counter-measures, but direct health consequences from accident related radiation-exposures have not been observed beyond the acute effects (30 employees and emergency workers) and small number of stochastic effects from thyroid cancers (possible 4000 cancers, of which 15 died) (Socol, 2015). The increase in thyroid cancers stems largely from continued exposure to contaminated milk and food in the weeks following the accident.

On the other hand, there was enormous human suffering from the largely unjustified evacuations. About 4,000,000 people were officially declared victims, triggering radiophobia (i.e., irrational fear of radiation doses) and a social stigma with being an 'exposed' person (WHO, 2006). Psycho-social effects among those affected by the accident were comparable to those from other major disasters, such as earthquakes, floods, and fires. Physicians in Europe also advised pregnant women to undergo abortions due to radiation exposure, even though levels concerned were vastly below those likely to have teratogenic effects. As a result, the fetal death toll due to fear of radiation was much greater than fatalities that can be attributed to the accident (UNSCEAR, 2000).

It has been over 30 years since the Chernobyl accident, but these lessons on the actual health effects of radiation exposure have not been learned, at least by Dr. Fairlie, which is again apparent in Section 5.2.2.

5.2.2 Fukushima Daiichi Accident

There were no fatalities or health effects owing to radiation exposure for the Fukushima Daiichi accident and yet more than 1000 people died within two years following the accident owing to various evacuation-related, largely psychosomatic, problems owing to the pervasive myths and misperceptions about the threat of radiation (e.g. heightened anxiety, suicides, paralyzing fatalism, increased smoking and alcohol dependency) (Socol, 2015). An increase in health effects, such as thyroid cancers, are not anticipated post-Fukushima since measures were taken to substantially lower exposure (e.g., removed contaminated milk and food) (UNSCEAR, 2017).

Dr. Fairlie states that “official figures between 2011 and 2015 about 2000 deaths occurred from the radiation-related evacuations due to ill-health and suicides, especially among elderly people”. In checking the reference cited, there was no information contained therein to support this statement. It is also ironic that the fatalities attributable to these evacuations stem solely from a fear of radiation, since no evacuations were even needed in Fukushima to protect the public from exposure to radiation. The maximum dose received by members of the public fell below the protective initial 20 to 100 mSv band (max 15 mSv in first 4 months, with 97.4% <5 mSv), and the subsequent longer-term 1 to 20 mSv band (i.e., recommended limits from the International Commission of Radiation Protection (ICRP) which are also consistent with PNERP (Shigenobu et al., 2013)). The decision in Japan to use 1 mSv/y as the initial threshold for evacuations, against the recommendation of the ICRP at the time of the emergency, induced tremendous human, social and economic losses (ICRP 2011, as quoted in Sutou, 2016).

6 GENERAL EDITORIAL COMMENTS

6.1 Terminology and Units

In Dr. Fairlie’s 2018 March report, there are repeated misleading uses of the phrases or words ‘conservative’, ‘no assumptions’, ‘significant efforts’, ‘scientifically inaccurate’, ‘preferred’, ‘viewed as underestimates’, ‘widely acknowledged’, ‘reasonable to assume’, and ‘correct to two significant figures’. These terms are intended to illicit trust, a sense of reliability and significance, even where there is no scientific data to corroborate the statements.

As for scientific units, Dr. Fairlie consistently rounds numbers up, even when it is not appropriate to do so. For example, on Page 11 of the report, in his estimate of yearly exposure he incorrectly rounded up the dose rate (i.e., it should have been 2.2 – 4.2 mSv/y, not 2.5 – 5 mSv/y).

6.2 Fairlie’s References

In the report, there was found to be substantial self-referencing to the author’s own work and use of the open resource, Wikipedia. The issue with using Wikipedia, other than it is not an acceptable quality assured source of reliable information, is the ease with which entries can be manipulated. Wikipedia is a useful starting point for research to obtain references to original peer-reviewed publications but should not be cited since it is easy to change the content. As for self-referencing, this is acceptable if used in moderation and that you are referencing your previous peer-reviewed publications.

Dr. Fairlie refers to an actual collective dose estimate for Fukushima Daiichi accident from UNSCEAR (2013) in his report (i.e., 48,000 person Sv), but then references his own website for the estimate of fatalities, not the original source. UNSCEAR (2013) states that exposures fell well below the thresholds for deterministic effects, which is consistent with the observation that no acute health effects (e.g., acute radiation syndrome) were reported. As for stochastic effects, UNSCEAR (2013) stated that a "general radiation-related increase in the incidence of health effects among the exposed population would not be expected to be discernible over the baseline level". In short, UNSCEAR (2013) estimates no fatalities or health effects from the Fukushima Daiichi accident.

Dr. Fairlie often refers in his 2018 March report to sources of information or "several studies" but does not provide an actual reference to enable to reader to confirm. For example, most of the sources of information listed at the bottom of Page 11 and the studies referred to in the footnote 18 on Page 15. It should also be noted that on Page 23, the reference to footnote 20 should be footnote 26.

In the Foreword of the Dr. Fairlie report, Wikipedia is referenced in the endnotes, but he should have instead sought out and referred to any peer-reviewed publications listed in this source. As for the other 13 endnotes listed, five of them were published by a biased source since the Ontario Clean Air Alliance is funding the report, three of them are non-peer reviewed magazine or newspaper articles. The CRL 'major' accident and OPG PNGS operating cost references need better context, since 'major' is a relative term with no indication regarding magnitude (which was low) and nuclear energy remains one of the cheaper forms of electricity production. Endnote 13 does not link to an article, only a note that states "we are sorry your request could not be found". Endnote 4 is referencing an unsecured and suspect site, so could not be checked. In short, it appears that only Endnote 1 was presented with proper context and a link that could be confirmed, but the author should have looked up and referenced the actual Act to which he is referring, not a website. On the other hand, there is a higher percentage of credible reference sources cited in the main report, but unfortunately many are still used out of context or with redirection (e.g., Page 28 Endnote 31).

6.3 Other Assumptions and Redirection

The 2018 March report written by Dr. Fairlie also contains numerous statements that constitute a clear re-direction of sound science, as exemplified with Dr. Fairlie's reference to a value from UNSCEAR (2013) mixed in with his own estimations to make it appear that UNSCEAR concluded something different than what is written in the report.

On Page 9, Dr. Fairlie states that "it is important to note however that this study does NOT make any assumptions or develop any scenarios regarding a specific possible accident at Pickering". The report is riddled with assumptions, including the sentence that followed which stated that "instead it uses actual Japanese fallout patterns". That IS an assumption. The meteorology and climate of these two regions, amongst other factors, are substantially different.

There is a misleading description of radiation dose units on Page 11 of Dr. Fairlie's report regarding the use of the micro-Sv. He states that "even this is often too large and a smaller unit is used." Simply because something is small, but measurable, does not indicate that there is a risk. It is a unit of measure and nothing more, and if anything, that low limit of detection should provide comfort, not concern.

Dr. Fairlie states that he has applied a conservative cut-off of 10 years, and yet he doesn't credit potential (and likely) clean-up efforts. Use of 'conservatism' is misleading, since he writes as if he is under-estimating, which he is in fact not. Clean-up efforts in Japan post-Fukushima also started within months following the accident (IAEA, 2014).

7 CONCLUSIONS AND RECOMMENDATIONS

Scientists should be held accountable for the perpetuation of "false science". Decisions on the future of electricity production in Ontario need to be based on factual scientific evidence, not myth.

The public wants to be engaged and to be in a position where they can make well-informed decisions, but the public largely depends on scientists for this information. It is important for the public stakeholders and neighboring communities to have a credible and trusted source of such information, and the credibility of the CNSC is very important in this regard. Nuclear power is an example of an industry which requires a technically competent, strong but fair, and credible regulator.

It is recommended that Dr. Fairlie re-consider his position and the statements made in the "A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effects" report in light of the comments provided in this review. In our opinion, there should be more focus on tools and / or strategies to further mitigate the risks posed by these misperceptions on decisions related to the future of electricity production in Ontario.

8 REFERENCES

CNSC, 2018a. Licence Renewal for Ontario Power Generation Inc. Pickering Nuclear Generating Station. Commission Public Hearing – Part 1. 2018 March 5th. CMD 18-H6.

CNSC, 2018b. Transcript of Pickering Public Hearing of 2018 April 4th. CNSC 2018-H-03.

CNSC, 2015a. Safety cases and probabilistic safety assessments. 2015 July 20. Canadian Nuclear Safety Commission.

CNSC, 2015b. Severe accident progression without operator intervention. Darlington Facility.

CNSC, 2013, CNSC Integrated Action Plan on the Lessons Learned from the Fukushima Daiichi Nuclear Accident, 2013.

CNSC, 2011. CNSC Fukushima Task Force Report. INFO-0824.

Corrice, L., 2015. Ian Fairlie on Fukushima: Errors and Omissions. The Hiroshima Syndrome. https://www.hiroshimasyndrome.com/fukushima-fud/ian-fairlie-on-fukushima-errors-and-omissions.html

Couture, P. 2018. Hydro-Quebec va offrir des tariffs variables selon l'heure du jour. Le Journal de Montreal. 2018 April 26.

Fairlie, I., 2018. A Fukushima-Level Nuclear Disaster at Pickering: An Assessment of Effects. Prepared for the Ontario Clean Air Alliance, March 2018.

Fairlie I, Sumner D. 2006. The Other Report on Chernobyl (TORCH). Berlin, Brussels, Kiev:Greens/EFA in the European Parliament.

Henriques, S., 2015. Four Years of Progress: Action Plan on Nuclear Safety. IAEA.

Hirschber, S., Spiekerman, G., Dones, R. 1998. Severe accidents in the energy sector. Project GaBE: Comprehensive Assessment of Energy Systems. PSI Bericht Nr. 98-16.

IAEA, 2018. IAEA Fukushima Status Updates: Events and highlights on the progress related to recovery operations at Fukushima Daiichi Nuclear Power Station. 2018 March 5th. https://www.iaea.org/newscenter/focus/fukushima/status-update

IAEA, 2015. IAEA Director General's report on the Fukushima Daiichi accident, Technical volumes 1 to 5.

IAEA, 2014. The Fukushima Daiichi Accident. Report by the Director General. IAEA Pub1710.

ICRP, 2011. Fukushima nuclear power plant accident. International Commission on Radiological Protection ref: 4847-5603-4313. Mar 21, 2011.

Leppold, C., Tanimoto, T., Tsubokura, M., 2016. Public health after a nuclear disaster: beyond radiation risks. *Bulletin of the World Health Organization* 94: 859-860.

Meneley, D.A., Muzumdar, A.P., 2009. Power Reactor Safety Comparison -- a Limited Review. Proceedings of CNS 30th Annual Conference, Calgary, AB, 2009 May 31-June 3.

Nagataki, S., Takamura, N., Kamiya, K., Akashi, M. 2013. Measurements of Individual Radiation Doses in Residents Living Around the Fukushima Nuclear Power Plant. Radiation Research, 180(5): 439-447.

OCC, 2018. Pickering Continued Operations: An Impact Analysis on Ontario's Economy.

OPG, 2017. Environmental Risk Assessment Report for Pickering Nuclear. Ontario Power Generation. P-REP-07701-00001, R000.

PNERP, 2017. Provincial Nuclear Emergency Response Plan. Master Plan – Province of Ontario. Office of the Fire Marshal and Emergency Management and the Ministry of Community Safety and Correctional Services. Ontario

Socol, Y. 2015. Reconsidering health consequences of the Chernobyl accident. International Dose Response Society. Dose-Response 13(1): 1-10.

Sotou, S. 2016. A message to Fukushima: nothing to fear but fear itself. Genes and Environment. 38 (12): 1-9.

TEPCO, 2017. Nuclear Safety Reform Plan. FY2017Q1 Progress Report. Tokyo Electric Power Company Holdings, Inc. 2017 August 4.

UNSCEAR, 2000. Exposures and effects of the Chernobyl accident. Volume II Annex J of the 2000 United Nations Scientific Committee on the Effects of Atomic Radiation Report to the General Assembly.

UNSCEAR, 2014. Sources, Effects and Risks of Ionizing Radiation. Volume I: Report to the General Assembly and Scientific Annex A. Levels and effects of radiation exposure due to the nuclear accident after the 2011 Great East Japan earthquake and tsunami. UNSCEAR 2013 Report. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations sales publication E.14.IX.1. United Nations, New York, 2014.

UNSCEAR, 2015. Developments since the 2013 UNSCEAR Report on the Levels and Effects of Radiation Exposure due to the Nuclear Accident following the Great East- Japan Earthquake and

Tsunami. A 2015 white paper to guide the Scientific Committee's future programme of work. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations, New York, 2015.

UNSCEAR, 2016. Developments since the 2013 UNSCEAR Report on the Levels and Effects of Radiation Exposure due to the Nuclear Accident following the Great East- Japan Earthquake and Tsunami. A 2016 white paper to guide the Scientific Committee's future programme of work. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations, New York, 2016.

UNSCEAR, 2017. UNSCEAR developments since the 2013 UNSCEAR report on the levels and effects of radiation exposure due to the nuclear accident following the Great East Japan earthquake and tsunami. A 2017 white paper to guide the Scientific Committee’s future programme of work, United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations, New York, 2017.

Whitlock, J.J., Garland, W.J., Milgram, M.S., 1995. Effects Contributing to Positive Coolant Void Reactivity in CANDU. Trans. Am. Nucl. Soc.,72, 329, ISSN: 0003-018X.

WHO, 2006. Health effects of the Chernobyl accident: an overview, April 2006. World Health Organization. http://www.who.int/ionizing_radiation/chernobyl/backgrounder

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