Nuclear Power in the Prairies

Laura Bowman
Staff Counsel
Environmental Law Centre

September 2011

Library and Archives Canada Cataloguing in Publication

Bowman, Laura, 1980-
Nuclear power in the Prairies [electronic resource] / Laura Bowman.

Includes bibliographical references.
Electronic monograph in PDF format.
Issued also in print format.
ISBN 978-0-921503-88-0

1. Nuclear energy--Government policy--Canada. 2. Nuclear energy--Law and legislation--Canada. 3. Nuclear energy-- Environmental aspects--Canada. I. Environmental Law Centre (Alta.) II. Title.

HD9698.C22B69 2011a 333.792'40971 C2011-906237-2

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, or otherwise without permission from the Environmental Law Centre, #800, 10025 – 106 Street, Edmonton, Alberta, Canada, T5J 1G4.

Copyright © 2011
Environmental Law Centre

Acknowledgements

The writing and publication of this paper was made possible by the Alberta Law Foundation and the Law Foundation of Saskatchewan. The support of these Law Foundations for the project is gratefully acknowledged.

I am indebted to Iris Djurfors, librarian at the ELC who tirelessly obtained research materials, sometimes from difficult locations. I would also like to thank the Canadian Nuclear Safety Commission, the University of Alberta, and the Saskatchewan Research Council for providing licensing information through online materials and requests.

L.B.

About the Environmental Law Centre

The Environmental Law Centre (ELC) was established in 1982 to provide Albertans with an objective source of information about environmental and natural resources law and policy. Its vision is a clean, healthy and diverse environment protected through informed citizen participation and sound law and policy, effectively applied.

The Centre's mission is to ensure that laws, policies and legal processes protect the environment. In pursuit of this mission, the Centre seeks the following ends:

- Enactment and effective enforcement of sound environmental laws and policies; and
- Informed public participation in environmental regulatory, law-making and decision-making processes.

Table of Contents

Executive Summary

This report is a discussion of the existing environmental laws and regulations governing the routine operation of nuclear reactors in Canada. We argue that provincial regulation of nuclear power facilities in Saskatchewan and Alberta should be enhanced before any are built in these provinces.

This report provides an overview of how nuclear power is regulated in Canada at the federal and provincial levels and legal barriers and opportunities for provincial regulation. We have identified persistent gaps in federal regulation of nuclear facilities in Canada. In particular the current approaches to health in relation to radioactive releases and the regulation of the environmental impacts of radioactive releases lack a compelling rationale. There are also gaps in federal regulation of non-radioactive hazardous pollution and aquatic impacts from nuclear power facilities. We argue in this report that the provinces have jurisdiction that they should exercise in these areas to develop regulations and standards for any future nuclear power plants in the prairies.

This report does not deal with safety or environmental issues that result from catastrophic nuclear power facility accidents. During the preparation of this report a major earthquake and tsunami hit Japan resulting in a series of accidents at the Fukushima nuclear power plant, garnering global attention. While the effects of accidents at this scale are outside the scope of our research, we feel this report provides the public with important information on nuclear regulation that will assist them in appreciating these events. This report was also drafted in the context of the Darlington New Build Joint Panel Review in Ontario. This was the first ever review panel for a new nuclear power plant in Canada. The ELC followed these proceedings with interest and obtained important new information from these proceedings on potential impacts and existing federal and provincial regulatory practices.

Recommendations

Alberta and Saskatchewan should address the following regulatory issues prior to authorizing a nuclear power facility:

1. Review risk-acceptability for radiation protection of the public and identify appropriate public health and environmental protection levels.

    - Review the 1 millisievert (mSv) public dose limit to address public health and environmental effects of radiation in the environment.

    - Study and implement ecologically relevant environmental limits for radionuclides in air, soil and water.

    - Implement a precautionary approach to radiation protection that recognizes the linear no threshold (LNT) model.

2. Revise environmental assessment legislation to ensure that both large and small reactors are subject to mandatory provincial environmental assessments. These assessments should be helpful in evaluating whether environmental and public health risks posed by nuclear power plants are acceptable in comparison to alternative energy technologies.

3. Adopt the 20 becquerel/litre (Bq/L) tritium and 100 Bq/L carbon-14 drinking water levels recommended in Ontario and by the World Health Organization as interim drinking water levels and evaluate the potential effects of radionuclide releases into drinking water.

4. Create best available technologies and practice standards that are implemented through environmental and electricity approval legislation to minimize contaminant releases from nuclear power facilities.

5. Create water allocation, impingement and entrainment regulations that minimize harm to aquatic ecosystems from cooling systems by nuclear power facilities. Once-through cooling systems should be banned.

6. Enact, in a transparent manner, waste legislation that provides clear standards for reporting and managing radioactive waste sites, including non-radioactive and mixed wastes from nuclear power facilities.

7. Develop technical capacity to evaluate best technologies and practices in the nuclear power sector to minimize hazardous waste and radionuclide releases into the environment. Strive to improve upon existing practices and technologies through effective, enforceable regulation (to the extent that it is compatible with occupational health and overall safety).

Background to the report

Nuclear power is being considered in Alberta as a central government direction to deal with electricity generation issues. On March 26, 2009, the Department of Energy released a panel report: *Report on Nuclear Power and Alberta*.[1] The panel concluded that nuclear power was an option to meet forecasted growth in electricity demand in Alberta but that the ultimate decision to build a nuclear plant in Alberta was a private sector decision. The Government of Alberta also released a public opinion poll on nuclear power and suggested that nuclear power projects will be considered on a "case by case" basis.

On March 31, 2009, the Saskatchewan government released a report: *Capturing the full potential of the uranium value chain in Saskatchewan*.[2] This report recommended that Saskatchewan include nuclear as part of the province's long-range energy mix. The report was met with considerable controversy. On April 29, 2009, the Legislative Assembly of Saskatchewan approved an inquiry into meeting electricity demand in the province. The government released an August 2009 public consultation report on the future of uranium in Saskatchewan. In December 2009, the Saskatchewan Government announced that it would consider nuclear power in the future and that this approach would include a plan applying to the entire prairie region. The Saskatchewan Government directed SaskPower to "continue including nuclear power in the range of energy options available for additional baseload generation capacity in the medium and long term." Currently, Saskatchewan is considering building a small nuclear power reactor.

This report discusses the existing regulatory matrix in Alberta and Saskatchewan as it may apply to any future nuclear generation proposals. The report is focused on explaining how provincial laws and regulations in Alberta and Saskatchewan may be used to regulate the environmental aspects of nuclear generation and how these laws and regulations interact with federal jurisdiction. Part I of this report discusses what aspects of nuclear power generation are federal and where the provinces have authority to regulate. Part II addresses gaps in federal and provincial regulation of environmental protection at nuclear power facilities in more detail and recommends reforms to provincial laws to address those gaps.

The report is limited to issues covering the routine environmental aspects of nuclear power generation and does not cover supply-chain issues such as mining, milling, or research facilities, public participation, regulatory independence, safety from accidents, the long-term storage and disposal of nuclear fuel waste, and other issues. While these issues are important, this report addresses those aspects of nuclear power generation that are amenable to provincial regulation in detail and is designed to give the public, policy makers and others a broad-based understanding of environmental protection issues in nuclear power.

---

[1] Nuclear Power Expert Panel, *Report on Nuclear Power and Alberta* (February 2, 2000) <http://www.energy.alberta.ca/Electricity/pdfs/NuclearPowerReport.pdf>

[2] Uranium Development Partnership, *Capturing the full potential of the uranium value chain in Saskatchewan*, (March 31, 2009) online: <http://www.gov.sk.ca/adx/aspx/adxGetMedia.aspx?mediaId=767&PN=Shared>

Part I - Regulatory History of Nuclear Power

Wartime genesis

Canada was very involved in developing nuclear weapons during World War II, including participating in various aspects of the Manhattan project. One weapons innovation was the use of Deuterium (or "heavy water") or graphite as a "moderator" to absorb neutrons in the appropriate amounts in combination with natural uranium "enriched" with Uranium-235.[3] It was during this period that the precursor to the CANDU (Canadian Deuterium Uranium) reactor was developed for military purposes.

The moderator reactor model was first built in Chalk River, Ontario. This reactor went into operation in 1945 and was the first one to do so outside the United States.[4] A second Chalk River reactor went into operation in 1947.[5] These reactors were created to assist in the production of Plutonium-239 and Uranium-233 for weapons and were operated by the Atomic Energy Division of the National Research Council.[6] The NRX (National Research Experiment) reactor was designed specifically to extract plutonium for weapons.[7] The CANDU, therefore, has defense implications because of its design relationship to a weapons facility. Canadian reactors continue to have international security implications when they are exported due largely to the ability to extract plutonium from uranium used in the reactors.[8]

Post war shift to "civilian" power technology

It is crucial to understand that the first nuclear regulatory legislation in Canada followed on the heels of the atomic bombs detonated at Hiroshima and Nagasaki, and that while the Canadian program shifted to civilian power, the weapons context of the Cold War was very much on the minds of those designing Canada's nuclear regulatory system. Canada developed federal legislation at the same time as other countries in 1945-1946.[9] In 1946, the Atomic Energy Control Board (AECB) was established, and the now commercial-oriented research program at Chalk River was passed on to Atomic Energy of Canada Limited (AECL), a federal Crown corporation, for commercial development.[10] Utility experts were asked to run AECL, including

---

[3] J.S. Foster & G.L. Brooks, "CANDU Origins and Evolution, an Overview of the Early CANDU Program Prepared from Information Provided by John S. Foster" (2001), online: <http://canteach.candu.org>.
[4] Atomic Energy of Canada Ltd., *Canada Enters the Nuclear Age* (Montreal: McGill-Queens University Press, 1997) at 5. See also James Lorne Gray, "Early Decisions in the Development of the CANDU Program," (1987) 1:2 *Canadian Nuclear Journal*. The reactor was called ZEEP for "Zero Energy Experimental Pile". The second one was called NRX (National Research Experiment). A third early reactor is the NRU (National Research Universal), which is still in use.
[5] See R. Bothwell, *Eldorado: Canada's National Uranium Company* (Toronto: University of Toronto Press, 1984).
[6] *Canada Enters the Nuclear Age, supra* note 4; Gray, *supra* note 4.
[7] Canadian Nuclear Safety Commission, *Decommissioning of a plutonium recovery laboratory at Chalk River Laboratories* (September 13, 2004).
[8] Department of Reconstruction, Press Release, "Canada's Role in the Atomic Bomb Drama" (13 August 1945).
[9] *Ibid.* at 19-29.
[10] *Canada Enters the Nuclear Age, supra* note 4 at 6-8.

the chief engineer of Ontario Hydro.[11] The initial version of the *Atomic Energy Control Act* created a five-member board, one of which was to be President of the National Research Council.[12] The Act empowered the Board to make regulations on all phases of atomic energy including mining, prospecting,[13] ownership, use of prescribed substances and transportation. The Board was also empowered to create and acquire companies. The objective of the Board was to provide atomic research, policy and security advice to the government.[14] Initially the Board did not regulate health and safety at any nuclear power or other nuclear facilities. In 1952, the NRX reactor partially melted down, which resulted in temporary abandonment of that project.[15] There was also a serious accident involving the NRU reactor in 1958. In 1959, the Board assumed increased responsibility for the health and safety of workers and the public.[16] The AECB also acquired powers to prohibit and authorize reactors.[17]

From the very beginning, building commercial power reactors was a joint federal and provincial project. In 1959, AECL and Ontario Hydro began to develop a small power reactor to be located at Douglas Point.[18] This reactor started up in 1968.[19] In 1964, work began on the first two commercial reactors at Pickering, Ontario.[20] These reactors were a joint federal-provincial project in which Ontario Hydro constructed the reactors and supplied the electricity-generating part of the plant, while AECL paid the difference between the cost of the nuclear reactor and a coal fired steam generator.[21]

Joint federal-provincial electric utilities are not unusual. Many earlier hydroelectric developments in Canada were on trans-boundary waters such as the St. Lawrence River or Niagara Falls, and had to be facilitated through legislation at the federal level in some aspect.[22] Legal decisions on early utilities works in Eastern Canada clarified that electric utilities located entirely within the province were considered, on their face, to be local works and undertakings under the *Constitution Act, 1867* and therefore within provincial jurisdiction.[23] The federal

---

[11] *Ibid.*
[12] *Atomic Energy Control Act*, 1946, 10 Geo. VI c.37.
[13] *Ibid*., s.9(c).
[14] G.H. Sims, *A History of the Atomic Energy Control Board* (Ottawa: Minister of Supply and Services Canada, 1981) at 19-29.
[15] Jedicke, P. "The NRX Incident" (Canadian Nuclear Society), online: <http://media.cns-snc.ca/history/nrx.html>.
[16] Canada. Auditor General, *1985 Report of the Auditor General of Canada,* (Ottawa: Queen's Printer, 1985) Chapter 8 – Atomic Energy Control Board at para. 3.
[17] Sims, *supra* note14 at 120.
[18] Gray, *supra* note 4.
[19] *Ibid.* Also see Atomic Energy of Canada Ltd., "The Douglas Point Story" (June 1984) *Power Projections.* Online: <http://media.cns-snc.ca/history/DouglasPoint/DouglasPoint.html>
[20] Gray, *ibid.*
[21] *Ibid.*
[22] For example, see the federal *International Rapids Power Development Act,* R.S.C. 1952, c. 157, which approved an agreement of the previous year between the Government of Canada and the Government of Ontario providing for the development of the power resources in the International Rapids section of the St. Lawrence River.
[23] *Re Ontario Energy Board* (1986), 57 O.R. (2d) 281 (Div.Ct.) at 290; *Hull Electric Co. v. Ottawa Electric Co.*, [1902] A.C. 237 (P.C.); *Hewson v. Ontario Power Co.* (1905), 36 S.C.R. 596; *Ottawa Valley Power Co. v. The Hydro-Electric Power Commission,* [1937] O.R. 265, 70; *Beauharnois Light, Heat and Power*

government, however, has jurisdiction over interprovincial works and undertakings, as well as declared works and undertakings.[24] In the 1970s, international regulation of nuclear technology and materials began to become more formalized. The role of the AECB was to implement Canada's international obligations.[25] The 1970 *Non-proliferation Treaty* (*NPT*) required safeguards be developed with the International Atomic Energy Agency (IAEA).[26]

Early debates over jurisdiction for health and safety at nuclear facilities

Early AECB licences incorporated provincial health and safety laws. For example, one condition of early licences was that "subject to the Atomic Energy Control regulations, any applicable provincial statutes and regulations...in so far as they deal with mine safety and cognate matters, are to be observed and complied with in relation to the said property and to all operations undertaken in connection therewith."[27] However, the *Pronto Uranium* decision[28] in 1956 resulted in a more extensive role for the AECB, and later the Canadian Nuclear Safety Commission (CNSC), in uranium mining. This decision suggested that uranium regulation may be within federal jurisdiction.

Uranium mine regulation was very controversial. Many provinces sought greater control over the regulating uranium mines through a series of provincial commissions. These included the Ontario Hamm Commission (1974),[29] the Saskatchewan Bayda Commission (1977),[30] the British Columbia Bates Commission and the Nova Scotia McLeave commission.[31] Provinces argued that AECB jurisdiction was limited to national security and foreign policy issues.[32] In particular, the McLeave Commission expressed concerns about the lack of jurisprudence available on where the boundary between Nova Scotia environmental legislation and AECB regulation actually lay.[33] It encouraged using Nova Scotia environmental legislation to enter into agreements with Canada regarding the application of provincial legislation to uranium mines. It finally

---

Co. Ltd.. v. The Hydro-Electric Power Commission of Ontario, [1937] O.R. 796; *Fulton v. Energy Resources Conservation Board*, [1981] 1 S.C.R. 153.

[24] *The Constitution Act, 1867* (U.K.), 30 & 31 Vict., c. 3, s.92(10); and see *Northern Telecom Ltd. v. Communications Workers.,* [1980] 1 S.C.R. 115 at 132; *British Columbia Electric Ry. Co. Ltd. v. Canadian National Ry. Co.,* [1932] S.C.R. 161 at 170; *Nuclear Non-Proliferation Treaty,* [1968] 729 U.N.T.S. 161 [NPT].

[25] Sims, *supra* note 14 at 200.

[26] NPT, *supra* note 24.

[27] Atomic Energy Control Board, *Brief to the Royal Commission on the Health and Safety of Workers in Mines in Ontario*, (3 June 1975), as cited in Bayda, *Cuff Lake Board of Inquiry, Final Report*, (Saskatoon, May 31, 1978) at 124 [Bayda].

[28] *Pronto Uranium Mines Ltd. v. Ontario Labour Relations Board et al.; Algom Uranium Mines Ltd. V. Ontario Labour Relations Board et al.,* [1956] O.R. 862 (Ont. Sup. Ct.) [*Pronto Uranium*].

[29] Sims, *supra* note 14 at 54.

[30] Bayda, *supra* note 27; Stewart Elgie, "Canadian Regulation of Uranium Tailings Disposal: a Glowing Controversy" (1989) 8:2 UCLA J. Envtl. L. & Policy 145 at 149 [Elgie].

[31] R.J. McCleave, Nova Scotia, *Report of the Commission of Inquiry on Uranium*, (Halifax, 1985) [McCleave].

[32] Bayda, *supra* note 27 at 124-125. Also see Elgie, *supra* note 30.

[33] McCleave, *supra* note 31 at 19-23.

recommended that the province assert as much control as possible over uranium mines.[34] In that province the ban on uranium mining put in place in 1982 remains.

In 1976, the federal Law Reform Commission reported that the *Atomic Energy Control Act* was outdated in its regulation of uranium mining health and safety. In 1978, a bill proposing a revised version of the Act died on the order paper when Parliament prorogued.[35] Accordingly an expanded AECB role took some time to develop.

Further reforms to the AECB mandate in the 1980s eventually led to the creation of the Nuclear Safety Commission through new legislation in the late 1990s, with more extensive powers over health, safety and the environment. At the time these changes were proposed the AECB Chair noted that over time "the mandate of the AECB has evolved from one chiefly concerned with security to one that also focuses strongly on the control of the health, safety and environmental consequences of nuclear pursuits."[36] The Board also noted that the new legislation would better enable the new Commission to cooperate with the provinces.[37] Natural Resources Canada officials also commented at that time that the new legislation:[38]

> [R]efers directly to the environment as the concern of the nuclear regulator, something which the current statute does not do. It is not intended that the commission duplicate the responsibilities of federal and provincial environmental authorities. Rather, the reference is a reflection of appropriate public and political concern that the environment must be considered, along with people, in the regulatory activities of the commission.

The eventual development of extensive powers over health and environmental matters under the *Nuclear Safety and Control Act* would come later in the mandate of Canada's nuclear power regulator and was intended to ensure that the federal regulator could include public health and environmental considerations and cooperate with the provinces on these issues, rather than replace provincial involvement. The defining aspects of nuclear power jurisdiction federally are safety from major accidents, international aspects and security. The provinces all along have played a role in electricity generation regulation and environmental and safety issues at nuclear facilities.

---

[34] *Ibid.* at 32.
[35] Bruce Doern, *The Atomic Energy Control Board: an evaluation of regulatory and administrative processes and procedures* (Ottawa : Law Reform Commission of Canada, 1976); Auditor General, *supra* note 16 at 8.7.
[36] House Standing Committee on Natural Resources, E*vidence* (26 September 1996), online: <http://www.parl.gc.ca/35/Archives/committees352/natu/evidence/24_96-09-26/natu24_blk101.html>.
[37] *Ibid.*
[38] Senate Committee on Energy, the Environment and Natural Resources, Issue 15 - Evidence (11 March 1997), online: <http://www.parl.gc.ca/35/2/parlbus/commbus/senate/com-e/enrg-e/15eva-e.htm?Language=E&Parl=35&Ses=2&comm_id=5>.

Nuclear Safety and Control Act

The primary legislation in Canada regulating nuclear facilities is the *Nuclear Safety and Control Act (NSCA).*[39] The *NSCA* regulates nuclear substances, facilities, equipment and information across Canada. The Act has two main purposes that are set out in s.3 as follows:

> 3. The purpose of this Act is to provide for
>
> (a) the limitation, to a reasonable level and in a manner that is consistent with Canada's international obligations, of the risks to national security, the health and safety of persons and the environment that are associated with the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information; and
>
> (b) the implementation in Canada of measures to which Canada has agreed respecting international control of the development, production and use of nuclear energy, including the non-proliferation of nuclear weapons and nuclear explosive devices.

The *NSCA* regulates nuclear facilities and substances to a "reasonable level" that is consistent with international obligations, including protecting the health and safety of persons and the environment. The *NSCA* created the Canadian Nuclear Safety Commission (CNSC) as the successor to the Atomic Energy Control Board under the previous *Atomic Energy Control Act*.[40] The objects of the commission under s.9 of the Act are as follows:

> (a) to regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to
>
> (i) prevent unreasonable risk, to the environment and to the health and safety of persons, associated with that development, production, possession or use,
>
> (ii) prevent unreasonable risk to national security associated with that development, production, possession or use, and
>
> (iii) achieve conformity with measures of control and international obligations to which Canada has agreed; and
>
> (b) to disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the

[39] *Nuclear Safety and Control* Act, S.C., 1997, c.9 [*NSCA*].
[40] *Atomic Energy Control Act*, R.S., c.11.

> environment and on the health and safety of persons, of the development, production, possession and use referred to in paragraph (a).

Under the *NSCA*, the Commission is a non-expert, specialist tribunal appointed by federal Cabinet.[41] The CNSC employs a large number of technical and scientific staff to assist it in regulating nuclear facilities and substances; however, the commissioners themselves can come from any background.

Licensing of nuclear reactors – health, safety and environment

The most important regulatory provision for nuclear power facilities is s.24 of the Act.[42] This provision allows the CNSC to licence nuclear facilities. These licences may contain any term or condition that the CNSC considers necessary. Section 24(4) requires that no licence be issued unless in the opinion of the Commission the applicant "will make adequate provision for the protection of" health, safety and the environment. Section 26(e) prohibits anyone from preparing a site for, constructing, operating, modifying, decommissioning or abandoning a nuclear facility without a licence.

The *Class I Nuclear Facilities Regulations* define a Class IA nuclear facility to include nuclear power reactors.[43] The regulations require information on health, safety and environmental impacts be included in licence applications for all reactors.[44] This includes environmental protection policies and procedures, effluent monitoring and reporting and a public information program on environmental and health effects. Applications for licences to construct and operate a site must include information such as points of release and limits for any hazardous and nuclear substances;[45] policies, methods and procedures for operation; measures for mitigating environmental effects; and environmental release control measures.[46] However, there are no mandatory requirements or criteria relating to what is or is not permitted.

In the early 2000s, Canada shifted from the *Atomic Energy Control Act* regime to the *Nuclear Safety and Control Act* regime, resulting in explicit new statutory provisions allowing the CNSC to consider environmental protection in its licensing activities. The *NSCA* explicitly obliges the Commission to consider environmental protection. Section 9(a) notes that the objectives of the Commission include "to regulate . . . in order to (i) prevent unreasonable risk, to the environment. . ." Further, section 24(4) of the Act states: "No licence may be issued, renewed, amended or replaced unless, in the opinion of the Commission, the applicant …(b) will, in carrying out that activity, make adequate provision for the protection of the environment…" The CNSC has full discretion over what constitutes "adequate" environmental protection and what constitutes an "unreasonable risk" to the environment. To date, the CNSC does not have any

---

[41] *NSCA*, *supra* note 39, s.10(1).
[42] *Ibid*., s.24.
[43] *Class I Nuclear Facilities Regulations,* S.O.R. /2000-204, s.1.
[44] *Ibid.,* ss.3-4.
[45] *Ibid.,* s.5(j).
[46] *Ibid.,* ss.5-6.

published standards for the protection of non-human biota from radiation, thermal or physical impacts or releases of hazardous materials from nuclear power facilities.[47]

The CNSC's jurisdiction over nuclear waste comes from the *NSCA* and is articulated in CNSC regulatory documents.[48] While neither the *NSCA* nor its associated regulations define radioactive waste, CNSC Regulatory Policy P-290, *Managing Radioactive Waste*, asserts that radioactive waste is "any liquid, gaseous or solid material that contains a nuclear substance, as defined in section 2 of the *NSCA* and for which the owner of the material foresees no further use and the owner had declared as waste. By definition, a radioactive waste may contain non-radioactive constituents."

Waste disposal facilities are Class IB facilities under the *Class I Nuclear Facilities Regulations* if they are not on the site of an existing nuclear facility.[49] A waste facility is only a prescribed "nuclear facility" under s.19(a) of the *General Nuclear Safety and Control Regulations* if it is a facility managing, storing or disposing of waste containing radioactive nuclear substances and the nuclear waste contained in the facility is 10^{15} Bq or more. It is important to note that not all the waste must be nuclear substances, it need only "contain" them. This means that waste that is a mixture of nuclear substances and other types of waste (for example heavy metals) is included as is suggested by the guide. Likewise s.2 of the *Nuclear Safety and Control Act* treats a waste facility as a nuclear facility regulated by the Act where it is a facility for the disposal of a nuclear substance generated at another nuclear facility.[50]

It is important to note that a range of radioactive waste facilities are not licenced by the CNSC. To be regulated, a facility must be for management, storage or disposal and have waste meeting the radioactivity threshold or it must be a facility for the "disposal" of a nuclear substance generated at another nuclear facility. Other facilities containing naturally occurring radioactive substances are not regulated by the CNSC.

---

[47] In 2002-2003 the CNSC commissioned an Advisory Committee on Radiation Protection of Non-Human Biota. The CNSC eventually rejected the recommendations of that committee and instead relies on human radiation protection measures to protect the environment.

[48] CNSC Policy P-299, "Regulatory Fundamentals", CNSC Policy P-290, "Managing Radioactive Waste", and CNSC Regulatory Guide G-320, "Assessing the Long Term Safety of Radioactive Waste Management."

[49] *Supra,* note 43, s.1.

[50] *Ibid., General Nuclear Safety and Control Regulations,* SOR/2000-202, s.19; *NSCA, supra* note 39, s.2.

Legal and jurisdictional issues in nuclear regulation

Canadian constitutional framework

Jurisdiction over nuclear power, or indeed any other aspect of nuclear regulation, is not spelled out in the Canadian Constitution. Instead, federal jurisdiction over various aspects of nuclear power has been found to reside in other powers set out in sections 91 and 92 of the *Constitution Act, 1867*.[51] An activity like nuclear power development may have many aspects, some of which are federally regulated and some of which are provincially regulated.[52] This is referred to as the "double aspect doctrine." The history of Canadian constitutional law has been to allow for a fair amount of interplay and overlap between federal and provincial powers.[53] This is the case particularly with environmental regulation. The Supreme Court of Canada has generally supported broad overlap in environmental regulation, applying the double aspect doctrine generously where the purpose of legislation is environmental protection.[54] The Court commented in *Friends of the Oldman River*:[55]

> [T]hat the environment is not, as such, a subject matter of legislation under the Constitution Act, 1867. As it was put there, 'the Constitution Act, 1867 has not assigned the matter of "environment" *sui generis* to either the provinces or Parliament'. ... Rather, it is a diffuse subject that cuts across many different areas of constitutional responsibility, some federal, some provincial.

In *R. v. Hydro-Québec*, the Supreme Court of Canada provided the method of constitutional analysis for matters concerning the environment:[56]

> If a provision dealing with the environment is really aimed at promoting the dominant purpose of the statute or at addressing the impact of a statutory scheme, and the scheme itself is valid, then so is the provision.

In *Ontario v. Canadian Pacific Ltd.* the Supreme Court of Canada commented on the role of societal values and environmental issues, explaining that broad prohibitions on pollution in provincial legislation were constitutionally valid:[57]

---

[51] *The Constitution Act, 1867, supra* note 24.
[52] *Law Society of British Columbia v. Mangat*, 2001 SCC 67 at paras. 48-50 and *Hodge v. The Queen* (1883), 9 App. Cas. 117 at 130.
[53] *Citizens Insurance Co. of Canada v. Parsons* (1881), 7 App. Cas. 96 (P.C.); *General Motors of Canada Ltd. v. City National Leasing,* [1989] 1 S.C.R. 641 (CanLii) at 30; *Reference re Firearms Act (Can.)*, 2000 SCC 31, [2000] 1 S.C.R. 783; *Saumur v. City of Quebec*, 1953 CanLII 3 (S.C.C.), [1953] 2 S.C.R. 299; *Ward v. Canada (Attorney General)*, [2002] 1 S.C.R. 569, 2002 SCC 17 at para. 18.
[54] *114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town)*, 2001 SCC 40 [2001] 2 S.C.R. 241, at paras. 33-43.
[55] *Friends of the Oldman River Society v. Canada (Minister of Transport)*, [1992] 1 S.C.R. 3 at 63-65, cited in *Spraytech, ibid.* at para. 33.
[56] *R. v. Hydro-Québec,* [1997] 3 S.C.R. 21 at paras. 112-116.
[57] *Ontario v. Canadian Pacific Ltd.*, [1995] 2 S.C.R. 1031 at para. 55 (emphasis added). This statement was made in the context of discussing whether the provincial *Environmental Protection Act* was unconstitutionally vague. However, the SCC had earlier dismissed a division of powers argument,

> Societal values are highly relevant in assessing whether a general pollution prohibition, such as s. 13(1)(*a*) EPA, provides fair notice to citizens of prohibited conduct....Recent environmental disasters, such as the Love Canal, the Mississauga train derailment, the chemical spill at Bhopal, the Chernobyl nuclear accident, and the *Exxon Valdez* oil spill, have served as lightning rods for public attention and concern.

The Court particularly highlighted the need to address societal values in the context of nuclear power by noting the Chernobyl nuclear power reactor accident above. In the federal context, environmental regulation is typically sourced to either the criminal law power[58] or the national concern doctrine.[59] The national concern doctrine will be discussed more below. Nuclear has not yet been examined in relation to the criminal law power.[60]

There are three traditional grounds that support federal regulation of some aspects of nuclear energy. First, that federal legislation has declared nuclear energy to be a "work" for the general advantage of Canada under s. 92(10)(c) of the *Constitution Act, 1867*; second, the power over nuclear energy falls under the general power for "peace, order and good government" set out in the preamble to s.91 of the *Constitution Act, 1867;* and third, that it falls under matters of national defence.[61] Federal jurisdiction over nuclear energy regulation was first asserted in 1946 when the *Atomic Energy Control Act* was enacted, s.18 of which declared works and undertakings for the production, use and application of atomic energy to be federal works under s.92(10)(c) of the *Constitution Act, 1867*.[62] The modern version of this provision is found in the *Nuclear Safety and Control Act.*[63] Section 71 reads:

> Any work or undertaking constructed for the development, production or use of nuclear energy or for the mining, production, refinement, conversion, enrichment, processing, reprocessing, possession or use of a nuclear substance or for the production, possession or use of prescribed equipment or prescribed information is declared to be a work or undertaking for the general advantage of Canada.

Despite this, jurisdiction over nuclear power has primarily been found under the peace, order and good government (POGG) branch of federal jurisdiction set out in the preamble to s.91 of the *Constitution Act, 1867*.[64] This is governed by the "national concern" test explained by the

---

holding that the Act applied to federal undertakings; see: *Ontario v. Canadian Pacific Ltd*., [1995] 2 S.C.R. 1028, relying on a 19th Century railway undertaking case from the Privy Council.

[58] *Hydro-Quebec, supra* note 56.

[59] *R. v. Crown Zellerbach Canada Ltd.,* [1988] 1 S.C.R. 401 [*Crown Zellerbach*].

[60] *Hydro-Quebec*, *supra* note 56.

[61] *The Constitution Act,1867, supra* note 24, ss.91(7), 92(10)(c).

[62] Supra *note 12.* Section 18 reads: "All works and undertakings whether heretofore constructed or hereafter to be constructed,

(a) for the production, use and application of atomic energy,
(b) for research or investigation with respect to atomic energy, and
(c) for the production, refining, or treatment of prescribed substances,

are and each of them declared to be works or a work for the general advantage of Canada."

[63] *NSCA, supra* note 39, c. 9, s.71.

[64] *The Constitution Act, 1867*, *supra* note 24.

Supreme Court of Canada in *Crown Zellerbach.*[65] This national concern doctrine applies to matters which, although originally matters of a local or private nature in a province, have since, in the absence of national emergency, become matters of national concern. Under the *Crown Zellerbach* test, for a matter to qualify as a matter of national concern it must have a singleness, distinctiveness and indivisibility that clearly distinguishes it from matters of provincial concern and an impact on provincial jurisdiction that is acceptable, given the province's jurisdiction.[66]

In *Pronto Uranium Mines v. Ontario Labour Relations Board*, the Ontario Supreme Court in 1956 found that the production of nuclear energy was part of Canada's federal powers over POGG.[67] The Court commented that it was "essential in the national interest to control and supervise atomic energy, and also to enable Canada to participate in measures for the international control of that energy" for civil and military purposes.[68]

Over a decade later in *Denison Mines Ltd. v. Attorney-General of Canada,* the Ontario High Court again considered federal jurisdiction over the regulation of nuclear energy.[69] This time the Court relied on the creation of the International Atomic Energy Agency (IAEA) and the application of international safeguards to the production of that material. The High Court indicated that for the IAEA to have adequate control it was necessary to have federal jurisdiction.[70]

Finally, in the 1990s, the Supreme Court of Canada considered jurisdictional issues in nuclear power. In *Ontario Hydro v. Ontario (Labour Relations Board)*,[71] the Supreme Court of Canada examined whether labour relations at nuclear reactors were federal or provincial. It was argued that *Pronto Uranium* was not consistent with the modern application of the "national concern" branch of POGG as articulated by the court in *Crown Zellerbach;*[72] however, La Forest J., writing for the majority of the Court, felt that nuclear power facilities met all three branches of the "national concern" test:[73]

> There can surely be no doubt that the production, use and application of atomic energy constitute a matter of national concern. It is predominantly extra-provincial and international in character and implications, and possesses sufficiently distinct and separate characteristics to make it subject to Parliament's residual power. ...The strategic and security aspects of nuclear power in relation to national defence and the catastrophe and near catastrophe associated with its

---

[65] *Crown Zellerbach, supra* note 59; *Attorney General of Ontario v. Canada Temperance Federation*, [1946] A.C. 193 (P.C.) at 205-206.
[66] The actual wording is "a scale of impact on provincial jurisdiction that is reconcilable with the fundamental distribution of legislative power…"
[67] *Pronto Uranium, supra* note 28.
[68] *Ibid*.
[69] [1973] 1 O.R. 797 (H.C.), at 808; [1972] 32 D.L.R. (3d) 419.
[70] *Ibid.*
[71] *Ontario Hydro v. Ontario (Labour Relations Board),* [1993] 3 S.C.R. 327, 1993 CanLII 72 [*Ontario Hydro*].
[72] *Crown Zellerbach, supra* note 59.
[73] *Ontario Hydro, supra* note 71 at 61 (CanLII).

> peaceful use and development at Chernobyl and Three Mile Island bespeak its national character and uniqueness.

The Supreme Court was in full agreement that the production, use and application of nuclear energy is within federal jurisdiction under the POGG power.[74] In *Ontario Hydro,* the Court did not explain the extra-provincial or international character of nuclear power. Nor did it mention any particular "distinct and separate characteristics" that make it divisible from provincial jurisdiction. Perhaps most surprisingly, no mention was made of the provincial inability features of the *Crown Zellerbach* test. In determining that labour relations were part of the POGG jurisdiction over nuclear energy, the Court made reference primarily to the "inherent potential dangers" of nuclear power. This is presumably a reference to the potential for weapons uses and catastrophic accidents. Accordingly, it would appear to be these aspects of nuclear power that most clearly meet the "national concern" test, and which may form the "core" of the POGG power that the provinces cannot regulate.

With respect to the declaratory power under s.92(10)(c), the majority of the Court in *Ontario Hydro* confirmed that general provincial legislation applies to nuclear power facilities so long as it is not "in relation to" an "integral" part of nuclear power facilities as declared works.[75] The Court felt that labour relations were integral to maintaining safety at nuclear power facilities and were therefore outside provincial jurisdiction, a finding that was later reversed through legislation.[76]

Accordingly, while the Supreme Court of Canada made the labour relations aspect of nuclear energy production quite clear, it explained only a few principles over works generally which can be applied to determine when provincial regulation is allowed and when an aspect of nuclear power is so "integral" to nuclear power under POGG or nuclear power as a "work" that provincial laws do not apply. Most importantly, the decision in *Ontario Hydro* did not give much indication regarding what environmental, health and safety aspects, outside of catastrophic accident prevention, might be subject to provincial or concurrent federal-provincial regulation. Lamer C.J., in his concurring reasons, highlighted the need for federal jurisdiction to be broad

---

[74] This aspect of the decision is *obiter* meaning it does not bind future courts. What was before the court was only whether labour relations at nuclear power facilities owned by provincial utilities are within federal jurisdiction.

[75] *Ontario Hydro, supra* note 71 at 48 (CanLII).

[76] See *Ontario Hydro Nuclear Facilities Exclusion from Part I of the Canada Labour Code Regulations (Industrial Relations),* S.O.R./98-179. Other regulations exclude this facility from parts II and III as well. See also *Point Lepreau, New Brunswick Nuclear Facility Exclusion Regulations (Parts I, II and III of the Canada Labour Code and the Non-smokers' Health Act),* S.O.R./2008-76 and regulatory analysis in *Point Lepreau, New Brunswick Nuclear Facility Exclusion Regulations (Parts I, II and III of the Canada Labour Code and the Non-smokers' Health Act)*, P.C. 2008-547 March 11, 2008 C. Gaz 2008.II.542 and in *Ontario Hydro Nuclear Facilities Exclusion from Part I, II and II of the Canada Labour Code Regulations Registration, April 1, 1998, C. Gaz.* 1998.II indicating that federal control over labour relations in nuclear facilities added a "level of complexity" and that incorporation of provincial regulations would fix this by reversing the 1993 Supreme Court decision. Also note that in a subsequent decision, *Syndicat professionnel des ingénieurs d'Hydro-Québec v. Hydro-Québec,* [1995] 3 F.C. 3 (C.A.) the Federal Court of Appeal held that there was "no connection" between the activities of Hydro-Quebec at its Gentilly II nuclear station and the *Canada Labour Code* such that federal legislation over labour relations could apply to it.

enough in scope to encompass those items that are subject to close international monitoring by the IAEA.[77] IAEA regulations do not govern environmental protection but do speak to standards in human radiation protection.[78]

In *Energy Probe et al. v. Canada (Attorney General) et al.,* the Ontario Divisional Court upheld federal liability caps on nuclear power accidents based on federal jurisdiction over nuclear energy more generally.[79] The approach was similar to *Ontario Hydro* in that the basis for federal jurisdiction was clearly linked to safety, security and international agreements. The Court commented that "the consequences of a nuclear incident cannot be divorced from the development of atomic energy; they are as much a matter of national concern as the development aspects..."[80] In particular, the Court seemed concerned with the interprovincial aspects of a major nuclear accident, commenting that it was "of particular importance and of national concern to have a single compensation scheme."[81] Finally, the economic aspect of the liability scheme was "an integral part of the federal government's national concern to legislate for the economic consequences of a nuclear incident as a way to foster the 'promotion, use and application of atomic energy' for peaceful purposes."[82] The Court placed heavy weight on the historical context for the enactment of the *Nuclear Liability Act* (*NLA*), noting that it was necessary for economic reasons related to the promotion of nuclear power. In this, the Court clearly disagreed with the plaintiff's characterization of the *NLA* as relating primarily to liability within the province. Instead, it characterized the *NLA* as being "to facilitate the development of nuclear energy for peaceful purposes."[83] To the Court, the legislated liability scheme merely represented a logical approach to what would otherwise be a complex damages and negligence issue.[84]

The extent to which provincial laws apply to federal undertakings is a very complex area of the law. Core cases generally deal with ports, Indian reserves, airports and railways. This area of the law has evolved considerably since *Bell Canada (1988)*.[85] In the last five years, there have been four significant Supreme Court of Canada decisions considering *Bell Canada (1988).* In *Canadian Western Bank,* the Court set the stage for the modern approach.[86] In that case, the Court emphasized the continuation of the double aspect and incidental effects doctrines. It noted that the doctrines of paramountcy and interjurisdictional immunity would sometimes limit even minor effects of provincial laws on federal subjects.[87] It established that in order to consider the application of a provincial law to a federal work or undertaking it is important to understand the scope and core of the federal power.[88] Second, the pith and substance of the provincial law

---

[77] *Ontario Hydro, supra* note 71 per Lamer C.J. at 26 (CanLII).
[78] IAEA, Safety Series 115 "International Basic Safety Standards for Protection against Ionizing Radiation" (Vienna: IAEA, 1996).
[79] 1994 Can LII 7247 (O.N.S.C.).
[80] *Ibid.* at para. 56.
[81] *Ibid* at para. 60.
[82] *Ibid.* at para. 61.
[83] *Ibid.* at para. 34.
[84] *Ibid.* at paras. 196-205.
[85] *Bell Canada v. Quebec (Commission de la santé et de la sécurité du travail*), [1988] 1 S.C.R. 749.
[86] *Canadian Western Bank v. Alberta*, 2007 SCC 22, [2007] 2 S.C.R. 3 [*Canadian Western Bank*].
[87] *Ibid.* at paras. 25-32.
[88] *British Columbia (Attorney General) v. Lafarge Canada Inc*., [2007] 2 S.C.R. 86, 2007 SCC 23 at para. 118 [*Lafarge*]; also see Bastarache J.'s concurring reasons in *Canadian Western Bank, supra* note 86 at 117.

should be examined. Third, the degree to which the provincial law affects the core of the federal power (does it "impair" it?) should be considered. Finally, it should be considered whether there is an operational conflict between provincial and federal laws that will make it impossible to comply with both. The Supreme Court of Canada in *Canadian Western Bank* cited with approval the cases of *Ontario v. Canadian Pacific Ltd.*[89] and *R v. T.N.T. Canada Inc.*[90] which upheld the application of provincial environmental pollution laws to federal undertakings:[91]

> Of greater relevance to the present appeal is the line of cases that have applied provincial environmental law to federal entities engaged in activities regulated federally. In *Ontario v. Canadian Pacific*, the federally regulated railway was held to be subject to the Ontario *Environmental Protection Act* with respect to smoke it caused by burning dead grass along its right-of-way, despite the fact that the fires were set by the railway company to comply with the federal *Railway Act*. The Ontario Court of Appeal held that the principle of interjurisdictional immunity did not apply (see (1993), 13 O.R. (3d) 389), and an appeal to this Court was unanimously dismissed with brief reasons. In *TNT Canada*, an interprovincial trucking company was held bound by provincial regulations governing the carriage of PCB waste. As MacKinnon A.C.J.O. observed, at p. 303:
>
> In the same way that the province can regulate speed limits and the mechanical conditions of vehicles on the roads of the province for the protection and safety of other highway users, it can set conditions for the carriage of particular toxic substances within the province, provided that the conditions do not interfere in any substantial way with the carrier's general or particular carriage of goods, and are not in conflict either directly or indirectly with federal legislation in the field.

The Supreme Court of Canada signalled that provincial environmental laws can still apply to federal works and undertakings unless they conflict with federal laws. There are other cases in the transportation sector dealing with federally regulated airports and ports that take a different approach than the cases dealing with general "environmental" regulation.[92] These cases present considerable difficulty in applying provincial land use planning laws to federal undertakings. It is clear that particular transportation activities like shipping and aerodromes may be more susceptible to judicial policies seeking to avoid "wandering" airplanes and ships and this line of cases may not reflect the overall trend in this area of constitutional jurisdiction. On the other hand, they do signal that major federal projects may be difficult for provinces to plan for or regulate, not only from a land use perspective, but from any perspective that might impair the core of the federal power in question.[93]

---

[89] [1993] O.J. No. 1082 (Ont. C.A.); also see *Canadian National Railway v. Ontario*, (1992), 7 O.R. (3d) 97 at 101.
[90] (1986), 58 O.R. (2d) 410, 1 C.E.L.R. (N.S.); appeal allowed (1986), 58 O.R. (2d) 410 (C.A.).
[91] *Canadian Western Bank, supra* note 86 at para. 66.
[92] *Quebec (A.G.) v. Lacombe,* 2010 SCC 38; *Quebec (A.G.) v. Canadian Owners and Pilots Association,* 2010 SCC 39; *Construction Montcalm Inc. v. Minimum Wage Commission,* [1979] 1 S.C.R. 754; and *Lafarge, supra* note 88.
[93] For an example of this approach, see *New Brunswick (Environment) v. Canadian Pacific Ltd.,* 1993 CanLII 6910 (N.B. Q.B.) where the New Brunswick court held that the failure to register the abandonment

This approach creates difficulties because broad provincial legislation over land use planning and environmental matters has been upheld by lower courts for some time in relation to federal undertakings. For example, in the *Ontario v. Canadian Pacific* case cited by the Supreme Court of Canada with approval in *Canadian Western Bank,* the Ontario Divisional Court characterized the provincial law and its purpose and effects as broad environmental legislation, not directed at the regulation of federal undertakings.[94] A similar approach has been taken in cases dealing with the application of provincial law on Indian reserves[95] and an important Ontario Court of Appeal case on the application of zoning laws to ports[96] compared to the more restrictive line of cases respecting airports.[97]

The Ontario Court of Appeal took a similar approach in *R v. TNT Canada Inc.*[98] In that case, an interprovincial transportation operation was charged using regulations under the Ontario *Environmental Protection Act* for unlawfully "managing" PCB waste. TNT Canada Inc. was a large trucking company with operations across Canada. Its regular business and undertaking was comprised primarily of interprovincial and international motor transport. The company transported a PCB contaminated transformer from Regina to Ontario. The Ontario Court of Appeal held that the purpose of Ontario regulations was "to protect the health and safety of people in Ontario, and in that connection deals with the local environment."[99] The Court rejected arguments that the legislation was inapplicable to an interprovincial transportation undertaking, noting the absence of an operational conflict and stating that the provincial law "does not impair the respondent's basic functions in any degree."[100]

In the lower courts, cases like *Ontario v. Canadian Pacific* and *R. v. TNT* have ruled the day with respect to environmental regulation of federal works, including nuclear power. In *Edward v. Beaver Smith*, the New Brunswick Provincial Court held that an employee who released an ozone depleting substance from the Point Lepreau nuclear power facility in New Brunswick in the course of a fire safety training course could be charged under the provincial *Clean Air Act*.[101] In upholding the jurisdiction of the province, the court commented:[102]

---

of a railway undertaking for an environmental assessment under the New Brunswick *Clean Environment Act* constituted an intrusion into the management and operation of the railway. However, the court's explanation for this was very brief.

[94] See *Canadian National Railway Co. v. Ontario (Director under the Environmental Protection Act),* [1991] 3 O.R. (3d) 609 appeal to CA dismissed: [1992] O.J. No. 317 and leave to appeal dismissed; *Ontario v. Canadian Pacific Ltd.,* [1995] 2 S.C.R. 1028**: "**We are all of the view that the judgment *Canadian Pacific Railway Co. v. Corporation of the Parish of Notre Dame de Bonsecours*, [1899] A.C. 367, governs the first issue in this appeal and, accordingly, the appeal with respect to that ground fails, and the first constitutional question is answered in the affirmative."

[95] *Cardinal v. Attorney General of Alberta*, [1974] S.C.R. 695 at 703.

[96] *Hamilton Harbour Commissioners v. Hamilton (City)* (1978), 21 O.R. (2d) 459 at 491.

[97] At that time best typified by *Construction Montcalm Inc. v. Minimum Wage Commission,* [1979] 1 S.C.R. 754.

[98] *Supra* note 90.

[99] *Ibid.* at para.14.

[100] *Ibid.* at para.18.

[101] 2002 CanLII 45497 (N.B. P.C.).

[102] *Ibid*. at 9.

> It is unknown whether the conduct was "intimately related to the federal interests in nuclear energy" as a "matter completely in the daily control of an operating nuclear facility." The importance of safety in every industrial operation is clear. However, with nothing more than what is before me, it is difficult to discern if the conduct complained of falls only under federal interests in nuclear energy as contemplated by the "declared work" status of a nuclear plant.

The approach taken in *Edward v. Beaver Smith* is logical in that it requires the party challenging the jurisdiction of the province to present cogent evidence establishing that an intrusion into day-to-day management or other federal core competencies for a declared work is actually present.[103]

A complete analysis requires an extensive examination of the provincial law and its purpose preceding any discussion of how it might overlap with federal powers. Key to this middle-ground approach is examining the federal power in detail. In the context of nuclear power, examining the scope of federal jurisdiction and the core of federal power is necessary.

Summary: jurisdiction over the environmental aspects of nuclear power

The best approach to identifying the scope of federal interests in the regulation of the environmental aspects of nuclear power is one that is mindful of the historical context for its development, the nature of governing legislation and practical realities related to the development of electricity generally. This requires understanding the safety and security focus of nuclear treaties and that the regulatory aspects of nuclear power go beyond those related to preventing catastrophic accidents. Nuclear power regulation engages diverse subjects such as environmental issues, electricity generation and economic regulation that have diverse constitutional dimensions.

Canadian courts have recognized that federal powers related to nuclear matters are rooted in safety from large accidents and security issues by frequently identifying the national defence context of nuclear power development, security implications under international treaties and the potential for catastrophic accidents.[104] Some Canadian courts have made special note of safety and security as the grounding for federal powers over nuclear regulation, which suggests that these areas, rather than environmental regulation *per se*, make up the core of those powers. For other federal works and undertakings, environmental regulation has been treated as its own category of subject matter for division of powers purposes, and broad environmental regulations have been applied to federal works without controversy in many cases.

All of this suggests that the provinces have wide scope to regulate matters that fall outside major safety, defence and security issues, particularly those that are not regulated by international treaties. Federal jurisdiction over the environment in the nuclear context may be broadly

---

[103] A more recent example of this more evidence-based approach to determining the scope of federal powers is found in *Directeur des poursuites criminelles et pénales c. Alcan inc*., 2009 QCCQ 1638 (CanLII).

[104] References to the inherently dangerous character of nuclear power, and particularly the Chernobyl and Three Mile Island accidents are found in *Energy Probe, supra* note 79 and *Ontario Hydro*, *supra* note 71.

concurrent with provincial jurisdiction, as it has been in most cases in Canada involving federal works. Provincial environmental regulation, public health regulation and electricity planning are unlikely to meet the national concern test in *Crown Zellerbach* and will have varying, if not often tenuous, connections to the status of nuclear power facilities as declared works. The decision whether or not to build a nuclear facility could also fall under provincial authority through the operation of s.92A of the *Constitution Act, 1867,* which gives the provinces authority to manage the electricity system and sites for its generation. The case for provincial jurisdiction will be stronger where provincial powers are grounded in clear provincial subject areas like property protection or its authority over regulation of the electricity system under provincial statutes.

Although the mandate of the Canadian Nuclear Safety Commission (CNSC) has expanded to health and environmental matters under the *NSCA* scheme since the early days of nuclear regulation, the core mandate of the CNSC and most of its regulatory functions continue to be dedicated to safety in the context of catastrophic accidents and security. This reflects the state of international nuclear regulation of safety and security and the fact that the purpose of the *NSCA* is largely to ensure compliance with international standards. Consistent with *Ontario Hydro,* the *NSCA* covers the development and production of nuclear energy and the production and possession of nuclear substances and prescribed equipment and information. The CNSC's mandate is primarily exercised in relation to radiation protection and not more generally in relation to health and environmental protection.

This does not mean that *NSCA* jurisdiction to regulate health and environment is outside federal jurisdiction. However, it does mean that some of the powers under the *NSCA* are not necessarily exclusive. Regulation of environmental issues like water use, routine toxic and radioactive releases and waste management is difficult to justify under either POGG, using the test in *Crown Zellerbach* such as provincial divisibility, or under the federal power over works and undertakings. Likewise, the regime for federal regulation of environmental matters under *R v. Hydro Quebec,* which relies on a criminal law scheme, seems inappropriate where the regulations require little more than taking of "appropriate measures." Such measures, if put in place by provinces, should only be struck where they would conflict with federal safety and security measures and policies in the sense that dual compliance is not possible.

Provincial legislation in relation to nuclear regulation

Alberta

Alberta regulates radiation safety under the *Radiation Protection Act* (*RPA)*.[105] The *RPA* regulates radiation sources, which are defined as devices or substances that emit radiation other than those regulated by the *NSCA*.

The *Environmental Protection and Enhancement Act* (*EPEA*) regulates substance releases, including radioactivity, into the environment.[106] The *Activities Designation Regulation*[107] defines a "power plant" as a plant that produces steam or thermal electrical power and has a rated production output of greater than one megawatt under peak load.[108] The construction, operation or reclamation of a power plant requires an approval.[109] Conditions can be included in the approval and the approval is subject to public comment and appeal by directly affected persons. The *Substance Release Regulation* does not contain limits or codes of practice for release of radioactive substances from power plants.[110] The *Release Reporting Regulation* governs reporting of releases of any substances that may have an adverse effect under *EPEA*.[111] Radioactive materials that fall within the Class 7 dangerous goods classification under the federal *Transportation of Dangerous Goods Act* are exempt from the *EPEA Release Reporting Regulation* and *EPEA* reporting requirements.[112]

The *Waste Control Regulation* under *EPEA* exempts any waste (whether radioactive or not) "regulated under" *NSCA* from the definition of "hazardous waste."[113] The definition of "waste" under the regulation does not mention radioactive waste but would appear to be broad enough to include it.[114]

There is an existing radioactive waste site in Edmonton, Alberta, that stores waste from the University of Alberta research reactor: the Cloverbar Hazardous Waste Management Facility. The approval for this site requires sample record keeping and methodology for solid waste, water and wastewater, and leaching.[115] It requires that the approval holder "shall not release a substance or cause to be released a substance that causes or may cause impairment, degradation or alteration of the quality of natural resources"[116] into the air as well as a requirement that the

---

[105] *Radiation Protection Act,* R.S.A. 2000, c. R-2.
[106] *Environmental Protection and Enhancement Act*, R.S.A. 2000, c. E-12, s.1(mmm).
[107] Alta. Reg. 276/2003.
[108] *Ibid*., s. 2(1)(vv).
[109] *Ibid*.; also see s.5(1).
[110] *Substance Release Regulation*, Alta. Reg. 124/1993.
[111] Alta. Reg. 117/1993.
[112] *Ibid.,* s. 2(b).
[113] *Waste Control Regulation*, Alta. Reg. 192/1996.
[114] *Ibid.;* under s.1(ll), "waste" means any solid or liquid material or product or combination of them that is intended to be treated or disposed of or that is intended to be stored and then treated or disposed of, but does not include recyclables.
[115] Alberta Environment, Cloverbar Hazardous Waste Management Facility approval under the *Environmental Protection and Enhancement Act*, (2006),No. 225631-00-00 s. 2.2-2.3.
[116] *Ibid*., 4.1.2.

approval holder "shall not release any substances from the facility to the surrounding watershed."[117] It sets limits for overall radionuclide concentration including specific radionuclides (^{3}H, ^{14}C and ^{125}I) in kBq/L and provides that the approval holder may only release industrial wastewater if it is less than a total for all radionuclides of 70 kBq/L. It also requires a groundwater monitoring program, quarterly monitoring reports and other conditions. The Alberta approval for another waste management facility containing radioactive waste, the Ellerslie approval, requires groundwater monitoring for both radionuclides and non- radioactive dissolved metals, pH, conductivity and volatile organic compounds.[118] Alberta has exercised its jurisdiction over both radioactive and hazardous releases from nuclear facilities in Alberta, even if it has not done so strictly on the basis that it is "hazardous waste." For comparative purposes, the CNSC Waste Nuclear Substance License for Cloverbar requires only annual reporting and contains within its terms no specific conditions or derived release limits.[119]

The *Water Act* in Alberta requires a licence for water diversion and works that divert water.[120] Water use for cooling in CANDU nuclear reactors is considerable and is discussed in more detail later in this report. The provisions of the *Water Act* would generally apply to require licences for water use by nuclear power facilities.

Electricity system regulation and planning

In Alberta, electricity planning is limited to transmission planning and transmission and generation approvals. Generation has been privatized and is initiated by private operators. Electricity generation approvals are under the jurisdiction of the Alberta Utilities Commission (AUC). The AUC reviews needs assessments prepared by the Alberta Electric System Operator (AESO) and reviews individual transmission infrastructure and generation applications. These approvals are governed by the *Alberta Utilities Commission Act* (*AUCA*), *Electric Utilities Act* (*EUA*) and *Hydro and Electric Energy Act* (*HEEA*).[121] The *HEEA* defines "power plant" as a facility that generates and gathers electric energy from any source. Sections 5(1) and 19(1) of the *HEEA* allow the AUC to make regulations governing power plant approvals. This includes conditions 6uyand measures for the protection of life, property and wildlife. Under the *EUA*, all generating units that have a maximum capability of 5 megawatts or greater are required to offer their energy into the power pool, which would include nuclear power. Under the *EUA* a "generating unit" means the component of a power plant that produces, from any source, electric energy and ancillary services, and includes some associated facilities. A generator will apply to the AUC for approval to construct a generating unit under s.11 of the *HEEA*. The AUC has a mandate to determine whether the approval of a generating unit is in the public interest under s.17 of the *AUCA*, having regard to the social and economic effects of the plant and its effects on the environment.

---

[117] *Ibid*., 4.2.1.
[118] Alberta Environment, Ellerslie Hazardous Waste Management Facility Approval under the *Environmental Protection and Enhancement Act,* (2009) No. 20370-02-00 at 6.
[119] CNSC, Waste Nuclear Substance Licence WNSL-W2-3701.0/2017 University of Alberta Cloverbar (2007).
[120] R.S.A. 2000, c.W-3.
[121] *Alberta Utilities Commission Act,* S.A. 2007, c. A-37.2; *Electric Utilities Act,* S.A. 2003, c. E-5.1; *Hydro and Electric Energy Act,* R.S.A. 2000, c. H-16.

Since these pieces of legislation define generation in terms of electrical energy from any source, nuclear would be subject to the public interest determination of the AUC, including any environmental conditions. Explicitly, the AUC has jurisdiction to impose conditions in the public interest and there is no reason this should not include evaluations of radiation protection, hazardous waste and protection of the physical and chemical aspects of the environment. Under the AUC's legislation, Alberta has the explicit ability to determine whether or not to build a nuclear reactor facility. Moreover, the AUC has the power to create rules that could govern approval requirements for these facilities. Section 76(1)(a) of the *AUCA* allows the AUC to make rules governing any matter or person within its jurisdiction, including procedures and processes applicable to locating, building, constructing and operating facilities or infrastructure over which the AUC has jurisdiction. Section 77 also allows the creation of standards, guidelines and codes of practice.

The AUC is bound by land use planning decisions made under the *Alberta Land Stewardship Act*, which permits Cabinet to create regional plans.[122] The most developed plan to date is the Lower Athabasca Plan, which is not finished. However, the advice to government on this plan included advice to: "[e]xplore and capitalize on synergies available through integration of energy sources (e.g., geothermal, hydropower, and potentially nuclear) in the development of oil sands."[123]

Saskatchewan

Radiation protection

The Saskatchewan *Radiation Health and Safety Act, 1985* only regulates ionizing radiation equipment or installations, not substances or facilities releasing radiation.[124] Saskatchewan's *Environmental Management and Protection Act, 2002* (*EMPA*) regulates adverse effects from discharges into the environment. It requires authorizations for discharges of a substance into the environment in an amount, concentration, level or rate of release that may cause an adverse effect.[125] This legislation also creates a duty to report discharges and take remedial measures.[126] It also regulates adverse effects on water quality.[127] The *Waste Dangerous Goods Regulations* under *EMPA* do not apply to radioactive materials under an *Atomic Energy Control Act* licence.[128] *Water Regulations* under *EMPA* contain radiological screening parameters (Bq/L) and maximum acceptable concentrations for uranium (mg/L) that apply to waterworks for human consumption.[129] The *Saskatchewan Watershed Authority Act, 2005* requires authorization for the

---

[122] S.A. 2009, c.A-26.8.
[123] Lower Athabasca Regional Advisory Council, "Advice to the Government of Alberta Regarding a Vision for the Lower Athabasca Region" (2010) online: <http://landuse.alberta.ca/RegionalPlans/LowerAthabasca/documents/LARP-VisionForLowerAthabascaRegion-Aug2010.pdf>.
[124] S.S. 1984-85-86, c. R-1.1.
[125] *Environmental Management and Protection Act*, *2002*, S.S. 2002, c. E-10.21, s. 4(1) [*EMPA*].
[126] *Ibid*., ss. 5, 7.
[127] *Ibid*., s. 16.
[128] *Hazardous Substances and Waste Dangerous Goods Regulations*, RRS c. E-10.2 Reg 3, s. 5(1)(c).
[129] *Water Regulations,* R.R.S., c. E-10.21, Reg 1 ss. 31 and 34(1).

diversion of water and construction of works for non-domestic purposes in Saskatchewan.[130] Authorization for a nuclear power facility would be an industrial use under the regulations, which define industrial use to include thermal electricity generation.[131]

The *Environmental Spill Control Regulations* require reporting of radiological spills in any amount.[132] The *Mineral Industry Environmental Protection Regulations, 1996* also provide mean concentrations (in mg/L) for uranium, thorium and radon for liquid effluent.[133] This demonstrates that Saskatchewan has already exercised some authority to regulate radioactive substances, including those applicable in the nuclear power context. However, in the case of these regulations, it has done so using chemical concentrations (mg/L) rather than radiation-related parameters (Bq/L).

The *Clean Air Act* regulates air contaminants and pollutants, defined as the presence of contaminants in concentrations that are likely to be injurious to health, safety or property.[134] Contaminants include solids, liquids and gases.[135] Although this does not expressly include radionuclides or radiation, radionuclides are matter that can be present in these forms and can contribute to air pollution.

Saskatchewan has also extensively regulated existing nuclear facilities in that province, including those that are also licensed by federal regulators. For example, in Saskatchewan, the *Hazardous Substances and Waste Dangerous Goods Regulations*[136] exempt radioactive materials regulated by the *Atomic Energy Control Board Act*. It is unclear to what extent Saskatchewan might regulate non-radioactive hazardous material in CNSC waste facilities. The Saskatchewan *Public Health Act*, *1994* defines a "serious public health threat" to include the presence or the threat of the presence of radioactive material if it poses a significant risk to the health of many people.[137]

Saskatchewan issues operating approvals to uranium mines under the *Clean Air Act* and the *Environmental Management and Protection Act* and regulations.[138] In addition to this, Saskatchewan regulates various aspects of uranium mine operations by making surface rights conditional on meeting occupational health and other standards. Environmental approvals authorize the operation of air pollution equipment, pollutant control facilities, landfills, sewage and waste disposal. In most respects this approval is similar in terms of monitoring, reporting and other criteria to the Alberta approval for the Cloverbar Waste Facility. In addition, Saskatchewan uranium mine approvals contain requirements for state of environment reporting and contingency plans. These approvals govern air discharges of radionuclides including

---

[130] S.S. 2005, c. S-35.03.
[131] *Saskatchewan Watershed Authority Regulations*, R.S.S., c.S-35.03, Reg. 1, s. 4.
[132] *Environmental Spill Control Regulations*, R.S.S., c. D-14, Reg. 1.
[133] R.R.S., c. E-10.2, Reg. 7.
[134] S.S. 1986-87-88, c. C-12.1.
[135] *Ibid*., s .2.
[136] *Supra* note 128, s. 5(1)(c).
[137] *Public Health Act*, *1994*, S.S. 1994, c. P-37.1, s. 2 (jj.1).; also see *Public Health Act,* R.S.A. 2000, c.P-37, s. 1(hh.1)(v) with a similar definition of "public health emergency."
[138] Saskatchewan Ministry of the Environment, Approval to Operate AREVA McLean Lake Operation (PO-10-110).

uranium, thorium and radon (in mg/L).[139] There are also pit dewatering water quality objectives for radionuclides and water quality parameters listed for radionuclides.[140] The scope of existing approvals in Saskatchewan confirms that the province has a role in regulating a wide variety of technological issues and control of releases of radionuclides into the environment. In the nuclear power context these same regulatory powers could be either applied or used to pass provincial regulations for emissions controls and radioactive release limits at nuclear power facilities.

However, Saskatchewan does not issue approvals to the research reactor at the Saskatchewan Research Council on the basis that it does not release emissions.[141] There also do not appear to be any approvals related to groundwater activation from interactions with the reactor pool.[142] The annual compliance report for this reactor notes a variety of radioactive noble gases present in the reactor and indicates that "head space purge" activities release radionuclides into the environment.[143] This leaves unclear the extent to which Saskatchewan purports to regulate radioactive emissions other than those from uranium mines. A personal communication with Saskatchewan Environment indicated that Saskatchewan would regulate a nuclear reactor that released emissions under provincial legislation.[144]

Electricity regulation

The Saskatchewan electricity system is controlled by the Power Corporation: SaskPower under the *Power Corporation Act.*[145] Section 8(1)(a) of the *Power Corporation Act* gives SaskPower oversight of "the generation, transmission, distribution, purchase, sale and supply of electrical energy." SaskPower's board of directors answers to the responsible Minister. SaskPower has the legislative authority to oversee decisions regarding prospective power sources, which includes power system planning decisions. As with other provincial governments, Saskatchewan, through SaskPower and the Minister, has the authority to determine whether or not to build nuclear power facilities within the province.[146] SaskPower tables electricity system planning recommendations with the Crown and Central Agencies Committee of the Saskatchewan Legislative Assembly, which then issues a report.[147] In December, 2009, the Energy and Resources Minister accepted recommendations from public consultations that "additional information and consultation are required, particularly as they relate to any future decision to pursue nuclear power in Saskatchewan." However, the Minister also directed

---

[139] *Ibid*., Schedule 1, Schedule 2.
[140] *Ibid*., Schedule 3.
[141] This is so despite the fact that this reactor releases radioactive gases such as argon-41, xenon-133 and xenon-135; SRC "SLOWPOKE-2 Facility Operating Manual" (undated) at 30-31. This document was accessed through a provincial freedom of information request, however significant portions of this manual relating to effluents and emissions were redacted including the locations of radiation monitors and the nature of the substances released.
[142] *Ibid*. at 31-33.
[143] [author redacted] Saskatchewan Research Council, Environment and Forestry Division. *Limited Report: SRC SLOWPOKE 2 Facility Annual Compliance Report, April 1 2009- March 31, 2010* (SRC Publication No. 12736-1E10) (Saskatoon: SRC June 2010).
[144] E-mail from Tim Moulding, Saskatchewan Ministry of Environment, to Laura Bowman (28 February, 2011).
[145] *Power Corporation Act*, R.S.S. 1978, c. P-19.
[146] *Ibid*., s. 8(1).
[147] *Ibid.*

SaskPower to "continue including nuclear power in the range of energy options available for additional baseload generation capacity in the medium and long term after 2020."[148] There are no legal requirements for any regulatory board to approve a nuclear power facility from an electricity planning point of view.

The Saskatchewan *Planning and Development Act* permits Cabinet to make regulations adopting provincial land use policies and statements of provincial interest.[149] Official community plans are also subject to approval by the Minister. Section 62 requires development permits where required by a zoning bylaw. Under the Act "development" means, except in section 194, the carrying out of any building, engineering, mining or other operations in, on or over land or the making of any material change in the use or intensity of the use of any building or land. Nuclear power or other electricity generation projects are "public works," which is defined as "systems for the production, distribution or transmission of electricity."[150] Official community plans can address public works;[151] however, Cabinet has the power to exempt some public works.[152] Accordingly, the Act gives powers to municipalities and the Minister to plan for nuclear power infrastructure and gives some approval authority, subject to exemption by Cabinet.

Ontario

The Ontario *Environmental Protection Act* prohibits the release of harmful substances into air or water without a permit unless the releases are in accordance with the regulations.[153] As in most other provinces, this includes a prohibition on discharging a contaminant into the natural environment if the discharge causes or may cause an adverse effect.[154] It also requires approvals for waste management sites.[155] Under this Act, nuclear power is regulated under the *Effluent Monitoring And Effluent Limits — Electric Power Generation Sector Regulation.*[156] This regulation provides monitoring and effluent limits for specified non-radioactive wastes released, even when they are released from a radioactive waste handling facility. The regulated parameters include zinc, phosphorus, suspended solids, iron, oil and grease for all three nuclear generating stations in Ontario. However, there are no effluent limits or monitoring requirements for lead, mercury, ammonia, sulphuric acid, hydrazine or other toxic substances that are released from nuclear power facilities in Ontario. Certificates for air emissions are issued only for non-radioactive substances released by Ontario nuclear facilities.[157] Nuclear power facilities in Ontario are required to obtain permits to take water and approvals for sewage works under the *Ontario Water Resources Act.*[158]

---

[148] Saskatchewan, News Release, "Government Announces Strategic Direction On Uranium Development" (December 17, 2009), online: <http://www.gov.sk.ca/news?newsId=4c9d1ce3-a344-4b4e-a0f5-a1e02670cbea>.
[149] *Planning and Development Act*, S.S. 2007, c. P-13.2.
[150] *Ibid*., s. 1.
[151] *Ibid*., s. 102.
[152] *Ibid*., s. 232.
[153] *Environmental Protection Act*, R.S.O. 1990, c. E.19, s.6, s.9, s.14.
[154] *Ibid.,* s. 14.
[155] *Ibid.,* s. 25.
[156] O. Reg. 215/95.
[157] Daniel Pankov (Ontario Ministry of the Environment) letter to Alan R. Graham (Joint Review Panel, Darlington New Nuclear Power Plant Project) dated June 15, 2010.
[158] R.S.O. 1990, c. O-40, s. 52, 53.

Although provincial legislation would appear to apply on its face to waste generated from nuclear facilities as non-hazardous waste, Ontario does not issue approvals for waste facilities licenced by the CNSC.[159] Requests for copies of environmental approvals for nuclear generating stations and related waste facilities in Ontario were denied by Ontario Ministry of the Environment representatives.

New Brunswick

As mentioned in the jurisdictional chapter, New Brunswick has successfully enforced pollution legislation against the Point Lepreau Nuclear Generation Station (NGS) for releases of non-radioactive hazardous materials, in that case ozone.[160] New Brunswick has passed regulations under the *Community Planning Act* to regulate development around the Point Lepreau NGS.[161] Under the *Clean Environment Act,* the *Water Quality Regulation* defines "water pollution" to include the addition of a radioactive substance, requiring approval.[162] New Brunswick has passed other regulations related to the refurbishment of Point Lepreau, including regulations under the *Industrial Relations Act*[163] and the *Boiler and Pressure Vessel Act*,[164] the latter of which prescribes some American and CNSC reactor design standards.

Quebec

The Quebec *Environment Quality Act* includes radioactive substances within the definition of "hazardous material";[165] however, substances regulated by the CNSC are exempted.[166] Radiation is included in the definition of a "contaminant" in the Act.[167] Section 90 provides that "[t]he Minister shall have the duty to supervise and control sources of radiation, plasmas, fields, material waves, pressure and any other energy vector." The Gentilly nuclear generating station in Quebec is controlled by Hydro-Québec under the *Hydro-Québec Act.*[168] Quebec has exercised its jurisdiction across the nuclear power sector by requiring full public hearings for dry fuel storage at the Gentilly reactor as of 1994.[169] The current Quebec energy policy is to "limit the role played by nuclear energy in Québec by developing hydroelectric resources."[170]

---

[159] Canadian Nuclear Safety Commission, *Record of Proceedings Including Reasons For Decision in the Matter of Atomic Energy of Canada Limited* (Ottawa: Canadian Nuclear Safety Commission, 2009), paras. 23-24.
[160] *Edward v. Beaver Smith*, *supra* note 101.
[161] *Point Lepreau Basic Planning Statement Adoption Regulation,* N.B. Reg. 83-218 and the *Point Lepreau Site Regulation*, N.B. Reg. 84-82.
[162] N.B. Reg. 82-126, s. 2(1), s. 3.
[163] *Major Projects Regulation*, N.B. Reg. 90-51, s.7 designating the refurbishment of Point Lepreau as a major project under the Act, except for the activities of the New Brunswick Power Nuclear Corporation.
[164] *Boiler and Pressure Vessel Act*, S.N.B. 1976, c. B-7.1; *Standards Regulation*, N.B. Reg. 84-177; and *Boiler and Pressure Vessel Code*, N.B. Reg. 84-174.
[165] *Environment Quality Act*, R.S.Q., c. Q-2, s.1(21).
[166] *Regulation respecting hazardous materials*, R.R.Q., c. Q. 2, r. 32, s. 2(13).
[167] *Supra* note 165, s. 1(5).
[168] *Hydro-Québec Act*, R.S.Q., c. H-5.
[169] Quebec, Bureau d'audiences publiques sur l'environnement, "Dry Storage of Irradiated Nuclear Fuel from the Gentilly 2 Power Station" (1994).
[170] Government of Quebec, "Highlights on Energy: Hydroelectricity", online: <http://www.mrnf.gouv.qc.ca/english/energy/hydroelectricity/index.jsp>.

Summary

Both Saskatchewan and Alberta, as well as other provinces, already regulate nuclear facilities within their jurisdiction for the protection of health and the environment from pollution. Most have already have exercised powers to regulate radionuclides in drinking water from a public health standpoint. Both consider radioactive substances explicitly within their jurisdiction under public health and environmental legislation. Across Canada the degree of regulation varies but appears to be more widely exercised in Quebec than Ontario, with New Brunswick somewhere in the middle.

Discharge regulation varies widely, sometimes including only hazardous materials that are not radioactive and sometimes including a wide range of materials. Discharge regulations do not appear to have been applied to research reactors in the prairies. Alberta has regulated radioactive releases from waste management facilities and Saskatchewan has regulated radioactive releases from uranium mines. In Saskatchewan, only chemical concentration parameters have been included in the regulations for some radioactive releases, making it unclear if Saskatchewan would also regulate radioactivity if a nuclear power facility was built in that province.

All provinces have powers to regulate nuclear power reactors through both electricity approval processes and land use planning decisions. The example of the Cloverbar Waste Management facility in Alberta and the Quebec approach to waste management at Gentilly shows that there is a strong role for provinces to regulate pollution from nuclear power and associated waste management facilities. In addition to pollution regulation, both Alberta and Saskatchewan have broad powers to make decisions about their electricity systems. These powers can be utilized to help determine risk acceptability of nuclear power in comparison to alternative forms of electricity.

Environmental Assessment (EA)

The *Convention on Nuclear Safety* requires that parties establish procedures "for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment."[171] Environmental assessments of nuclear reactors are conducted federally under the *Canadian Environmental Assessment Act* (*CEAA*).[172]

Part III of the *Inclusion List Regulations* outlines specific nuclear facility activities that trigger an environmental assessment. An environmental assessment is triggered, for example, when abandoning, disposing or releasing a nuclear substance into the environment.[173] The *Law List Regulations* also provide that an environmental assessment is required for any action taken by the CNSC under the *Nuclear Safety and Control Act* in respect of the issuance or amendment of a licence under s. 24(2) and 37(2).[174] The renewal of an operating licence is not included in the *Law List Regulations* and is not an assessment trigger unless there are changes to the licence. Part 4 of the *Exclusion List Regulations* exempts certain activities from assessment, including modifications to a nuclear facility where that facility has already been assessed and proposed modification of an essential system within a nuclear facility that is not near a water body.[175]

Where an assessment is triggered, a screening level assessment is required unless the project is listed in the *Comprehensive Study List Regulations.*[176] Part 6 of those regulations provide for comprehensive studies of the proposed construction, decommissioning, abandonment, or an expansion increasing production capacity more than 35 per cent, of nuclear power reactors that produce more than 25 MW of thermal energy;[177] and of some off-site waste storage and disposal facilities for nuclear substances.[178] Under recent amendments to *CEAA*, the CNSC is the lead authority for all comprehensive federal assessments of nuclear facilities.[179]

The purposes of *CEAA* are, among other things, to ensure that projects are considered in a careful and precautionary manner and encourage federal authorities to promote sustainable development and take actions to achieve or maintain a healthy environment.[180] Section 16 of *CEAA* requires that every screening or comprehensive study of a project include a consideration of cumulative effects, mitigation measures and any other matter relevant to the project, such as need for and alternatives to the project. For comprehensive studies, alternatives to the project are specifically required.[181]

---

[171] *Convention on Nuclear Safety,* 17 June 1994, 33 I.L.M. 1514 (entered into force on 24 October 1996).
[172] *Canadian Environmental Assessment Act*, S.C. 1992, c. 37.
[173] S.O.R./94-637.
[174] *Law List Regulations,* S.O.R./94-636.
[175] *Exclusion List Regulations,* 2007, S.O.R./2007-108.
[176] S.O.R./94-638.
[177] *Ibid.,* s. 19(d).
[178] *Ibid.,* s. 19(g).
[179] *Jobs and Economic Growth Act,* S.C. 2010, c. 12, Part 20.
[180] *CEAA*, *supra* note 172, s. 4.
[181] *Ibid.,* s. 16(1) and 16(2).

These requirements were examined in *Inverhuron & District Ratepayers Ass. v. Canada (Minister of The Environment)*, in which a ratepayers association challenged a CNSC decision that used the linear no-threshold model.[182] They argued that all radiation impacts were "significant adverse environmental effects" under *CEAA*. However, the CNSC successfully argued before the Federal Court of Appeal that in conducting environmental assessments the CNSC may find that a radiological impact that is below the 1 mSv limit is not "significant" for the purposes of the *CEAA* assessment. The ratepayers group unsuccessfully tried to equate the "as low as reasonably achievable standard" (discussed in more detail on page 37 of this report) and the requirements of s. 16 of *CEAA* and argued that the CNSC must adopt the alternative that had the least environmental impacts. The Federal Court of Appeal rejected this, holding that it was open to the CNSC to adopt any one of the alternatives that had no significant adverse environmental effects. The Court did not consider the precautionary principle in this case because it was not included in the notice of appeal.

The CNSC has a pattern in terms of how it addresses alternatives in environmental assessments.[183] In many cases, CNSC staff have apparently misunderstood the requirements of s. 16 of *CEAA*. For example, in one environmental assessment the CNSC determined:[184]

> The Commission asked Cameco if it would consider alternatives to the project including moving to Ward 2 as suggested by some intervenors. Cameco responded that under the Comprehensive Study there was a requirement to consider alternative means of carrying out the project, not alternatives to the project. CNSC staff added that alternatives to the project would be considered a new project and pointed out that the required alternative means to carry out the project had to be also considered feasible from Cameco's perspective.

This is a strained interpretation of s. 16 by CNSC staff. In an operational policy statement the Canadian Environmental Assessment Agency commented on the difference between "alternative means" and "alternatives to" in comprehensive study assessments.[185] Under *CEAA*, alternatives to a project are not themselves new projects, but rather are identified in the course of a project assessment as alternative ways of meeting a project need, not simply alternative means of carrying out the project. While the inclusion of alternatives to the project in an environmental assessment under *CEAA* is discretionary, the above reasoning does not clarify whether and how the Commission has exercised that discretion and for what reason. The analysis above is also inconsistent with the CNSC staff review procedure policy document released by the CNSC for alternatives to and alternative means in the nuclear power context, which duplicates the operational policy statement described above.[186] For the review of the new Darlington nuclear

---

[182] 2001 FCA 203 (CanLII).
[183] CNSC, *Record of Proceedings and Reasons for Decision in the matter of Cameco Corporation, Environmental Assessment Track Report Regarding Cameco Corporation's Vision 2010 Project for the Conversion Facility in Port Hope, Ontario* (6 November 2008) at 10, para. 147.
[184] *Ibid.*
[185] Canadian Environmental Assessment Agency, Operational Policy Statement, "Addressing 'need for', 'purpose of' , 'alternatives to" and 'alternative means' under CEAA" (2007), online: <http://www.ceaa.gc.ca/default.asp?lang=En&n=5C072E13-1>.
[186] CNSC, "Staff Review Procedure: Proponent Environmental Impact Statement (EIS) For a New Nuclear Power Plant, Alternative Means of Undertaking the Project and Alternatives to the Project", (2008), online:

power plant, the Joint Review Panel Guidelines required the proponent, Ontario Power Geneation (OPG), to:[187]

> identify and discuss other technically and economically feasible methods of producing electricity other than the construction and operation of the OPG Darlington NNPP that are within the control and/or interests of OPG. As an assessment of provincial energy policy is not within the terms of reference of this joint review panel, the alternatives to the project need not include alternatives that are contrary to Ontario's formal plans or directives. However, the EIS must explain where this rationale has been applied to exclude consideration of possible alternatives to the project.

OPG to date has not done this in the Darlington new build assessment, and has presented only alternative means of carrying out the project in the form of various nuclear technology options. In the case of the Pickering Environmental Assessment the CNSC further commented that:[188]

> consideration of need for and alternatives to the project should not become an indirect means of the CNSC going into areas such as energy policy or economic regulation which are not part of its mandate.

The CNSC cited *Sharp v. Canada* for this proposition.[189] In *Sharp,* the Federal Court of Appeal found that the Canadian Transportation Agency was limited by its mandate to consider only matters under its statute and not issues relating to need or alternatives to building a railway.[190] It remains an open question whether *Sharp* is good law after the Supreme Court of Canada case in *MiningWatch,* which dealt to some extent with discretion for the Department of Fisheries and Oceans to include matters respecting mining that were outside its direct mandate in the *Fisheries Act*.[191] That case has now overtaken other cases that took a similar approach to *Sharp.*[192]

The approach of the CNSC is that it views the alternatives to a project as if it is bounded by provincial energy policies. It therefore does not identify its mandate to consider what is "reasonable" under the *NSCA* as enabling it to identify what is reasonable risk to health, safety,

---

<http://www.nuclearsafety.gc.ca/eng/pdfs/Staff_Review_Procedures/effects_of_the_project_on_the_environment/SRP-EIS-Alternative_Means_of_Undertaking_the_Project_and_Alternatives_to_the_Project_e.pdf>.

[187] OPG Joint Review Panel, "Guidelines for the Preparation of the Environmental Impact Statement for Ontario Power Generation's Darlington New Nuclear Power Plant Project" (2009) s. 7.2.

[188] CNSC, *Record of Proceedings, including Reasons for Decisions In the Matter of Environmental Assessment under the Canadian Environmental Assessment Act of the Proposed return to service of the Pickering 'A' Nuclear Generating Station* Proponent Ontario Power Generation Inc. (16 February 2001) at 10.

[189] *Sharp v. Canada* [1999] 4 F.C. 363 (C.A.) [*Sharp*]

[190] *Ibid*.

[191] *MiningWatch Canada v. Canada (Fisheries and Oceans)*, 2010 SCC 2.

[192] See, for example, *Prairie Acid Rain Coalition v. Canada (Minister of Fisheries and Oceans)*, 2006 FCA 31, [2006] 3 F.C.R. 610. There is also an issue whether this approach is consistent with *Friends of the Oldman River Society v. Canada (Minister of Transport)*, [1992] 1 S.C.R. 3; at 72-72 "the scope of assessment is not confined to the particular head of power under which the Government of Canada has a decision-making responsibility ..."

the environment or national security in light of the possible alternative energy technologies that are available. Arguably, identifying alternatives is core to determinations about the acceptability of risk that are central to the CNSC's mandate to assess whether risks are "reasonable." Effectively, the CNSC views such questions about alternatives that might pose fewer or different types of risk than nuclear power facilities as being within provincial jurisdiction. This leaves it entirely up to provinces to ensure that a precautionary approach is used to determine the acceptability of risk, in light of potential alternatives.[193]

Provincial environmental assessments

Ontario

In Ontario, nuclear reactors are excluded from environmental assessments because they are not designated undertakings under the Ontario *Electricity Projects Regulation*, which identifies electricity projects that are subject to the Ontario *Environmental Assessment Act*.[194]

Quebec

In Quebec, the refurbishment and modification of the Gentilly 2 nuclear reactor and its associated waste sites were subject to provincial environmental assessment processes. These were conducted under Article 2 of the environmental assessment regulations under the Quebec *Environmental Quality Act*, which requires an environmental assessment for constructing or expanding a fission or fusion reactor; a manufacturing, processing or reprocessing of nuclear fuel; or the disposal or storage of radioactive waste.[195] All nuclear installations and their associated works require a provincial environmental assessment.[196] Provincial environmental assessment approvals require effluent monitoring and reports to the Quebec Minister. The Gentilly 2 project was also subject to a public hearing by the Bureau d'audiences publiques sur l'environnement, which issued a report and recommendations.[197]

New Brunswick

In New Brunswick, environmental assessments are conducted under the *Environmental Impact Assessment Regulation - Clean Environment Act.*[198] Listed undertakings include all electric power generating facilities with a production rating of three megawatts or more, all waste disposal facilities or systems and all facilities for the processing of radioactive materials. This includes any modification, extension, abandonment, demolition or rehabilitation. The

---

[193] See also S. Berger, "Environmental Law Developments in Nuclear Energy" (OECD, 2007), online: <http://www.oecd-nea.org/law/nlbfr/documents/055_073_ArticleBergerStanley.pdf>.
[194] *Environmental Assessment Act*, R.S.O. 1990, c. E.18, *Electricity Projects*, O. Reg. 116/01.
[195] RRQ, 1981, c. Q-2, r. 23; *Environmental Quality Act*, *supra* note 165.
[196] *Environmental Quality Act, ibid*. Sched. A (c).
[197] Bureau d'audiences publiques sur l'environnement. ''Projet de modification des installations de stockage des déchets radioactifs et réfection de Gentilly-2, Rapport d'enquête et d'audience publique'' (Report 207) (Quebec : Bureau d'audiences publiques sur l'environnement, 2005).
[198] *Clean Environment Act*, R.S.N.B. 1973, c. C-6; *Environmental Impact Assessment Regulation*, N.B. Reg. 87-83.

Environmental Impact Assessment Regulation prescribes all facilities for the processing of radioactive materials as undertakings.[199] All undertakings must be registered and the Minister determines whether an environmental assessment is required. In New Brunswick, environmental assessment registration has been required for nuclear waste sites but evidently not for the refurbishment of the Point Lepreau reactor.

Saskatchewan

The Saskatchewan *Environmental Assessment Act* requires a proponent of a development to conduct an environmental impact assessment.[200] A "development" means any project, operation or activity or alteration or expansion of any project, operation or activity which is likely to cause unregulated pollution, affect endangered environmental features, "substantially utilize" any provincial resource or cause public concern along with other criteria.[201]

To determine this, the Environmental Assessment Branch conducts an initial environmental evaluation to screen against the above criteria. Then the Saskatchewan Environmental Assessment Review Panel reviews the proposals in relation to the criteria.[202] There is a 30-60 day public comment period for environmental assessment documents and a public notice requirement.[203] The Environmental Assessment Branch may also issue Technical Review Comments. Under ss. 8 and 15 the Minister must give approval before a development may proceed. The Act creates automatic liability for damage from unapproved developments.[204]

The *Environmental Assessment Act* in Saskatchewan is very basic and much is left to policy. Although the Act does not require a cumulative impacts assessment, the Environmental Assessment Branch typically requires it.[205] On its face the criteria could easily be applied to require an environmental assessment of nuclear power and nuclear waste facilities. This Act has been applied to uranium mine and mill decommissioning projects as well as to project changes in uranium mines.[206]

Alberta

The *Environmental Protection and Enhancement Act* governs environmental assessments in Alberta.[207] Part 2 provides for environmental assessment of activities. Projects for which environmental assessments are mandatory receive an initial screening and then a full

---

[199] *Ibid.*
[200] S.S. 1979-80, c. E-10.1, s.9(1).
[201] *Ibid.,* s .2(d).
[202] *Ibid.,* s. 14.
[203] *Ibid.,* s. 10, s. 12.
[204] *Ibid.,* s. 23(1).
[205] Saskatchewan Environmental Society, "Environmental Asssessment in Saskatchewan," online: <http://www.environmlentalsociety.ca/resources/Environmental%20Assessment%20in%20Saskatchewan.pdf>.
[206] Saskatchewan, "Specific Guidelines for the Preparation of an Environmental Impact Statement", Caribou Project, Areva Resources Inc. (2001), online: <http://www.environment.gov.sk.ca/2007-001ProjectSpecificGuidelines>.
[207] *Supra* note 106.

assessment.[208] Projects that are not mandatory can be required to have an environmental assessment at the discretion of the Director or the Minister.[209] Projects requiring a full assessment are prescribed in a regulation as mandatory activities.[210] The construction, operation or modification of a thermal electrical power generating plant that uses non-gaseous fuel and has a capacity of 100 megawatts (MW) or greater is designated as a mandatory activity.[211] This description should apply to nuclear power reactors so long as they meet the 100 MW threshold; however, some small nuclear power reactors may produce less than 100 MW. An environmental assessment could be triggered by Schedule 1(d) of the *Environmental Assessment (Mandatory and Exempted Activities) Regulation*, which provides that the construction or operation of a water diversion structure and canals with a capacity greater than 15 cubic metres per second is a mandatory activity.[212] Similar to the power threshold, it is unclear if small reactors would trigger this. Other activities that are not exempted by the regulation can be subject to an environmental assessment at the discretion of the Director.[213]

Summary

Not all provinces require environmental assessments for nuclear facilities. Provinces use inconsistent criteria to determine whether an assessment is required. In Alberta, a reactor proposal would require a mandatory assessment only if it met the thresholds in Alberta legislation, although a discretionary provincial assessment would still be possible. A lower but still relevant threshold exists for federal comprehensive studies. Accordingly, a small reactor in Alberta would currently not require anything beyond a federal screening. A large reactor would require a comprehensive study federally and a mandatory provincial environmental assessment. In Saskatchewan, a provincial environmental assessment could be required of a reactor of any size, but this largely depends on the opinion of the regulators in that province. In Saskatchewan, it is not clear whether an environmental assessment would be required for any size of nuclear reactor, as the application of criteria for assessment is difficult to forecast. In Alberta, an environmental assessment is required only for a reactor over 100 MW or that uses sufficient water. This leaves both provinces vulnerable to small reactor applications that might not be subject to provincial environmental assessment. Both provinces should explicitly require the environmental assessment of small and large reactors.

---

[208] *Ibid,.* s. 44(1).
[209] *Ibid.*, s. 41, 43, 47.
[210] *Environmental Assessment (Mandatory and Exempted Activities) Regulation*, Alta. Reg. 111/1993.
[211] *Ibid*., Schedule 1 (k).
[212] *Ibid*., Schedule 1 (d).
[213] *EPEA, supra* note 106**,** ss. 41-45.

Part II – Regulatory Gaps and Recommendations

Radiation Protection

Radiation protection of the public under the Nuclear Safety and Control Act

The CNSC, in accordance with its mandate under the *NSCA,* uses the radiation protection methodology set out in International Atomic Energy Agency (IAEA) documents.[214] The central mandate of the IAEA is to ensure peaceful uses of nuclear materials. It is also mandated to establish and adopt standards for health, safety and the protection of property. These standards are not compulsory, and the IAEA has no enforceable inspection or shutdown powers.[215]

The IAEA and the World Health Organization (WHO) have published a document entitled *Basic Safety Standards in Radiation Protection.*[216] The legal status of this document is essentially that it is "soft law": it is persuasive but not binding on member states. [217] The IAEA also prescribes that each source shall be optimized in order that the magnitude of the doses and number of people exposed, as well as the likelihood of incurring exposures, be kept "as low as reasonably achievable" (ALARA).[218] Regulators are required to ensure that the cumulative effects of each annual release of radioactive material are restricted so that the dose in any year to a member of the public is "unlikely" to exceed any relevant dose limit.[219] The International Commission on Radiological Protection (ICRP) 1 mSv annual effective public dose and some of the methodology of calculation are prescribed in this document. [220] It also includes committed effective dose calculations per unit of intake for members of the public for each radionuclide.[221]

Convention on Nuclear Safety

Canada is a signatory to the Vienna *Convention on Nuclear Safety* (1994).[222] The convention requires that each state have in place a regulatory framework for active civil nuclear power plants. The Convention's objectives include "to establish and maintain effective defences in nuclear installations against potential radiological hazards in order to protect individuals, society and the environment from harmful effects of ionizing radiation from such installations."[223] The

---

[214] *NSCA, supra* note 37, s.9.
[215] S. Tromans, *Nuclear Law,* 2d ed. (Portland: Hart Publishing, 2010) at 45.
[216] IAEA, Safety Series 115 "International Basic Safety Standards For Protection Against Ionizing Radiation" (Vienna: IAEA, 1996), online: <http://www-pub.iaea.org/mtcd/publications/pdf/ss-115-web/pub996_web-1a.pdf>.
[217] See K. Boustany, "The Development of Nuclear Law-Making or the Art of Legal 'Evasion'" 61 Nuclear Law Bulletin. See also L. La Fayette, "International Environmental Law and the Problems of Nuclear Safety" (1993) 5 J.Envtl.L. 31 which argues for binding safety standards.
[218] IAEA, *supra* note 216 at 22, s. 2.24.
[219] *Ibid*. at 232., s. 26(b).
[220] *Ibid*. at 22.
[221] *Ibid*. at sch. II 92-93, 166.
[222] *Convention on Nuclear Safety, supra* note 171.
[223] *Ibid.* Article 1.

Convention requires that each party have an independent regulator and sets out general principles of safety and responsibility for safety. It also requires that each state establish appropriate procedures for "evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment."[224] Canadian authorities report regularly on compliance with the *Convention*, which is overseen by the IAEA. The other significant treaty overseen by the IAEA is the *Joint Convention on the Safety of Fuel Waste*.[225] The treaty also requires member states to "provide for effective protection of individuals, society and the environment, by applying at the national level suitable protective methods…" and "aim to avoid imposing undue burdens on future generations."[226] It also requires states to "take the appropriate steps to ensure that at all stages of radioactive waste management individuals, society and the environment are adequately protected against radiological and other hazards."[227]

The IAEA provides further guidance in documents such as *Ethical Considerations in Protecting the Environment from the Effects of Ionizing Radiation*,[228] *Modeling the migration and accumulation of radionuclide in forest ecosystems*[229] and considerations set out in the *Principles of Radioactive Waste Management*[230] and *Safety Fundamentals for Radioactive Waste*.[231] Principle 2 of *Safety Fundamentals* is "Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment." The IAEA has interpreted this to mean that "it can normally be assumed that protection of humans against the radiological hazard from the waste, subject to an appropriate definition of the critical group, satisfies the need to protect the environment."[232] As with the ICRP, the IAEA asserts that the "fundamental safety objective of protecting people – individually and collectively – and the environment has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks."[233] The IAEA also comments on the role of government in regulating

---

[224] *Ibid.* Article 17.
[225] *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management,* 29 September 1997, 36 I.L.M. 1431 (entered into force 18 June 2001). Other IAEA treaties include *Convention on Early Notification of a Nuclear Accident*, 26 September 1986 (entered into force 27 October 1986), online: International Atomic Energy Agency <http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc335.shtml>. *Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency,* 26 September 1986, online: International Atomic Energy Agency <http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc336.shtml>. *The Convention on the Physical Protection of Nuclear Material*, 3 March 1980, online: International Atomic Energy Agency <http://www.iaea.org/Publications/Documents/Infcircs/Others/inf274r1.shtml>.
[226] *Ibid.,* Article 4(iv) and (vii).
[227] *Ibid.,* Article 11.
[228] IAEA, "Ethical considerations in protecting the environment from the effects of ionizing radiation" (Vienna, Austria: 2002), online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1270_prn.pdf>.
[229] IAEA, "Modeling the migration and accumulation of radionuclide in forest ecosystems" (Vienna: IAEA, 2002), online: <http://www-pub.iaea.org/MTCD/publications/PDF/Biomass1_web.pdf>.
[230] IAEA, Safety Series No. 111-F, "The Principles of Radioactive Waste Management" (Vienna: IAEA 1995)
[231] IAEA, Safety Fundamentals, "Fundamental Safety Principles" (Vienna: IAEA, 2006), online: <http://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf>.
[232] IAEA, Safety Standards Series WS-G-1.1 "Near Surface Disposal of Radioactive Waste*",* (Vienna: IAEA, 1999), at 18, online: <http://www-pub.iaea.org/MTCD/publications/PDF/P073_scr.pdf>.
[233] IAEA, *ibid*. at 4.

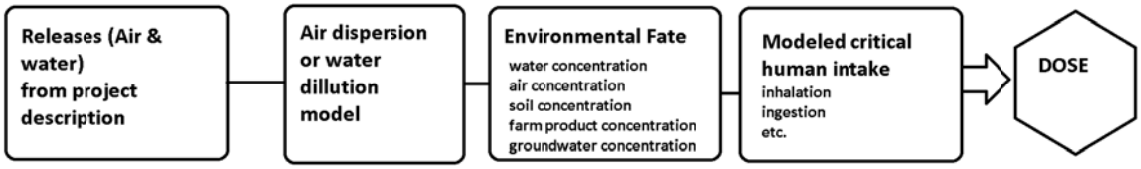
nuclear safety.[234] The IAEA produces publications on design standards and general safety issues.[235] This includes safety documents for heavy water reactors.[236]

ICRP – International Commission on Radiological Protection

Radiation protection from ionizing radiation internationally is researched by the International Commission on Radiological Protection. The ICRP is a non-governmental advisory body that provides recommendations and guidance to national regulators and the IAEA. The object of the ICRP is "to advance for the public benefit the science of Radiological Protection, in particular by providing recommendations and guidance on all aspects of radiation protection."[237] The ICRP recommends an effective dose limit of 1 mSv for any combination of external and internal doses, received or committed in one year, excluding natural background radiation and medical or therapeutic exposures to the public.[238]

ICRP radiation protection concepts

Radiation protection measurements are expressed in effective doses, for example, the dose to the public or "public dose." Effective doses for the public are calculated from environmental data and estimated using a theoretical person (reference person, representative person or critical group/person) that has certain prescribed characteristics (for example an adult male) and behaviour (e.g., lives near the nuclear facility). The exposure and doses of that person are modeled to determine the effective public dose. The concept of a reference person is used to "typify the most highly exposed individuals."[239] Accordingly, the public dose is the modeled exposure of the critical or reference person converted to an absorbed dose that is then converted into equivalent and effective doses based on radiation and tissue weighting factors.



Above is an example of a simplified dose model using environmental exposures to calculate dose (based on an example from the Darlington Nuclear Reactor Joint Panel Review in Ontario).[240]

---

[234] *Ibid.*, at 7.
[235] IAEA, Safety Series, INSAG-5, "The Safety of Nuclear Power", (Vienna: IAEA, 1992).
[236] IAEA, "Generic Safety Issues for Nuclear Power Plants with Pressurized Heavy Water Reactors and Measures for their Resolution". (Vienna: IAEA, 2007), online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1554_web.pdf>.
[237] ICRP "Constitution," online: <http://www.icrp.org/docs/constitution.pdf>.
[238] ICRP, "Draft 2007 Recommendations of the ICRP for consultation" (2006), online: <http://www.icrp.org/docs/ICRP_Recs_02_276_06_web_cons_5_June.pdf> at 47.
[239] *Ibid*.
[240] Ontario Power Generation, *Radiation and Radioactivity Environment Assessment Of Environmental Effects Technical Support Document New Nuclear - Darlington Environmental Assessment* (SENES Consultants Ltd., August 2009) at 2-4. Also see notes 261-262 *infra*.

Each stage of the dose modeling process requires making guesses or assumptions about how radioactive releases behave in the environment (whether they settle in soils and sediments etc.) and how people in the critical group might be exposed (how much they contact, breathe and eat contaminated matter); finally, calculations are done to estimate what the harm from that exposure might be to different tissues in the body, which is expressed as a dose. Modeling doses is a highly uncertain exercise and one whose accuracy is difficult to verify. In the evaluation of radiation doses, models are necessary to simulate the geometry of the external exposure, the biokinetics of the intake and retention of radionuclides in the human body, and the human anatomy. In many cases these models and their parameter values have been developed from experimental investigations and human studies in order to derive "best estimates" or "central estimates" for the model. Similar considerations apply to the choice of tissue and radiation weighting factors. The ICRP recognizes that there are appreciable uncertainties in the values of some of the parameters and in the formulation of models for dose assessments.[241]

Estimating probability of deleterious effects on health from radiation doses of less than a few hundred mSv has been the subject of extensive debate. There is very limited evidence of observable effects at low levels and so risks must be estimated. The US Committee on the Biological Effects of Ionizing Radiation (BEIR), and, internationally, the deliberations of the ICRP and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) all use different models to estimate harm from low levels of radiation. The current accepted model of harm from low doses of radiation is the linear no threshold (LNT) model, which predicts that effects from radiation decrease in proportion to the radiation dose.[242] Put simply, this model does not predict zero effects unless radiation doses are zero. Because most of these models extrapolate risks from large doses of radiation experienced by atomic bomb survivors, it is simply unknown whether the modeled risks of small doses are accurate.[243] There are many influences on the relationships between the biological consequences of doses received from various kinds of radiation. To represent these influences, the concept of "relative biological effectiveness," or RBE, was introduced by the ICRP.[244] RBE factors for different types of radiation are also controversial. Accordingly, doses are best understood as highly uncertain guesses about likely harm from exposure to radiation to theoretical persons.

---

[241] ICRP, *supra*, note 238 at 77.

[242] National Academy of Sciences, “Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2,” (2005) Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council. “There is a linear dose-response relationship between exposure to ionizing radiation and the development of radiation-induced solid cancers in humans. The committee further judges it unlikely that a threshold exists for the induction of cancers...” Executive summary at 7-10, online: <http://www.nap.edu/nap-cgi/report.cgi?record_id=11340&type=pdfxsum> at 7-10. Full text at <http://www.nap.edu/openbook.php?record_id=11340&page=1>. Also see David J. Brenner et al., "Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know".2003 100:24 Proceedings of the National Academy of Sciences 13761. <http://www.pnas.org/cgi/content/full/100/24/13761>; and Bernard L. Cohen, “Test of the linear-no threshold model theory of radiation carcinogenesis for inhaled radiation decay products” (1995) Health Physics 157, online: <http://www.phyast.pitt.edu/~blc/LNT-1995.PDF>.

[243] ICRP, "Low-dose Extrapolation of Radiation-related Cancer Risk" (2005) 35:4 Annals of the ICRP; ATDSR, “Health Consultation: Tritium Releases and Potential Offsite Exposures” (2002), online: <http://www.atsdr.cdc.gov/HAC/pha/pha.asp?docid=1162&pg=4>.

[244] ICRP, *ibid.*

ICRP approach to risk and harm using 1 mSv public dose

The aims of the ICRP recommendations are "to contribute to an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human endeavors and actions that may be associated with such exposure."[245] In justifying the use of a 1 mSv annual public dose, the ICRP indicates that "1 mSv applies to situations where individuals receive exposures – usually planned – that are of no direct benefit to them but there is a benefit to society."[246] Explicitly, the ICRP has developed the dose recommendations with a philosophy that:[247]

> [O]ptimization is not minimization. It is the result of an evaluation, which carefully balances the detriment from the exposure (economic, human, social, political, etc.) and the resources available for the protection of individuals. Thus the best option is not necessarily the one with the lowest dose.

Accordingly, the ICRP recommendations are best understood as a scientifically informed policy document, focused on regulatory optimization, not a pure public health recommendation.

The ICRP assesses the lifetime risk from a single exposure to 1 mSv to be 1 in 14,000. This level of risk includes outcomes such as fatal cancer, severe hereditary effects and non-fatal cancers weighted for severity. For a lifetime exposure of 1 mSv per year over 70 years, the total risk is predicted to be about 1 in 200.[248] The risk of other types of health effects (biological endpoints) are not included. Potential non-fatal health effects include reproductive effects and less serious cancers. Accordingly, the use of 1 mSv represents a fixed assessment of the reasonableness of risk to the public of some serious harms from planned radiation exposure from any nuclear facilities. This stands in contrast to the public health concept of *de minimus* or "negligible" risk that is often used, which is one in a million.[249]

It should be noted that this 1 mSv optimization is applied universally to public radiation exposure. In other words the ICRP predicts that 1 mSv is "optimal" in that the benefits of further reductions to public doses are not justified by the costs in every situation, regardless of the actual costs or benefits of reduction in the context of a particular planned release. In a sense, therefore, the ICRP treats the 1 in 14000 and 1 in 200 risk levels as negligible, even though they are not

---

[245] ICRP, *supra* note 238 at 12.
[246] *Ibid*. at 55.
[247] *Ibid.* at 59.
[248] ICRP, Publication 60: "The 1990 Recommendations of the ICRP" 21:1.3 *Annals of the ICRP*, ICRP, 1990 recommendations of the ICRP, *Radiological Protection Bulletin* 119 (Supplement), (Chilton: National Radiological Protection Board,1990).
[249] Ed. Lester Breslow. Gale Cengage,"Acceptable Risk."*Encyclopedia of Public Health*. 2002. eNotes.com. 2006. (18 Feb, 2011), online: <http://www.enotes.com/public-health-encyclopedia/acceptable-risk> For an explanation of the use of de minimus risk in Canadian public and environmental health, see Health Canada "Federal Contaminated Site Risk Assessment in Canada Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA) at Appendix B, online: <http://www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/part-partie_i/appendix-b-annexe-eng.php>. Also see Health Canada. (1996) Health-Based Tolerable Daily Intakes/Concentrations and Tumorigenic Doses/Concentrations for Priority Substances. Ottawa: Environmental Health Directorate, Health Canada. Report No. 96-EHD-194.

one in a million. This is likely due to the uncertainty resulting from the LNT model. Nevertheless, research under the LNT model emphasizes that although the risks at low doses of radiation are believed to be small, they are still capable of having public health significance:[250]

> [I]t is unlikely that we will be able to directly and precisely quantify cancer risks in human populations at doses much below 10 mSv. Our inability to quantify such risks does not, however, imply that the corresponding societal risks are necessarily negligible; a very small risk, if applied to a large number of individuals, can result in a significant public health problem.

Accordingly the current situation is that there are estimates of risk at low doses and models that suggest that the threshold for risk from ionizing radiation is zero. However, direct observable evidence is not available to precisely quantify those risks. Based on this, the ICRP has determined that 1 mSv is the optimal level of radiation dose for the public by any particular radiation-releasing activity. The ICRP has estimated the risks of doses at this level, and these estimates place the risk at non-negligible levels, but these predictions are not verifiable.

ICRP and protection of non-humans

The ICRP approach to radiological protection does not make a distinction between protection of humans and protection of non-human biota. It assumes that protection of humans means that "other living things are also likely to be sufficiently protected" or "other species are not put at risk." Some observers have agreed with this conclusion.[251] Others have challenged this, pointing out that receiving environments often experience much higher doses than the critical group.[252]

In 2000, the ICRP began to develop research on environmental protection from radiation. In 2007, the ICRP made recommendations to amend its general aims to include preventing or reducing the frequency of deleterious radiation effects in the environment to a level where they would have a negligible impact on the maintenance of biodiversity, conservation of species, or health and status of natural habitats, communities and ecosystems. In 2008, the ICRP released a discussion document on the development of "reference animals and plants" for environmental dose calculations.[253] Reference animals and plants are hypothetical entities, with the assumed

---

[250] Brenner, *supra* note 242.

[251] World Nuclear Organization, "Overview of Ecological Risk Assessments Conducted for Sites with Enhanced Radiaoctivity" (SENES Consultants Ltd., 2007) at ES-2, online: <http://www.world-nuclear.org/uploadedFiles/org/reference/Press_Releases/wna-senes-1107.pdf>.

[252] See, for example, R. M. Alexakhin et al., "Biospheric approach as a compromise between hygienic and ecological approaches to radiological protection of the environment" (2009) 4(55) Radioprotection 655; S. Caroll, "Radiological protection of the environment from an NGO perspective" (2009) 44(5) 439; and I.I. Kyrshev et al., "Radioecological impact from radionuclide releases into rivers" (2002) Radioprotection - Colloques, 37(C1) C1-51 showing the highest doses from a facility are received by aquatic organisms, not reference groups.

[253] J. Valentin, ICRP Publication 108 "The Concept and Use of Reference Animals and Plants for the purposes of Environmental Protection," Annals of the ICRP 38(4-6), online: <http://www.icrp.org/docs/Environm_ICRP_found_doc_for_web_cons.pdf>; ICRP, Publication 91 "A Framework for Assessing the Impact of Ionising Radiation on Non-human Species." Annals of the ICRP 33:3.

basic biological characteristics of a particular family of plant or animal. This shift is best understood as an attempt to use a similar approach taken with humans to model doses to selected "reference" organisms. This approach has been criticized for not reflecting ecological issues and not being based on scientifically defensible criteria.[254] The European Community has extensively researched and commented on different regulatory approaches to the protection of non-human biota, but there is no clear international regulatory standard or approach.[255]

CNSC prescribed committed effective doses (mSv/yr)

The *Radiation Protection Regulations* under the *Nuclear Safety and Control Act* prescribe the ICRP public dose limit, which is 1 mSv per calendar year for members of the public from all regulated nuclear facilities, including nuclear power plants.[256] Moreover, there are prescribed equivalent doses for organs set out in s.14. If a dose is exceeded, the regulations require the licensee to notify the person and investigate and report to the CNSC.[257]

As Low as Reasonably Achievable (ALARA)

The *Convention on Nuclear Safety*, Article 15, requires that radiation exposure to workers and the public must be as low as reasonably achievable, and that no individual shall be exposed to doses exceeding national dose limits.[258] This requirement is repeated in IAEA Safety Standards.[259] The OECD and ICRP also endorse this concept.[260] In Canada, the *Radiation Protection Regulations*[261] require that radiation protection programs be in place for all licensees to keep doses to persons "as low as reasonably achievable."[262] This regulation also sets out prescribed doses.

The CNSC equates ALARA with dose reduction "without significant expenditures." The CNSC uses a 50 µSv/yr dose for the public as a proxy for ALARA:[263]

> Licensees are expected to reduce doses where this can be done without significant expenditures. To minimize the commitment of resources that are likely to have a poor return in safety improvement, the CNSC may consider that an ALARA

---

[254] S. Caroll, *supra* note 252 at 440.
[255] J.L. Hingston, *et al*. "Deliverable 3 - A review of approaches to protection of the environment from chemicals and ionising radiation: Requirements and recommendations for a common framework." (PROTECT Project, 2007), online: <https://wiki.ceh.ac.uk/download/attachments/115016283/PROTECTWP1DeliverableD310-12-07FINAL.pdf?version=1&modificationDate=1263808844000>.
[256] *Radiation Protection Regulations*, SOR/2000-203, s.13
[257] *Ibid*., s. 16.
[258] IAEA, *supra* note 171.
[259] IAEA, *supra* note 216 at 22.
[260] OECD. "Radiation Protection, Effluent Release Options from Nuclear Installations, Technical Background and Regulatory Aspects" (Danvers: OECD, 2003) at 55.
[261] *Radiation Protection Regulations, supra* note 256.
[262] *Ibid.,* s. 4.
[263] Canadian Nuclear Safety Commission, Regulatory Guide-129*, Revision 1, Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)* (Ottawa: CNSC, 2004) at 3, online: <http://dsp-psd.pwgsc.gc.ca/Collection/CC173-3-2-129-1E.pdf>.

assessment, beyond the initial analysis, is not required in the following circumstances:

1. individual occupational doses are unlikely to exceed 1 mSv per year,
2. dose to individual members of the public is unlikely to exceed 50 µSv per year, and
3. the annual collective dose (both occupational and public) is unlikely to exceed the 1 person-Sv.

The ALARA concept is intended for the protection of humans, and it is defined only as a concept of protection of persons from ionizing radiation;[264] however, it is occasionally referenced by the CNSC as a general environmental protection measure. It is unclear what the meaning of the term is in that context.

Derived release limits

Derived Release Limits (DRL) for radionuclide releases from nuclear facilities in Canada are set to ensure that the annual dose to the critical group (reference person) does not exceed 1 mSv. The release limit itself actually reflects the full ICRP and *Radiation Protection Regulations* dose limit. Canadian nuclear plants usually set their operating targets below 1% of the DRL. It is important to understand that the DRL varies depending on the site, exposure pathways and modeled characteristics and habits of critical groups.[265] For nuclear power facilities, the CNSC sets DRLs for tritium 14C, noble gases, iodine-131 and particulate matter emissions. [266]

Although DRLs are expressed as an annual release limit, weekly and monthly rates of release are further controlled. For gaseous releases, the maintained limit is the annual DRL divided by 52 weeks. Liquid release limits represent the annual DRL divided by 12 months. Weekly airborne releases and monthly liquid releases at each nuclear generating station are compared to the respective weekly and monthly limits, and are usually reported to the CNSC on a quarterly basis.[267] Radiation protection programs for nuclear power reactors are usually included in licence appendices including the derived release limits.[268]

---

[264] There is a lack of consistency between CNSC guides and Canadian Standards Association documents regarding the meaning of ALARA. For example, CSA, CSA-N288.1-M87 "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities" (August 1987) at 9 defines ALARA as "a level of individual or collective dose or intake of effluent release or of any other parameter related to a radiation dose, such that the cost of reduction to a lower level would under the given circumstances exceed the resulting health benefit."

[265] IAEA, Technical reports series no. 421, "Management of Waste Containing Tritium and Carbon-14" (Vienna: IAEA, 2004) at 17-18, online: <http://www-pub.iaea.org/MTCD/publications/PDF/TRS421_web.pdf>.

[266] CNSC "Radioactive Release Data from Canadian Nuclear Power Plants 1999-2008" (Ottawa: CNSC, September 2009), online: <http://www.cnsc-ccsn.gc.ca/pubs_catalogue/uploads/INFO0210_R13_e.pdf>.

[267] *Ibid*.

[268] The CNSC does not make licence appendices available to the public without a formal access to information request. The ELC was unable to obtain licence appendices for any nuclear facilities with the exception of the Saskatchewan Research Council (obtained through provincial freedom of information process) in the research in preparation for this report due to access to information delays.

Since 1987, DRL calculations have been based on a method recommended by the Canadian Standards Association (CSA).[269] These are explained in the Derived Release Guidance document published by CSA and the CANDU owners group.[270] These quantities are based on limiting releases to levels less than or equal to the prescribed public dose limit of 1 mSv.[271] The standards for calculating DRLs from nuclear facilities are based on the 1 mSv public dose and not impacts on non-human organisms. Depending on the difference between exposure to non-human biota and the critical group, radiation protection may not extend to non-human biota.

For instance, in the CSA guide, radionuclides that are not released from the site of interest do not have to be considered. This may leave the cumulative impact of radiation doses to both human and non-human biota unassessed. Similarly, if a source of water is not used by members of the public near the site (i.e., the critical group is not exposed to the water), the aquatic contamination does not need to be addressed.[272] There is a high level of variation in DRLs used in Canada; for example, the Gentilly 2 nuclear reactor is located near a farm and it is considered that a member of the critical group consumes water from the St. Lawrence River 3 kilometres downstream of the station resulting in a low release limit. In contrast, the Point Lepreau nuclear power reactor is located in a relatively remote area and airborne releases from the Point Lepreau nuclear power plant tend to be higher than those from Gentilly 2.[273] This situation does not appear to be fully in accordance with the IAEA *Safety Guide,* discussed below, and does not provide protection for non-human biota.

Action levels

Action levels are safety measures that are not directly related to release limits or annual public doses. The *Radiation Protection Regulations* further set out defined "action levels," which, if reached, represent a potential loss of control of the radiation protection at a facility. Accordingly, action levels assist in determining if the radiation protection system is working. Action levels are defined in s.6 of the *Radiation Protection Regulations* only with respect to

---

[269] See CSA, *supra* note 264; and the update CSA, Nuclear, N288.1-08, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities" 2d ed. (2008) ; CSA, Nuclear, N288.4-10, "Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills." Also see Joint Working Group of Radiation Protection Bureau Health Canada "Recommendations on Dose Coefficients for Assessing Doses From Accidental Radionuclide Releases to the Environment" (Ottawa, 1999), online: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/radiation/dose/doseassess.pdf>; and D. Hart, Derived Release Limits Guidance (COG-06-3090-R2-I) (Toronto: CANDU Owners Group, November 2008) online: <http://www.csagroup.org/repository/ca/COG-06-3090-R2-I-FINAL.pdf>.

[270] Hart, *Ibid*.

[271] CNSC, Information, INFO-079, "Tritium Releases and Dose Consequences in Canada in 2006" (2009) at 2, online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-52-2009-eng.pdf>. However the use of 1 mSv is not consistent. For example, in CSA *supra* note 264 at 11 the dose limits for calculating DRLs are said to be the "effective dose equivalent received in a year from external sources plus the committed effective dose equivalent from all radioactive substances that would enter the body during that year not to exceed 0.005 Sv", although this version is out of date.; while D. Hart, *supra* note 269 calculates the DRL based on 1 mSv.

[272] D. Hart, *supra* note 269 at 3.

[273] IAEA, TR-Series 421 "Management of waste containing tritium and carbon-14. (Vienna: IAEA, 2004), online: <http://www-pub.iaea.org/MTCD/publications/PDF/TRS421_web.pdf> at 6.

safety. However, the CNSC appears to assume that environmental protection is included.[274] Nuclear generating stations use environmental action levels developed based on the CNSC Regulatory Guide. Subsection 6(2) of the *Radiation Protection Regulations* requires an operator to investigate and identify the cause and report to the commission when an action level is reached. Action levels themselves are prescribed in operating licences.

Environmental and health protection from radioactivity

Environmental radiation issues in nuclear power

Canadian-Deuterium-Uranium (CANDU) nuclear power facilities are the only type of commercial nuclear power facility currently in operation in Canada. Accordingly, this evaluation discusses the typical environmental issues experienced from CANDU operation. Notably, the use of small reactors developed using other reactor types may pose other environmental challenges that are beyond the scope of this paper.

CANDU reactors result in releases of tritium oxide, iodine-131, radioactive particulate, noble gases and carbon-14.[275] Members of the public and non-human organisms may be exposed to radiation through a variety of pathways. These include immersion in radioactive plumes, inhalation, exposure from radionuclides that are deposited on the body or on other materials, and ingestion of contaminated food or water.[276] The nature of any exposure will depend on environmental factors like weather and the characteristics and behaviour (age, gender, body size, inhalation etc.) of a particular organism. The effects of radiation on health of humans or non-human biota vary and include effects inherited from parents (hereditable genetic effects), cancer (somatic effects), reproductive effects and even circulatory, digestive and respiratory diseases.[277] In wildlife, effects include morbidity due to immune weakening, reproductive effects because of damage to reproductive systems (embryos, gonads), cell damage (cytogenetic effects) and stimulation of defence mechanisms.[278]

International approaches to protection of the environment from radiation

In 1992, the IAEA published an assessment of radiation effects on land-based plants and animals.[279] This resulted in estimates of chronic dose rates that were unlikely to impact

---

[274] Canadian Nuclear Safety Commission, *Developing and Using Action Levels,* Regulatory Guide G-228 (Ottawa: Canadian Nuclear Safety Commission, 2001).
[275] Mark Winfield *et al*., *Nuclear Power in Canada: an examination of risks, impacts and sustainability*, (Toronto: Pembina Institute, 2006) at 66.
[276] Health Canada, *Recommendations on Dose Coefficients for Assessing Doses from Accidental Radionuclide Releases to the Environment* (Ottawa: Health Canada, 1999) at 2, online: <http://dsp-psd.communication.gc.ca/Collection/H46-1-33-1999E.pdf>.
[277] See M.P. Little, "Risks associated with ionizing radiation Environmental pollution and health" (2003) 68:1 British Medical Bulletin 259, online: <http://bmb.oxfordjournals.org/content/68/1/259.full>.
[278] See T.B. Sazykina, "A system of dose-effects relationships for the northern wildlife: Radiation protection criteria" (2005) 40:1 Radioprotection S889.
[279] IAEA, Technical Report 332 "Effects of ionising radiation on plants and animals at levels implied by current radiation protection standards," (Vienna: IAEA, 1992).

reproduction in those populations. In 1996, the UNSCEAR produced a report on the effects of ionizing radiation on non-human organisms. This report also provided chronic dose rates.[280] Research conducted by CNSC staff for the IAEA in the early 2000s has derived estimated no effects levels for radiation in non-human biota as well.[281] Other researchers have used different approaches and have estimated doses for non-humans and expressed these by radionuclide specific criteria and included parameters for air, soil, marine and freshwater concentrations at CANDU sites.[282] Although a wide range of modeling and research has been done, regulators struggle to translate current knowledge into a regulatory requirement.[283] There are highly variable approaches that differ in terms of the biological effects that are examined, time period of exposure and the scope of organisms studied. These are expressed as absorbed doses rather than committed effective doses and are therefore difficult to compare to human doses. The result is that there is no consistent approach to environmental protection from radiation from nuclear facilities in Canada.

Decision not to regulate radionuclides under CEPA

In 2003, Health Canada and Environment Canada assessed whether or not to add uranium and uranium decay products to Schedule 1 of the *Canadian Environmental Protection Act, 1999* (*CEPA*).[284] The *CEPA* assessment calculated risk quotients for various aquatic organisms from nuclear power reactors to be less than 1, meaning that it is low risk that aquatic organisms would be impacted.[285] However, the calculation methodology for calculating these and the research relied upon was not provided or described. Other researchers have found, at least in the case of the Pickering reactor, that risk quotients to terrestrial biota exceed this level, meaning that the risk is higher.[286]

---

[280] UNSCEAR, 1996, Report to the UN General Assembly (New York: UNSCEAR, 1996), online: <http://www.unscear.org/unscear/en/publications/1996.html> cited with approval in UNSCEAR Sources and effects of Ionizing Radiation v.1 (New York, UNSCEAR, 2010) at 18, online: <http://www.unscear.org/docs/reports/2008/09-86753_Report_2008_GA_Report.pdf>.

[281] G.A. Bird, P.A. Thompson *et. al*.," Assessment of the impact of radionuclide releases from Canadian nuclear facilities on non-human biota", at 241 in IAEA, *Protection of the Environment from Ionising Radiation* (Vienna: IAEA, 2003), online: <http://www-pub.iaea.org/mtcd/publications/pdf/csp-17_web.pdf> at 242.

[282] S.L. Chouhan, "Environmental radionuclide concentrations below which non-human biota experience no effects," (2009), 44(5) Radioprotection 107 at 113.

[283] C.M. Larsson, "Regulation and decision-making in environmental radiation protection"(2005) 40:1 Radioprotection S905.

[284] National Pollutant Release Inventory, *Releases of Radionuclides from Nuclear Facilities (Impact on Non-human Biota) Priority Substances List Assessment Report* (Environment Canada, 2004) [NPRI], online: <http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/assess-eval/radionuclides-eng.pdf>. Also see Environment Canada, "Canadian Environmental Protection Act, 1999. Priority Substances List PSL2 Assessment Report Releases of Radionuclides from Nuclear Facilities (Impact on Non-Human Biota) – Revised Draft" (Ottawa: Environment Canada and Health Canada, 2001).

[285] *Ibid*. at 89. A "risk quotient" represents the exposure of an organism divided by toxicity.

[286] N.A. Beresford *et al*., "Deliverable 4 Evaluation of approaches for protecting the environment from ionising radiation in a regulatory context."(PROTECT, 2008) at 51, online: <https://wiki.ceh.ac.uk/download/attachments/115016283/PROTECTWP2deliverableFinal.pdf?version=1&modificationDate=1263808930000>.

The assessment recommended that radionuclides from mines and mills be added to Schedule 1 but not radionuclides released from other facilities. In the end, none were added to the Schedule and instead an agreement was signed between the CNSC and Environment Canada to "avoid duplication."[287] The result is that radionuclides are not considered "toxic" under *CEPA* and the CNSC remains the only federal regulator of the environmental or health effects of radionuclides from nuclear power reactors.

Environmental and health impacts of tritium

A CANDU reactor is a heavy water reactor that produces tritium, most of which comes from the moderator heavy water (Deuterium or D_2O). Tritium is released from nuclear power facilities in Canada in the form of elemental tritium (Darlington reactor only) and tritium oxide. Tritium is a well-studied radionuclide for radiation impacts to humans. This information is derived from laboratory studies involving animals and is supplemented by theoretical studies of the physics of radiation exposure.[288] Tritium is of particular biological concern because it behaves like hydrogen. Tritiated hydrogen (HTO) can act like water and bind to organic molecules inside an organism (organically bound tritium or OBT). Beta radiation from tritium does not penetrate the human body, so tritium must generally be ingested or otherwise absorbed by the body to cause harm.[289] Tritium may induce lethality, fetal abnormalities and genetic and reproductive effects in humans and other organisms.[290]

There is no consensus on the harm caused by radiation from tritium on non-human organisms.[291] Harm is expressed as relative biological effectiveness (RBE) factors.[292] These are numbers that express the relative amount of damage that a specific type of radiation can inflict on biological tissues. The higher that number, the more damaging that type of radiation. The 2003, *CEPA* assessment for tritium proposed an RBE factor of 40 for non-human organisms and concluded that population level effects on non-human organisms are not predicted overall from tritium releases in Canada.[293] Differences in approach depend in large part on the biological endpoint (or type of harm) used to calculate the RBE. For humans the ICRP and CNSC use an RBE of one for tritium, based on gamma radiation.[294] The CNSC has noted that the "the weight of the evidence points to an RBE factor of 2 or more."[295] RBE values for tritium vary considerably because tritium emits multiple types of radiation and existing studies use different biological

---

[287] *Memorandum Of Understanding (MOU) Between The Canadian Nuclear Safety Commission (CNSC) and Environment Canada (EC)* (Ottawa: CNSC, 2004).
[288] ATDSR, "Health Consultation: Tritium Releases and Potential Offsite Exposures" (11 March 2002), online: <http://www.atsdr.cdc.gov/HAC/pha/pha.asp?docid=1162&pg=4>.
[289] CNSC, INFO-0799, "Health Effects, Dosimetry and Radiological Protection of Tritium" (Ottawa: Public Works and Government Services, 2010), online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-58-2010-eng.pdf>.
[290] *Ibid*. at 17.
[291] CNSC, INFO-0730, "Protection of Non-Human Biota From Ionizing Radiation" (Ottawa: CNSC, 2002), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/I0730en.pdf>.
[292] These weighting factors were identified in CNSC *ibid.,* in the range of 5 to 20 for alpha particles, a dose rate criterion of 3 mGy/d (1 Gy/a) and radiation weighting factors of 1 for all gamma and beta radiation and 10 for alpha radiation, at iv.
[293] NPRI, *supra* note 284 at 88-90.
[294] ICRP, Publication 92 "Relative Biological Effectiveness" *Annals of the ICRP*.
[295] CNSC, *supra* note 289 at 146.

effects as the basis for calculating the RBE.[296] Accordingly, the harmful effects of tritium on both non-humans and humans is highly uncertain and very controversial.

Releases of tritium by nuclear reactors in Canada

According to the CNSC, a CANDU nuclear reactor typically releases about 58,000 GBq of tritium into the air and about 110,000 GBq into the water each year.[297] Heavy water tritium contributes up to half of the annual dose received by workers and up to 20% of the radioactivity released into the environment.[298] The *CEPA* assessment noted that for organisms exposed to routine discharges from nuclear power plants and some waste management facilities, more than 60% of the radiation dose is from tritium.[299]

The 2006 releases for Canadian CANDU reactors were 1% or less of the derived release limits for these facilities over an annual period.[300] This means that they release much less than the facility release limit using current techniques and that the modeled doses to the public are much lower than the dose limit of 1 mSv. However, the public health impacts of these exposures are largely unknown.

Ontario Power Generation environmental monitoring data shows that tritium levels in some lakes and streams around Ontario nuclear power reactors sometimes exceed 100 Bq/L.[301] The average concentrations in the Great Lakes with nearby nuclear power facilities in the late 1990s were about 5 Bq/L compared to 2 Bq/L for other Great Lakes.[302] A 2002 CNSC study found that groundwater values ranged up to 30 Bq/L in one well close to Pickering Nuclear Power Plant and about twice this in some seasonal wells close to Bruce Nuclear Power Plant. Tritium samples from some drinking water wells close to a small tritium-handling facility have ranged up to 230 Bq/L, with most being less than 50 Bq/L.[303] Food samples from near nuclear plants in Ontario are in the range of 50-200 Bq/L.[304] Accordingly, tritium levels in Canadian environments are highly variable but sometimes at levels of potential significance for environmental and human health impact. There is no environmental quality guideline for tritium in aquatic environments,

---

[296] *Ibid*. at 98.
[297] T. Jamieson, Presentation to University of Ontario Institute of Technology (Ottawa: CNSC, February 2009), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/20090224-CNSC-Tritium-Studies-Project-UoIT-Tjamieson-Presentation-e.pdf>.
[298] IAEA, Technical Document, IAEA-TECDOC-1650, "Good Practices in Heavy Water Reactor Operation" (Vienna: IAEA 2010), at 66, online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1650_web.pdf>.
[299] NPRI, *supra* note 284 at 70.
[300] CNSC, "Tritium Releases and Dose Consequences in Canada 2006" (Ottawa: 2006) at 17, online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-52-2009-eng.pdf>.
[301] Ontario Power Generation, "Annual Summary And Assessment Of Environmental Radiological Data For 2006" (Toronto: OPG, 2007) at 24, online: <www.opg.com/pdf/Nuclear%20Reports%20and%20Publications/Annual%20Summary%20and%20Assesment%20of%20Environmental%20Radiological%20Data%202006%20-%20Bruce%20Site.pdf>.
[302] R. V. Osborne, RSP-0153-1, Tritium in the Canadian Environment: Levels and Health Effects (Deep River, Ranasara Consultants Inc., 22 March 2002) at 8, online: <http://www.odwac.gov.on.ca/standards_review/tritium/Osborne_CNSC-RSP-0153-1.pdf>..
[303] *Ibid*. at 8.
[304] *Ibid*. at 8.

soils or air in Canada. There are no tritium regulations, requirements or guidelines for the protection of non-human biota in Canada.

Technical and operational standards to prevent release of tritium

The IAEA has a technical series paper on the management of routine releases of waste containing tritium and carbon-14.[305] Reactor vault airborne emissions of tritium must be controlled in heavy water facilities such as CANDU reactors.[306] Tritium is continuously produced within the CANDU reactor through neutron capture by the heavy water (Deuterium). In order to materially lower tritium concentrations, the heavy water must itself have low concentrations of tritium. There are various technologies available for detritiation of heavy water with varying levels of effectiveness.[307] Other strategies have included better maintenance of dryers (dehumidifiers) that confine tritium in the event of leaks of tritiated water.

Tritium escapes into the reactor building when there is water leakage from the moderator and coolant system. Some tritium may escape during the detritiation process.[308] Other factors in tritium release include the rate of diffusion through different materials used in the facility.[309] Tritium can also be produced at an increased rate by the presence of "CRUD" (Chalk River Unidentified Deposits), which are typically iron oxides that form on fuel rods.[310] CRUD can be reduced by controlling the coolant chemistry. Devices can be used that trap gaseous tritium and collect it in separate tanks.[311] The CNSC evaluated facilities handling tritium under the *Tritium Studies Project*. This evaluation was released in an information document entitled *Evaluation of Facilities Handling Tritium.*[312] This study identified some general best practices for handling tritium that "could" become regulatory requirements. However, it is not clear from the document how these best practices make the necessary trade-offs between worker protection and protection of the public. These are not regulatory requirements, with the exception of the Darlington Nuclear Power facility in Ontario, which has a tritium removal facility that forms part of its licence requirements.[313]

Human health impacts of tritium

The *Tritium Studies Project* was directed at whether or not to reform drinking water standards and to provide public education on tritium. The CNSC has developed from this project an

---

[305] IAEA, Management of waste containing tritium and carbon-14. (TR-Series 421) (Vienna, IAEA, 2004), online: <http://www-pub.iaea.org/MTCD/publications?PDF?TRS421_web.pdf>.
[306] *Ibid.* at 66.
[307] *Ibid.* at 64, 67-69.
[308] *Ibid*. at 43.
[309] *Ibid.* at 50.
[310] *Ibid.* at 51.
[311] *Ibid.*
[312] CNSC, "Evaluation of Facilities Handling Tritium" (Ottawa: Minister of Public Works and Government Services Canada, 2010).
[313] The concentration of tritium in any tritiated deuterium oxide feedstock to be treated in the Darlington Tritium Removal Facility shall not exceed 1.26 TBq/kg D2O (34 Ci/kg D2O).

overview document entitled *Standards and Guidelines for Tritium in Drinking Water.*[314] The CNSC's interpretation of the results of the epidemiological studies reviewed for the *Tritium Studies Project* were that "[e]xisting information does not provide enough detail to estimate the health risks of tritium exposure, specifically."[315]

Tritium in federal and provincial drinking water guidelines

The federal guideline for tritium is 7000 Bq/L in drinking water.[316] The *Guidelines for Canadian Drinking Water Quality* published by Health Canada include radiological parameters for drinking water. These *Guidelines* are adopted by some provincial regulators. The maximum concentrations of radionuclides in public water supplies in the *Guidelines* assume water intake rates for adults to arrive at a limit that is 10% of the 1 mSv public dose limit.[317] Multiple radionuclides are added together under a formula provided in the *Guidelines*.[318]

Both Saskatchewan and Alberta use the 7000 Bq/L standard for tritium. In Saskatchewan, the *Drinking Water Quality Standards and Objectives* rely on the Health Canada *Guidelines* methods.[319] These standards are enforceable under the *Water Regulations, 2002*.[320] The standards apply to "waterworks" under the regulations. In Alberta, the *Potable Water Regulation*[321] under the *Environmental Protection and Enhancement Act*[322] relies on the *Guidelines for Canadian Drinking Water Quality*, published by Health Canada, and lists parameters in the *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*.[323]

---

[314] CNSC, "Standards and Guidelines for Tritium in Drinking Water" (Ottawa: CNSC, 2008), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/info_0766_e.pdf>.
[315] Patsy Thompson, "Balancing Science and Public Health Policy Considerations in the Regulation of Tritium in Drinking Water: The CNSC Perspective" (Ottawa: Canadian Nuclear Safety Commission, 2010), online: <http://www.cnsc-ccsn.gc.ca/eng/pdfs/Presentations/CNSC_Staff/2010/August_27_2010-Tritium_in_Drinking_Water-McMaster_University_Presentation_e.PDF>.
[316] Health Canada, "Guidelines for Canadian Drinking Water Quality" (2010) at 6, online: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/2010-sum_guide-res_recom/sum_guide-res_recom-eng.pdf>.
[317] *Ibid.* at 14.
[318] *Ibid*. at 14-15. Also see "Summary Table of Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment - Guidelines for Canadian Drinking Water Quality" (Ottawa: Health Canada , December 2010), online: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/2010-sum_guide-res_recom/sum_guide-res_recom-eng.pdf>.
[319] Saskatchewan "Saskatchewan's Drinking Water Quality Standards and Objectives", online: <http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=765,758,253,94,88,Documents&MediaID=330&Filename=Drinking+Water+Quality+Standards+and+Objectives.pdf&I=English>.
[320] *Water Regulations*, *supra* note 129.
[321] Alta. Reg 277/2003, s .6.
[322] *Supra* note 106.
[323] Health Canada, *supra* note 316; Alberta Environment, *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems* (Drinking Water Branch, 2006), online: <http://environment.gov.ab.ca/info/library/6979.pdf>.

CNSC data shows that tritium levels in municipal drinking water near nuclear power facilities are in the 6.4-18 Bq/L range typically while levels in milk in the vicinity are higher.[324] Well water used by critical groups is also higher: in the 60 and 70 Bq/L range.[325] These radioactivity levels are translated into doses to critical groups (expressed in Sv) based on models of how the group would be exposed to these sources. The CNSC uses 50 µSv as the regulatory guide for what is assumed to be ALARA. The data on doses to the public from tritium exceed this amount near some nuclear facilities and are generally between 0.1 and 100 µSv.[326] For nuclear power facilities most are below this limit and are generally between 0.1 and 2 µSv.[327] For new facilities, the *Tritium Studies* project makes several recommendations:

1. A design objective for tritium level in groundwater of 100 Bq/L.
2. A controlled zone within the licensee's control to ensure that the design objective of 100 Bq/L would be achieved at the perimeter.
3. Design criteria for release points (stacks) to ensure the effective dispersion of tritium in an atmospheric plume.

There is some indication that the CNSC will consider moving to a 100 Bq/L standard for drinking water as a result of the project.[328] This would mean that acceptable tritium levels in the environment would no longer be dependent on only the 1 mSv public dose limit. However, the CNSC does not regulate drinking water consumption in the provinces and it would be necessary for the provinces to adopt this level for it to be effective as a public health requirement. No document in the CNSC *Tritium Studies Project* explains why the full public dose is still used to derive release limits from nuclear power facilities or how this is consistent with ALARA or achieving the proposed groundwater objectives. Indeed, current technologies already in use at nuclear power facilities show unequivocally that much lower release limits are reasonably achievable, as is discussed below.

Ontario approaches to tritium in drinking water

In Ontario, the use of the 7000 Bq/L standard for tritium in drinking water is controversial. The Ontario Advisory Committee on Environmental Standards (ACES) recommended a reduction of the limit to 20 Bq/L in 1994.[329] In 2006 Toronto Public Health issued formal complaints about tritium in Toronto's drinking water. This led to the Ontario Drinking Water Advisory Council (ODWAC) doing a public health assessment on tritium in drinking water in 2009.[330] The ODWAC recommended that Ontario reduce the guideline level to 20 Bq/L.

---

[324] P. Thompson, *supra* note 315.
[325] *Ibid.*
[326] *Ibid.*
[327] *Ibid.*
[328] *Ibid.*
[329] Advisory Committee on Environmental Standards, AECS Report 94-01, "A Standard for Tritium: A recommendation to the Minister of Environment and Energy" (Toronto: AECS, 1994), online: <http://www.odwac.gov.on.ca/standards_review/tritium/1994_ACES_Report_Tritium.pdf>.
[330] Ontario Drinking Water Advisory Council, "Report and Advice on the Ontario Drinking Water Quality Standard for Tritium" (Toronto: Ontario Minister of the Environment, 2009), online: <http://www.odwac.gov.on.ca/reports/052109_ODWAC_Tritium_Report.pdf>.

Unlike the "optimization" approach of the ICRP, the ODWAC aimed for a derived risk level of 1 excess cancer in a million people based on a lifetime of exposure (70 years) or "negligible" public health risk. The ODWAC also relied on the findings of the Ontario *Walkerton Inquiry* to establish risk goals, specifically adopting the comment that "(i)n setting drinking water quality standards, the objective should be such that, if the standards are met, a reasonable and informed person would feel safe drinking the water."[331] Using that standard, the acceptable risk limit was identified as between 7 and 109 Bq/L. Ultimately the ODWAC determined that 20 Bq/L was achievable at Ontario nuclear power facilities.[332]

The ACES and ODWAC reports highlight the difference between the ICRP approach relied on by the CNSC and that used elsewhere in public health risk assessment. First, the ICRP approach uses serious or fatal cancer and hereditary effects to determine safety. In the ACES and ODWAC reports, other effects such as non-fatal cancer and reproductive effects are also evaluated for safety. Second, the ICRP approach has been broadly criticized for not taking into account sensitive populations (non-adults, fetuses, etc.) and the multiple exposure pathways (inhalation, absorption, ingestion) that tritium presents. ACES and ODWAC accepted some of these criticisms and modified their risk assessment approach to address them. Finally, ACES and ODWAC lowered acceptable risk further due to additional uncertainty over the RBE of tritium. One notable element of the ODWAC and ACES reports is that they clearly outlined the process for determining the guideline level. However, Ontario has not amended the regulations under the *Safe Drinking Water Act*, which still uses 7000 Bq/L.[333]

International comparison – tritium in drinking water

The World Health Organization (WHO) relies on a reference dose level or effective dose of 0.1 mSv from one year's consumption of drinking water. This represents 10% of the public dose level of 1 mSv and is similar to the approach used by Health Canada in the *Guidelines*. This is rounded up to establish a guideline level of 10,000 Bq/L of tritium in drinking water.[334]

Many jurisdictions have set lower limits for tritium in drinking water including an EU limit of 100 Bq/L and a limit in the US of 740 Bq/L.[335] Some of these differences relate to whether these jurisdictions use the 1 mSv annual public dose, or a lower one. California uses a public health goal of only 14.8 Bq/L.[336] This is based on a lifetime cancer (not fatality) risk of one in a million (similar to the Ontario ODWAC/ACES approach).

Other radionuclides from nuclear power facilities

CANDU reactors also release carbon-14, noble gases and iodine-131. Of these, most attention centres on carbon-14. CANDU reactors have comparatively high rates of carbon-14 production

---

[331] *Ibid*. at 40.
[332] *Ibid.* at 43-44.
[333] *Ontario Drinking Water Quality Standards*, O. Reg. 169/03.
[334] CNSC *Standards*, *supra* note 314 at 16.
[335] *Ibid*. at 15.
[336] *Ibid*. at 18.

because of the use of heavy water.[337] Carbon-14 is a radioactive isotope of carbon and is a pure beta emitter with a half-life of 5730 years.[338] Carbon-14 has high mobility in the environment, and is released to the external environment through gaseous and liquid discharges and though the disposal of solid radioactive waste.

The range of annual releases to air of radionuclides other than tritium from a CANDU facility are much lower, particularly in comparison to the 1 mSv-based derived release limits.[339] Likewise, in water, carbon-14 releases are much lower than tritium.[340]

Nuclear power facilities release levels well below the DRLs for each facility. This means that releases from these facilities are essentially unregulated from the perspective of requiring operators to control their normal operating releases or employ techniques to minimize their releases.

The CNSC does not release data on cesium-137 and strontium-90 inventories or emissions from nuclear power facilities.[341] There are inventories of Cesium-137 at CANDU reactors.[342] There are no derived release limits for these substances in power reactors. These substances are not discussed in this report due to lack of available information on whether or how these substances are released during normal reactor operations.

Environmental and health risks and pathways

Carbon-14

Carbon-14 is believed to be easily transferred during biological processes and soil–plant interactions. The human body treats carbon-14 like other carbon. Inhaled $^{14}CO_2$ (carbon dioxide-14) enters many components of body tissue. The biological half-life of carbon-14 is approximately 40 days. It has been found that accumulation of carbon-14 in the human body via respiration is small compared with that from ingestion of contaminated food. Carbon-14 can be easily concentrated in the food chain. Studies have shown concentration factors of 5000 for fish and mollusks and 2000 for soil sediments.[343]

---

[337] Man-Sung Yim & Francois Caron "Life cycle and management of carbon-14 from nuclear power generation" 2006 Progress in Nuclear Energy 48 at 2–3, online: <http://chemistry.laurentian.ca/NR/rdonlyres/DC14CD43-913E-445E-AC5D-C129A78E03AC/0/sdarticle.pdf>.

[338] IAEA, Management of waste containing tritium and carbon-14. (TR-Series 421) (Vienna, IAEA, 2004), online: <http://www-pub.iaea.org/MTCD/publications/PDF/TRS421_web.pdf> at 3.

[339] Winfield, *supra* note 275 at 67 and 71, compared with CNSC, INFO-210 (Rev 3) "Radioactive Release Data from Canadian Nuclear Power Plants 1999-2008" (Ottawa: September 2009) at 2.

[340] Winfield, *ibid.* at 67-71.

[341] B. A. Ahier and B. L. Tracy, "Radionuclides in the Great Lakes basin." (1995) 103 (Suppl 9) Environmental Health Perspectives, 89, online: <http://ehp.niehs.nih.gov/members/1995/Suppl-9/ahier-full.html>.

[342] G. Edwards, "Risks of Operating CANDU nuclear power plants" (Toronto: Greenpeace, 2008) provides some data on Cesium-137 inventories and risks.

[343] IAEA, *Management of waste containing tritium and carbon-14* (TR-Series 421) (Vienna, IAEA, 2004) online: <http://www-pub.iaea.org/MTCD/publications/PDF/TRS421_web.pdf> at 3

Iodine-131

Iodine is biologically mobile and selectively radiates the thyroid gland when taken into the body.[344] Releases of iodine-131 from reactors are widely variable and depend on the reactor coolant leakage rate. Since it is a volatile element, iodine-131 is readily released to the atmosphere in the event of an accident.[345] The absorbed dose in the thyroid is about 1000 times that in other organs and tissues.[346] The most significant exposure route for environmental radioiodine is the air-vegetation-livestock-milk pathway. However, the iodine-131 content of milk samples collected monthly from farms near nuclear generating stations in Ontario are usually not detectable.[347]

Noble gases

The noble gases are xenons, kryptons, helium, neon, argon and radon. These may be inhaled or sometimes absorbed through the skin. Radon is the greatest health concern. The most significant dose is to the lung due to the inhalation and accumulation of gasses attached to dust within the respiratory tract.[348] Radon presents considerable cancer risks.[349] Noble gases are released from Canadian nuclear power facilities and are subject to derived release limits.

Public health standards for other radionuclides

The CNSC regulates radioactive particulates in the air, noble gases and other airborne radionuclides, as well as releases of radionuclides into water through the use of DRLs. DRLs regulate the radioactivity of releases to prevent exposure beyond the public dose limit of 1 mSv. The quantities of radionuclides that are released are not regulated and there are no standards for outdoor air or water quality for radionuclides (other than uranium) with the exception of drinking water.

Health Canada's *Guidelines for Canadian Drinking Water* include radiological parameters for maximum allowable concentrations (MACs) for radionuclides. These are adopted by some provincial regulators in the same way as those described for tritium. The full set of Health Canada *Guidelines* for these substances are as follows:[350]

Cesium-137 (^{137}Cs)	10 Bq/L
Iodine-131 (^{131}I)	6 Bq/L
Lead-210 (^{210}Pb)	0.2 Bq/L
Radium-226 (^{226}Ra)	0.5 Bq/L
Strontium-90 (^{90}Sr)	5 Bq/L

[344] Ahier and Tracy, *supra* note 341.
[345] *Ibid*.
[346] *Ibid.*
[347] *Ibid.*
[348] *Ibid.*
[349] World Health Organization, Fact Sheet No. 291 "Radon and Cancer" (September 2009), online: <http://www.who.int/ionizing_radiation/env/radon/en/>.
[350] *Supra* note 316

Carbon-14 (^{14}C) (old) [351]	200 Bq/L

The WHO guideline levels for radionuclides in drinking water are 100 Bq/L for carbon-14 or half the old Canadian guideline amounts.[352] WHO documents state that derivation of a guideline value for iodine on the basis of information on the effects of iodine is "inappropriate" because there are few relevant data on the effects of iodine.[353]

Design standards for carbon-14

Older CANDU reactors release large quantities of gaseous carbon-14, while newer ones sometimes produce lower amounts. Reducing or avoiding the use of certain chemicals (for example, nitrogen) in reactor operations can reduce the production of carbon-14. One of the pathways for carbon-14 emissions is venting and purging the moderator cover gas and the heat transport system. Reducing the frequency of these events reduces the release of carbon-14. There are a variety of scrubbers that can capture CO_2 (carbon dioxide) when carbon-14 is converted into CO_2; however, such technologies can be costly.[354] Carbon-14 can be removed from liquid waste based on similar principles. However, there are no specific design standards for prevention of carbon-14 release in Canada.

Summary and comments

Environmental impacts of radionuclide releases are largely unknown and difficult to estimate. Current approaches to radiation protection in Canada regulate public doses to protect the public from modeled radiation exposure. Release limits currently in place are not designed to protect non-human biota from radiation. The regulatory approach to derived release limits from nuclear power facilities does not require technical or operational best practices for the prevention and control of releases and there are no systematic design standards for release prevention or minimization.

Of all the radionuclides released into the environment by nuclear power reactors, tritium is by far of the greatest concern. The current approach to tritium regulation focuses on the DRLs for releases from nuclear facilities, which vary considerably according to modeled committed effective public doses up to 1 mSv/ year. This is combined with the 7000 Bq/L drinking water limit, which is fixed and widely accepted in Canadian jurisdictions, despite some pointed criticism. Neither limit reflects a comprehensive approach to public health risk assessment and the current approach to risk management is not justified in a transparent manner by Canadian authorities, who rely on the ICRP to validate this approach. These limits are derived using complex models where assumptions play a key role and effects are very uncertain. The result is

---

[351] Federal–Provincial–Territorial Committee on Drinking Water, "Summary of Guidelines for Canadian Drinking Water Quality" (April 2003) at 9, online: <http://www.health.gov.sk.ca/water-guidelines-water-quality>.
[352] World Health Organization, "Guidelines for Drinking Water Quality" vol.1 (Geneva: WHO, 2006), online: <http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf>.
[353] *Ibid*. at 201.
[354] IAEA, *supra* note 338 at 55, 60.

widespread uncertainty about the reliability of the risk assessment for human health exposure to tritium and other radionuclides.

The CNSC and the precautionary principle

The CNSC uses 1 mSv as the annual public effective dose limit for radiation protection purposes. This dose limit is used to calculate derived release limits from nuclear power facilities and relies on modeling of specific harmful effects (or endpoints) to a critical group. The modeled harm from this level of dose over a lifetime is that 1 in 200 are predicted to get fatal cancer, severe hereditary effects or non-fatal cancers. Reproductive and other effects are not included.

The CNSC has not fully exercised its mandate to explore what "reasonable risk" is. The CNSC relies on the dose limit recommended by the ICRP and included in its regulations to determine what is "reasonable." Although the CNSC evaluates the use of ICRP recommendations at a high level, it does not investigate the implications of the 1 mSv public dose limit for each facility. Arguably, the CNSC should independently assess risks from radiation releases from a particular facility and explaining why that risk is "reasonable." As the IAEA has noted, "If a regulatory body must rely entirely on the assessments of others, its independence may be compromised."[355]

Moreover, it is not clear that relying on the ICRP public dose limit, which weighs harm to the public against the costs and benefits to society without a true public health-based analysis is precautionary. Canada is a signatory to the Rio Declaration of 1992, principle 15 of which states:[356]

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be a reason for postponing measures to prevent environmental degradation.

This principle is included in the *Canadian Environmental Assessment Act*,[357] the *Canadian Environmental Protection Act, 1999,*[358] and other legislation. The argument that current approaches are precautionary includes that there is uncertainty about the harmful effects from low levels of ionizing radiation, thus the use of 1 mSv as a public effective dose limit is precautionary because it is well below the level of observed effects.[359]

This can be countered by noting that the precautionary principle does not require scientific proof, but rather is a tool for addressing risk precisely when scientific certainty is elusive. While radiation effects at high doses are well understood, doses at low levels are not. In the case of 1 mSv, the linear-no-threshold model accepted for radiation protection, as interpreted by the ICRP,

---

[355] C. Stoiber *et al*., "Handbook on Nuclear Law" (Vienna: IAEA, 2003) at 27.
[356] *Rio Declaration on Environment and Development* 1992, 31 I.L.M. 874 (1992) online: <http://www.jus.uio.no/lm/environmental.development.rio.declaration.1992.doc>.
[357] *Supra* note 172, s. 4(1).
[358] S.C. 1999, c.33, s. 2.
[359] Jacques Lavoie, "Precautionary Principle" International School of Nuclear Law Dissertation (Dec 15, 2009) at 9; also see K.L. Mossman et al., "The Precautionary Principle and Radiation Protection" (Spring 2002) 13 *Risk* 137.

predicts serious irreversible harm in the form of serious cancers, deaths and other non-negligible effects from doses of 1 mSv.

Using uncertainty about this model's accuracy to justify the use of the public dose limit is not truly precautionary. Rather, that approach relies on uncertainty to justify not taking further measures to prevent the harm predicted by the LNT model.[360] Properly interpreted, the principle provides a low threshold to establish that there is a risk. It is normally interpreted to only require an objective basis or reasonable concern that serious or irreversible harm could result from an activity.[361] This has also been described as "when no concrete threat to those resources has yet been demonstrated but initial scientific findings indicate a possible risk."[362] Other cases have emphasized that where there is sweeping uncertainty but nevertheless a possible risk, restrictive measures are still justified.[363] Commentators in the nuclear field appear to at times seriously misunderstand the threshold of evidence involved in precautionary regulation and have required proof of harm to impose restrictions beyond the public dose limit.[364]

Another aspect of the principle that is misunderstood in the nuclear context is that the principle also requires taking into account social factors and alternatives in determining the seriousness and acceptability of risk.[365] While the principle does not require a particular response, it does suggest that non-serious, reversible risk is what is to be achieved.[366]

One example of this was in the recent CNSC decision on the shipment of reactor components. In that case opponents cited the precautionary principle. CNSC staff misunderstood the principle to apply only to mitigation measures and accident probability:[367]

---

[360] The CNSC is currently reviewing its use of the LNT model for risk assessment (CNSC meeting minutes December 16, 2010), online: <http://www.cnsc.gc.ca/eng/commission/pdf/2010-11-03-Minutes-e-Edocs3648675.pdf>. The precautionary principle was argued in *Inter-Church Uranium Committee Educational Co-operative v. Canada (Atomic Energy Control Board),* 2002 FCT 994, [2003] 2 F.C. 288; however the Court refused to allow these arguments as they were not in the notice of appeal.

[361] *.ARCO Chemie Nederland and Others v. Minister van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* (Minister for Housing, Planning and the Environment) and Others C-418/97 and C-419/97, [2000] E.C.R. 1-4475, at paras. 36-40; *Thames Water Utilities Ltd. v. South East London Division, Bromley Magistrates Court,* C-252/05, [2007] E.C.R. I-3883, at para. 24; *Telstra Corporation Pty. Ltd. v. Hornsby Shire Council*, [2006] N.S.W. 133 (N.S.W.L.E.C. Australia); *A.P. Pollution Control Board v. Prof. M. v. Nayudu*, (1999) A.I.R. 2715 (Sup. Ct. India); *Godavarman v. Union of India and Ors*., (2006) A.I.R. 202 (Sup.Ct. India).

[362] *Monsanto and Others v. Presidenza del Consiglio and Others*, C-236/01, [2003] E.C.R. I-8105.

[363] *Commission v. Denmark*, C-192/01, [2003] E.C.R. I-09693 at para. 52.

[364] *Mossman*, *supra* note 359.

[365] *Telstra*, *supra* note 361.

[366] *Ibid.*

[367] CNSC, *Reasons for Decision in the matter of Bruce Power Inc. Application for a Transport Licence.* (28 and 29 September 2010) at para. 137, online: <http://www.nuclearsafety.gc.ca/eng/commission/pdf/2010-09-28-29-Decision-Bruce-SG-e-Final-Edocs3673548.pdf>. For other examples of interpretations of the principle see CNSC, *Reasons for Decision in the matter of Cameco Inc. Environmental Assessment Guidelines* (August 29, 2003) at 10 where the CNSC confuses "conservative safety evaluations" with the application of the principle in the regulatory context, online: <http://nuclearsafety.gc.ca/eng/commission/pdf/Cameco-Final-e.pdf>. This can in part be attributed to the fact that although intervenors regularly argue the principle, they rarely explain it to the commission or the CNSC staff.

> Some intervenors opposed the shipment, citing the precautionary principle. The Commission asked CNSC staff to explain the applicability of the precautionary principle in their review. CNSC staff responded that the precautionary principle suggests that when there is evidence of serious environmental effects, scientific uncertainty should not be an impediment to implementing measures to mitigate those effects. CNSC staff stated that, for the proposed shipment, there are very low probability accident and malfunction scenarios, and appropriate mitigation measures are in place. The Commission is of the view that the precautionary principle was followed because there are very low-probability accident and malfunction scenarios and appropriate mitigation measures are in place.

The precautionary principle requires more than mitigation where there is a risk of serious, irreversible harm. It requires looking at alternatives and social perceptions of risk to determine what cost-effective measures could avoid the harm. This decision did not indicate whether the harm was serious or irreversible nor explain how mitigation measures could make it otherwise, or explain how the measures imposed would prevent the harm in question. In the case of routine releases of radionuclides, an objective basis would seem to be (at least arguably) established by the combination of the LNT model and observed evidence of harm at higher doses.

Accordingly, a precautionary approach would typically strive for minimization, not optimization. This would particularly be the case where there are cost-effective means to minimize. The concept of ALARA, at least as it is applied in Canada, is very different from the precautionary principle. The CNSC approach to ALARA described above only requires dose reduction "without significant expenditures." It accordingly bears little resemblance to the precautionary principle and does not ensure that the principle is followed. With respect, such an approach is only precautionary if the costs and benefits of further dose reductions are actually weighed on a case-by-case basis against the reasonable belief in risk based on current scientific models of harm, along with an assessment of the seriousness or irreversibility of that risk. This is not the case in current approaches to radiation protection. In contrast, the UK and the European Community more generally apply the concept of best available techniques to prevent or reduce emissions and their environmental impact.[368]

This leaves Canada without any broader public health standards addressing cumulative impacts of multiple tritium exposure pathways for all potential health effects. It means that Canadian regulators are without the means to effectively address the total loading of tritium and other radionuclides in Canadian waterways, airsheds or soils from multiple sources. It also leaves Canada without environmental quality standards that can address impacts to any non-human organisms. The effects of current release levels on both humans and non-humans from nuclear facilities are essentially unknown.

Canadian risk acceptability documentation or evaluations are also lacking. Existing regulatory initiatives have not defined acceptable risk for exposure to radionuclides either for humans or non-human organisms from a public health or environmental risk standpoint. The only exception is Ontario's drinking water assessment for tritium. The impact of radionuclides released into the environment by nuclear power facilities is largely unknown but presents a potentially serious,

---

[368] Tromans, *Nuclear Law, supra* note 215 at 446-450.

irreversible risk. A more robust and transparent precautionary approach should be applied by Alberta and Saskatchewan.

For non-human organisms, risk acceptability for radionuclide releases from nuclear power plants should be evaluated in relation to environmental protection principles such as the precautionary principle and Canada's commitment to maintain biodiversity and sustainable ecosystems. Continued emphasis on reductions in radioactive releases only where costs are minimal is inappropriate in the environmental context. Such approaches ignore commitments to sustainable development, intergenerational equity and potential long-term impacts of releases on ecosystems. They also do not take a precautionary approach. Radionuclides are not easy to remove from ecosystems once they are released. The long-term effects of radionuclide releases are poorly understood but potentially serious.

A precautionary approach would recognize that known potential impacts to humans and the environment, based on the LNT model, from radioactive releases are capable of supporting the implementation of further controls on releases.

Recommendation

Alberta and Saskatchewan have the authority to go beyond the approach to radiation protection used by the CNSC to protect public health, property and the environment. Alberta and Saskatchewan should evaluate the science on potential public health implications and impacts on non-human biota of routine releases of radionuclides from nuclear power plants. These evaluations should include effects that are not included in the ICRP approach, such as reproductive effects, and include transparent evaluations of the effects of radiation on vulnerable groups like women and children.

Alberta and Saskatchewan should adopt a scientifically informed approach to releases of radionuclides from nuclear power facilities. This should include an evaluation of the best available control techniques (technological and operational) to prevent releases of radionuclides. They should evaluate whether such measures represent precautionary regulation and the potential effects of releases on future generations and ecosystems. Such an evaluation should precede the approval process for any nuclear power facility and include opportunities for the public and medical professionals to provide input into acceptable risk levels.

Even though there is scientific uncertainty about the effects of current release levels of radionuclides, Alberta and Saskatchewan should recognize that the 1 mSv dose limit does not represent a public health standard, or even a cost-benefit analysis for a particular nuclear power reactor. Provincial regulators are not bound by the optimization approach of the ICRP, which prairie residents did not develop. The ICRP approach should not replace a careful evaluation of release control options for a specific reactor design.

Provinces have the jurisdictional power to go beyond this dose limit and adopt a regulatory approach that ensures that releases are effectively minimized and that releases from any nuclear power reactor reflect a socially acceptable risk.

Alberta should add limits for radionuclides to the *Substance Release Regulation* and the *Release Reporting Regulation* and remove the exemption from reporting for Class 7 dangerous goods. Alberta should enact regulations under the *Environmental Protection and Enhancement Act* and the *Public Health Act,* specifying public health and environmental protection standards for releases of radionuclides from nuclear power facilities. The Alberta Utilities Commission should develop technological and operational standards for the prevention of releases of radioactive substances from nuclear power plants.

Saskatchewan should add screening parameters and maximum acceptable concentrations for other radionuclides to the *Water Regulations* under the *Environmental Management and Protection Act* and the *Clean Air Act* should be amended to ensure that it expressly includes limits for radioactive materials released from nuclear power facilities that reflect public health and environmental protection. Saskatchewan should consider revising its electricity legislation to create a process for approvals and permit conditions for nuclear power plants.

Hazardous releases from nuclear facilities

Nuclear power facilities release a range of hazardous substances that are not by themselves radioactive. For example, nuclear reactors release ammonia, hydrazine, greenhouse gases, carbon monoxide, oxides of nitrogen, sulphur dioxide and particulate matter (PM) from standby generator testing, heavy metals, as well as other hazardous material from incinerating on-site waste.[369]

A large power reactor will typically release hazardous or toxic substances to the air and water during routine operation of the facility. For example, the Darlington power reactor in Ontario monitors releases of sulphur dioxide (SO_2), nitrous oxides (NOx), and carbon dioxide (CO_2) to air. It also has reportable releases of ozone-depleting substances (CFC-11, CFC-12 and HCFC-22) originating from air conditioning; sodium hypochlorite, which is used to control zebra mussels in some cooling water systems; and ammonia and hydrazine to air and water.[370] Other substances are reported under the *Canadian Environmental Protection Act, 1999,* including lead, mercury and particulate matter.[371] Metals like lead, mercury and cadmium are wastes produced by batteries, radiation shielding materials, electrical and lighting equipment and condenser tubes. Federal reporting indicates that most reactors in Canada have released between 10,000 kg and 100,000 kg of lead during a year, with mercury and cadmium being much smaller amounts.[372] Some facilities, such as the Pickering nuclear reactor, also use substantial amounts of asbestos.[373]

---

[369] M. Winfield, *supra* note 275 at 61.
[370] CNSC, "Information and Recommendations from Canadian Nuclear Safety Commission Staff Regarding Ontario Power Generation Inc. Renewal of the Darlington Nuclear Generating Station Operating Licence" (Public Hearing Day 1 November 1, 2007).
[371] National Pollutant Release Inventory, *2009 Facility & Substance Information for Ontario Power Generation - Darlington Nuclear* (Ottawa: Environment Canada, 2009), online: <http://www.ec.gc.ca/pdb/websol/querysite/facility_substance_summary_e.cfm?opt_npri_id=0000003163&opt_report_year=2009>.
[372] Winfield, *supra* note 275 at 64.
[373] *Ibid*. at 65.

The *Nuclear Safety and Control Act* gives the CNSC powers over non-radioactive hazardous waste. Under the regulations, "hazardous waste" is any non-nuclear substance that "is used or produced in the course of carrying on a licensed activity and that may pose a risk to the environment or the health and safety of persons."[374] The *Class I Nuclear Facilities Regulations* require information about hazardous releases in licence applications for nuclear reactors.[375] Section 12 of the *General Nuclear Safety and Control Regulations* provides that every licensee shall "take all reasonable precautions to control the release of radioactive nuclear substances or hazardous substances within the site of the licensed activity and into the environment as a result of the licensed activity."[376] Section 17 requires unlicensed hazardous releases be reported. This generally leads to the expectation that such releases will conform to the ALARA principle. However, ALARA is only described in guidance documents in relation to the 1 mSv public radiation dose and not in terms of non-radioactive releases. It is not clear from CNSC regulatory policies what the appropriate parameters are for non-radiological contaminants and there is little guidance for operators regarding how to ensure non-radioactive hazardous releases are ALARA.

CNSC staff evaluate hazardous waste handling systems by confirming that the facility meets International Standards Organization (ISO) requirements for managing system components. The CNSC evaluates this using an environmental performance index. The index weighs the following criteria:[377]

- Tritium and carbon-14 emissions (primary dose-to-public contributors);
- Number of spills;
- Number of chemical waste drums on site;
- Volume of low and intermediate radioactive waste generated;
- Thermal performance index; and
- Number of regulatory infractions.

The evaluation methodology for routine releases of hazardous substances is not particularly clear. In a review of the Darlington licence renewal application in 2007, CNSC staff noted that:[378]

> [W]hile OPG has been reporting unplanned releases of hazardous substances, OPG has not been reporting to the CNSC on monitoring results for routine releases of hazardous substances, as required by the licence…. OPG has been advised of this non-compliance. CNSC staff will continue to monitor this issue…

Despite this gap in information, the rating for Darlington's environmental protection facility remained high using the index and the facility was found to meet all requirements for environmental protection. It is unclear how non-radioactive releases are weighed overall in that calculation.

---

[374] *General Nuclear Safety and Control Regulations*, *supra* note 50, s. 1.
[375] *Supra* note 43.
[376] *General Nuclear Safety and Control Regulations*, *supra* note 50, s. 12(1)(f).
[377] CNSC, *supra* note 370 at 59.
[378] *Ibid.* at 65.

For large power reactors, CNSC requires reporting of hazardous releases. A revision of the CNSC Regulatory Document 99.2 on reporting requirements for power reactors is currently under consultation by the CNSC.[379] However, this lists no specific parameters or thresholds for reporting or release of hazardous substances. The Darlington nuclear power licence does not contain any specific hazardous release thresholds. Power reactor facilities report non-radiological toxic substance releases under the *Canadian Environmental Protection Act* to the National Pollutant Release Inventory. However, the same standards are not applied to research reactors. An examination of the small research reactor licencing document for the Saskatchewan Research Council's SLOWPOKE-2 Reactor shows that the licensee is not required to keep records of releases of non-nuclear substances.[380] The operating manual for the reactor has only one paragraph on "non-radiation hazards." The ELC obtained this through a provincial access to information request; however, the only clear information that is not redacted is "there are no unusual in-house hazards that can be foreseen."[381] The most recent compliance report does not contain any non-radiological parameters.[382] This demonstrates that there is currently no single CNSC approach to controlling hazardous releases from reactors.

The CNSC Regulatory document, *Site Evaluation for New Nuclear Power Plants,* intends to "set out the expectations" of CNSC regarding site evaluation for new plants. RD-346 offers some criteria regarding non-radiological impacts of a nuclear power plant on the local environment.[383]

At many nuclear facilities it remains unclear who is responsible for ensuring that routine hazardous substances are managed properly. Although provincial hazardous waste laws will normally apply, the extent to which provincial authorities are enforcing permit requirements is not clear. In conducting research for this project, few examples of hazardous release or hazardous waste management approvals were available from provincial regulators for CNSC regulated facilities.

The CNSC has jurisdiction under the *NSCA* to regulate hazardous waste from nuclear facilities, but it has not developed consistent approaches or standards for the regulation of hazardous waste. The CNSC does not seem to give much weight to routine hazardous releases in its evaluation of nuclear power plant licence applications.[384] There are no clear public health, safety, waste management or environmental standards applied in the control of hazardous

---

[379] CNSC, Regulatory Document, RD-99.2, *Reporting Requirements for Operating Nuclear Power Plants: Compliance Monitoring* November 2010- DRAFT) (Ottawa: Public Works and Government Services, 2010) at 5, requiring reporting of routine and unplanned releases of hazardous substances. The associated guidance document provides "no further guidance at this time" on environmental protection performance reporting (at 10).

[380] Saskatchewan Research Council, "SLOWPOKE 2 Reactor, Non-Power Reactor Operating Licence" (NPROL-19.04/2013) conditions 5.2 and 5.3 and Appendix B require reporting for radioactive substances only.

[381] [Author redacted], "Facility Site Description and Operating Manual for the SLOWPOKE 2 Reactor" (Revision 2) (Saskatchewan Research Council, SLOWPOKE 2 Committee, January 1997) at 36.

[382] Saskatchewan Research Council, *supra* note 143.

[383] CNSC, Regulatory Document, RD-346, Draft, "Site Evaluation for New Nuclear Power Plants,"(Ottawa: October 2007) Table 5.1. Also see commentary in Gordon Thompson, *Design and Siting Criteria for Nuclear Power Plants in the 21st Century* (Cambridge, Massachusetts: Greenpeace, January 2008), online: <http://www.cnsc-ccsn.gc.ca/fr/pdfs/irss_report_greenpeace.pdf>.

[384] CNSC, *supra* note 370 at 55-69.

releases from nuclear power facilities at the federal level. Provincial authorities should not assume that CNSC standards for hazardous waste are equivalent to their own.

In an October 2009 decision regarding the licencing of a nuclear waste site in Ontario, the CNSC was asked to rule on its jurisdiction over the waste in question, a mixture of radioactive and non-radioactive waste. The CNSC held that it has full regulatory authority over any nuclear substances or contamination from nuclear substances and full authority to regulate the discharge of radioactive and hazardous substances associated with or arising from an activity that is licensable under the *NSCA*. The CNSC held that it did not regulate industrial waste or the discharge to the environment of substances not associated with the nuclear industry "unless or until that waste is commingled with, or is an integral part of, the nuclear-related licensed activity." However, the CNSC ruled that its jurisdiction over both nuclear waste or hazardous waste from nuclear facilities is not exclusive, stating that: "[t]he Commission notes that the issuance of the licence does not obviate the need for the licence applicant to seek any applicable provincial authorizations."[385]

With respect to hazardous effluent from nuclear power reactors' cooling systems released into areas frequented by fish, section 36(3) of the federal *Fisheries Act* would apply, which prohibits the discharge of a substance deleterious to fish.[386] However, this provision is not currently enforced against nuclear power facilities in Canada.[387]

Recommendation

Currently, the CNSC does not ensure that power reactors are accurately reporting their hazardous releases and fails to transparently assess the potential impacts of hazardous waste management on human health and the environment at nuclear power and associated waste facilities. Alberta and Saskatchewan should amend their waste regulations to ensure that waste releases from nuclear power facilities are regulated to the same standards as other facilities in the province.

Currently, Alberta exempts any waste regulated by the CNSC from the definition of "hazardous waste."[388] Saskatchewan regulations currently exempt only radioactive waste regulated by federal authorities. Provinces should regulate to ensure that mixed waste and hazardous waste from nuclear power facilities are properly managed. Moreover, Alberta and Saskatchewan should review their substance release provisions under *EPEA* and *EMPA* to ensure that nuclear reactors and associated waste facility releases are regulated for public health and environmental protection and to ensure accurate reporting.

Aquatic environment-facility interactions

One of the most dramatic impacts from nuclear power facility operations is not the radioactive releases from the facility, but instead the thermal plumes, fish impingement and entrainment in

---

[385] Canadian Nuclear Safety Commission, *Record of Proceedings Including Reasons For Decision in the Matter of Atomic Energy of Canada Limited* (Ottawa: CNSC, 2009), paras. 23-24.
[386] R.S.C., 1985, c .F-14.
[387] See Transcript, *infra* note 395.
[388] See Part I of this report "Provincial legislation in relation to nuclear regulation" at 32.

the cooling water system. Nuclear power plants, like conventional power plants, require large volumes of water for cooling. Fish *impingement* refers to fish that are killed by being sucked against the cooling water intake screens, designed to prevent fish from entering the pipe. Many factors will affect fish impingement, such as the rate of intake, the volume of intake, whether or not some species are attracted to the intake, the location of the intake and others. Research shows that there is a linear relationship between volume and catch rates.[389] *Entrainment* is a term generally used to describe the fate of organisms that are drawn into the cooling water intake structure and enter the cooling system. Millions of fish eggs are entrained in the existing Darlington Nuclear Generation cooling system every year.[390]

Aquatic species mortality is a major concern with any nuclear power plant. The amount of flow, rate of flow and site of cooling water intake openings relative to fish and aquatic habitat are important design and operational issues. Nuclear power facilities are characterized by a high volume of water use for cooling purposes. This leads to water losses through steam, and loss of individual fish and fish eggs into the cooling water intake. In the most recent environmental assessment for the new Darlington nuclear power plant it was predicted that some species of benthic invertebrates and fish might be lost altogether from lake bed disruptions and impingement mortality or entrainment associated with operation of the once-through cooling intake. If cooling towers were used, the impact is predicted to be smaller.[391]

However, impacts can be in the millions of fish and fish larvae. For example, the Darlington Reactor assessment outlined past impacts at that facility as follows:[392]

	Species	Impinged	Entrained
Darlington NGS	Alewife, round goby, carp and other species	14,119 (2006) 26,020 (2007)	16,833,776 (2004) 7,601,306 (2006)

Provinces regulate water use by industrial facilities through water allocation legislation. The federal Department of Fisheries and Oceans (DFO) may regulate impingement and entrainment and nuclear facilities are normally required to complete an Application for Authorization for Works or Undertakings Affecting Fish Habitats under s.35(2) of the *Fisheries Act*.[393] They also require approval under section 32 of the *Fisheries Act,* which states that no person shall destroy

---

[389] P.A. Henderson, comments on aquatic issues relating to the proposed New Nuclear Darlington (NND) power Plant" (Toronto: Pices Conservation, 2010) at 3-6, online: <http://www.waterkeeper.ca/wp-content/themes/waterkeeper/documents/DarlingtonNB/Henderson.pdf>.
[390] *Ibid*.
[391] *Ibid*.
[392] OPG, "Aquatic Environment Assessment Of Environmental Effects Technical Support Document 06 New Nuclear - Darlington Environmental Assessment" (Golder, September 2009) at 59, 3-27 online: <http://www.opg.com/power/nuclear/darlington/EA_Process/Technical%20Support%20Documents/06%20Aquatic%20Environment%20Assessment%20of%20Environmental%20Effects%20TSD.pdf>.
[393] *Fisheries Act, supra* note 386.

fish by any means other than fishing except as authorized by the Minister.[394] Existing nuclear facilities in Canada are commonly out of compliance with s.32 of the *Fisheries Act*.[395] Section 30 of the *Fisheries Act* requires a fish guard or a screen, covering, or netting over the entrance or intake so as to prevent the passage of fish into such water intake, ditch, channel or canal for water intakes for power generation in fisheries waters. Fisheries and Oceans also provides guidelines for impingement and entrainment, but these are not applicable to existing nuclear facilities.[396]

Canadian regulators, including the federal Department of Fisheries and Oceans, do not apply best available technology standards that require the elimination of "once-through" cooling systems, which result in higher impingement and entrainment of aquatic organisms through cooling intakes than do other technologies like cooling towers.[397] An example of a "best available technology" approach is that used in New York state and California, which have both banned once-through cooling.[398] Wet closed-cycle cooling can also reduce cooling water requirements by approximately 93-98 percent from that required by once-through cooling technology.[399] Notably, the CNSC does not require new nuclear power facilities to use lower-impact cooling towers that are now required in some other jurisdictions.[400]

Thermal discharge

Cooling water is discharged at considerably warmer temperatures than at intake and can result in what is referred to as a "thermal plume." Impacts of thermal plumes vary depending on the receiving environment, dilution, the types of species and the temperature tolerance of those species. Thermal plumes are considered a deleterious substance under section 36 of the *Fisheries Act,* which is administered by Environment Canada.[401] If a thermal plume is hot enough to cause either acute lethality or a chronic effect to fish, then that would be considered an offence under the *Fisheries Act*. Impact assessments of thermal plumes include the Bruce Power

---

[394] OPG, *supra* note 374. at ES-2; DFO, "Freshwater Intake End-of-Pipe Fish Screen Guideline" (Ottawa: Public Works, 1995), online: <http://www.dfo-mpo.gc.ca/Library/223669.pdf>.
[395] Darlington New Nuclear Power Plant Project Joint Review Panel, (24 March 2011), Transcript Volume 4 at 55-62, online: <http://www.waterkeeper.ca/wp-content/themes/waterkeeper/documents/DarlingtonNB/DarlingtonTranscriptMarch241011.pdf>.
[396] DFO, "Guidelines for Minimizing Entrainment and Impingement of Aquatic Organisms at Marine Intakes in BC" (Ottawa: DFO, 1991) CMRFAS 2098, online: <http://www.dfo-mpo.gc.ca/Library/121776.pdf>.
[397] A "once-through" system is designed to withdraw water from a natural or other water source, use it at the facility to support contact and/or noncontact cooling uses, and then discharge it to a waterbody without recirculation.
[398] New York State Department of Environmental Conservation, Draft DEC Policy, "Best Technology Available (BTA) for Cooling Water Intake Structures" (March 4, 2010) establishing "Dry closed-cycle cooling as the performance goal for all new industrial facilities" in some areas. Dry closed-cycle cooling is a system that uses air flow, rather than the evaporation of water, to remove heat from the power station in order to reduce or eliminate the consumptive use of surface waters.
[399] *Ibid*. at 4. In a wet closed-cycle system the water is usually sent to a cooling canal, channel, pond, or tower to allow waste heat to be dissipated to the atmosphere and then is returned to the system. New source water (makeup water) is added to the system to replenish losses.
[400] California's State Water Resources Control Board, "Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling" (May 4, 2010).
[401] See Transcript, *supra* note 395.

facility in Tiverton, Ontario. In 2008, CNSC staff developed evaluation criteria through an internal assessment.[402] This included the use of federal and provincial generic temperature criteria for aquatic life[403] and waterbody-specific provincial effluent guidelines and thermal standards.[404] The Ontario Ministry of the Environment regulates thermal discharge from nuclear power plants under the *Ontario Water Resources Act*.[405] Fish habitat can also be impacted by thermal plumes. Larger fish may avoid the plume and are harmed by being denied access to habitat. Thermal impacts are felt by eggs and younger fish who have difficulty swimming.[406] Cooling systems also use chlorination and other chemical additives to keep bacteria out of the cooling system, which is in turn released when the discharge occurs.[407] This can also be regulated under section 35 of the *Fisheries Act*.[408]

The CNSC does not apply standards for regulating the thermal plume in relation to cooling system type, mitigation technologies or temperature parameters that must be met. Moreover the existing CNSC review approach does not include clear requirements for monitoring, follow up or long-term evaluation of the impacts of thermal plumes on aquatic ecosystems.[409] The CNSC assesses what is "reasonable" on a case-by-case basis.[410] Both cooling towers and once-through cooling were considered as technology options in the environmental assessment of the recently proposed Darlington reactor, but once-through cooling continues to be the preferred option due to its lower cost.[411] This situation highlights the lack of clear federal and provincial standards for mitigating cooling water impacts. The CNSC has taken the issue more seriously in recent years, including ordering the Pickering nuclear power facility in Ontario to reduce its fish losses.[412] In 2007, CNSC staff concluded that ongoing fish mortality, due to impingement and entrainment in the cooling water intake of both Pickering facilities, constituted an unreasonable risk to the environment. CNSC staff said that the Department of Fisheries and Oceans had expressed concerns with fish losses and concluded that OPG had not implemented available mitigation measures. Consequently, CNSC staff requested that OPG implement mitigation measures in accordance with a strict timetable.[413] OPG has now identified improved barrier net and fish

---

[402] CNSC, "Thermal Plume Effects on the Aquatic Environment", online: <http://www.nuclearsafety.gc.ca/eng/pdfs/Staff_Review_Procedures/effects_of_the_project_on_the_environment/SRP-EIS-Thermal_Plume_Effects_in_Aquatic_Environment_e.pdf>.
[403] Based on Canadian Council of Ministers of the Environment, "Canadian Environmental Quality Guidelines, (Winnipeg: 1999), temperature guideline.
[404] Based on Ontario Ministry of Environment, "Water Management – Policies, Guidelines" Provincial Water Quality Objectives for the Ministry of Environment and Energy, (1999).
[405] *Supra* note 158. A request by ELC to obtain a copy of this type of approval was denied by the Ontario Ministry of the Environment.
[406] P.A. Henderson, *supra* note 389 at 16.
[407] *Ibid*. at 20.
[408] *Ibid*.
[409] See CNSC, "Reasons for Decision: Ontario Power Generation application to renew Pickering NGS A Operating Licence" (September 20, 2010) at 24, online: <http://nuclearsafety.gc.ca/eng/commission/pdf/2010-05-21-Decision-OPG-PickeringA-e-Edocs3609970.pdf>.
[410] OPG, *supra* note 392; CNSC, *supra* note 383.
[411] OPG, *ibid.*
[412] In October 2008 the CNSC issued requirements for OPG to implement mitigation measures for fish protection at Pickering to reduce fish impingement by 80%, reduce fish entrainment by 60% and conduct a study to determine thermal discharge impact on fish. See note 413, *infra.*
[413] CNSC, *supra* note 409 at 24.

stocking or habitat restoration to mitigate its impact and installed a barrier net that is removed in winter.[414] However, OPG is not modifying the cooling system design itself. Although the CNSC has expressed concerns about this system they have not taken any regulatory action.[415]

Summary

There are major gaps in regulating facility-environment interactions at nuclear power facilities. It is unclear whether the CNSC, the Department of Fisheries and Oceans or provincial authorities are responsible for ensuring the prevention of impingement and entrainment and addressing thermal plume impacts.

Alberta can regulate water withdrawals from nuclear power facilities under the existing *Water Act* and Saskatchewan can do so under the *Saskatchewan Watershed Authority Act*. However, there are currently no standards relating to thermal-electric cooling systems at nuclear power plants under this legislation.

Due to the alarming impacts of these systems at existing nuclear facilities in Canada, Alberta and Saskatchewan should consider a ban on once-through cooling systems used in other provinces and these provinces should develop clear technological, operational and other standards to ensure that aquatic species and their habitats are adequately protected.

[414] OPG presentation, Pickering Nuclear Power Facility (2010), online: <http://www.opg.com/community/activities/pickering/PCAC%20MinutesAppendix/10.06.22%20PCAC%20Minutes%20Appendix%202.pdf>.
[415] CNSC, *supra* note 409 at 25.

Conclusion

There is a surprising array of regulatory gaps in the nuclear power sector at both the federal and provincial levels. Provincial regulators have become involved in an array of different issues that affect public health, waste management and electricity regulation since the beginning of the nuclear industry. However, as the mandate of federal regulators has expanded, provinces have largely not kept pace.

One of the most prevalent arguments for nuclear power is that it might help fight climate change. However, the failure of regulators to create a process that evaluates alternative electricity options in relation to nuclear has made it impossible to weigh the costs and benefits of nuclear in the context of electricity planning. Although the mandate of the CNSC is on its face to assess the "reasonableness" of risks posed by nuclear, it excludes the broader context in which nuclear power operates from its evaluations. This context, where nuclear fits in the overall electricity planning system, is provincial jurisdiction and the provinces have a clear role in addressing these questions.

The CNSC has, to date, read its mandate narrowly in relation to environmental protection. First and foremost it has regulated releases into the environment to ensure that the public is not exposed to more than the 1 mSv annual public dose. The use of this dose limit reflects international radiation protection standards that are designed to promote and optimize the use of nuclear power rather than strictly protect public health. From a public health standpoint the CNSC has relied too much on the concept of ALARA and has not confronted uncertainty about the public health impacts of releases below the 1 mSv annual public dose.

Broader environmental protection has been largely neglected by federal regulators, including the protection of non-humans from exposure to radiation and the regulation of routine hazardous releases. Federally, Canada does not have standards for non-radioactive hazardous releases or waste management from nuclear power facilities that are comparable to provincial requirements.

Provinces have jurisdiction over environmental protection, the management of sites for the production of electricity, public health, property, civil liability and other areas that should be used to address some of these gaps. Provinces have the power to protect their citizens from the potential impacts of nuclear power facilities. The legislative amendments involved in improving provincial regulation of nuclear are fairly straightforward, but the capacity-building required to implement some of those changes will be significant.

Appendix I - Glossary

AECA – *Atomic Energy Control Act*

AECB – Atomic Energy Control Board

AECL – Atomic Energy of Canada Limited

Action Level – An amount of radiation that represents a safety concern, because it indicates that radiation protection systems might not be operating properly.

ALARA – "As low as reasonably achievable." An approach to control or manage radiation exposures (both individual and collective to the workforce and the public) and releases of radioactive material to the environment as low as social, technical, economic, practical, and public policy considerations permit.

BEIR – Biological Effects of Ionizing Radiation, a report commissioned by the National Academy of Sciences.

Bq – Becquerel is a unit of *radioactivity* that refers to the rate of atomic decay of a material over a time period. 1 Bq is one disintegration of an atom per second. 1 TBq = 1 Terabecquerel (10^{12} Bq); 1 GBq = 1 Gigabecquerel (10^{9} Bq).

CANDU – Canadian Deuterium-Uranium, the type of heavy-water (deuterium) reactor used commercially in Canada.

CEAA – *Canadian Environmental Assessment Act*

CEPA – *Canadian Environmental Protection Act, 1999*

CNSC – Canadian Nuclear Safety Commission

Critical Group/Person – Theoretical person used to estimate radiation doses.

CSA – Canadian Standards Association

DRL – Derived Release Limit, a limit on radiation releases that is derived from the allowable radiation dose (for example, the 1 mSv annual public dose).

Dose – a quantity that reflects how much radiation is absorbed by living tissue and the harm it may cause.

IAEA – International Atomic Energy Agency

ICRP – International Commission on Radiological Protection

LNT – the "linear no threshold" model for predicting harm from radiation at low doses.

MAC – Maximum allowable concentration

NRU – National Research Universal Reactor in Chalk River, Ontario

NRX – National Research Experiment Reactor in Chalk River, Ontario

NSCA – *Nuclear Safety and Control Act*

Reference Person – See Critical Group

RBE – Relative Biological Effectiveness

Sv – Sievert; a unit of radiation dose that quantifies the biological effects of ionizing radiation: 1 mSv (Millisievert) = 0.001 Sv and microsievert (1 μSv) = 0.000001 Sv.

UNSCEAR – United Nations Scientific Commission on the Effects of Atomic Radiation

WHO – World Health Organization

Appendix II - About ionizing radiation[416]

Ionizing radiation occurs when an atom is unstable. An atom may be unstable when it has an imbalance between the number of negatively charged electrons and positively charged protons in the nucleus. These atoms are called isotopes. The number of neutrons in the nucleus of that element is the *isotope* of that element. A radioactive isotope of a substance is called a radionuclide. The atomic weight of a substance will be the number of protons and neutrons added together. Accordingly uranium-238 has 92 protons and 146 neutrons. The "wrong" number of neutrons will mean more radioactivity (i.e. less stable). When unstable, these atoms decay by releasing energy to become more stable. This is the release of radiation in the form of alpha, beta, gamma or X-ray radiation which are known as ionizing radiation.

Radioactivity refers to the rate of atomic decay of a material over a time period and this is expressed internationally in becquerels (Bq). 1 Bq is one disintegration of an atom per second.

Exposure is the amount of radiation traveling through the air. Note that the exposure measurement in the air will not be the same as the dose received by tissue because dose will depend on the nature of the absorbing material. Exposure can be converted to a dose thorough a conversion calculation.

The Sievert (Sv) of radiation is a unit used to measure the *equivalent dose* of ionizing radiation into biological tissue. This is usually expressed in millisieverts (mSv). To calculate the *effective dose*, the absorbed dose is weighted using a radiation weighting factor (W_R). The equivalent dose to a tissue is found by multiplying the absorbed dose by the weighting factor for radiation type. Different types of radiation have different weighting factors. This is also expressed as the Relative Biological Effectiveness (RBE) of a radiation source. There is a great deal of uncertainty about the appropriate weighting factors to be used.

The *committed equivalent dose* is the sum of the total lifetime exposure for a particular radionuclide. Further weighting can be done using the weighting factor for the type of tissue (W_T). The result is an effective dose that is the total of the equivalent dose for each type of tissue. Each type of tissue has its own weighting factor. The tissue weighting factor will express the sensitivity of the tissue to radiation.

Effective dose is used in radiation protection to compare the probable risk of specific types of effects from different kinds of exposure. It is not intended as a measure for short-term or threshold effects of radiation exposure such as erythema, radiation sickness or death.

The *committed effective dose* is the sum of all exposures to different tissues by different radionuclides in a lifetime. Committed dose also sometimes refers to internal exposure from

[416] Information in this section is adapted from J. Valentin ed., "The 2007 Recommendations of the ICRP in the annals of the ICRP publication 103, 37(2-4) (2007); and Herman Cember et al. ed. *Introduction to Health Physics* (4th ed) (McGraw Hill Medical: 2009) Chapter 6, Radiation Dosimetry; also see Health Canada "Radiation Doses" and "Ionising Radiation" (2005), online: <http://www.hc-sc.gc.ca/hc-ps/ed-ud/event-incident/radiolog/info/details-eng.php>.

inhaling, absorbing or ingesting a radionuclide. Canadian regulations use the *committed effective dose* over an annual period.

The term *collective dose* means the product of the number of individuals in a group and the average dose to those individuals. It is expressed as a person-Sievert (person-Sv).

Reference Person (or "critical group") is a theoretical individual or group that receives the most exposure from a regulated source. For example, a reference person may be a 58 kg female who is 120 cm tall or a 70 kg male who is 170 cm tall and various other physical characteristics.

Appendix III - Nuclear power facilities in Canada

Bruce Nuclear Generating Stations A and B Licensee: Bruce Power Inc. Location: Kincardine, Ontario	Kincardine hosts two nuclear generating stations, Bruce-A and Bruce-B. Bruce-A consists of four pressurized heavy water reactors. The station commenced operation in 1976. Bruce Power Inc. is engaged in a project for the return to service of reactor Units 1 and 2, which are currently laid-up. In 2003 reactor Units 3 and 4 were refueled for service. Bruce-B consists of four pressurized heavy water reactors. This station commenced operation in 1984 and continues to operate today.
Pickering Nuclear Generating Stations A and B Licensee: Ontario Power Generation (OPG) Inc. Location: Pickering, Ontario	Pickering hosts two nuclear generating stations, Pickering-A and Pickering-B. Both stations consist of four pressurized heavy water reactors. Pickering-A commenced operation in 1971. Units 2 and 3 are currently laid-up, and OPG is progressing with a project to place them in a safe storage state. Pickering-B commenced operation in 1982 and continues to operate today.
Darlington Nuclear Generating Station Licensee: Ontario Power Generation (OPG) Inc. Location: Bowmanville, Ontario	Darlington Nuclear Generating Station consists of four pressurized heavy water reactors. The station commenced operation in 1989 and continues to operate today.
Gentilly-2 Nuclear Generating Station Licensee: Hydro-Québec Location: Gentilly, Québec	Gentilly-2 Nuclear Generating Station consists of one pressurized heavy water reactor. The station commenced operation in 1982 and continues to operate today.
Point Lepreau Nuclear Generating Station Licensee: New Brunswick Power Nuclear Location:Point Lepreau, New Brunswick	Point Lepreau Nuclear Generating Station consists of one pressurized heavy water reactor. The station commenced operation in 1982 and continues to operate today.

Source: Canadian Nuclear Safety Commission

Bibliography

Legislation and Regulations

Domestic

Activities Designation Regulation, Alta. Reg. 276/2003.

Alberta Land Stewardship Act, S.A. 2009, c. A-26.8.

Alberta Utilities Commission Act, S.A. 2007, c. A-37.2.

Atomic Energy Control Act, 1946, 10 Geo. VI c. 37.

Boiler and Pressure Vessel Act, S.N.B. 1976, c. B-7.1.

Boiler and Pressure Vessel Code, N.B. Reg. 84-174.

Canadian Environmental Assessment Act, S.C. 1992, c. 37.

Canadian Environmental Protection Act, 1999, S.C. 1999, c. 33.

Class I Nuclear Facilities Regulations, S.O.R./2000-204.

Clean Air Act, S.S. 1986-87-88, c. C-12.1.

Clean Environment Act, R.S.N.B. 1973, c. C-6.

Comprehensive Study List Regulations, S.O.R./94-638.

Constitution Act, 1867, (U.K.), 30 & 31 Vict., c. 3, reprinted in R.S.C. 1985, AppII, No.5.

Effluent Monitoring and Effluent Limits – Electric Power Generation Sector, O. Reg. 215/95.

Electric Utilities Act, S.A. 2003, c. E-5.1.

Electricity Projects, O. Reg. 116/01.

Environmental Assessment (Mandatory and Exempted Activities) Regulation, Alta. Reg. 111/1993.

Environmental Assessment Act, R.S.O. 1990, c. E.18.

Environmental Assessment Act, S.S. 1979-80, c. E-10.1.

Environmental Impact Assessment Regulation, N.B. Reg. 87-83.

Environmental Management and Protection Act, 2002, S.S. 2002, c. E-10.21.

Environmental Protection Act, R.S.O. 1990, c. E.19.

Environmental Protection and Enhancement Act, R.S.A. 2000, c. E-12.

Environment Quality Act, R.S.Q., c. Q-2.

Environmental Spill Control Regulations, R.R.S., c. D-14, Reg. 1.

Exclusion List Regulations, *2007*, S.O.R./2007-108.

Fisheries Act, R.S.C. 1985, c. F-14.

General Nuclear Safety and Control Regulations, S.O.R./2000-202.

Hazardous Substances and Waste Dangerous Goods Regulations, R.R.S., c. E-10.2, Reg. 3.

Hydro and Electric Energy Act, R.S.A. 2000, c. H-16.

Hydro-Québec Act, R.S.Q., c. H-5.

Inclusion List Regulations, S.O.R./94-637.

International Rapids Power Development Act, R.S.C. 1952, c. 157.

Jobs and Economic Growth Act, S.C. 2010, c. 12.

Law List Regulations, S.O.R./94-636.

Major Projects Regulation, N.B. Reg. 90-51.

Mineral Industry Environmental Protection Regulations, 1996, R.R.S., c. E-10.2, Reg. 7.

Nuclear Safety and Control Act, S.C. 1997, c. 9.

Ontario Drinking Water Quality Standards, O. Reg. 169/03.

Ontario Hydro Nuclear Facilities Exclusion from Part I of the Canada Labour Code Regulations (Industrial Relations), S.O.R./98-179.

Ontario Water Resources Act, R.S.O. 1990, c. O-40.

Planning and Development Act, S.S. 2007, c. P-13.2.

Point Lepreau Basic Planning Statement Adoption Regulation, N.B. Reg. 83-218.

Point Lepreau Site Regulation, N.B. Reg. 84-82.

Point Lepreau, New Brunswick Nuclear Facility Exclusion Regulations (Parts I, II and III of the Canada Labour Code and the Non-smokers' Health Act), S.O.R./2008-76.

Potable Water Regulation, Alta. Reg. 227/2003.

Power Corporation Act, R.S.S. 1978, c. P-19.

Public Health Act, 1994, S.S. 1994, c. P-37.1.

Public Health Act, R.S.A. 2000, c. P-37.

Radiation Health and Safety Act, *1985*, S.S. 1984-85-86, c. R-1.1.

Radiation Protection Act, R.S.A. 2000, c. R-2.

Radiation Protection Regulations, S.O.R./2000-203.

Regulation respecting environmental impact assessment and review, R.R.Q. 1981, c. Q-2, r. 23.

Regulation respecting hazardous materials, R.R.Q., c. Q-2, r. 32.

Release Reporting Regulation, Alta. Reg. 117/1993.

Saskatchewan Watershed Authority Act, *2005*, S.S. 2005, c. S-35.03.

Saskatchewan Watershed Authority Regulations, R.S.S., c. S-35.03, Reg. 1.

Substance Release Regulation, Alta. Reg. 124/1993.

Waste Control Regulation, Alta. Reg. 192/1996.

Water Act, R.S.A. 2000, c. W-3.

Water Quality Regulation, N.B. Reg. 82-126.

Water Regulations, R.R.S., c. E-10.2, Reg. 1.

International

Convention on Nuclear Safety, 17 June 1994, 33 I.L.M. 1514 (entered into force 24 October 1996).

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 29 September 1997, 36 I.L.M. 1431 (entered into force 18 June 2001).

Nuclear Non-Proliferation Treaty, 1 July 1968,[1968] 729 U.N.T.S. 161 (entered into force 5 March 1970).

Jurisprudence

Domestic Cases

114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town of), 2001 SCC 40 [2001] 2 S.C.R. 241.

820099 Ontario Inc v. Harold E. Ballard Ltd., [1993] O.J. No. 1082 (Ont. C.A.).

Attorney General of Ontario v. Canada Temperance Federation, [1946] A.C. 193 (P.C.).

Beauharnois Light, Heat and Power Co. Ltd. v. The Hydro-Electric Power Commission of Ontario, [1937] O.R. 796.

Bell Canada v. Quebec (Commission de la santé et de la sécurité du travail), [1988] 1 S.C.R. 749.

British Columbia (Attorney General) v. Lafarge Canada Inc., 2007 SCC 23, [2007] 2 S.C.R. 86.

British Columbia Electric Railway. Co. Ltd. v. Canadian National Railway. Co., [1932] S.C.R. 161.

Canadian National Railway Co. v. Ontario (Director under the Environmental Protection Act), [1991] 3 O.R. (3d) 609; appeal to CA dismissed: [1992] O.J. No. 317; and leave to appeal dismissed, *Ontario v. Canadian Pacific Ltd.,* [1995] 2 S.C.R. 1028.

Canadian Nuclear Safety Commission, *Reasons for Decision in the matter of Cameco Inc. Environmental Assessment Guidelines* (29 August 2003).

———, *Information and Recommendations from Canadian Nuclear Safety Commission Staff Regarding Ontario Power Generation Inc. Renewal of the Darlington Nuclear Generating Station Operating Licence* (1 November 2007).

———, *Reasons for Decision Re Ontario Power Generation Application to Renew Pickering NGS A Operating Licence* (20 September 2010), online: <http://nuclearsafety.gc.ca/eng/commission/pdf/2010-05-21-Decision-OPG-PickeringA-e-Edocs3609970.pdf>.

———, *Record of Proceedings Including Reasons For Decision Re Atomic Energy of Canada Ltd.* (16 October 2009).

———, *Reasons for Decision Re Bruce Power Inc. Application for a Transport Licence* (28 and 29 September 2010), online: <http://www.nuclearsafety.gc.ca/eng/commission/pdf/2010-09-28-29-Decision-Bruce-SG-e-Final-Edocs3673548.pdf>.

———, *Record of Proceedings and Reasons for Decision Re Cameco Corporation, Environmental Assessment Track Report Regarding Cameco Corporation's Vision 2010 Project for the Conversion Facility in Port Hope, Ontario* (6 November 2008).

———, *Record of Proceedings Including Reasons for Decision Re Environmental Assessment under the Canadian Environmental Assessment Act of the Proposed return to service of the Pickering 'A' Nuclear Generating Station*, Proponent Ontario Power Generation Inc. (16 February 2001).

Canadian Pacific Railway Co. v. Corporation of the Parish of Notre Dame de Bonsecours, [1899] A.C. 367.

Canadian Western Bank v. Alberta, 2007 SCC 22, [2007] 2 S.C.R. 3.

Cardinal v. Attorney General of Alberta, [1974] S.C.R. 695 at 703.

Citizens Insurance Co. of Canada v. Parsons (1881), 7 App. Cas. 96 (P.C.).

Construction Montcalm Inc. v. Minimum Wage Commission, [1979] 1 S.C.R. 754.

Denison Mines Ltd. v. Attorney General of Canada, [1973] 1 O.R. 797 (H.C.), [1972] 32 D.L.R. (3d) 419.

Directeur des poursuites criminelles et pénales c. Alcan inc., 2009 QCCQ 1638 (CanLII).

Edward v. Beaver Smith, 2002 CanLII 45497 (N.B P.C.).

Energy Probe v. Canada (A.G.), 1994 Can LII 7247 (O.N.S.C.).

Friends of the Oldman River Society v. Canada (Minister of Transport), [1992] 1 S.C.R. 3.

Fulton v. Energy Resources Conservation Board, [1981] 1 S.C.R. 153.

General Motors of Canada Ltd. v. City National Leasing, [1989] 1 S.C.R. 641.

Hamilton Harbour Commissioners v. Hamilton (City of) (1978), 21 O.R. (2d) 459.

Hewson v. Ontario Power Co. (1905), 36 S.C.R. 596.

Hodge v. The Queen (1883), 9 App. Cas. 117

Hull Electric Co. v. Ottawa Electric Co., [1902] A.C. 237 (P.C.).

Inter-Church Uranium Committee Educational Co-operative v. Canada (Atomic Energy Control Board), 2002 FCT 994, [2003] 2 F.C. 288

Law Society of British Columbia v. Mangat, 2001 SCC 67, [2001] 3 S.C.R. 113.

MiningWatch Canada v. Canada (Fisheries and Oceans), 2010 SCC 2, [2010] 1 S.C.R. 6.

New Brunswick (Environment) v. Canadian Pacific Ltd., 1993 CanLII 6910 (N.B.Q.B.).

Northern Telecom Ltd. v. Communications Workers., [1980] 1 S.C.R. 115.

Ontario v. Canadian Pacific Ltd., [1995] 2 S.C.R. 1028, 1995 CanLII 111.

———, [1995] 2 S.C.R. 1031, 1995 CanLII 112.

Ontario Hydro v. Ontario (Labour Relations Board), [1993] 3 S.C.R. 327, 1993 CanLII 72.

Ottawa Valley Power Co. v. The Hydro-Electric Power Commission, [1937] O.R. 265.

Prairie Acid Rain Coalition v. Canada (Minister of Fisheries and Oceans), 2006 FCA 31, [2006] 3 F.C.R. 610.

Pronto Uranium Mines Ltd. v. Ontario Labour Relations Board, [1956] O.R. 862 (Ont. Sup. Ct.).

Quebec (A.G.) v. Canadian Owners and Pilots Association, 2010 SCC 39, [2010] 2 S.C.R. 536.

Quebec (A.G.) v. Lacombe, 2010 SCC 38, [2010] 2 S.C.R. 453.

R. v. Crown Zellerbach Canada Ltd., [1988] 1 S.C.R. 401

R. v. Hydro-Québec, [1997] 3 S.C.R. 213.

Re Ontario Energy Board (1986), 57 O.R. (2d) 281 (Div.Ct.).

Reference re Firearms Act (Can.), 2000 SCC 31, [2000] 1 S.C.R. 783, 2000 SCC 31 (CanLII).

Saumur v. Quebec, (City of), [1953] 2 S.C.R. 299; 1953 CanLII 3 (S.C.C.).

Sharp v. Canada (Transportation Agency) [1999] 4 F.C. 363 (C.A.).

Syndicat professionnel des ingénieurs d'Hydro-Québec v. Hydro-Québec, [1995] 3 F.C. 3 (C.A.)

TNT Canada Inc. v. Ontario, (1986), 58 O.R. (2d) 410, 1 C.E.L.R. (N.S.); appeal allowed (1986), 58 O.R. (2d) 410 (C.A.).

International cases

A.P. Pollution Control Board v. Prof. M. V. Nayudu, (1999) AIR 1999 SC 812.

ARCO Chemie Nederland and Others, C-4189/97 and C-419/97 [2000] E.C.R. I-4475.

Commission v. Denmark, C-192/01, [2003] E.C.R. I-09693.

Godavarman v. Union of India and Ors., (2006) AIR. 2005 SC 4256.

Monsanto Agricolturi Italia SpA v. Presidenza del Consiglio dei Ministri, C-236/01, [2003] E.C.R. I-8105.

Telstra Corporation Pty. Ltd. v. Hornsby Shire Council, [2006] NSW 133 (N.S.W.L.E.C. Australia).

Thames Water Utilities Ltd. v. South East London Division, Bromley Magistrates Court, C-252/05, [2007] E.C.R. I-3883.

Secondary Sources

Agency for Toxic Substances and Disease Registry. "Health Consultation: Tritium Releases and Potential Offsite Exposures"2002, online: <http://www.atsdr.cdc.gov/HAC/pha/pha.asp?docid=1162&pg=4>.

Ahier, B.A. & Tracy, B.L. "Radionuclides in the Great Lakes basin" (1995) 103:S-9 Environmental Health Perspectives 89, online: < http://ehp.niehs.nih.gov/members/1995/Suppl-9/ahier-full.html>.

Alberta Environment. Cloverbar Hazardous Waste Management Facility approval under the *Environmental Protection and Enhancement Act*, (2006) No. 225631-00-00.

———. Ellerslie Hazardous Waste Management Facility Approval under the *Environmental Protection and Enhancement Act*, (2009) No. 20370-02-00.

———. *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage System*s (EdmontonDrinking Water Branch, 2006), online: <http://environment.gov.ab.ca/info/library/6979.pdf>.

Alexakhin, R.M., Kazakhov, S.V. & Linge, I.I. "Biospheric approach as a compromise between hygienic and ecological approaches to radiological protection of the environment" (2009) 4:55 Radioprotection 655.

Atomic Energy of Canada Ltd. *Canada Enters the Nuclear Age*: *A Technical History of Atomic Energy of Canada Ltd.* (Montreal: McGill-Queens University Press, 1997).

———. "The Douglas Point Story" (1984) Power Projections, online: <http://media.cns-snc.ca/history/DouglasPoint/DouglasPoint.html>.

Bayda. *Cuff Lake Board of Inquiry: Final Report*, (Saskatoon, 1978).

Beresford, N.A., *et al*. "Deliverable 4 Evaluation of approaches for protecting the environment from ionising radiation in a regulatory context" (2008) PROTECT, online: <https://wiki.ceh.ac.uk/download/attachments/115016283/PROTECTWP2deliverableFinal.pdf?version=1&modificationDate=1263808930000>.

Berger, Stanley David. "Environmental Law Developments in Nuclear Energy" (2007) OECD, online: <http://www.oecd-nea.org/law/nlbfr/documents/055_073_ArticleBergerStanley.pdf>.

Bird, Thompson *et al*. "Assessment of the impact of radionuclide releases from Canadian nuclear facilities on non-human biota" in International Atomic Energy Agency, *Protection of the Environment from Ionising Radiation* (Vienna: IAEA, 2003), online: <http://www-pub.iaea.org/mtcd/publications/pdf/csp-17_web.pdf> .

Bothwell, Robert. *Eldorado: Canada's National Uranium Company* (Toronto: University of Toronto Press, 1984).

Boustany, Katia. "The Development of Nuclear Law-Making or the Art of Legal 'Evasion" (1998) 61 Law Bulletin.

Brenner, David, *et al*. "Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know", (2003) 100:24 Proceedings of the National Academy of Sciences 13761, online: <http://www.pnas.org/cgi/content/full/100/24/13761>.

Breslow, Lester. ed., Gale Cengage "Acceptable Risk." (2002) Encyclopedia of Public Health, online: <http://www.enotes.com/public-health-encyclopedia/acceptable-risk> . Accessed 18 February 2011.

California. State Water Resources Control Board, "Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling" (2010).

Canada, Auditor General. *Report of the Auditor General of Canada*, (Ottawa: Queen's Printer, 1985) Chapter 8 – Atomic Energy Control Board.

Canadian Council of Ministers of the Environment. "Temperature guideline:", *Canadian Environmental Quality Guidelines*, (Winnipeg, 1999).

Canadian Environmental Assessment Agency. "Operational Policy Statement: Addressing 'need for', 'purpose of' , 'alternatives to' and 'alternative means' under CEAA" (2007) online: <http://www.ceaa.gc.ca/default.asp?lang=En&n=5C072E13-1>.

Canadian Nuclear Safety Commission. *Decommissioning of a plutonium recovery laboratory at Chalk River Laboratories* (2004), 04-01-6503.

———. "Evaluation of Facilities Handling Tritium" (Ottawa: Minister of Public Works and Government Services Canada, 2010).

———. INFO-0730, "Protection of Non-Human Biota From Ionizing Radiation" (Ottawa: CNSC, 2002), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/I0730en.pdf>.

———. INFO-0799, "Health Effects, Dosimetry and Radiological Protection of Tritium" (Ottawa: Public Works and Government Services, 2010), online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-58-2010-eng.pdf>.

———. INFO-210 (Revision 3) "Radioactive Release Data from Canadian Nuclear Power Plants 199-2008" (Ottawa: September 2009)

———. Information, INFO-079, "Tritium Releases and Dose Consequences in Canada in 2006" (December 2009), online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-52-2009-eng.pdf>.

———. Meeting Minutes, (16 December 2010), online: <http://www.cnsc.gc.ca/eng/commission/pdf/2010-11-03-Minutes-e-Edocs3648675.pdf>.

———. Policy P-290: "Managing Radioactive Waste", (Ottawa: CNSC, 2004).

———. Policy P-299: "Regulatory Fundamentals", (Ottawa:CNSC, 2005).

———. "Radioactive Release Data from Canadian Nuclear Power Plants 1999-2008" (Ottawa: CNSC, 2009), online: <http://www.cnsc-ccsn.gc.ca/pubs_catalogue/uploads/INFO0210_R13_e.pdf>.

———. Regulatory Document RD-99.2, Draft: Reporting Requirements for Operating Nuclear Power Plants: Compliance Monitoring (Ottawa: Public Works and Government Services, 2010).

———. Regulatory Document RD-346, Draft: "Site Evaluation for New Nuclear Power Plants"(Ottawa, 2007) Table 5.1.

———. Regulatory Guide G-129, Revision 1: "Keeping Radiation Exposures and Doses As Low as Reasonably Achievable" (Ottawa: CNSC, 2004), online: <http://dsp-psd.pwgsc.gc.ca/Collection/CC173-3-2-129-1E.pdf>.

———. Regulatory Guide G-228: "*Developing and Using Action Levels"*, (Ottawa: CNSC 2001).

———. Regulatory Guide G-320: "Assessing the Long Term Safety of Radioactive Waste Management, (Ottawa: CNSC, 2006)."

———. "Staff Review Procedure: Proponent Environmental Impact Statement (EIS) For a New Nuclear Power Plant, Alternative Means of Undertaking the Project and Alternatives to the Project" (2008), online: <http://www.nuclearsafety.gc.ca/eng/pdfs/Staff_Review_Procedures/effects_of_the_project_on_the_environment/SRP-EIS-Alternative_Means_of_Undertaking_the_Project_and_Alternatives_to_the_Project_e.pdf>

———. "Standards and Guidelines for Tritium in Drinking Water" (Ottawa: CNSC, 2008), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/info_0766_e.pdf>.

———. "Thermal Plume Effects on the Aquatic Environment" (2008), online: <http://www.nuclearsafety.gc.ca/eng/pdfs/Staff_Review_Procedures/effects_of_the_project_on_the_environment/SRP-EIS-Thermal_Plume_Effects_in_Aquatic_Environment_e.pdf>.

———. "Tritium Releases and Dose Consequences in Canada" (Ottawa: 2006), online: <http://dsp-psd.pwgsc.gc.ca/collections/collection_2010/ccsn-cnsc/CC172-52-2009-eng.pdf>.

———. Waste Nuclear Substance Licence *WNSL-W2-3701.0/2017* University of Alberta Cloverbar (2007).

Canadian Standards Association, CSA-N288.1-M87 "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities" (1987).

———. Nuclear, N288.1-08, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities" 2nd ed. (2008).

———. Nuclear, N288.4-10, "Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills" (2010).

Carroll, S. "Radiological protection of the environment from an NGO perspective" (2009) 44:5 Radioprotection 439.

Chouhan, S.L. Yankovich, T.I. & Davis, P.A., "Environmental radionuclide concentrations below which non-human biota experience no effects" (2009) 44:5 Radioprotection 107.

Cohen, Bernard L. "Test of the linear-no threshold model theory of radiation carcinogenesis for inhaled radiation decay products" (1995) 68:2 Health Physics 157, online: <http://www.phyast.pitt.edu/~blc/LNT-1995.PDF>.

Darlington New Nuclear Power Plant Project Joint Review Panel. Hearing Transcript (2011) V. 4, online: <http://www.waterkeeper.ca/wp-content/themes/waterkeeper/documents/DarlingtonNB/DarlingtonTranscriptMarch241011.pdf>.

Department of Fisheries and Oceans. "Freshwater Intake End-of-Pipe Fish Screen Guideline" (Ottawa: Public Works, 1995), online: <http://www.dfo-mpo.gc.ca/Library/223669.pdf>.

———. "Guidelines for Minimizing Entrainment and Impingement of Aquatic Organisms at Marine Intakes in BC" (Ottawa: DFO, 1991) CMRFAS 2098, online: <http://www.dfo-mpo.gc.ca/Library/121776.pdf>.

Department of Reconstruction, Press Release. "Canada's Role in the Atomic Bomb Drama" (13August 1945).

Doern, G. Bruce. *The Atomic Energy Control Board: an evaluation of regulatory and administrative processes and procedures* (Ottawa : Law Reform Commission of Canada, 1976).

Edwards, G. "Risks of Operating CANDU nuclear power plants" (Toronto: Greenpeace, 2008).

Elgie, Stewart. "Canadian Regulation of Uranium Tailings Disposal: a Glowing Controversy" (1989) 8:2 UCLA J. Envtl L. & Pol'y 145.

Environment Canada, *Canadian Environmental Protection Act.* "Priority Substances List PSL2 Assessment Report Releases of Radionuclides from Nuclear Facilities (Impact on Non-Human Biota)" – Revised Draft (Ottawa: Environment Canada and Health Canada, 2001).

Federal–Provincial–Territorial Committee on Drinking Water. "Summary of Guidelines for Canadian Drinking Water Quality" (2003), online: <http://www.health.gov.sk.ca/water-guidelines-water-quality>.

Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. "Guidelines for Canadian Drinking Water Quality" (Ottawa: Health Canada , 2010), online: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/2010-sum_guide-res_recom/sum_guide-res_recom-eng.pdf>.

Foster, J.S. & Brooks, G.L. "CANDU Origins and Evolution, an Overview of the Early CANDU Program Prepared from Information Provided by John S. Foster" (2001), online: <http://canteach.candu.org>.

Gray, J.L. "Early Decisions in the Development of the CANDU Program" (1987) 1:2 Canadian Nuclear Journal.

Hart, D. *Derived Release Limits Guidance* (Toronto: CANDU Owners Group, 2008), online: <http://www.csagroup.org//repository/ca/COG-06-3090-R2-I-FINAL.pdf>.

Health Canada. "Federal Contaminated Site Risk Assessment in Canada Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA)", online: <http://www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/part-partie_i/appendix-b-annexe-eng.php>.

———. "Health-Based Tolerable Daily Intakes/Concentrations and Tumorigenic Doses/Concentrations for Priority Substances". (Ottawa: Environmental Health Directorate, 1996) Report No. 96-EHD-194.

———. Joint Working Group of Radiation Protection Bureau "Recommendations on Dose Coefficients for Assessing Doses From Accidental Radionuclide Releases to the Environment" (Ottawa:Health Canada, 1999), online: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/radiation/dose/doseassess.pdf>.

———. "Recommendations on Dose Coefficients for Assessing Doses from Accidental Radionuclide Releases to the Environment" (Ottawa: Health Canada, 1999), online: <http://dsp-psd.communication.gc.ca/Collection/H46-1-33-1999E.pdf>.

Hingston, J. L., *et al*. "Deliverable 3 - A review of approaches to protection of the environment from chemicals and ionising radiation: Requirements and recommendations for a common framework." (PROTECT Project, 2007), online: <https://wiki.ceh.ac.uk/download/attachments/115016283/PROTECTWP1DeliverableD310-12-07FINAL.pdf?version=1&modificationDate=1263808844000>.

House Standing Committee on Natural Resources. "Evidence" (26 September 1996), online: <http://www.parl.gc.ca/35/Archives/committees352/natu/evidence/24_96-09-26/natu24_blk101.html>.

International Atomic Energy Agency. "Ethical considerations in protecting the environment from the effects of ionizing radiation" (Vienna: IAEA, 2002), online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1270_prn.pdf>.

———. "Generic Safety Issues for Nuclear Power Plants with Pressurized Heavy Water Reactors and Measures for their Resolution" (Vienna: IAEA, 2007), online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1554_web.pdf>.

———. Management of waste containing tritium and carbon-14. (TR-Series 421) (Vienna, IAEA, 2004) online: <http://www-pub.iaea.org/MTCD/publications/PDF/TRS421_web.pdf>

———. "Modeling the migration and accumulation of radionuclide in forest ecosystems" (Vienna: IAEA, 2002), online: <http://www-pub.iaea.org/MTCD/publications/PDF/Biomass1_web.pdf>.

———. Safety Fundamentals 1, "Fundamental Safety Principles" (Vienna: IAEA, 2006), online: <http://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf>.

———. Safety Series 111-F, "The Principles of Radioactive Waste Management" (Vienna: IAEA 1995).

———. Safety Series 115, International Basic Safety Standards For Protection Against Ionizing Radiation (Vienna: IAEA, 1996), online: <http://www-pub.iaea.org/mtcd/publications/pdf/ss-115-web/pub996_web-1a.pdf>.

———. Safety Series INSAG-5, "The Safety of Nuclear Power" (Vienna: IAEA, 1992).

———. Safety Standards WS-G-1.1, "Near Surface Disposal of Radioactive Waste", Safety Standards (Vienna: IAEA, 1999), online: <http://www-pub.iaea.org/MTCD/publications/PDF/P073_scr.pdf>.

———. Technical Document, 1650, "Good Practices in Heavy Water Reactor Operation" (Vienna: IAEA, 2010), online: <http://www-pub.iaea.org/MTCD/publications/PDF/te_1650_web.pdf>.

———. Technical Report 332 "Effects of ionising radiation on plants and animals at levels implied by current radiation protection standards" (Vienna: IAEA, 1992).

International Commission on Radiological Protection. "1990 Recommendations of the ICRP" Radiological Protection Bulletin 119 (Supplement). (Chilton: National Radiological Protection Board,1990)

———. "Constitution" (1987), online: <http://www.icrp.org/docs/constitution.pdf>.

———. "Draft 2007 Recommendations of the ICRP For Consultation" (2006), online: <http://www.icrp.org/docs/ICRP_Recs_02_276_06_web_cons_5_June.pdf>.

———. "Low-dose Extrapolation of Radiation-related Cancer Risk" (2005) 35:4 Annals of the ICRP.

———. Publication 60:"The 1990 Recommendations of the ICRP" Annals of the ICRP, 21:1.3.

———. Publication 91:"A Framework for Assessing the Impact of Ionising Radiation on Non-human Species" Annals of the ICRP 33:3.

———. Publication 108:Valentin, J., ed., "The Concept and Use of Reference Animals and Plants for the purposes of Environmental Protection," (2008) Annals of the ICRP 38:4-6, online: <http://www.icrp.org/docs/Environm_ICRP_found_doc_for_web_cons.pdf>.

Jamieson, Terry. CNSC Tritium Studies Project, Presentation to University of Ontario Institute of Technology (Ottawa: CNSC, 2009), online: <http://nuclearsafety.gc.ca/pubs_catalogue/uploads/20090224-CNSC-Tritium-Studies-Project-UoIT-Tjamieson-Presentation-e.pdf>.

Jedicke, Peter. "The NRX Incident" Canadian Nuclear Society, online: <http://media.cns-snc.ca/history/nrx.html>.

Kyrshev, I.I., & Sazykina, T.G. "Radioecological impact from radionuclide releases into rivers" (2002) 37:C1 Radioprotection 51.

La Fayette. "International Environmental Law and the Problems of Nuclear Safety" (1993) 5 J. Envtl. L. 31.

Larsson, C.-M. "Regulation and decision-making in environmental radiation protection"(2005) 40:1 Radioprotection S905.

Lavoie, J. "Precautionary Principle" International School of Nuclear Law Dissertation (2009).

Little, M.P. "Risks associated with ionizing radiation: Environmental pollution and health" (2003) 68:1 British Medical Bulletin 259, online: <http://bmb.oxfordjournals.org/content/68/1/259.full>.

Lower Athabasca Regional Advisory Council. "Advice to the Government of Alberta Regarding a Vision for the Lower Athabasca Region" (2010), online: <http://www.ceaa.gc.ca/050/documents/45413/45413E.pdf>.

McCleave. Nova Scotia, *Report of the Commission of Inquiry on Uranium*, (Halifax 1985).

"Memorandum Of Understanding (MOU) Between The Canadian Nuclear Safety Commission (CNSC) and Environment Canada (EC)", (Ottawa: CNSC, 2004).

Mossman, K.L., *et al*. "The Precautionary Principle and Radiation Protection" (2002) 13 Risk:Health, Safety, and the Environment 137.

National Academy of Sciences. "Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2" (2005) Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council.

National Pollutant Release Inventory. *2009 Facility & Substance Information for Ontario Power Generation - Darlington Nuclear* (Ottawa: Environment Canada, 2009), online: <http://www.ec.gc.ca/pdb/websol/querysite/facility_substance_summary_e.cfm?opt_npri_id=0000003163&opt_report_year=2009>.

———. *Priority Substances List Assessment Report:Releases of Radionuclides from Nuclear Facilities (Impact on Non-human Biota)* (Environment Canada, 2004), online: <http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/assess-eval/radionuclides-eng.pdf>.

Nuclear Power Expert Panel. *Report on Nuclear Power and Alberta* (2009), online: <http://www.energy.alberta.ca/Electricity/pdfs/NuclearPowerReport.pdf>.

Ontario, Ministry of Environment. "Water Management – Policies, Guidelines", *Provincial Water Quality Objectives for the Ministry of Environment and Energy* (1999).

Ontario Atomic Energy Control Board. "Brief to the Royal Commission on the Health and Safety of Workers in Mines in Ontario"(Toronto: Ministry of the A.G., 1976), online: <http://www.archive.org/details/reportofroyworkmine00onta>.

Ontario Drinking Water Advisory Council. "Report and Advice on the Ontario Drinking Water Quality Standard for Tritium" (Toronto: Ontario Minister of the Environment, 2009), online: <http://www.odwac.gov.on.ca/reports/052109_ODWAC_Tritium_Report.pdf>.

Ontario Power Generation "Annual Summary And Assessment Of Environmental Radiological Data For 2006" (Toronto: OPG, 2007), online: <http://www.opg.com/pdf/Nuclear%20Reports%20and%20Publications/Annual%20Summary%20and%20Assesment%20of%20Environmental%20Radiological%20Data%202006%20-%20Bruce%20Site.pdf>.

———. "Aquatic Environment Assessment Of Environmental Effects" Technical Support Document, New Nuclear - Darlington Environmental Assessment (Golder, 2009), online: <http://www.opg.com/power/nuclear/darlington/EA_Process/Technical%20Support%20Documents/06%20Aquatic%20Environment%20Assessment%20of%20Environmental%20Effects%20TSD.pdf>.

———. Joint Review Panel, "Guidelines for the Preparation of the Environmental Impact Statement for Ontario Power Generation's Darlington New Nuclear Power Plant Project" (2009).

———. Presentation; Pickering Nuclear Power Facility (2010), online: <http://www.opg.com/community/activities/pickering/PCAC%20MinutesAppendix/10.06.22%20PCAC%20Minutes%20Appendix%202.pdf>.

———. "Radiation and Radioactivity Environment Assessment Of Environmental Effects" Technical Support Document, New Nuclear - Darlington Environmental Assessment (SENES Consultants Ltd., 2009).

Organization for Economic Cooperation and Development. "Radiation Protection, Effluent Release Options from Nuclear Installations, Technical Background and Regulatory Aspects" (Danvers: OECD, 2003).

Osborne, Richard V. RSP-0153-1, "Tritium in the Canadian Environment: Levels and Health Effects" (2002), online: <http://www.odwac.gov.on.ca/standards_review/tritium/Osborne_CNSC-RSP-0153-1.pdf>.

Quebec, Bureau d'audiences publiques sur l'environnement. "Dry Storage of Irradiated Nuclear Fuel from the Gentilly 2 Power Station" (1994), online: <http://www.bape.gouv.qc.ca/sections/rapports/publications/bape087.pdf>.

———. "Projet de modification des installations de stockage des déchets radioactifs et réfection de Gentilly-2, Rapport d'enquête et d'audience publique" 207 (Quebec: Bureau d'audiences publiques sur l'environnement, 2005).

Quebec, Resources Naturelles et Faune. "Highlights on Energy: Hydroelectricity"(2011), online: <http://www.mrnf.gouv.qc.ca/english/energy/hydroelectricity/index.jsp>.

Rio Declaration on Environment and Development 1992. 31 I.L.M. 874 (1992), online: <http://www.jus.uio.no/lm/environmental.development.rio.declaration.1992.doc>.

Saskatchewan. News Release, "Government Announces Strategic Direction On Uranium Development" (December 17, 2009), online: <http://www.gov.sk.ca/news?newsId=4c9d1ce3-a344-4b4e-a0f5-a1e02670cbea>.

———. "Saskatchewan's Drinking Water Quality Standards and Objectives" (2006), online: <http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=765,758,253,94,88,Documents&MediaID=330&Filename=Drinking+Water+Quality+Standards+and+Objectives.pdf&l=English>.

———. "Specific Guidelines for the Preparation of an Environmental Impact Statement" Caribou Project, Areva Resources Canada Inc. (2007), online: <http://www.environment.gov.sk.ca/2007-001ProjectSpecificGuidelines>.

Saskatchewan Environmental Society, "Environmental Asssessment in Saskatchewan", online: <http://www.environmentalsociety.ca/resources/Environmental%20Assessment%20in%20Saskatchewan.pdf>.

Saskatchewan Research Council, "SLOWPOKE-2 Reactor, Non-Power Reactor Operating Licence" NPROL-19.04/2013.

Sazykina, "A system of dose-effects relationships for the northern wildlife: Radiation protection criteria" (2005) 40:1 Radioprotection S889.

Senate Committee on Energy. the Environment and Natural Resources, Issue 15, *Evidence* (11 March 1997), online: <http://www.parl.gc.ca/35/2/parlbus/commbus/senate/com-e/enrg-e/15eva-e.htm?Language=E&Parl=35&Ses=2&comm_id=5>.

Sims, Gordon H.E. *A History of the Atomic Energy Control Board* (Ottawa: Minister of Supply and Services Canada, 1981) .

Stoiber, C., *et al*. "Handbook on Nuclear Law" (Vienna: IAEA, 2003), online: <http://www-pub.iaea.org/mtcd/publications/pdf/pub1160_web.pdf>.

Thompson, Gordon. *Design and Siting Criteria for Nuclear Power Plants in the 21st Century* (Cambridge, Massachusetts: Greenpeace, 2008), online: <http://www.cnsc-ccsn.gc.ca/fr/pdfs/irss_report_greenpeace.pdf>.

Thompson, Patsy. "Balancing Science and Public Health Policy Considerations in the Regulation of Tritium in Drinking Water: The CNSC Perspective" (Ottawa: CNSC, 2010), online: <http://www.cnsc-ccsn.gc.ca/eng/pdfs/Presentations/CNSC_Staff/2010/August_27_2010-Tritium_in_Drinking_Water-McMaster_University_Presentation_e.PDF>.

Tromans, Stephen. *Nuclear Law* 2d ed. (Portland: Hart Publishing, 2010).

United Nations Scientific Committee on the Effects of Atomic Radiation. *1996 Report to the UN General Assembly* (New York: UNSCEAR, 1996), online: <http://www.unscear.org/docs/reports/1996/> .

———. *Sources and effects of Ionizing Radiation*, v.1 (New York: UNSCEAR, 2010), online: <http://www.unscear.org/docs/reports/2008/09-86753_Report_2008_GA_Report.pdf>.

Uranium Development Partnership. *Capturing the full potential of the uranium value chain in Saskatchewan*, (2009) online: <http://www.gov.sk.ca/adx/aspx/adxGetMedia.aspx?mediaId=767&PN=Shared>.

Winfield *et al*. *Nuclear Power in Canada: an examination of risks, impacts and sustainability*, (Toronto: Pembina Institute, 2006)

World Health Organization. Fact Sheet 291 "Radon and Cancer" (2009), online: <http://www.who.int/ionizing_radiation/env/radon/en/>.

———. "Guidelines for Drinking Water Quality" 1 (Geneva: WHO, 2006), online: <http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf>.

World Nuclear Organization. "Overview of Ecological Risk Assessments Conducted for Sites with Enhanced Radiaoctivity" (SENES Consultants Ltd., 2007), online: <http://www.world-nuclear.org/uploadedFiles/org/reference/Press_Releases/wna-senes-1107.pdf>.

Yim, Man-Sung, Caron, Francois. "Life cycle and management of carbon-14 from nuclear power generation" (2006) 48 Progress in Nuclear Energy, online: <http://chemistry.laurentian.ca/NR/rdonlyres/DC14CD43-913E-445E-AC5D-C129A78E03AC/0/sdarticle.pdf>.

[Author redacted]. "Facility Site Description and Operating Manual for the SLOWPOKE-2 Reactor" (Revision 2) (Saskatchewan Research Council, SLOWPOKE-2 Committee, 1997).

[Author redacted]. Saskatchewan Research Council, Environment and Forestry Division. "Limited Report: SRC SLOWPOKE 2 Facility Annual Compliance Report, April 1 2009-March 31, 2010" 12736-1E10 (Saskatoon: SRC, 2010).

[Author redacted]. "SRC SLOWPOKE-2 Facility Annual Compliance Report" (Saskatoon: SRC, 2010)