INTERNATIONAL INSTITUTE OF CONCERN FOR PUBLIC HEALTH

Deep Geological Repository Joint Review Panel Hearing

Written Submission in Support of an Oral Intervention

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The International Institute of Concern for Public Health (IICPH) is a Canadian-based non-profit international organization founded in 1984. The key principle under which IICPH operates is that a safe environment is a fundamental human right.

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PREAMBLE TO SUBMISSION BY IICPH

Ontario Power Generation (OPG) has submitted its proposal for the construction and operation of a deep geological repository (DGR) for the long-term management of low-and intermediate-level radioactive waste (L&ILW) produced by OPG owned nuclear power reactors. OPG's proposal, referred to as the "DGR Project", includes the site preparation and construction of the DGR as well as its operation, decommissioning and abandonment. The proposed DGR Project is situated at the Bruce nuclear site, approximately one kilometre from the shore of Lake Huron.

IICPH is well-experienced in a wide range of nuclear issues and in issues concerned with the effects of exposure to radiation, low-level radiation in particular, on human health and the environment. We have been following the developments of OPG's proposed DGR for L&ILW for quite some time, and have a strong interest in participating in the public hearings conducted by the Joint review Panel (JRP) under the *Canadian Environmental Assessment Act* (CEAA).

IICPH's primary focus in its submission is on the potential adverse health effects of this Project, especially for communities located in the vicinity of the DGR. We have also addressed a broad range of other issues, including the harmful effects of exposure to low-level radiation; the DGR L&ILW inventory; the long-term safety of the proposed DGR; accident and malfunction scenarios, in particular a worst-case scenario analysis; cumulative impacts; and international experiences to date with DGRs for similar wastes.

Our examination of the Environmental Assessment and a number of its supporting documents has led us to conclude that OPG's proposed DGR Project would be very dangerous and costly, with highly questionable results. There is no guarantee that a DGR as proposed will prevent the migration of radionuclides into the biosphere for even hundreds of thousands, let alone millions of years.

It is our view that allowing this Project to be carried out will do great and totally unnecessary harm to the environment, health and economic well-being of millions of people now and well into the future. IICPH is therefore recommending that the Joint Review Panel reject OPG's proposed DGR Project.

The submission has been prepared by Anna Tilman, Vice-President of IICPH. Contributions to sections of this submission have been made by:

Stephen Hazell - Worst-Case Scenario Analysis; and

Dr. Linda Harvey and Joseph Mangano – Health Issues

INTRODUCTORY REMARKS

The Bruce nuclear site, located in the municipality of Kincardine, about 250 kilometres from Toronto, on the shores of Lake Huron, is one of the largest nuclear complexes in the world. The site includes two operating nuclear stations, Bruce A and Bruce B, comprised of eight nuclear reactors, the Western Waste Management Facility (WWMF), the Western Used Fuel Dry Storage Facility, the Douglas Point nuclear reactor and its related radioactive waste storage site, an on-site landfill, two Heavy Water Production plants (currently being decommissioned), various water supply and processing facilities, and numerous administrative and support buildings.

The WWMF, owned and operated by Ontario Power Generation (OPG), has been in operation since 1974. This complex facility processes and provides interim storage for the low and intermediate radioactive wastes (L &ILW) produced by twenty OPG-owned nuclear reactors at the Bruce, Pickering and Darlington nuclear generating stations. The WWMF also houses an incinerator used for reducing the volume of LLW.

OPG has proposed to build a deep geologic repository (DGR) at the Bruce nuclear site adjacent to the WWMF, approximately one kilometre from the shores of Lake Huron. The DGR is intended to serve as the long-term storage facility for all of the L&ILW that is currently stored at the WWMF, and for similar wastes produced by the continued operation and refurbishment of OPG-owned nuclear generating stations until their end-of-life.

The DGR Project, as described in the Environmental Impact Statement (EIS), entails preparation of the site, and the construction, operation, decommissioning and abandonment of the above-ground and below-ground facilities of the proposed DGR.[1]

This submission provides comments on the proposed Project as a whole, and on specific elements in the Environmental Impact Statement and technical documents in support of the Project. It addresses issues related to the long-term safety of the proposed DGR and its potential impacts on human health, and many other issues, including cumulative impacts of the proposed Project, and accidents and malfunctions, with particular attention to worst-case scenarios. We are also providing an overview of international experiences with DGRs, with emphasis on public concerns regarding these facilities.

OPG has categorically stated that the DGR would be capable of safely isolating these wastes from people and the environment over the hundreds and thousands of years that the wastes will remain radioactive. OPG also finds it preferable to other options it has considered for the long-term management of this waste. The Environmental Assessment has concluded that the DGR Project is “not likely to result in any significant adverse effects on the environment, the health and safety of workers, the public or non-human biota”. [2]

We do not support the conclusions of the Environmental Assessment. It is our view that OPG has not made the case for the repository, and OPG’s confidence in the safety of a DGR has no scientific basis.

[1] Environmental Impact Statement (EIS) Vol. 1 Context
[2] EIS Summary p. 58

The DGR Project is acknowledged to be the first-of-a-kind. As such, it poses unique and untested challenges. It is massive, complex and dangerous. The wastes it will receive contain many types of material, including used reactor components and the like, which contain highly radioactive, long-lasting radionuclides.

No computer models upon which the long-term safety of DGRs is predicated can accurately take into account all the complexities that could compromise the integrity of the DGR. Natural systems are far too complicated and ever-changing for a complete, accurate model to be possible. Thus, there is no valid scientific basis for OPG to presume or predict that this repository can safely contain and isolate radioactive wastes from the biosphere for hundreds of thousands and millions of years without any harm to the environment, or human life and health.

Furthermore, from a social and public perspective, the proposed DGR will not address the numerous issues and public concerns regarding the disposal of radioactive waste. Nor can it be assumed that this means of storing radioactive waste will not burden future generations.

With respect to the EIS, we note several serious shortcomings. Among many other things, it has not made a case that this repository is needed now, or even decades from now. A fulsome examination of the health effects through all stages of the DGR and far into the future has not been carried out. The potential for severe malfunctions and accident scenarios that could compromise and/or lead to the complete failure of the DGR to contain these wastes has not been adequately addressed. The full range of the potential cumulative impacts of the repository on human health and the environment has not been considered. These issues amongst numerous others will be discussed in this submission.

Therefore, because the proposed means of storing this highly hazardous material has not been conclusively proven to fully protect human health and the environment for as long as it remains harmful, we recommend that the Joint Review Panel reject OPG's proposed Project. Furthermore, because OPG has stated that current storage methods are safe for another fifty years, we find no reason to pursue this project at this time.

PART 1: OVERVIEW OF PROJECT

A. The Concept of a DGR - Background

In light of OPG's proposal for a DGR for storing L&ILW, we are reviewing the concept of a DGR itself and the development of that concept by Atomic Energy of Canada Limited (AECL). It was originally intended for the ultimate safe disposal of Canada's nuclear fuel wastes.

In the 1970s, in the wake of public concern over nuclear fuel wastes (also referred to as high-level waste (HLW) or spent fuel), a number of commissions and studies were established to explore methods to dispose of these wastes that would isolate them for the indefinite future.[3]

The concept proposed by AECL was deep geological disposal in the plutonic rock of the Canadian Shield. The multiple barrier containment system, natural and engineered, would be expected to retain the various components of the wastes, and delay the migration of radioactive and chemical contaminants to the earth's surface, for several thousands to hundred thousands of years, by which time substantial radioactive decay would have taken place. In about 500 years, the site would be closed and considered "passively safe", in other words, essentially abandoned.[4]

In 1989, the AECL concept for the disposal of Canada's nuclear fuel waste underwent a public review under the federal environmental assessment process conducted by a Panel (known as the Seaborn Panel). The key findings of the Panel, issued in 1998, found that while technically feasible, the AECL concept had not been demonstrated to be safe from a social perspective, and had not been demonstrated to have public support.

The *Nuclear Fuel Waste Act* (NFWA), enacted November 2002, was an outcome of the Panel report. [5] Under the *Act,* the Nuclear Waste Management Organization (NWMO) was established as the agency responsible for developing and implementing a long-term project to manage all of Canada's nuclear fuel waste currently stored in interim facilities throughout Canada.[6]

In 2005, the NWMO recommended an approach of "Adaptive Phase Management for the centralized containment and isolation of the nuclear fuel wastes in a suitable rock formation, such as the crystalline rock of the Canadian Shield or Ordovician sedimentary rock", (in other words, a DGR) over other disposal methods such as storage at nuclear sites, and centralized

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[3] Royal Commission on Environmental Pollution Sixth Report (1976); Chairman Sir Brian (now Lord) Flowers: http://www.no2nuclearpower.org.uk/reports/waste_disposal.php/ [para 181, page 81]; Race Against Time: The Ontario Royal Commission on Electric Power Planning Interim Report on Nuclear Power in Ontario Chairman Arthur Porter(1978) http://www.ontla.on.ca/library/repository/mon/25006/15833.pdf

[4] AECL concept: http://www.ceaa-acee.gc.ca/default.asp?lang=En&n=0B83BD43-1&offset=1&toc=show

[5] Nuclear Fuel Waste Act (NFWA) 2002: http://www.parl.gc.ca/HousePublications/Publication.aspx?Pub=Bill&Doc=C-27&Language=E&Mode=1&Parl=37&Ses=1&File=37#7; see also *Report of the Nuclear Fuel Waste Management And Disposal Concept Environmental Assessment* (Seaborn Panel Report) February 1998: http://www.acee.gc.ca/default.asp?lang=En&n=0B83BD43-1&offset=1&toc=show

[6] The Panel recommended that the agency be at "arm's length" from the nuclear industry and AECL. Instead, the government placed the nuclear utilities (Ontario Power Generation (OPG), Hydro Québec, New Brunswick Power, and AECL) in sole charge of the NWMO.

storage above or below ground. [7] The Federal Government endorsed NWMO's recommendation on June 14, 2007.[8] In May 2010, the NWMO began its search for a host community for this DGR. [9]

B. Current Practice for Storing L&ILW-Western Waste Management Facility (WWMF)

Low-and intermediate-level wastes (L&ILW) include every kind of radioactive waste produced by nuclear reactors, other than irradiated fuel. These wastes range from radioactively contaminated materials from cleaning and maintenance to very hazardous radioactive waste consisting of used reactor components.

For approximately forty years, the WWMF at the Bruce nuclear site has provided interim storage and processing for all the L&ILW produced by OPG's 20 nuclear reactors. The WWMF also operates an incinerator to reduce the volume of the LLW.

LLW, which constitutes about 90 % of the total volume of L&ILW, is divided into three categories: incinerable, compactable and non-processible. Approximately 50-70 % of the LLW is incinerated at the WWMF incinerator, and the resulting ash is stored at the WWMF. 10-20% of LLW is compactible, and the remainder of this waste is non-processible. All of the intermediate-level wastes (ILW) are non-processible. The "non-processible" wastes constitute about 25% of all wastes received, but make up about 55% by volume of the waste stored at WWMF.

From time to time, radioactive liquids and low-level waste liquids are shipped to a waste incinerator in the US, and the ash is returned to the WWMF for storage.[10]

As of 2010, approximately 84,000 m^3 of L&ILW is stored at the WWMF. 74,000 m^3 of the waste designated as LLW is stored at the WWMF in a variety of stackable carbon-steel containers in warehouse structures, known as Low-level Storage Buildings (LLSBs). There are currently eleven of these LLSBs. 10,000 m^3 of ILW is stored above or below ground in shielded structures. The irradiated fuel channel waste from Bruce A, which is ILW, is stored in concrete containers with stainless steel inner and outer shells.[11]

The wastes stored in LLSBs and in all other storage structures at the WWMF are continually monitored and can be easily retrieved. All WWMF storage structures have a minimum design life of 50 years.

OPG has estimated that approximately 5,000 to 7,000 m^3 of new L&ILW will be produced each year by Ontario's reactors. After volume reduction (via incineration and compaction of LLW), this will result in 2,000 to 3,000 m^3 of new L&ILW to be stored annually.

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[7] Adapted Phase Management http://www.nwmo.ca/uploads_managed/MediaFiles/676_6-18AdaptivePhasedManagement_TechnicalDescription.pdf p. 27

[8] *NFWA* Section 12(2)

[9] As of August 2012, twenty-one communities have expressed interest in exploring their suitability as a potential site. www.nwmo.ca/sitingprocess

[10] OPG responses to Joint Review Panel August 27, 2012

[11] Environmental Impact Statement (EIS) Summary Report p. 9, EIS Vol 1 Sec. 3

C. Description of Proposed DGR Project

Ontario Power Generation (OPG) is undergoing a multi-year planning and regulatory approvals process for a deep geologic repository (DGR) for the long-term management of the low and intermediate level waste (L&ILW) produced by OPG-owned nuclear reactors. Currently, this waste is stored centrally at OPG's Western Waste Management Facility (WWMF).

OPG's proposal involves the construction of the DGR in sedimentary bedrock beneath the Bruce nuclear site near the existing WWMF. The DGR is to be about 680 metres deep in limestone overlain by a 200-metre-thick cap of shale.[12] Planned operations include activities required to operate and maintain the DGR facility, including the transfer of waste from the WWMF to the DGR, the emplacement of wastes in rooms within the DGR, and the closure of these rooms.

The proposed DGR Project requires that an environmental assessment (EA) be conducted under the Canadian Environmental Assessment Act (CEAA) because the proponent, OPG, will require a licence from the Canadian Nuclear Safety Commission (CNSC) in order for the DGR Project to proceed.

The DGR Project is divided into four phases:[13]

<u>Phase 1- Site preparation and construction:</u> This includes all activities associated with developing the DGR Project up until the first waste is deposited there. Underground facilities include access-ways (shafts and tunnels), emplacement rooms, and various underground service areas and installations. Surface facilities include underground access and ventilation buildings, a Waste Package Receipt Building (WPRB) and related infrastructure. This work is estimated to take about five to seven years to complete.

<u>Phase 2 - Operations:</u> This includes the period during which waste is emplaced in the DGR, as well as a period of monitoring prior to the initiation of decommissioning activities. This phase is expected to last approximately 40 to 45 years, with waste being placed for the first 35 to 40 years, and the subsequent monitoring to be carried out for a period that would be decided at some future time.

<u>Phase 3 - Decommissioning:</u> This includes dismantling surface buildings and sealing the shafts. It is expected to begin immediately following operations and to take approximately five to six years to complete.

<u>Phase 4 - Abandonment and long-term performance:</u> This phase begins upon the completion of decommissioning. It includes institutional controls for a period up to three hundred years.

Approximately 1,000,000 m^3 of waste rock will be produced during the underground construction of the DGR.[14] Waste rock piles, covering 9 ha and measuring 15 m high for the full excavated volume of rock, are to be located at a waste rock management area (WRMA) on the DGR Project site.

All stormwater run-off from the DGR surface infrastructure area, the WRMA and underground water are to drain into the stormwater management pond and discharge into the existing Bruce

[12] EIS Summary http://www.ceaa.gc.ca/050/documents_staticpost/17520/49818/summary.pdf
[13] Environmental Impact Statement (EIS) Vol. 1: Sections 4.6, Fig 4.2-1
[14] Ibid Section 4.4

nuclear site drainage ditch network for release to MacPherson Bay (Lake Huron). The overall footprint of the WRMA, including its stormwater management system is approximately 17 ha.[15]

The EIS indicates that ventilation air will be supplied to ensure that there is a reliable supply of fresh air ("breathable air") to workers in underground workplaces throughout the DGR Project; contaminants will be diluted and removed; personnel will not be exposed to levels of noxious gases that exceed regulatory limits; levels of explosive gases will not exceed explosive limits; and temperatures within the DGR will be maintained so that it remains safe and acceptable for both personnel health and infrastructure integrity. Air quality underground will be monitored, and radiological protection controls will be placed at the entrance to prevent the spread of contamination into the eating area during the operations phase. During construction, conventional mining practices (washing down and misting muck piles) will be used to control underground dust.[16]

The size of the DGR Project surface facilities is approximately 30 ha, including the construction laydown areas and the area designated for waste rock management. The area of the underground facilities will be approximately 40 ha. The Bruce A nuclear generating station is located to the north of the DGR Project site, and the operating Bruce B nuclear generating station to the southwest.

The volume of L&ILW at 2052 (the anticipated shutdown date of the last reactor unit) is projected to be about 170,000 m^3. Over its lifetime, the DGR will receive approximately 50,000 packages, nominally representing a total emplaced volume of 200,000 m^3.

While the wastes will be retrievable, OPG has no plans to retrieve them as it considers the DGR wastes to have no value.[17]

No specific plans have been given for passive controls to mark the location of the DGR for future generations. OPG has indicated that control mechanisms would not be required for another 50 to 100 years, at which time "it is expected several countries will be in the same position, and that a solution will be developed with international consensus."[18]

The construction cost of the DGR is currently estimated to be about $1 billion. An existing segregated fund established by OPG (Decommissioning Fund) will be used to pay the cost of the DGR Project.[19]

OPG has contracted the Nuclear Waste Management Organization (NWMO) to provide technical and other services for the proposed DGR Project throughout the regulatory process, and also to provide design and construction services.

[15] Ibid Section 4.4.1.5
[16] Ibid Section 4.4.3.1
[17] Ibid Section 4.8
[18] Ibid Section 4.12
[19] Ibid Sections 1.2.5 and 4.7.2.3

D. Comments on the Description of the Proposed DGR

This section examines specific issues related to the description and scope of the proposed Project.

- Time periods for phases: The estimated time periods for completing the four phases of the proposed Project are unrealistic, given the nature of the work needed and the potential for accidents, delays, etc. What plans are in place to deal with delays?
- Retrievability of Wastes: It is unclear how these wastes would be retrievable if the shafts are sealed. What would happen if it were necessary to retrieve these wastes quickly, for example because of a serious breach of containment?
- Waste rock and the Stormwater System: According to the EIS, "the pond is sized to retain stormwater run-off for a sufficiently long period of time to settle out suspended solids. The entire stormwater management system is sized to safely pass run-off from a large storm event (e.g., 1:100 storm event), with no damage to the system. The stormwater management pond is sized to provide a retention area to retain the 6 hour, 25 mm rain event."[20]

  Macpherson Bay, part of Lake Huron, is the avenue for discharges from activities not only from constructing the DGR, but other activities at the Bruce site. Why is it even acceptable to discharge wastes from such activities into this body of water?

  The recent storm in Toronto, July 8 2013, was unpredicted. Over 90 mm of rain fell within just two hours, resulting in major flooding and infrastructure damage. The torrential rainfall in Alberta in June 2013 resulted in major floods, enormous property damage and major evacuation. It was also not predicted. So it is completely wrong to assume that manmade or natural stormwater systems can safely stave off the effects of a large, severe storm event.

- Ventilation System, Dust Control: What is "breathable air"? What is considered to be "adequate" in terms of airflow? How can all contaminants be removed? What contaminants are not likely to be removed? According to the EIS, exposure to noxious gases, including explosive gases, are not to exceed limits. Are these limits even safe? What about cumulative effects of exposure to a host of contaminants, air pollutants and noxious gases? How are the health assessments to be made both prior to working underground and afterwards?

  What are the impacts, singularly and cumulatively, from continual drilling and blasting operations (noise, vibration) on workers underground, and on local residents? What are the potential effects of this work on structures (buildings, roads) nearby?

E. The Incinerator

The incinerator at WWMF, operating 24/7, emits a wide range of pollutants including volatile organic substances, dioxins and furans, particulate matter, metals, and radionuclides. The resulting ash is stored at the WWMF.

[20] Ibid Section 4.4.1.5

Approximately 60% of the LLW is incinerated, which significantly reduces the volume of LLW requiring storage at the WWMF. Otherwise, the DGR would have to be more than double the proposed size to store all of the LLW that has been and will be produced.

However, no reference is made in the EIS to the incinerator, other than indicating that it is used for volume reduction. Therefore, no information has been given on whether the incinerator will continue operating for the duration of the proposed Project, or what allowance has been made for shutdowns, breakdowns, upgrades, etc. of the incinerator, or on the health and environmental hazards from incineration.

OPG's response to questions on the incinerator operations was as follows:[21]

> Radioactive waste incineration is currently used for waste volume reduction at OPG's Western Waste Management Facility (WWMF). As well, from time to time, radioactive liquids and low level radioactive waste solids are shipped to a licensed waste incinerator in the US with resulting ash returned to the WWMF for storage. It is not intended to have an incinerator on the DGR site.

Clearly, OPG has not properly addressed the questions regarding incineration. The proposed DGR for storing L&ILRW depends very much on incineration of LLW to reduce the volume of this waste. If the incinerator breaks down, or is out of service, as does happen, what plans are in place to deal with LLW? Does OPG plan to ship this waste to the US for incineration, and spread its contaminants elsewhere, or is there any other option in the works to reduce the volume of LLW? If so, that should clearly be stated.

The health and environmental issues associated with incinerating radioactive waste have not been addressed, which is a very serious omission indeed. Nor is there any consideration of the incinerator under the Accidents and Malfunctions or Cumulative Effects Assessment Sections of the EIS.

F. Capacity and Contents of the Proposed DGR

In this section, we examine issues that arise from the lack of clarity regarding the overall capacity of the proposed DGR, and what types of waste may be stored in it.

According to the EIS [Section 3.4]:

> "In the future, an additional approximately 135,000 m³ of L&ILW is expected to be produced during the decommissioning of the reactors and the associated nuclear waste storage facilities. The majority of this waste (i.e., >85%) will likely be LLW. The currently proposed DGR Project does not include management of decommissioning waste."
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> OPG, in its responses to Information requests as to the capacity of the proposed DGR, stated that the "the host geological formation has significant potential for expansion within the Lower Cobourg Formation" and that "the potential to expand the DGR to accommodate up to 400,000 m^3 of waste has been assessed with the conclusion that this could be done, and

[21] IR EIS-04-106, 121

could likely be expanded beyond a factor of two."[22] So the proposed DGR clearly has the potential to store the decommissioning waste.

Table 10.4-3 of the EIS further states that:

> The decommissioning waste from OPG-owned or operated reactors will, at some point in the future, be relocated to a suitable long-term management site. The long-term management of decommissioning waste is not expected to start before 2050. **Although no site has been identified, the DGR Hosting Agreement includes provision for decommissioning waste to be placed in the DGR Project and the EIS Guidelines stipulate that consideration of placing decommissioning waste in the DGR be included in the cumulative effects assessment. [Emphasis added]** The assessment is based on emplacement of decommissioning waste in an extension of the DGR (approximately doubling the underground capacity). The management of decommissioning waste at the DGR would require a separate EA process.

According to OPG, in a letter to the CNSC that was revealed at the Pickering re-licensing hearing on May 29, 2013:

> Decommissioning LLW and ILW will be disposed of at a regional facility located in Ontario, approximately equidistant from OPG's nuclear stations.

The question remains as to whether there will be yet another DGR site for storing decommissioning waste, or whether there is a plan to store this waste at the proposed DGR at the Bruce site. The above statements from OPG are confusing and contradictory. However, it appears as though OPG (and NWMO) are committed to a DGR for storing the decommissioning waste from OPG reactors in a DGR, but are leaving all options open as to its location.

OPG's proposal for this DGR for L&ILW at the Bruce nuclear site has been in the works for several years. The determination as to whether this Project will be approved depends on the outcome of the environmental assessment, and then the Federal Government. No other site is being sought for a DGR for L&ILW. At the same time, the NWMO is pursuing a site for storing nuclear fuel wastes. This has raised uncertainty and confusion, as to whether the DGR Project at Bruce could also end up being the DGR for Canada's nuclear fuel waste. A number of considerations make this plausible. For example;

- OPG's assessment of the technical suitability of the Bruce nuclear site geology is not specific to a repository for L&ILW. The conditions that make the Bruce Nuclear site suitable for the DGR L&ILW Project are identical to those conditions that NWMO will consider for a DGR for nuclear fuel waste.
- NWMO's inclusion of Ordovician sedimentary rock, in addition to the crystalline rock of the Canadian Shield, as a suitable formation for the DGR for nuclear fuel wastes has left the door open for examining sites not on the Canadian Shield, such as the Bruce DGR site which consists of sedimentary rock (limestone and dolomite).

[22] Information Requests EIS-04-145 and EIS 10-494.

- The volume of HLW that needs to be stored is a relatively small portion (roughly 10%) of the volume of L&ILW,[23] so capacity is not an issue. The difference lies in the type of containment needed for HLW and the placement of these containers in the repository.

The difference between this proposed DGR and the DGR proposed for nuclear fuel wastes may have more to do with the process and legality than technical matters.

In response to public concerns on this matter, OPG has stated that this could not occur because OPG does not have the legal ability to establish a DGR for used fuel; the regulatory process would not allow OPG to put used nuclear fuel into a DGR licensed for L&ILW; OPG has made a public commitment that used fuel would not be placed in the L&ILW DGR; nor has OPG or the NWMO evaluated the technical potential to do such a transformation, and there are no plans to do so.[24]

These assertions do not rule out the possibility that the Bruce DGR site could eventually be used to store nuclear fuel wastes.

There are other issues pertaining to the acceptability of nuclear fuel wastes at Bruce, such as;

- The Municipality of Kincardine has signed a hosting agreement with OPG for the construction and operation of the proposed DGR for L&ILW, with the understanding that the proposed DGR would not be used for nuclear fuel waste (HLW). But ILW already contains high-level radioactive waste resulting from fissioning in the nuclear reactor.
- The communities in the region of the Bruce site and the Bruce Nuclear Station lie within the Saugeen Ojibway Nation (SON) Traditional Territory. In their submission to the Joint Review Panel on the proposed DGR, SON clearly indicated that a DGR for nuclear fuel waste is not wanted within their territory.[25]

Laws and regulations can be amended. Host agreements can be altered by new councils. Nothing is carved in stone.

G. Justification for the DGR

The WWMF has been storing L&ILW for almost forty years. All of the LLW is stored in a variety of containers above ground in warehouses. The ILW is stored either above ground or below ground in a variety of shielded structures. All WWMF containers have a designed storage life of fifty years. This waste is continually monitored and can be easily retrieved. If a container is found to be unsatisfactory, it is repackaged (i.e., overpacked).

According to the EIS, [Section 1.2.1];

“current storage practices are safe and could be continued safely for many decades.”

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[23] Inventory of Radioactive Waste in Canada, March 2012 http://publications.gc.ca/collections/collection_2012/eacl-aecl/CC3-1-2012-eng.pdf

[24] OPG Responses August 27, 2012 http://www.ceaa-acee.gc.ca/050/documents/p17520/80955E.pdf

[25] Saugeen Ojibway Nations’(SON) Submission, August 9 2012: http://www.ceaa-acee.gc.ca/050/documents/p17520/80907E.pdf

"The WWMF has an excellent safety record and could be relied upon to protect the health and safety of the public and the environment for many more decades, provided institutional controls exist."

While the refurbishment waste from Bruce A reactors (considered to be ILW) is at the WWMF, the re-tube (refurbishment) waste from Pickering A is stored at the Pickering Nuclear Generating Station, and is considered too bulky to be safely transported to the Bruce site. Therefore it will not be stored in the DGR.

Given that all L&ILW is already being stored either at the reactor site or at Bruce, and this storage is considered safe and all the waste is retrievable, why is a DGR even being considered?

In fact, not too long ago (2003), OPG's plan for long term disposal/management was to have a LLW facility in place by 2015, and an intermediate-level radioactive waste facility in place by 2035. The plan also indicated that intermediate-level wastes could be co-managed with used nuclear fuel pending review of the long-term management of used nuclear fuel by the NWMO and the Government of Canada.[26]

Furthermore, deep geological repositories (DGRs) have really been intended as a means for long-term storage for nuclear fuel waste, i.e., spent fuel, not for L&ILW. So it is not clear why a DGR is even being proposed for L&ILW.

Even though, according to the EIS 1-1, current storage practices are safe and could be continued for many decades, OPG's long-term plan is to manage these wastes in a long-term facility. But that does not necessarily mean a DGR facility. Nor does that mean a central location for all of this waste. In fact, by OPG's own admission, that is not possible because of Pickering's re-tube waste, which is on site at the Pickering Nuclear Generating station and cannot be transported because of its size and its highly radioactive contents.

So we are questioning the necessity to carry out this massive project. The site preparation, the excavation of rock, and the construction of surface buildings, the waste rock management area, the stormwater pond, and the underground facilities , as well as packing and overpacking the waste on site for removal to the DGR, and transporting it from other OPG nuclear sites, are all very intensive and expensive undertakings.

Every aspect of this project comes with particular and in some cases unique concerns. Is it not preferable to store the waste above ground or where it is easily monitored and retrievable rather than bury it 680 metres deep just off the shore of Lake Huron?

The NWMO, which is responsible for preparing all the documentation for OPG's Project, is the same agency that has been given the responsibility to search for a site to build a DGR to store all of Canada's nuclear fuel waste. The search for such a site is currently on-going, coincident with the proposed DGR project for L&ILW at the Bruce site. This coincidence has caused confusion and worry for members of the public, particularly regarding the Bruce site.

As noted in one of NWMO's background papers on the "Public Perception of Radiation" [27],

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[26] NWMO Background Papers 7-2 Rennick& Associates July 2003 p. 29

[27] Ibid p. 49

> The public tends not to distinguish between different levels of radioactivity. They see exposure as possibly causing health effects, and thus focus on the consequence and not the low probability of a health problem from most LLRW. This may be due to confusion over the classification system, lack of trust in the managers or indifference. Discussion of management options for used nuclear fuel with communities where other initiatives are ongoing with respect to the long-term management of LLRW (or even hazardous wastes) can create unnecessary confusion and conflict.

We concur with this observation.

PART 2: LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTES FOR THE DGR

A. Classification of L&ILW

In Canada, low-and intermediate-level radioactive waste is defined by exclusion. In other words, if a waste is radioactive, but is neither used nuclear fuel waste (high-level waste, (HLW)) nor uranium mine and mill tailings, it is classified as low level radioactive waste (LLW) and intermediate level wastes (ILW).[28]

There are several problems with this "exclusion" approach. Firstly, one can only understand what L&ILW really is by being given a detailed inventory of its contents. Being told what it is not does not tell us what it is. Secondly, there is no clear distinction between these two categories. As a result, L&ILW is not restricted to wastes that contain relatively low concentrations of radionuclides compared with nuclear fuel wastes. Rather, these wastes can range from very low-level waste with low hazard to waste that is highly hazardous over long time frames, which requires much more secure containment and much better shielding. Thirdly, the inherent ambiguity as to what precisely is included in LLW and ILW has resulted in varying descriptions of these wastes that tend to very much depend on the context and the circumstances in which these terms are applied.

B. Descriptions of L&ILW

The EIS has described L&ILW by the type of material, or equipment that is contaminated with radionuclides. For example;[29]

> LLW consists of mops, rags, paper towels, temporary floor coverings, floor sweepings, protective clothing, and hardware items such as tools. It also includes steam generator segments.
>
> ILW consists of ion exchange resins, filters and irradiated reactor core components. There is usually a caveat indicating that while the majority of LLW is processed through incineration or compaction for volume reduction, because of its physical condition and greater levels of radioactivity, ILW is "non-processible".

Two other descriptions of LLW&ILW in the EIS are as follows[30]**:**

1. LLW consists of non-fuel waste in which the concentration or quantity of radionuclides is above the clearance levels and exemption quantities established by the Nuclear Substances and Radiation Devices Regulations [32], and which contain primarily short-lived radionuclides (i.e., half-lives shorter than or equal to 30 years). LLW normally does not require significant shielding for worker protection during handling and storage.

   ILW consists of non-fuel waste containing significant quantities of long-lived radionuclides. ILW often requires shielding for worker protection during handling.

[28] NWMO Background Papers 7-2 Rennick& Associates p. 22
[29] EIS Section 3.1, Tables 4.5-1,4.5-2
[30] EIS Section 4.5 The classification is consistent with Canadian Standards Association (CSA) N292.3

2. **LLW** – Radioactive waste in which the concentration or quantity of radionuclides is above the clearance levels established by the regulatory body (CNSC), and which contains primarily short-lived radionuclides (half-lives shorter than or equal to 30-years).

   ILW – Radioactive non-fuel waste, containing significant quantities of long-lived radionuclides (generally refers to half-lives greater than 30 years).

   (Note: This set of definitions is found in the Appendix of the EIS.[31])

These definitions introduce the term "clearance levels", that is levels at which radioactive materials can be freely released into the environment into landfills, and through recycled products, into the marketplace, without any regulatory control or consumer knowledge.

The vagueness and inconsistency in these descriptions and the use of terms such as "clearance levels", "non-processible", "radiation fields", and "half-lives", easily leads to confusion as to the nature of these wastes and how hazardous they are. For example, if L&ILW is described as being mainly low-level in terms of quantities (volume), this creates an impression that they pose very little harm. However, quantities are not as much the issue as activity and half-life. For example, ILW contains many highly radioactive long-living radionuclides that are produced by fissioning in a nuclear reactor, albeit in much smaller amounts (in volume and activity) than is found in nuclear fuel waste.

C. Wastes to be placed in the DGR [32]

The proposed DGR is to accept operational and refurbishment L&ILW from OPG's reactors, but not decommissioning waste, at least not at this stage. The DGR will not accept used nuclear fuel or recognizable fuel fragments, or liquid wastes (except for small amounts associated with solid wastes). The waste consists typically of industrial materials, including steel, plastics, other metals, and inorganic substances contaminated with radioactivity.

In addition to radionuclides, L&ILW contains various hazardous elements, such as asbestos, heavy metals including uranium, cadmium, mercury, chromium, thallium and lead, and numerous organic materials, such as polycyclic aromatic hydrocarbons (PAHs), chlorinated benzenes and phenols, and dioxins and furans produced in the incinerator and trapped in the ash. Metals like chromium, nickel and lead in container materials (i.e., stainless steel, lead shielding) are also present.

D. Waste Volumes in the DGR

The forecasted volume of the total emplaced waste in the DGR is estimated to be about 200,000 m^3, about 75% of which is operational LLW. Refurbishment L&ILW makes up about 10% of the emplaced volume (21,700 m^3), 62% of which is ILW. Thus ILW accounts for more than 60% of the radionuclide inventory at 2062.[33]

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[31] Ibid Vol. 1 Acronyms (p.15.27)
[32] Ibid Section 4.5, Table 4.5.3-1, 4.5.3
[33] EIS Summary p. 10, EIS Section 4.5.1

This forecast is subject to change. For example, it does not take into account OPG's decision not to refurbish Pickering B, or factors such as "improvements to waste processing technology" or changes in repository storage technology.

E. Inventory of Radionuclides in L&ILW in the DGR

The following table, extracted from Table 4.5.2-1 in the EIS, shows the half-lives and activities (in Becquerels, Bq) for operational and refurbishment L&ILW at the year 2062 for a selection of radionuclides in the DGR. It also indicates the particle or ray emitted (α, β, and γ) in the first step of the decay chain for each specific radionuclide, which was not provided in the EIS.[34]

Table 1: L&ILW Inventory in the DGR at 2062

Nuclide	Half-Life (years)	Operational LLW (Bq)	Operational ILW (Bq)	Refurbished L&ILW (Bq)	Total (Bq)	Decay mode
Americium-241 (Am-241)	4.3 E+ 02	3.3E+07	1.0E+09	2.0 E+13	2.4E+12	α
Carbon-14 (C-14)	5.70E+03	1.4E+12	5.4E+15	6.6E+14	6.1E+15	β
Clorine-36 (Cl-36)	3.0 E+05	5.4E+ 08	7.4E + 08	1.4 E + 12	1.4E+12	β
Cobalt-60 (Co-60)	5.30E+00	1.7 E+ 11	3.5 E +12	9.0 E+14	9.0E+14	β
Cesium-137(Cs-137)+ Barium-137m (Ba-137m)	3.00E+01	1.3E+13	9.4E+13	5.4E+11	1.1E+14	β
Tritium (H-3)	1.20E+01	8.5E+14	1.5E+14	4.8E+12	1.0E+15	β
Iodine-129 (I-129)	1.60E+07	1.2E+06	1.3+08	1.0E+06	1.3E+08	β
Niobium -94 (Nb-94)	2.00E+04	2.2E+10	1.2E+11	4.6E+15	4.6E+15	β
Neptunium-237 (Np-237)	2.10E+06	3.2E+06	1.1E+07	1.2E+08	1.3E+08	α
Nickel-59 (Ni-59)	7.50E+04	2.1E+09	3.6E+11	3.6E+13	3.6E+13	β
Plutonium-238 (Pu-238)	8.80E+01	8.5E+09	2.7E+10	4.6E+11	5.0E+11	α
Plutonium-239 (Pu-239)	2.40E+04	2.2E+10	7.7E+10	8.2E+11	9.2E+11	α
Plutonium-240 (Pu-240)	6.50E+03	3.0E+10	1.1E+11	1.2E+12	1.3E+12	α
Plutonium-241 (Pu-241)	1.40E+01	6.8E+10	1.6E+12	1.9E+11	1.9E+12	α
Plutonium-242 (Pu-242)	3.80E+05	3.2E+07	1.0E+08	1.2E+09	1.3E+09	α
Radium -226 (Ra-226)	1.60E+03	3.8E+09			3.8E+09	α
Selenium -79 (Se-79)	3.80E+05	1.5E+06	4.5E+06	1.3E+10	1.3E+10	β
Strontium-90 (Sr-90)+ Yttrium-90 (Y-90)	2.90E+01	3.0E+12	4.2E+13	9.3E+12	5.4E+13	β
Technetium-99 (Tc-99)	2.10E+05	5.2E+07	8.4E+08	6.0E+10	6.1E+10	β
Uranium-234 (U-234)	2.50E+05	3.6E+07	1.1E+08	1.3E+09	1.4E+09	α
Uranium-235 (U-235)	7.00E+08	5.6E+05	1.9E+06	2.1E+07	2.3E+07	α
Uranium-238 (U-238)	4.50E+09	4.2E+09	1.4E+08	1.7E+09	6.0E+09	α
Zirconium-93 (Zr-93)	1.50E+06	1.6E+06	6.7E+11	2.1E+14	2.1E+14	β,γ
Total (as per Table 4.5.2-1)		**8.7E+14**	**5.7E+15**	**1.1E+16**	**1.7E+16**	

[34] Note: The notation 1.6E+06 is 1.6 x 10^6

Upon the expected closure of the DGR in 2062, the total activity of operational L&ILW is estimated to be 6.6 x 10^{15} Bq. This is attributed mainly to the presence of the radionuclides H-3 and C-14. The total refurbishment L&ILW activity is primarily due to C-14, Co-60, Ni-63 and Nb-94.

The EIS anticipates that approximately 50 m^3 of LLW will generated each year over the course of the operations phase of the DGR. This would be mainly maintenance waste consisting of rags, paper, and protective clothing, and possibly some contaminated metal parts. This waste is to be collected and returned to the WWMF for processing and repackaging.[35]

Over long periods of time, according to the EIS, "the wastes and their containers are expected to degrade. The metals themselves do not break down but will degrade into inorganic salts, oxides or minerals. The organic materials will degrade into simpler compounds under microbially-mediated reactions."[36]

F. Comments on L&ILW Inventories: [Reference Inventory Report] [37]

i) Completeness of Inventories

Completeness of a waste inventory for the proposed DGR is absolutely essential. However, we have noted a number of deficiencies in the inventories provided in the Reference Inventory Report and the EIS. Some of the critical factors were identified in IICPH's submission to the Joint Review Panel on sufficiency of information in the EIS. [38] The following are some of these critical factors and other important ones that should have been addressed;

- Waste projections from any proposed new-build reactors in Ontario: This would significantly increase the activity (in Becquerels) and volume of these wastes.
- A complete list of all radionuclides in the waste, along with their half-lives ($\tau_{½}$) and activity (in Becquerels (Bq) or Bq/m^3): The total activity is greater than that shown.
- The ionizing particle(s) emitted by each radionuclide (α, β, and γ) and their progeny: This is vital information. It is important, for example, to know how many alpha particles are emitted, and what portion of activity results from alpha emitters. It is also important to include all stable end-products, particularly as many of these products are hazardous, and they affect the chemical activity within the repository, and the composition of decay products over time.
- Decommissioning waste from OPGs reactors: If these wastes are stored at the proposed DGR, it would greatly affect the level of ILW in the wastes and the volumes of waste. The inventories should also include these wastes to provide a comparison between the current DGR proposal by OPG and what may be proposed in the future for decommissioning waste from OPG's reactors. This inclusion is also necessary to assess

[35] EIS Section 4.8.5.3
[36] Ibid Section 4.5.4
[37] Reference Low and Intermediate Level Waste Inventory for the Deep Geological Repository: [Reference Inventory Report] http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Reference-L-ILW-Inventory.pdf
[38] IICPH submission May 23 2013: http://www.ceaa-acee.gc.ca/050/documents/p17520/89441E.pdf

the contribution of decommissioning waste to the cumulative impact of the proposed Projects, as the EI guidelines require.

ii) Other related issues

- The refurbished waste from re-tubing Pickering A in the late 1980s is stored at the Pickering Nuclear Generating Station. It is not intended to be shipped for storage at the proposed DGR at the Bruce site, purportedly because of the transportation issues caused by the size of the containers and the level of radioactivity. So the proposed DGR will not be storing all of the L&ILW from OPG's reactors.
- Many of the metals in the wastes (cadmium, lead and mercury in particular) are highly toxic in organic, inorganic or metallic form. The organic compounds (PCBs, dioxins and furans, PAHs) are also persistent, highly toxic, and known carcinogens. Any of these substances could have serious effects in containment that we have no knowledge of. While they may "degrade" into other compounds, that does not mean they will not be harmful.
- IICPH has also commented on the definitions of LLW and ILW, and the delineation between these two waste streams, if one even exists. Reference was made to definitions that were used in OPG's Proposed Environmental Assessment Screening Report for Darlington Refurbishment September 2012, E-doc 3917932.

  These definitions differentiated between these wastes by contact radiation fields, for example, "LLW is defined as waste with less than 10 mSv/h at 30 cm", while "ILW is defined as waste with contact radiation fields greater than 10 mSv/h at 30 cm."[39] As mentioned in the first section of this part of the submission, this once again demonstrates the inconsistencies in the definitions of these wastes.
- The difference between the activity levels of radionuclides in nuclear fuel wastes and in ILW should also be indicated. We question whether some of the wastes deemed to be ILW are really equivalent to high-level waste in terms of their activity.
- To our knowledge, the Reference Inventory Report of December 2010 has not been updated to include more information. This is a critical technical report. It is vital that it be as complete and as up-to-date as possible.
- The Reference Inventory Report provides the inventory of non-radioactive components in the waste (in kg at the year 2052).[40] It is not clear whether some of the substances listed in this Table are stable end products of the decay of the radionuclides in the wastes.

  OPG responded that "The list is not intended to include all stable end products of all radionuclides - only elements that are important for overall chemical composition or are otherwise important for the non-radiological safety case."

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[39] ibid
[40] Reference Inventory Report p. 23, Table 2.8

How does OPG judge what chemicals are “important”, especially in the case of a DGR over a very long term?[41]

Summary Comments

The DGR proposal reveals a rather disturbing situation that is unfortunately very typical of what is encountered in this industry.

With all the so-called scientific background, and the intricacies involved in every aspect of nuclear energy, there is no definition for these wastes, only vague verbal descriptors. Occasionally a term or unit varies even within the documents for a particular project, as well as between different projects.

The carelessness in developing the waste inventories is unacceptable. Every possible component and every variation in the contents of these wastes should be provided in inventories. No project should move forward without having all possible information at hand, and an acknowledgement that even so, there are many circumstances that are beyond existing knowledge.

[41] IR EIS-04-107

PART 3: HEALTH CONCERNS

A. Overview - Health Effects of Radioactive Waste

Radioactive wastes contain a wide variety of radionuclides, each with different physical and chemical properties. Each radionuclide decays differently and has a different half-life. As these elements “decay”, they generate heat and ionizing radiation in the form of particles and rays. The half-lives of these radionuclides range from seconds to millions of years. It takes about ten half-lives for radioactivity to diminish to a thousandth of its original level, and about twenty half-lives for it to diminish to a millionth of its original level.

Wastes referred to as Intermediate level Wastes (ILW) contain reactor components, such as resins, irradiated core components, pressure tubes and calandria tubes. The radionuclides contained in ILW material are products of nuclear fission, and are the same radionuclides as found in nuclear fuel waste. The difference between these waste streams lies in the amounts of these radionuclides and therefore their activity in Becquerels (disintegrations per second). Even though ILW wastes themselves are not concentrated enough to cause criticality, they contain highly radioactive radionuclides, many of which have very long half-lives. And all of them are highly toxic.

The long-lived radioactive isotopes remain extremely hazardous for centuries, even hundreds of thousands or millions of years. Once released into the biosphere, they work their way through the ecosystems, as do other industrial toxins. Some of the radionuclides are able to biomagnify up the food chain, thus becoming progressively more concentrated in foodstuffs and complex forms of life, including human life. Land which is contaminated by these radioactive poisons becomes unhealthy and even uninhabitable. [42]

The chemistry that determines how radioactive wastes will behave in a repository is very complicated, and not well understood. While some radionuclides may dissolve easily, and leak out of the repository in groundwater, others may attach to the backfill or the surrounding rock, and be contained more easily. Some radionuclides will escape more easily from deep repositories, because they are highly mobile in groundwater. When these radionuclides have long half-lives, they will reach the biosphere before they have decayed to any significant degree.

Some of the long-lasting radioactive isotopes in ILW are Plutonium, most commonly Pu-239 (half-life 24,100 years); Cesium-137 (half-life 30 years); Strontium-90 (half-life 30 years), Iodine-129 (half-life 15.7 million years); Chlorine-36 (half-life 300,000 years); Selenium-79 (half-life 295,000 years); Technetium-99 (half-life 212,000 years); and Carbon-14 (half-life of 5,715 years). [Refer to the table “L&ILW Inventory at 2062” on p. 15 of this submission]

Many of these radionuclides are biologically active, that is, they are actively taken up by the body and incorporated into our tissues. For example,

[42] Rock Solid? A GeneWatch UK consultancy report by Helen Wallace for Greenpeace International September 2010 p. 14 http://www.ceaa.gc.ca/050/documents/55688/55688E.pdf.

- Plutonium-239 is intensely carcinogenic if inhaled, and causes lung cancer in microscopic doses, as well as bone cancer and leukemia. With a half-life of 24,100 years, it remains deadly for hundreds of thousands of years.
- Cesium-137 behaves like potassium, an essential nutrient, and is absorbed and distributed throughout the body, concentrating in muscle tissue. Cesium ingestion causes a large number of different types of cancer.
- Strontium-90 replaces calcium. When absorbed into the body, it is deposited in bone and, with its 29-year-half life, continues to irradiate bone and bone marrow for decades. It causes bone cancer and leukemia.
- Iodine -129 concentrates in the thyroid gland and causes thyroid cancer and other problems.
- Selenium -79 bioaccumulates in organisms and biomagnifies in the food chain. While inside the body, it presents a health hazard due to the emission of beta particles during its radioactive decay, which causes cancer.
- Chlorine-36 is a beta emitter and a weak gamma emitter. When it is ingested, the beta emissions are highly carcinogenic.
- Technetium-99 bioaccumulates in the food chain, particularly in shellfish such as lobster.
- Carbon-14 exists mainly in irradiated metals (especially steels). It can escape from a repository as a gas in the form of carbon dioxide (CO_2) or methane (CH_4).

The uranium decay series (U-238) yields numerous long-living and short living radioactive isotopes. Of particular importance is Radium -226, which decays to Radon -222, which has a very short half-life of 3.8 days. It, in turn, decays to numerous radioactive isotopes including Polonium -218 (half-life of 3 minutes) and Polonium -210 (half-life of 138 days), one of the most deadly substances known, and finally to a stable isotope of lead (Pb-206). Every one of these radioactive progenies is highly toxic, and lead, the stable atom at the end of the decay chain, is a highly toxic metal.

Radon-222 is of particular concern for this DGR Project, because any build-up of radon gas in an enclosed space, such as a DGR, results in a build-up of radon progeny, which increases the radioactive hazard enormously. And when radon gas escapes into the atmosphere, the solid radon progeny are deposited on the soil and water below, entering into the food chain and hence the bodies of birds, animals, fish and insects.

The very long-term health consequences of these very long-lived radionuclides in the global environment are not known, but they are likely to be cumulative as the contamination accumulates.[43] Other radionuclides, such as tritium (half-life of 12 years) are very prevalent in this waste. Even though short-lived isotopes decay relatively quickly, they are highly toxic as well.

[43] http://www.psr.org/environment-and-health/environmental-health-policy-institute/responses/radiations-risk-to-public-health.html

B. Transport of Radionuclides in the Biosphere

Any release of long-lived radionuclides from an underground repository is an extremely serious threat to the health of the ecosystem.

Once radionuclides reach the biosphere, humans may be exposed to them in a variety of ways. Different radionuclides move in different ways in the near-surface environment, including in soils, lakes and streams. Multiple migration mechanisms are involved, including transport by air, water, particulate matter and biota.[44]

Radionuclide transfer from soils to food crops can vary considerably according to the radionuclide, plant species, soil types and times of deposition. The potential transfer of radionuclides in animal feed to domestic farm animals could contaminate the human food chain via meat and milk. The accumulation of radionuclides in invertebrates, including beetles, ants, spiders and millipedes, a major dietary component of many animals, is also a potential route into the human food chain. Repositories located near water bodies could discharge some radionuclides into the marine environment. There radionuclides could bioaccumulate in different species of fish.

Plants also play a role in the transport of radionuclides, such as plutonium, within the biosphere. For example, recent studies of the US plutonium-contaminated site at Savannah River have shown that a large proportion of the buried plutonium has unexpectedly migrated upward through the uptake in plants. Plutonium has also been detected in groundwater close to the vault at the Maišiagala shallow radioactive waste repository in Lithuania. Tritium and carbon-14 were also detected in groundwater at this site, possibly from the uptake of these radionuclides in plants.[45]

Other mechanisms of radionuclide transport and accumulation, as well as impacts, may well have been missed because the current approach to radiological protection is based on the simplification of natural systems, rather than acknowledging and addressing their complexity.

Any means of disposal of radioactive wastes carries a risk, and in the long term a certainty, of contamination of the environment with radioactive substances. This creates a definite risk of serious illness and death to humans, and serious effects on biota. [46]

C. Exposure to Low-Level Ionizing Radiation

a) No Safe Levels

First and foremost, there is no safe level of exposure to ionizing radiation. This has been clearly acknowledged in the National Research Council BEIR VII Report, entitled "Health Risks from Exposure to Low Levels of Ionizing Radiation". [47] Any exposure, including exposure to naturally

[44] Rock Solid? A GeneWatch UK consultancy report, p. 38,39September 2010 http://www.ceaa.gc.ca/050/documents/55688/55688E.pdf

[45] This facility operated from 1963 to 1989.http://www.lsc-international.org/conf/pfiles/lsc2008_415.pdf

[46] Busby, C. Pandora's Canister (Te Forsmark project) May 2012

[47] BEIR VII Report: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/beir_vii_final.pdf The BEIR VII report defines low doses as those in the range of near zero up to about 100 mSv of low-LET (linear energy transfer) radiation.

occurring background radiation, creates an increased risk of cancer. Therefore, from a health perspective, the maximum safe dose of ionizing radiation is zero. Any other value deemed "safe" is based on the degree of harm to human life and health that is tolerated by regulatory bodies.

According to the BEIR VII Report, approximately one individual in 1000 is predicted to develop cancer from an exposure to 10 mSv over a lifetime.[48] While the risk of low-dose exposure may be low for a given individual, when large numbers of people are exposed, the cumulative impact on the whole community may be very significant.

Radiation damage can affect any part of a cell, and can interfere with many cellular processes. Most importantly, damage to the genetic material of the cell can lead to the out-of-control growth of cancer cells, non-cancerous tumours, birth defects, hereditary illness, and immune system diseases.While this damage can sometimes be repaired by mechanisms within the cell, that is not always the case. Damage to eggs or sperm can be passed on to future generations.

Radiation from internal emitters is very different from external radiation, and far more dangerous. If a radioactive particle is inhaled or ingested, that particle will continue to emit radiation as long as it is in the body and the particle remains radioactive. When a person is exposed externally to a source of radioactivity, the exposure lasts only as long as the person remains close to the source of radiation.

Some radionuclides may bioaccumulate in an organism and biomagnify, i.e. build up in the food chain. For example, it may reach higher concentrations in fish or seafood than in the surrounding water, thereby posing a greater risk to anyone or any species eating the contaminated food than the surrounding water would.

Not all people exposed to radiation are affected equally. Children are much more vulnerable than adults to the effects of radiation, and foetuses are even more vulnerable. Thus its long maturation period makes the human species particularly vulnerable to radiation damage.

Radiation-induced bystander effect creates the possibility that extra-nuclear and extracellular effects may also contribute to the final biological consequences of exposure to low doses of radiation.[49] This issue is of particular concern for genetically susceptible populations.

b) Exposure Limits - International Commission on Radiological Protection (ICRP)

The currently allowable "safe" levels of exposure to ionizing radiation set by the International Commission on Radiological Protection (ICRP), and used by the CNSC and OPG, are 1 mSv/year for the general public and 100 mSv over 5 years with a maximum of 50 mSv in one year for nuclear energy workers.

The ICRP approach to setting limits is used primarily because it can quickly convert a multidimensional problem into a linear calculation that can readily be used in management decisions. In risk assessments, for example, in assessing long-term chronic exposure in the

[48] http://www.dep.state.pa.us/brp/radon_division/BEIR%20VII%20Preliminary%20Report.pdf

[49] **NIH Program Project on Radiation Bystander Effects: Mechanism;** Columbia University Center for Radiological Research www.radiation-bystander.columbia.edu/

aftermath of a disaster, and in worker compensation hearings, this methodology does not accurately determine all the harm that has been done, and denies justice to the victims. Just because these emissions lie below current standards or release limits does not mean that they do no harm.

IICPH has consistently argued that the ICRP limits are neither safe nor protective. Rather, they contain value judgements with respect to what harm is "acceptable" to the individual and to society, in return for what are seen as the "benefits" of the activities. The ICRP limits do not make proper allowance for the most vulnerable members of society. Nor do they take into account radiation-related health effects other than cancer. The limits for nuclear workers for maximum exposure allow the generation of 3.2 excess cases of fatal cancers per 100 workers over a 40-year career, which is inordinately out-of-line with limits set for exposure to non-radiological industrial toxins (one excess fatality per 10,000 or 1,000,000 workers).

Over the years, as more has been discovered about the hazards associated with certain substances, and the effects of radiation, standards have become more stringent. The limits currently in place are very likely to change with increased knowledge and awareness of the harm they can allow for present and future generations. For a Project such as the DGR, which in itself stretches over several decades, and must be able to safely contain radioactive waste for a millennium, or even millions of years, the use of the current limits is definitely not appropriate.

Ultimately, from a public health standpoint, no processed or manufactured forms of radionuclides should ever become bioavailable.

c) Linear No Threshold Model (LNT)

Much has been made by the CNSC of the fact that there are deviations from values predicted by the LNT at low doses in a number of biological systems. It is a fundamental property of biological systems that they respond, adapt, and attempt to repair. It is also in the nature of biological systems that they are complex, and a small amount of damage to a critical part of the system may cause a disproportionate injury. None of this means that any level of exposure to ionizing radiation is safe. It merely adds new layers of complexity, and therefore uncertainty, which makes a precautionary approach all the more imperative.

d) Fractions of Background

A position often taken by the CNSC is that because a given exposure is a small fraction of background levels, its effects will be trivial. This is based on two false assumptions. The first assumption is that the effects of background radiation are negligible, which is not the case. Background radiation gives us background levels of cancer and hereditary disease, and may contribute to the aging process. Any radiation exposures from man-made sources will be added to background, and will cause <u>additional</u> harm.

The second assumption is that a little more won't hurt. Biological organisms have adapted the best they can to the radiation levels they have been living with for thousands of years, not more. The DNA repair enzymes, while slightly inducible, have a finite capacity, and there are many types of radiation damage they can't repair. As soon as the demand for repair exceeds this capacity, damage will mount up rapidly, often in disproportion to the increased dose.

e) The Atomic Bomb Studies [50]

Most of the estimates of the effects of radiation exposure and cancer death risk used by ICRP are derived from studies of the survivors of the bombings of Hiroshima and Nagasaki, from intentional medical irradiation, and from a few high-dose accidents. However, the atomic bomb studies came after the setting of the radiation protection guidelines recommended by ICRP and followed internationally until 1990. The main recommendations were made in 1952, and while the first doses assigned to A-bomb survivors were not available until 1965.

The studies were undertaken by military researchers from both the US and Japan, and focused on cancer deaths of people near the epicentre. It is uncorrected for the healthy survivor effect, and does not include all of the radiation exposures of either cases or controls (because dose calculations omitted fallout, residual ground radiation, contamination of food and water, and individual medical X-rays.) Nor does it take into account all relevant biological mechanisms and endpoints of concern.

The Hiroshima exposure was a one-time dose largely composed of gamma and x-rays, since the bombs were exploded high in the air, producing very little fallout. The atomic bomb studies were designed to determine the effects of an atomic bomb, not the health effects of exposure to ionizing radiation. This is very different from the effects of the radionuclides released by nuclear testing, and by the accidents at Chernobyl and Fukushima, which have irretrievably polluted the environment with long-lived radionuclides such as cesium-137, strontium-90 and plutonium-239, that will continue to expose living creatures to ingested radionuclides for millions of years.

Furthermore, the radiation dose received by the Hiroshima and Nagasaki survivors from fallout, and the contamination of food, water and air, has never even been calculated. Hiroshima and Nagasaki studies of the non-cancer effects of exposure to ionizing radiation are either very poor or non-existent. Diabetes among Hiroshima males has shown a linear trend with dose for causing death. Since diabetes is not normally a first cause of death for this population, this indicates a relationship between radiation and the incidence of diabetes.

f) Tritium

Tritium is the most abundant radioactive isotope in L&ILW. It is a carcinogen, mutagen, teratogen and developmental toxin. Both gaseous and aqueous forms of tritium (HT and HTO respectively) are very radioactive and pervasive. HT permeates most materials, including rubber and many grades of steel, with relative ease. HTO, which is chemically identical and physically similar to ordinary water, very rapidly mixes everywhere.

Tritium is absorbed through inhalation, ingestion and dermal absorption. Of these, inhalation is the most dangerous. Once absorbed into the body, tritium can become incorporated into DNA, where it can give rise to cancers. In reproductive cells, it can give rise to hereditary defects and

[50] Dr. Rosalie Bertell: *Health Effects of Tritium* Submitted to the CNSC, November 27, 2006; http://www.psr.org/environment-and-health/environmental-health-policy-institute/responses/radiations-risk-to-public-health.html

diseases. It easily crosses the placenta, and can contribute to spontaneous abortions, stillbirths, and congenital malformations. The cells most at risk from tritium are those dividing at the time of exposure. Thus its effects are more severe in embryos and growing children, who have a high proportion of rapidly dividing cells.

Furthermore, when tritium spontaneously disintegrates, the resulting recoil excitation can disrupt chemical bonds. These disruptions, when repeated, cause chronic diseases such as allergies or hormonal dysfunction.[51]

CNSC continues to use the current Canada Guideline and Ontario Drinking Water Quality Standard for tritium of 7,000 Bq/L as being "safe". This level is partly based on a severe underestimation of the amount of damage caused in biological tissue by the beta particles emitted by tritium.[52] Despite long-standing recommendations by government bodies and other organizations to reduce this level to 20 Bq/L, based on current Canadian Federal (and Provincial) limits for hazardous chemicals, CNSC continues to use the current level of 7,000 Bq/L. [53]

D. Workforce Issues – Occupational Exposure

Nuclear workers and contract workers are being put at particular risk of exposure to hazardous substances. Not only are workers exposed to cancer-causing radiation and radionuclides, they are also exposed to air pollutants, noise, non-threshold carcinogens, and other toxic substances. This is an unconscionable burden to place on a particular segment of society, that is, workers at nuclear facilities. These substances are just as harmful to nuclear energy workers as they are to anyone else, and they should be afforded the same level of protection as the public.

Health Effects of Radiation on Nuclear Workers

A number of studies have been conducted on the Health Effects of Radiation on Nuclear Workers. The International Agency for Research on Cancer (IARC), a 15-Country Nuclear Worker Study published in 2005, assessed cancer risks following low doses of ionizing radiation. The study, the largest worker study ever conducted, examined over 400,000 nuclear energy workers

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51 http://iicph.org/files/health-effects-of-tritium.pdf (Dr. Rosalie Bertell)

52 The Relative Biological Effectiveness (RBE) is a factor used to indicate the amount of damage caused in biological tissue by a given type of radiation. The RBE for tritium is 1, and for alpha particles, 20. A consensus of scientific research finds that the RBE for tritium should be increased by a factor of two to three. http://tapcanada.org/wordpress/wp-content/uploads/cerrie-report-on-tritium.pdf

53 Ontario Drinking Water Advisory Council, *Report and Advice on the Ontario Drinking Water Quality Standard for Tritium* (Toronto: ODWAC, 2009) http://www.odwac.gov.on.ca/reports/052109_ODWAC_Tritium_Report.pdf; Canadian Environmental Law Association, *Comments to the Ontario Ministry of the Environment Regarding the Proposal to Adopt the Canadian Drinking Water Quality Guideline for Radiological Characteristics as an Ontario Drinking Water Objective for Radionuclides* (Toronto: CELA, October 1999). See also Canadian Environmental Law Association "Proposed Tritium Drinking Water Standard Too High Say Groups" (October 26 1999).

(NEWs) who wore a radiation dosimeter or badge, and who worked for at least one year in the nuclear industry in one of the 15 countries, including Canada[54].

This study found a small but significant increase in cancer risks, especially leukaemia, at the dose-rates typically received by the nuclear workers in this study. It also found that NEWs from Canada had the highest excess relative risk of mortality from all cancers (excluding leukaemia) among the 15 countries, and this excess risk was statistically significant.[55] A previous study conducted by Zablotska et al., specifically on the same Canadian nuclear workers examined by the IARC study, found that the relative risk/Sievert was higher for Canadian nuclear workers than for other nuclear workers and for the atomic bomb survivors. [56]

A plausible explanation for the higher cancer risks for Canadian workers could be an under-estimation of the harmful effects of exposures to tritium, in part or all of this population. [57]

The CNSC's June 2011 report on verifying the radiation risk for Canadian NEWS was essentially criticism and dismissal of the findings of the IARC study.[58]

Workers at nuclear plants are front-line. When a problem happens, they are the first to be called upon, if they are not already in the middle of it. This has certainly been the case at Fukushima and Chernobyl.

There are other cases where workers at nuclear facilities, not necessarily classified as nuclear workers but on contract, are placed in very dangerous situations. One major case is the "Alpha Incident" at the Bruce A station. In 2009 a number of building trades workers were engaged in the cutting and grinding of feeder pipes in one part of the Unit 1 reactor building (called the "reactor vault"). While they were cutting and grinding these pipes, the workers were not aware that radioactive particles from their work were being released into the general atmosphere of the large reactor building.

The airborne contaminated particulate that was released travelled through the vault, and any worker in the vault who inhaled it was unknowingly internally exposed to alpha radiation. Over 550 workers ingested various amounts of alpha-emitting particles, which resulted in internal exposure to alpha radiation for a long time afterwards.

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[54] Ethel Gilbert, Radiation Epidemiological Branch, National Cancer Institute: *Epidemiological Studies of Nuclear Workers* May 16, 2007 (IARC Report: Cardis et al. 2005) http://radepicourse2007.cancer.gov/content/presentations/slides/GILBERT_Workers_slides.pdf Refer also to http://www.nuclear-free.com/PDF/TAP_Fact_Sheet.pdf and http://www.iarc.fr/en/media-centre/pr/2005/pr166.html

[55] CNSC Report 2011 http://nuclearsafety.gc.ca/pubs_catalogue/uploads/INFO-0811-Verifying-Canadian-Nuclear-Energy-Worker-Radiation-Risk-A-Reanalysis-of-Cancer-Mortality-in-Canadian-Nuclear-Energy-Workers-1957-1994_e.pdf p.5

Zablotska l.B., Ashmore J.P., and Howe G.R: *Analysis of mortality among Canadian Nuclear Power Industry Workers after chronic low-dose exposure to ionizing radiation. Radiation Research* 161: 633-641 (2004). http://www.jstor.org/discover/10.2307/3581008?uid=3737720&uid=2129&uid=2&uid=70&uid=4&sid=21101139987693

[57] Dr. Rosalie Bertell: *Health Effects of Tritium*, Submitted to the CNSC, November 27, 2006

[58] http://nuclearsafety.gc.ca/pubs_catalogue/uploads/INFO-0811-Verifying-Canadian-Nuclear-Energy-Worker-Radiation-Risk-A-Reanalysis-of-Cancer-Mortality-in-Canadian-Nuclear-Energy-Workers-1957-1994_e.pdf

The long-term effects for these workers from internal exposure to alpha radiation is not known, or even discussed. Similar to exposure to other hazardous substances (e.g. asbestos), adverse health effects may not manifest themselves for twenty-five years or more. The effects on the children or grandchildren of people who have been exposed for several years to ionizing radiation (so-called low-level) may not even be attributed to the exposure to ionizing radiation suffered by their parents or grandparents.

E. Health Effects on Local Communities (and Workers)

For several decades numerous nuclear-related activities have been ongoing, including eight nuclear reactors, radioactive waste storage facilities (including the WWMF and its incinerator) a used fuel storage facility, and facilities that are no longer in operation, such as the Douglas Point Reactor. It goes without saying that such numerous operations have affected the environment of the local and regional area in which the Bruce site is located. It also stands to reason that people residing in the vicinity of the site, and workers at these facilities, especially nuclear workers, have long been exposed to a host of contaminants, especially radionuclides that would otherwise not have been there in the absence these operations.

So before this proposed DGR Project is even scheduled to begin, the health and well-being of the community will already have been compromised to some degree. But the extent to which this has happened is not really known, nor has it even been properly studied. It comes as no surprise that the Environmental Impact Statement (EIS) finds that the existing environment, and thus the health of these communities, has not been affected despite all these years of release of radionuclides from these activities during "routine operations, upsets, accidents, spills", and so on.

Radiation-induced cancer is of particular concern. It has long been evident that ionizing radiation causes childhood leukemia, a major indicator of the effects of radiation. The Atomic Energy Control Board (AECB), the predecessor to the CNSC, carried out two studies, Childhood Leukemia around Canadian Nuclear Facilities, (Phase 1 and Phase 2, 1989 and 1991 respectively) on the rates of childhood leukemia within 25 kilometres of the Pickering and Bruce Nuclear Generating Stations.

The results of these studies did show that childhood leukemia rates were 40 percent higher than the provincial average. However, the conclusion of the chief epidemiologist of AECB, Dr. Suzanne Fraser, was that this observed increase was "in fact, most likely due to chance". This position was not found tenable by Dr. David Hoel, an expert in the field of cancer effects and ionizing radiation, who concluded that:

> "the AECB study failed to follow appropriate statistical methods for analyzing radiation cancer epidemiological data which resulted in understating the statistical significance of the 40% increase."[59]

Twenty years after the AECB studies, the debate about the increase in childhood leukemia continues, with the CNSC's denial of increased childhood leukemia, or cancer in general, around

[59] Affidavit by Dr. Hoel In the Federal Court of Canada Trial Division December 1999 File No. T-906-99: Appendix D

nuclear facilities.[60] And once again, the methodology for this CNSC study has been found severely lacking. [61]

i) Cancer Incidence Rates

As no cancer incidence rates specific to the Regional Study Area or the Grey Bruce Health Unit were available, the cancer incidence rates for both the Grey Bruce Public Health Unit (PHU) and the South West Local Health Integration Network (LHIN) for the years 2001-3 were used to estimate the cancer incidence rates for the Regional Study Area to compare them to the rates in Ontario.

With reference to the cancer rates for different types of cancer, in comparison with the rates in Ontario as a whole, the EIS states (p. 6-282):

> "The statistical significance of the differences between the South West LHIN and Ontario was not available. In general, cancer incidence rates are higher in the South West LHIN compared to the province as a whole. With the exception of prostate cancer, cancer incidence rates in the South West Local Health Integration Network (LHIN) and the Grey Bruce Public Health Unit (PHU) are within 10% of Ontario incidence rates for the same type of cancer." As such, the South West LHIN and Grey Bruce PHU cancer incidence rates are considered to be comparable to Ontario rates due to many confounding factors that require consideration including lifestyle (smoking, alcohol consumption, obesity, etc.), genetic predisposition, access to medical care, and education. Also, while incidence rates appear to fluctuate, there are no apparent increasing trends for all types of cancers including prostate cancers."

In other words, none of the cancers can be linked directly to radiation exposure, according to OPG.[62]

Given that no statistical test of significance has been provided, no valid conclusion can be drawn. The lack of studies over so many years on cancer incidences is appalling. At the same time, it must be said that "*Absence of evidence is **not** evidence of absence!*"[63]

It is well known that ionizing radiation causes cancers. It is scientifically impossible to release massive numbers of radionuclides without causing any harm, especially when internal exposure to a single radioactive atom can be deadly.

ii) Construction Phase – Health Effects

The operations involved in preparing the site, such as blasting and excavation, and increased traffic, will result in increased emissions of "dust" and other contaminants. The range of air pollutants from these activities include Particulate Matter (fine and coarse, both inherently toxic to human health, and both containing toxic metals, some of them radioactive), Volatile Organic Compounds (VOCs), sulphur dioxide (SO_2), nitrous oxides (NOx), polycyclic aromatic

[60] The RADICON Study, CNSC May 2013 Summary: http://nuclearsafety.gc.ca/eng/pdfs/Reading-Room/healthstudies/Radiation-Incidence-Cancer-Around-Ontario-NPP.pdf
[61] Critique of the RADICON Study (CNSC), June 2013: Dr. Linda Harvey
[62] OPG's Response to Information Request EIS 08-390 p. 106-7
[63] A phrase used by many, including Carl Sagan, Astronomer, and Donald Rumsfeld, Military Strategist

hydrocarbons (PAHs), as well as many other contaminants. Many of these substances have been found toxic under the *Canadian Environmental Protection Act* (CEPA 1999).

Constructing a DGR at the Bruce Site will result in excessive disturbances of the land and noise from drilling and blasting operations and increased traffic on and off the Bruce site.

At the same time that this activity is going on, the Bruce plants are operating (when not shut down for repair); the incinerator is operating, (when not shut down for repair); the decommissioning of shuttered facilities may begin; and all the while the WWMF will continue to receive L&ILW from OPG's nuclear stations. So not only will local residents be affected by major construction operations, they will also continue to be exposed to radionuclides, and other hazardous contaminants.

A Project of this complexity, from construction to decommissioning, could extend well beyond the proposed time periods for each phase, as has been typically the case for nuclear projects and major projects in general. It poses many risks to human health and the environment, for example,

- The potential generational, long-term and cumulative effects from exposure to both radiological and hazardous non-radiological substances from contaminated groundwater, food and air.
- The effects of exposure to radioactivity on specific populations for which it could cause particularly high health risks, including but not limited to:
  - Repository workers who are exposed to occupational radioactivity;
  - Families of workers who are exposed through direct contact or genetic harm;
  - Local communities who live in closest proximity to and downwind of the proposed DGR;
  - Populations particularly vulnerable to the toxic properties of radioactivity, including foetuses, infants, pregnant women, the elderly, and people whose health is already compromised (e.g., asthmatics).
- The impacts on health and quality of life of local communities during the construction phase (noise, increased traffic, air quality, etc.).
- The impacts on workers and communities that would result from the accidents that could occur during every stage of the project, from construction, rock falls, the transfer of the waste, and any breach of containment.

F. Deficiencies in the EIS

The EIS has not carried out an adequate health study of the potential effects of the DGR on the physical and mental well-being of workers, the local communities, or the public in general. There are a great many human health effects throughout all stages of this Project, and for a very long time afterward, that needed to be addressed. These include:

- The conditions which are most readily caused by radiation, including childhood cancer, thyroid cancer, leukemia, breast cancer, birth defects, and infant mortality (among others). However, the EIS fails to recognize the range of health hazards to humans, and especially from exposure to low-level ionizing radiation.

- Many of the radionuclides in the waste are alpha emitters. Internal exposure to alpha particles is particularly dangerous. This factor alone deserves consideration, especially for workers who may be at the greatest risk of internal exposure to alpha particles.
- Many of the resulting stable progeny from the decay of radionuclides are heavy metals, such as mercury, lead, and thallium, which are very toxic to human health and the environment. This has not been discussed in the EIS.
- The lack of valid morbidity and mortality studies for cancer and other disorders in the local, regional, and national communities means that it is impossible to assess whether, and to what degree, the health and well-being of the local communities and the environment are being adversely affected during all phases of the proposed Project and in its aftermath.
- How are potential adverse health effects on transient populations to be monitored? This is especially the case for workers brought in at various stages of the proposed project who would not necessarily live within any of the boundaries of the study areas. It is also the case for people who move in or out of the areas over time.
- No comparative information on the experience with environmental contamination and health hazards from other L&ILW repositories, such as the ASSE II facility in Germany, and the Barnwell and Richland disposal facilities in the U.S., has been provided.
- The potential impact of drinking water contamination, due to the migration of toxic waste to groundwater, poses a threat to human health and the environment for countless future generations. Even if the level of radioactivity diminishes over time, enough will remain to cause serious harm for a millions of years. This is not addressed in the EIS.
- Geological changes over time will release radionuclides into the environment, during the hundreds of thousands and even millions of years that they remain dangerous.

All of these items, and many others, need to be dealt with in a fulsome, synergistic and cumulative manner. This has not been the case in the EIS or the other documents provided by the proponent.

PART 4: LONG-TERM SAFETY OF THE PROPOSED DGR

A. Overview

The proposed DGR for L&ILW is to be located approximately one kilometre inland from the shore of Lake Huron at a depth of about 680 metres. These wastes are to be placed deep in low permeability limestone overlain by about 200 metres of low permeability shale.

The low and intermediate-level radioactive wastes contain highly radioactive substances, similar to the radioactive substances as found in irradiated fuel. Some of them have extremely long half-lives, as long as hundreds of thousands to millions of years. However, the ability of these rock formations to block or even slow the migration of radionuclides from the repository is unproven.

Lake Huron, and its many interconnected waterways, is home to complex, interconnected ecological systems involving fish, plants, invertebrates, and other organisms, and is a source of drinking water for millions of people. Any degradation and contamination of the aquatic environment caused by radionuclides leaking out of the repository will have far-reaching consequences for all of these systems. Restoration and mitigation may never be able to repair the harm that this would do.

B. Breach of Containment

Several factors could compromise the containment barrier, resulting in releases of radioactivity and other hazardous material to the environment.[64] For example,

Corrosion

Over time, the containers of this waste will corrode. This corrosion could be accelerated by the high salinity deep underground; the radioactive materials within the containers; and the caving in and falling of rocks within the caverns.

Microbial activity within the repository could also have a number of adverse effects on the safety of a nuclear waste repository, including corrosion of waste containers.

The corrosion of the containers, along with some of the wastes, could release gases into the repository such as hydrogen gas, and carbon dioxide or methane containing Carbon-14.

The build-up of gas pressure in the repository, along with the degradation of organic material, could damage the natural barriers, allowing routes for radionuclides to escape through rock fractures or pores. A slow release of gas could also open up fractures in the backfill or rock, and speed up the release of some radionuclides from the repository.

The chemical and physical disturbances due to corrosion, gas generation and bio-mineralization, along with heat generated by radioactive decay, could impair the ability of backfill material to contain some radionuclides.

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[64] Rock Solid? A GeneWatch UK consultancy report September 2010 http://www.ceaa.gc.ca/050/documents/55688/55688E.pdf

Permeability and Stability of Rocks

- The limestone and shale of the repository are described as being of low (or very low) permeability. This means that these formations are, in fact, permeable. So from the outset, the conditions of the rock within the repository cannot provide an impervious barrier that would block the migration of radionuclides in the very long term.
- The excavation of the repository can damage adjacent zones of rock and thereby create fast routes for radionuclide escape. Rock bursts can occur due to the high pressure deep underground in the repository.
- Unidentified fractures and faults, or lack of understanding as to how water and gas will flow through fractures and faults, could lead to the release of radionuclides in groundwater much faster than expected.

Glaciation, Climate Change

- The effects of future glaciations pose one of the greatest long-term threats to the integrity of deep repositories. The next glaciation could occur 10,000 to 1,000,000 years in the future. This is the period where the greatest damage could occur to the repository. The long-term adverse effects could include faulting of the rock, rupture of containers, and penetration of surface waters or permafrost to the repository depth, which would, in turn, lead to failure of the barriers and faster dispersion of the waste.
- Climate change will change ecosystems significantly, including drastic changes from aquatic to terrestrial systems and vice versa as water levels rise or fall at a particular location. None of the current models on climate change take into account all of the effects that that climate change could have throughout the ecosystem. These models are being continuously refined as more experimental data becomes available. It is impossible to make accurate predictions on the impact of climate change over the very long term.

Earthquakes

During the lifetime of the repository, inactive faults could be reactivated. An earthquake could severely damage the entire containment system, including the backfill and host rocks.Even though the Bruce nuclear site is located in an area of low seismic activity, as indicated by historical records of earthquakes in the area of the proposed DGR dating back to the late 1800s, the length of recorded earthquake data has little relevance to earthquake hazard assessment over periods of hundreds of thousands of years. Therefore, it is not possible to assume, as the EIS does, “large earthquakes to be very unlikely” in the area.[65]

Human Factors

Future generations might accidentally dig a shaft into the rock around the repository or a well into contaminated groundwater above it, resulting in radioactive wastes being rapidly released. Deliberate intrusion is also possible. Human error during any of the stages of the Project could

[65]EIS Sections 6.2.10, 9.2.2.5

adversely and unintentionally affect the safety of the repository. This is one of the most difficult, if not impossible, factors to assess.

C. Limitations to Models

Many of the complex processes and interactions that could take place in the repository over hundreds of thousands to millions of years are poorly understood, or completely unknown. Computer models used to make predictions on the safety of the repository for the timescale needed would have to take into account all the complex processes and interactions that could occur over this period. This is an impossible task. As these computer models are not complete or accurate, they have no predictive value.

In fact, it has been argued that the verification and validation of numerical models of natural systems is impossible because natural systems are never closed.[66] Computer models can only be validated by the demonstration of agreement between observation and prediction. This is not possible when it depends on observations far into the future.

As a result, the computer models that are being used in the safety case involve numerous subjective, rather than objective, choices and assumptions, including how the performance of a model should be evaluated. This subjectivity can lead to overconfidence in a particular computer model and its underlying assumptions, since proper verification or validation are completely impossible.[67]

D. Policy Issues

A number of factors compromise the integrity of the long-term safety assessment process for DGRs, such as;

- Weakening of the safety assessment process because of commercial interests that favour the nuclear industry, and its need to implement DGRs as a means of alleviating public concerns regarding nuclear waste.
- The lack of resources (funding and expertise) for independent scrutiny of data and assumptions, which can strongly influence the safety case. Consequently, excessive reliance is placed on industry-funded research, which is inherently biased.
- The short-term economic benefits, as presented to host communities, can cause long-term repository safety to be compromised. Concerns about repository safety and impacts on future generations may not be properly addressed if communities are too economically dependent on the compensation, infrastructure, or jobs offered to them as compensation.
- The lack of a clearly defined inventory of radioactive wastes, and ambiguous definitions of what is considered as waste, can make the level of safety required seem lower than it actually is.

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[66] Oreskes, N., Schrader-Frechette, K., Belitz. K. 1994. Verification, validation and confirmation of numerical models in the Earth sciences. *Science* **263**: 641-646.
[67] Rock Solid? GeneWatch UK consultancy Report September 2010 p.41

Summary Comments on Long-Term Safety

This proposed Project requires certainty that these wastes can be retained in the repository, and safely isolated from the ecosystem, for hundreds of thousands and even millions of years. However, the ability of the rock formations at the proposed site to prevent the migration of radionuclides from the repository in the very long-term is not known, and cannot be determined with the degree of certainty that is required for storing radioactive wastes.

As there is no experience to date on which to base an assessment of long-term safety, and the models that are used to predict long-term safety cannot be verified or validated, then logic tells us that it is scientifically impossible to determine the long-term safety of the repository, when “safety” means that no radionuclides and other contaminants in this waste will be released into the environment, essentially forever.

The proposed DGR carries a risk, and in the long-term a certainty, of contamination of the environment with radioactive substances, causing serious effects on human health and biota.

Most importantly, a failure in any part of the repository, to say nothing of a complete failure of the repository, will have far-reaching consequences on human health and the environment.

Unfortunately, the inherent bias of the proponent infects all the technical studies that support this proposed Project, so that they minimize and even dismiss reasoned and logical concerns as to whether it is even possible to achieve long-term safety with a DGR.

At the same time, the great level of uncertainty as to the long-term safety of the repository must give serious pause to the merits of this Project. Caution and prudence must prevail.

At the very least, no action should be taken until we have the time to do a far better long-term safety assessment than we now have.

PART 5: MALFUNCTIONS AND ACCIDENTS

A. Overview

The Environmental Assessment (EA) concludes that, based on the criteria and boundary scenarios selected for malfunction and accidents, no residual adverse effects are expected as a result of an accident in any phase of the Project, or beyond. Nor does the Environmental Impact Statement (EIS) consider that malevolent acts are even possible.

Such simplistic, unfounded and unsubstantiated statements are unconscionable. Any discussion in the EIS on probability, credible accidents, etc., must address the possibility of a complete failure of the containment system, and the consequences of the release of long-living radionuclides and other hazardous contaminants into the biosphere. This could dramatically affect human health and the environment, not only for the present, but for countless future generations.

Unforeseen events and consequences from technical malfunctions and human error have caused and continue to cause many industrial accidents. Similarly, disruptive events such as severe storms and earthquakes can result in catastrophic long-lasting damage very quickly. A major disaster in a facility such as the proposed DGR could result in irreversible harm to the health and environment of hundreds of thousands and even millions of people, for a very, very long time.

No one can ever predict what human error will cause. The possibility of human error, or lack of judgement, can never be ignored, especially considering that human error was a primary cause of the catastrophes at Chernobyl and Fukushima, the partial meltdown at Three Mile Island, and so many other very serious accidents.

If simple human error is capable of unleashing vast destructive forces, human malfeasance can cause even greater harm.

Ignoring the possibility of a major accident is contrary to the precautionary principle, which requires a project to err on the side of caution, especially where there is a large degree of uncertainty, or the risk of very great harm. Some risks, such as the risk of contaminating the water, food and air which present and future generations rely upon, are simply too great to take.

The proponents of this Project must realistically assess both the risk and the costs of a major accident caused by human error, and also of one arising from human malevolence or interference.

The balance of this section, Stephen Hazell, Senior Counsel at Ecovision, Law focuses on worst-case scenarios as a category of accidents and malfunctions.

B. Worst-Case Scenario Analysis

Introduction

The purpose of worst-case scenario analysis is to avoid and mitigate for low-probability catastrophic events such as the BP Deepwater Horizon Oil spill, Enbridge Kalamazoo River spill, and the Fukushima Dai-chi and Chernobyl nuclear reactor disasters. For the DGR Project, a worst-case scenario could involve failure of containment of radionuclides from stored waste or waste being received leading to harm to the environment or human health.

This document comments on the adequacy of the environmental impact statement and related technical support document prepared for the Joint Panel Review for the Deep Geologic Repository (DGR) Project for Low and Intermediate Level Waste (L&ILW) with respect worst-case scenario analysis. This commentary is part of the submission of the International Institute of Concern for Public Health (IICPH) to the Joint Review Panel.

Environmental assessments under the Canadian Environmental Assessment Act (CEAA) assess environmental effects associated with accidents and malfunctions relating to projects but not generally those of worst-case scenarios. Worst-case scenario analysis is required under environmental assessment laws such as the 1984 Inuvialuit Final Agreement[68] as well as recently strengthened U.S. federal laws.[69] The Inuvialuit Final Agreement requirements led the Mackenzie Gas Project Joint Review Panel to undertake a worst-case scenario for those elements of the Project that were planned to take place within the Inuvialuit Settlement Region.[70]

IICPH maintains that a rigorous worst-case analysis is an essential element of the environmental assessment of the DGR Project. The potentially catastrophic environmental and health risks posed by nuclear waste and the fact that many radioactive elements in these wastes have very long half-lives means that particular attention should be paid to worst-case scenarios in the environmental assessment of the DGR Project.

Worst-case Scenario Analysis in the EIS for the DGR Project

The Environmental Impact Statement (EIS) for the DGR Project prepared by the proponent Ontario Power Generation (OPG) addresses the broad themes of worst-case scenarios in several ways. The DGR's overarching objective with respect to environmental effects and safety is stated as follows[71]: "The DGR must be able to safely isolate and contain L &ILW for tens of thousands of years and beyond without any significant adverse effects to the environment and members of the public."

[68] Section 13. (11) of the IFA requires "an estimate of the potential liability of the Proponents, determined on a worst-case scenario, taking into consideration the balance between economic factors, including the ability of the Proponents to pay, and environmental factors".

[69] *National Environmental Policy Act* 42 U.S.C. ss4321-4370f (2006), ELR Stat. NEPA ss2-209.

[70] *Foundation for a Sustainable Northern Future: Report of the Joint Review Panel for the Mackenzie Gas Project* December 2009.

[71] *Environmental Impact Statement Summary OPG's Deep Geologic Repository Project for Low and Intermediate-Level* Waste (March 2011) at 33.

The DGR Project EIS examines potential environmental effects associated with likely events, but also potential effects due to abnormal events (malfunctions, accidents and malevolent acts)[72]. Safety assessments for "likelihood" and "worst-case" accident scenarios are set out in the EIS for the pre-closure period of roughly 50 years and the post-closure period. These scenarios included fire and breach of a waste package in the pre-closure period and glaciation in the post-closure period. Human intrusion and severe shaft seal failure were identified as the only scenarios with potential for significant doses to persons living directly on top of the repository. The EIS considered these scenarios to be "very unlikely and any impacts further afield would be much smaller."[73] The EIS also review potential effects of the environment (i.e., natural hazards, climate change) on the DGR Project. The EIS concludes that there is not likely to be residual adverse effects in the case of natural hazards, nor will climate change influence the DGR Project.[74]

A specific technical support document (TSD) on malfunctions, accidents and malevolent acts was commissioned as part of the EIS[75]. This TSD did not specifically examine potential worst case scenarios but rather identified events, features or processes that could initiate a malfunction or accident, and determined the "credibility" of such events, processes or processes before undertaking detailed assessment.

The TSD concluded with respect to radiological malfunctions and accidents during the site preparation and construction, operations, and decommissioning phases that "radiological doses to humans, (including workers or members of the public and non-human biota do not exceed established dose limits for credible accident scenarios."[76] The TSD similarly concluded with respect to the abandonment and long-term performance that "While radiological doses to humans are significantly less than the does criterion for some scenarios, doses to humans resulting for other scenarios could be about 1 mSv/A. However, all scenarios considered are very unlikely and therefore the risk to humans is low."[77]

With respect to malevolent acts, the TSD concluded that "radiological consequences are expected to be bounded by those of malfunctions and accidents".[78]

Finally, the TSD concludes that adverse effects from malfunctions, accidents or malevolent acts can be mitigated through specific mitigation measures, preparation and execution of contingency plans and emergency preparedness measures.[79]

Commentary on Analysis in EIS

This commentary focuses on two key unstated assumptions in the EIS relating to development of a rigorous worst-case scenario analysis. The first assumption is that the geology and climate

[72] Ibid at 41.
[73] Ibid at 58.
[74] Ibid at 47.
[75] AMEC NSS Ltd. *Malfunctions, Accidents and Malevolent Acts Technical Support Document* March 2011.
[76] Ib*id at vi.*
[77] Ibid.
[78] Ibid.
[79] Ibid at 35-36.

of the DGR region will remain stable over a period of thousands of years**.** The second assumption is that the institutional capacity to operate, manage and regulate the DGR Project will not be impaired over the life-span of the project.

1. Geological and/or Climate lnstability

As suggested, the first assumption is that the geology and climate of the DGR region will remain stable over a period of thousands of years, and thus provide sufficient containment for the nuclear wastes stored in the DGR. However, the Wisconsian glacier retreated a mere 10,000 years ago, and phenomena such as uplift are still present that are responding to forces relating to the retreat of this glacier. A renewal of glaciation could bring forces to bear on the sedimentary rocks of the DGR region that cannot be predicted accurately at present in the opinion of IICPH. Further, seismic forces associated with renewed glaciation could also be dramatic and profound. As well, the effects of human-induced and other climate change possible related to cycles of glacial-interglacial periods over hundreds or thousands of years can also contribute to dramatic changes that are not understood and cannot be predicted with any assurance at present.

Geological and/or Climate Instability Scenarios

What scenarios leading to significant environmental or human health impacts can be envisaged on the assumption of geological and or climate instability?

At one end of the spectrum, dramatic increases in global temperatures and climate change-driven super storms could generate fissures in DGR-area rocks, leading to loss of containment. At the other end of the spectrum, advancing ice fields associated with a new glaciation period could generate earthquakes or gigantic pressure on the DGR-area rocks resulting in collapse in containment.

IICPH suggests two possible worst-case scenarios the first based on severe human-induced climate change; the second based on the onset of glaciation. A worst-case scenario analysis should be conducted for both scenarios given the extraordinary proposed longevity of the Project.

Scenario 1 – Geological Instability caused by Human-induced Climate Change

This scenario posits that dramatic increases in ambient global temperatures of say three degrees Celsius combined with super-powerful storms result in strong seismic forces that caused fissures in the sedimentary rocks of the DGR area resulting in loss of containment of nuclear waste stored in the DGR.

Scenario 2 – Geological Instability caused by Glaciation-driven Earthquakes

This scenario posits that deepening and advancing ice fields in northern Canada similar to the last glacial advance results in powerful seismic forces being created deep underground in the DGR area, also resulting in loss of containment of nuclear waste stored in the DGR.

2. Impairment of Institutional Capacity

IICPH asserts that the second assumption of unimpaired institutional capacity is unsupportable based on scientific evidence of global ecological trends as well as historical evidence of institutional longevity. This evidence suggests that there is a significant risk, if not a likelihood, that the institutional capacity to operate, manage and regulate the DGR Project will be seriously impaired over the 45 to 53 year pre-closure period of the DGR Project, with higher risks of impairment, albeit with less adverse radiological effects during the 300-year post-closure period.

The EIS for the DGR Project identifies four project phases as follows:

1. Site Preparation and Construction Phase (5 to 7 years)
2. Operations Phase (35 to 40 years)
3. Decommissioning Phase (5 to 6 years)
4. Abandonment and Long-term Performance Phase (up to 300 years).

Worst-case scenarios could be identified and analyzed for each of the four project phases. However, this Framework focuses on the first three of these phases (pre-closure) when radiation levels and the potential for adverse impacts on the environment and human health are at their highest.

Thus, IICPH doubts that Ontario Power Generation (or a successor organization) will be able to maintain the institutional capacity to operate and manage the DGR Project continuously throughout the 45 to 53 year pre-closure period as well as a further 300-year subsequent post-closure period. A related assumption, also unstated in the EIS, is that Canadian Nuclear Safety Commission (or a successor regulator) will also be able to continuously maintain its capacity to regulate the DGR Project effectively throughout the pre-closure period as well as during post-closure.

IICPH maintains that the question of institutional capacity to operate, manage and regulate a project is highly relevant if that project has a lengthy expected lifespan such as the DGR Project. Most environmental assessments do not assess the capacity of governments or proponents to manage and supervise a project throughout its lifespan. Recent environmental assessments (e.g., Mackenzie Gas Project (MGP) Joint Panel Review) with longer time frames (30 years in the case of the MGP) have addressed such government capacity. The MGP Joint Panel was so concerned about the commitment of governments to meet its legal obligations and delivering on its commitments with respect to project mitigation and management that it recommended that a mechanism be established to monitor the performance of governments in implementing the Joint Panel's recommendations. [80]

The longer the expected lifespan of the project, the more relevant is the institutional capacity issue. IICPH maintains that institutional capacity is an even more critical component for analysis of the DGR Project given its very long lifespan and the stated objective that the DGR "must be able to safely isolate and contain L &ILW for tens of thousands of years and beyond without any significant adverse effects to the environment and members of the public".

[80] Ibid at 613-14.

IICPH also maintains that the risks of impairment of operational, management and regulatory capacity are increasing, and that these increasing risks translate to higher risks that a worst case scenario could unfold for the DGR Project.

Historical Longevity of institutions - Institutions do not last forever. Historically, the longest-lived, continuously functioning institutions such as the Roman Catholic Church, the Roman empire/republic, and the Pharaonic Empire have endured for at most one or two millennia. Most states or empires don't last this long. The British Empire lasted 250 years; and the Third Reich just 12 (despite Hitler's claim that it would endure for 1000 years). Some institutions adapt to dramatic change (e.g., the United Kingdom, to the loss of its empire) while others collapse utterly with dramatic reductions in human populations (e.g., Roman Empire, Mayan civilization).

How likely is it that Canada will not have the ongoing capacity to operate, manage and regulate the Deep Geologic Repository effectively throughout the pre-closure period of roughly 50 years? IICPH asserts that there is abundant evidence based on the historical precedents of institutional longevity pointing to a significant risk of impairment or loss of institutional capacity could occur during the pre-closure period.

Ecological or Financial Crisis - Impairment or loss of institutional capacity could arise as a result of a global ecological or financial crisis. In 2010, the Worldwide Fund for Nature reported that the ecological footprint of humankind already exceeds the life-supporting capacity of the planet by roughly fifty per cent.[81] There is abundant scientific evidence that the biosphere is likely to experience dangerous levels of climate change if anthropogenic greenhouse gas emissions are not reduced dramatically by 2050.[82]

Several respected scholars have investigated the risks of civilizational collapse as a result of dramatic changes to the atmosphere, oceans or terrestrial ecosystems. In *Collapse: Why Societies Choose to Fail or Succeed* [83], Dr. Jared Diamond concludes: "Our world society is presently on a non-sustainable course, and any of our 12 problems of non-sustainability . . . would suffice to limit our lifestyle within the next several decades. They are like time bombs with fuses of less than 50 years."

In *The Upside of Down: Catastrophe, Creativity and the Renewal of Civilization*[84], Dr. Thomas Homer-Dixon contends that global order faces the risk of "synchronous failure", a cascading collapse of systems vital to human wellbeing due to a mix of "tectonic stresses" as follows:

- energy stress, especially from increasing scarcity of conventional oil;
- economic stress from greater global economic instability and widening income gaps between rich and poor;
- demographic stress from differentials in population growth rates between rich and poor societies and from expansion of megacities in poor societies;
- environmental stress from worsening damage to land, water forests, and fisheries; and,

[81] Worldwide Fund for Nature *Living Planet Report 2010.*

[82] Intergovernmental Panel on Climate Change*, Fourth Assessment Report* 2009.

[83] *Collapse: How Societies Choose to Fail or* Succeed (2005) Penguin Books.

[84] *The Upside of Down: Catastrophe, Creativity and the Renewal of* Civilization (2006) Alfred A. Knopf Canada.

- climate stress from changes in the composition of Earth's atmosphere.

Most recently, Dr. Paul Ehrlich has written that the growth in the world's population (to 7 billion) means there is only a 10% chance of avoiding a collapse of world civilization.[85]

IICPH concludes that the possibility of serious impairment or failure in institutional capacity to operate, manage and regulate the DGR Project during the pre-closure period is not remote; indeed it may even be likely.

Institutional Capacity Impairment Scenarios

What scenarios leading to significant environmental or human health impacts can be envisaged on the assumption of institutional capacity impairment?

Impairment of institutional capacity could take many forms over the next 50 years. At one end of the spectrum, reductions in budgets to operate, manage and regulate by Ontario Power Generation or governments could lead to severe financial pressures leading in turn to a higher risk of a worst-case scenario. At the other end of the spectrum, a financial collapse or ecological catastrophe caused by sudden dramatic increases in the price of oil, chronic droughts or floods in Canada or large-scale migrations of human populations into Canada from regions suffering such catastrophes could lead the operator or regulator of the DGR to abandon the project or change its mandate (such as to serve as a repository for high-level nuclear waste from reactors across Ontario).

IICPH suggests two possible scenarios based on the possibility that the operator of the DGR Project and governments experience institutional stresses during pre-closure period.

Scenario 3 – Reduced Staffing and Resources

Financial or other stresses on the DGR Project operator or on government institutions charging with regulating the DGR could result in the loss of on-site management staff at DGR. To what extent do the risks of containment breach during the pre-closure period increase if governments are simply unable or unwilling to pay operational and management staff at DGR? - What would happen to containment if the DGR Project loses electrical power for an indefinite period due to stresses on, of collapse of the DGR operator, or stresses on government institutions? This scenario would suggest that the Bruce Nuclear plants would be off-line. Emergency generators at DGR would only presumably operate for a period of time and then run out of fuel. What then?

Scenario 4 - Use of DGR for High-level waste

This scenario posits that government and utility funding and resources available for safe storage and management of radioactive wastes (including high-level wastes) has declined dramatically. This could have been due to global climate change impacts, a collapse of global financial institutions, or a rapid escalation in fossil fuel energy costs. Further, the scenario

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[85] *Paul Ehrlich, a prophet of global population doom who is gloomier than ever* The Guardian October 23, 2011.

posits that the DGR facility is the only operating repository for nuclear wastes in eastern Canada; high-level wastes continue to be stored, as currently, in facilities maintained at nuclear generating stations.

Given the funding, resource and political pressures plus growing volumes of high-level wasters, the DGR operator and regulator could feel compelled by circumstances *t*o receive high-level wastes as well as intermediate and low-level wastes. Add in a further element of this scenario, that the quality of waste packages deteriorates, also as a result of funding and resource constraints. In such a scenario, IICPH suggests that a serious containment breach would be quite plausible. Worse, inappropriate storage of high-level nuclear wastes in the DGR could increase the risk of a critical event at the DGR leading to a serious nuclear incident.

Conclusion and Recommendations

IICPH maintains that a rigorous worst-case analysis is an essential element of the environmental assessment of the DGR Project. The potentially catastrophic environmental and health risks posed by nuclear waste and the fact that many radioactive elements in these wastes have very long half-lives means that particular attention should be paid to worst-case scenarios in the environmental assessment of the DGR Project that could be driven by severe human-induced climate change or an onset of glaciation in the DGR area.

IICPH further concludes that the lengthy projected life-span of the DGR Project (roughly 50 years for pre-closure period; 300 years for post-closure period) means that the capacity of the utility and governments to operate, manage and regulate the DGR Project throughout the pre-closure period at least must be a key element of any worst-case scenario analysis.

IICPH therefore recommends that the DGR Joint Panel Review commission an independent worst-case scenario analysis that reflects the above concerns and builds on the work carried out pursuant to the Environmental Impact Statement.

PART 6: CUMULATIVE IMPACTS OF THE PROPOSED DGR PROJECT

For a project of this complexity and timeline, effects on the ecosystem and on human health are cumulative and very long-term.[86] Therefore, an assessment of cumulative effects must incorporate the broadest possible range of ongoing projects and activities, and any future projects that are either 'certain' to proceed or reasonably foreseeable, at the Bruce nuclear site and all other sites in the vicinity of the proposed DGR (i.e., the Regional Study Area) and well beyond, including the Great Lakes Region, during all phases of the DGR Project and in the very long term thereafter.

The integration of multiple stressors from all relevant human activities within the temporal and spatial boundaries for the assessment must be considered, at least at a conceptual level, and then examined for their combined potential to produce significant adverse effects.

In this submission, we are focussing on the cumulative effects on human health and on the Great Lakes Region. We are also focussing on specific contributors to cumulative effects that have not been addressed in the EIS.

A. Cumulative Health Effects

The long-term generational impacts of the proposed project on human health must be assessed, with special attention to workers and their families, and vulnerable populations (the foetus, children, women, especially pregnant women, the elderly, and the immune-compromised). All possible contaminants, radiological and non-radiological, must be considered from every facility at the Bruce nuclear site, as well as from the local and regional study areas and beyond, over a far more extensive area than the EIS has examined.

The effects of multiple pollutants on the human lung and on other organs and body systems (e.g. lung irritants, waterborne toxins, radiation and stress) are cumulative. Some of these may be additive or synergistic.

All releases of radionuclides, whether from accidents, malfunctions, or routine operations, have cumulative effects, especially because they cause an accumulation over time of many different harmful agents in the human body.

Any genetic errors or anomalies which are passed by heredity to the next generation are also cumulative, particularly if radionuclides continue to act on succeeding generations of offspring. The genomic instability (damage to the DNA repair enzymes) which can be induced after several generations of this must also be considered as a possible cumulative effect.

B. Cumulative Impacts in the Great Lakes Region

The cumulative effects of this Project in conjunction with the numerous nuclear-related activities in the Great Lakes region need to be considered.

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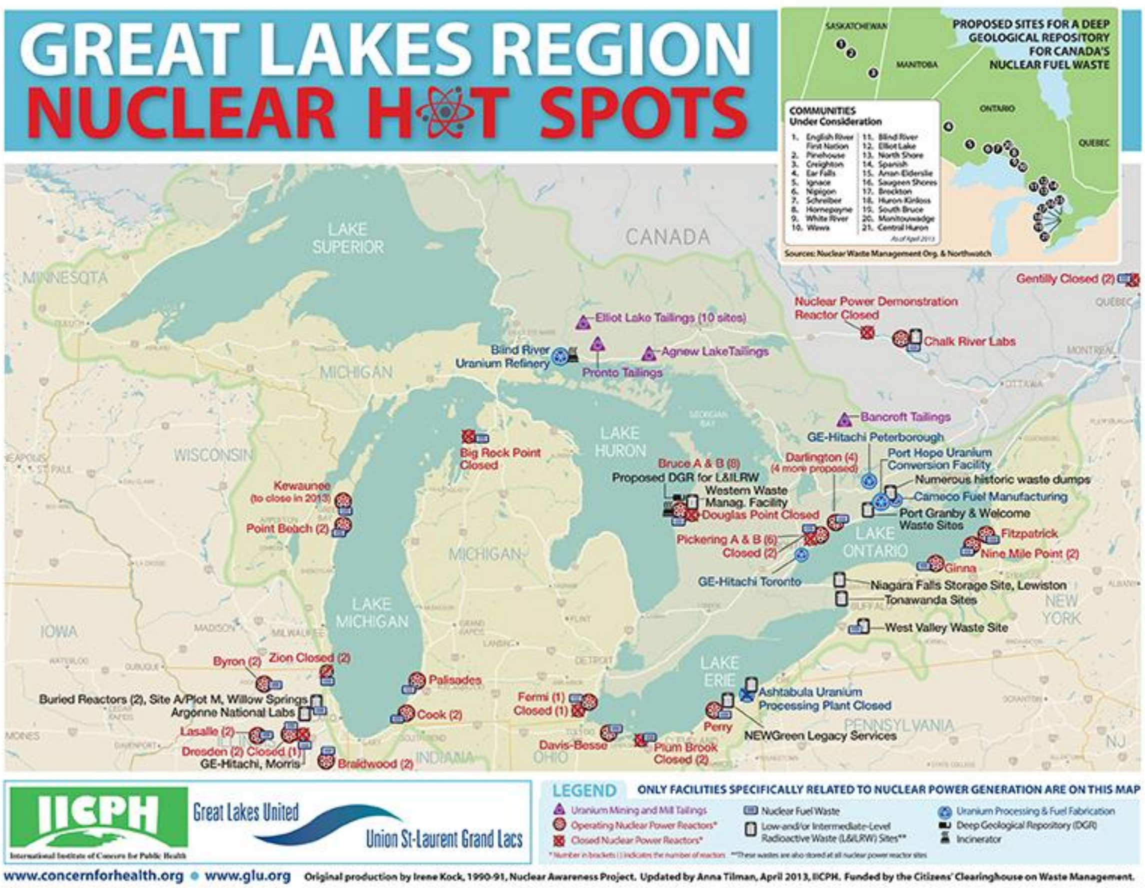
[86] P.N. Duinker and L.A. Greig. 2006. The importance of Cumulative Effects Assessment in Canada: Ailments and ideas for redeployment. Environmental management Vol. 32, No.2, pp. 153-161

The following map, Figure 1 "Great Lakes Region Nuclear Hotspots", illustrates the numerous activities relating to nuclear power production in the Great Lakes Region, including operating, closed and proposed nuclear power plants, uranium-processing facilities, tailings sites from uranium mining, and facilities that store and dispose of radioactive waste. Most of the nuclear power generation stations are located within one kilometre of a Great Lake.

The inset map shows potential sites being considered in Ontario for storing Canada's nuclear fuel waste. A number of these sites lie near the Bruce nuclear site. (Note: An enlarged map is provided in Appendix C of this submission).

Figure 1: Great Lakes Region Nuclear Hotspots Map



Every site on this map is a radioactive waste site, whether operating or not.[87] Every site has released and continues to release radionuclides and other hazardous substances into the waterways of Great Lakes Basin, resulting in adverse cumulative impacts on the ecosystem.

A DGR located about one kilometre from the shore of Lake Huron has potential environmental impacts not just locally and regionally, but internationally as well. Any additional releases of contaminants, in particular, radionuclides, from the DGR would result in long-term cumulative

[87] http://concernforhealth.org/new-binational-great-lakes-nuclear-map-identifies-nuclear-hot-spots/

adverse effects on human health and the environment, in ways that we may not even be able to fathom today.

Radiological contamination of the Great Lakes by Canadian nuclear facilities has already been recognized as a cause for concern by the International Joint Commission on Great Lakes Water Quality. The impacts will be multi-generational, because of the long-lived nature of many radio-isotopes in the radioactive waste.[88]

C. Other Issues

<u>The Incinerator</u>

The incinerator at the WWMF has been operating for many years as a means of reducing the volume of ILW waste to be stored, and presumably will need to be used to limit the quantity of waste to be stored in to the proposed DGR. However, the incinerator has not been included in the assessment that was carried out on cumulative effects.

Incineration of radioactive waste disperses to air, water and soil a wide range of contaminants, including volatile organic substances, particulate matter, dioxins and furans, metals, and radionuclides. It does not destroy metals or radionuclides, or reduce the radioactivity of wastes. Just a small fraction of radioactive and metallic emissions from incinerators can be captured by high efficiency filters. The smaller particles that pass through the filters are more readily absorbed by living organisms than larger ones, and more hazardous.

Radionuclides discharged from the incinerator are being widely distributed, accumulating over time, both on land and in water. Not only will they have an immediate adverse effect around the point of release from the incinerator, such effects will extend far into the future as they are recycled back into the global food web.[89]

The incremental increases in levels of radionuclides and other hazardous substances emitted by incineration year after year are cumulative, and therefore must be addressed in an assessment of cumulative effects, and especially regarding the cumulative effects on human health and the environment.[90]

<u>Decommissioning Waste</u>

The EIS Guidelines require that the emplacement of decommissioning waste at the Bruce nuclear site be included in the assessment of cumulative effects, even though it is not a project that is planned, or a project which is scheduled in the reasonably foreseeable future.[91]

The cumulative assessment that was done was based on placing decommissioning waste from OPG's reactors in an extension of the proposed DGR. This would require additional construction and emplacement activities, but as OPG has assumed that the long-term management of decommissioning waste would not start before 2050, "those activities would not likely be

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[88] International Joint Commission (IJC) Nuclear Task Force, *Inventory of Radionuclides for the Great Lakes,*1998;http://www.ijc.org/files/publications/C131.pdf

[89] http://www.waterkeeper.ca/2004/08/06/bruces-burning-secret/ Quote from Dr. Rosalie Bertell

[90] EIS Section 10 Tables 10.4-1 and 10.4-2

[91] Ibid Section 10-1

concurrent with the operation of the DGR Project, and not have any effect on the proposed DGR."[92] In any event, the EIS found that no cumulative effects would likely result from decommissioning wastes.

The EIS did not consider the cumulative effects of other means of storing OPG's decommissioning waste, for example, if it were stored in a DGR located elsewhere, or stored at the reactor sites, for example. Any means for the long-term storage of these wastes would have cumulative effects on the proposed DGR Project. Furthermore, the time at which the management of this waste is expected to start may very well lie within in the timeframes of the DGR Project, especially if there are delays. So it is essential to examine the cumulative effects of decommissioning wastes, regardless of where, how or when these wastes might be stored.

Nuclear Fuel Waste

The search by the NWMO for a site for a DGR to store Canada's nuclear fuel waste has not been addressed in the cumulative assessment of this Project. Various stages in this search are going on at the same time as the environmental assessment process for the proposed DGR Project for L&ILW at the Bruce site. The prospect of a DGR site for nuclear fuel waste being located near the Bruce site or by Lake Huron must be addressed and analyzed in this cumulative assessment, but this has not been done. Such a project would have a tremendous impact on its own, and in conjunction with the DGR Project proposed.

Complex Effects

The EIS guidelines state that the "EIS must include different forms of effects (e.g., synergistic, additive, induced, spatial or temporal) and identify impact pathways and trends." However, OPG does not describe whether or how complex effects (e.g., synergistic, interactive) were considered. As noted in the EIS, no adverse cumulative effects were identified.[93] Certainly in terms of the cumulative effects on human health, the assessment does not consider synergistic effects, and only considers complex effects over a very short term.

Summary

In summary, the assessment of cumulative effects that was done by the proponent falls far short of what is called for, given the nature of these wastes and the hazards they present, the sensitivity of the region, and the adverse consequences of any migration of this waste from the repository. Because it is so limited, it is no surprise that no adverse effects on human health and the environment are expected. As this Project is intended to safely isolate radioactive wastes from the ecosystem for hundreds of thousands, and even millions of years, the analysis of cumulative effects is a very important task that must be carried out far more completely and thoroughly. This is yet again a reason to question OPG's proposal.

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[92] Ibid Table 10.4.3
[93] Ibid Section 10.8

PART 7: INTERNATIONAL EXPERIENCES OF DGRS FOR L&ILW

A. Introductory Comments

In the fall of 2012, the Joint Review Panel (JRP) for the Environmental Assessment of the proposed DGR at the Bruce Nuclear Generating Station proposed by OPG for L&ILW toured three deep geologic repositories (DGRs) in different countries and phases of development or operation. The intent of these visits was to provide the panel members with further contextual understanding for its review of the proposed DGR project. These sites were chosen based on a review conducted by the Canadian Nuclear Safety Commission (CNSC) staff of their relevance to OPG's proposed DGR Project.[94]

Of six repositories that were considered by the CNSC Staff, the three repositories considered most relevant for the tour included:

Konrad Repository - Salzgitter, Germany (a former iron mine)

Waste Isolation Pilot Project (WIPP) - near Carlsbad, New Mexico

Final Repository for Radioactive Waste (SFR) - Forsmark, Sweden

The CNSC staff concluded that "the WIPP site (for general operations) and the Konrad site (for general construction and proposed operations) have the most relevance to the DGR project based on their depth, general geology, and the volume of low and intermediate level waste for disposal". The SFR site would, in CNSC staff's opinion, "be an alternate site from the WIPP to demonstrate operations". [95]

While both WIPP and the SFR have been operating for a number of years, (WIPP since 1999, and SFR since 1988), the Konrad mine is not yet operating, and is currently undergoing construction to convert it to a repository.

Clearly the complexity and uniqueness of each DGR make it difficult to compare these other DGRs to OPG's proposed DGR at the Bruce nuclear site. It is important to examine not only the geological conditions, and the types of wastes and volumes, but also the social and political situations. These considerations would include, for example, the location of the DGR within the local environment (especially waterbodies), the affected communities and their concerns regarding a repository for radioactive waste, and the transportation of this waste.

A "physical" visit to these facilities, conducted by the authorities in charge, cannot provide the pulse of the community regarding these projects, or the full history of these sites. It would have been much more important and meaningful to delve into the issues and concerns that have been raised by the local communities and the broader public, and the legal and political issues that have ensued regarding these DGRs. Some of these issues are the level and quality of public engagement, the approval process, the transportation of this waste through communities, the very hazardous nature of this waste, its effects on human health and the environment, and on a broader level, the long-term safety of DGRs, above all, whether it is even possible for them to permanently isolate this waste from the ecosystem over the very long term.

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[94] Canadian Nuclear Safety Commission (CNSC) May 28, 2012 E-doc 3938375

[95] Ibid p. 3

In addition to visits to these three sites, it would also have been worthwhile for the JRP to explore other sites which have already stored "L&ILW" and the experiences with those DGRs. This would have included, for example, the repositories in the Morsleben and Asse II salt mines in Germany, where very serious problems developed very early on in their operations. These included cave-ins and seepage of water into the repositories, threatening severe radioactive contamination of the surrounding areas, which caused the closure of these facilities within just twenty years or so.

The following sections take a closer look at the experiences to date with DGRs for L&ILW, primarily in Germany and the United States, but also in Sweden.

B. DGRs in Germany – An Overview

The DGRs in this section include two facilities that have stored L&ILW, namely Morsleben and Asse II, and the Konrad Repository, currently under construction.

i) Morsleben

Background and History

In 1970, an abandoned salt and potash mine, Bartensleben, located near the village of Morsleben in the former German Democratic Republic (GDR), was selected to be the central repository for L&ILW from nuclear facilities in the GDR. The mine was renamed the "Repository for Radioactive Waste Morsleben (ERAM)". The repository, approximately 500 metres in depth, was designed, constructed and commissioned during 1972-1978.

The repository is located in an Upper Permian salt structure formed approximately 230 million years ago, similar to the salt beds in Carlsbad, New Mexico. The overlying cap rock consists mainly of components insoluble in water, sealing off the top of the salt structure.

Storing nuclear waste in subterranean salt mining caves was deemed to be an ideal solution for isolating radioactive waste, based on the assumption that since salt has been in these formations for millions of years, no groundwater would be flowing through the structure for at least that long. Otherwise, the salt would have been carried away. Thus if radioactive waste were placed inside salt beds or caves, most of the waste would decay to non-radioactive elements before migrating out.[96]

Prior to its conversion to a repository, the mine underwent a trial phase of emplacement of nuclear waste from reactors in the former DRG.

The first operational license for the repository was granted in 1981 for a 5-year period. In 1986, this licence was replaced by a permanent operating licence issued by the GDR administration.

For the first twenty years of operations, (1971-91), approximately 14,400 m^3 meters of L&ILW was stored at the Morsleben repository. This waste came mainly from two nuclear power plants and a research reactor in the GDR. Following German reunification, in 1991, the repository came under the responsibility of the Federal Republic of Germany (FRG)'s Office for

[96] History of the Morsleben Repository
http://www.bfs.de/en/endlager/endlager_morsleben/historie.html

Radiation Protection (BfS), which then became the operator of the repository. The permanent operating licence that had been granted by the GDR in 1986 was considered to be a factual plan-approval decision which continued to be effective until June 30, 2000.

On February 20, 1991, due to a provisional district court order resulting from concerns over the long-term safety of the repository, emplacement operations at Morsleben were discontinued. However, just shortly afterwards, on June 25 1992, the Federal Constitutional Court revoked the decision of the district court. Consequently, emplacement operations were resumed in 1994 and continued for another four years, during which there was a dramatic increase in the amount of radioactive waste, an additional 22,320 m^3, emplaced in the repository.

In 1998, all emplacement operations ceased as a result of a lawsuit launched by Greenpeace. Subsequently, on April 12, 2001, the Federal Office for Radiation Protection (BfS) irrevocably waived acceptance of further radioactive waste and its disposal in the Morsleben repository, as this was no longer acceptable for safety reasons. [97]

By the end of 1998, approximately 36,800 m^3 of radioactive waste had been disposed of in the repository, close to its capacity of 40,000 m^3.

Since then, the stability of the salt domes has deteriorated, resulting in cave-ins. To avoid the imminent danger of collapse of sections of the mine, since 2003 the BfS has used about 900,000 m^3 of salt-concrete (a mixture of salt, concrete and other materials) as backfill to temporarily stabilize the mine. But because of the weight of the salt-concrete, this treatment could well be contributing to a potential collapse.[98]

Decommissioning Morsleben

The public hearing into the procedure for the decommissioning of the Morsleben repository began October 13 2011. The decommissioning concept presented by the BfS consisted of backfilling four million cubic metres of cavities with salt-concrete, and sealing the shafts of the Bartensleben mine and the adjacent ”twin” Marie mine, which was likely to be affected although it had not been used for storing radioactive waste.

A cavity in the immediate vicinity of the nuclear waste of about one million cubic metres was not to be backfilled, because of the potential generation of gas from the waste. It is estimated that it will take about fifteen years to implement these measures. The measures do not include retrieval of the waste once the decommissioning measures have concluded, as all accesses to the mine opening and thus to the emplaced waste would be backfilled and sealed.[99]

Approximately 13,000 people filed objections at the hearings. [100]

[97] Ibid

[98] Final Repository Morsleben (Germany) - A Collapsing Salt Mine in the Process of Closure October 2009 http://www.folkkampanjen.se/pdf_20091017_falk.pdf

[99] Decommissioning procedure: http://www.bfs.de/en/endlager/endlager_morsleben/historie.html

[100] http://www.nuclear-heritage.net/images/5/53/NuclearHeritage_Infoflyer_Morsleben_150dpi.pdf

Issues Ignored - the Uncertain Future of Morsleben

As early as 1969, the possibility of collapses in parts of the Morsleben mine was recognized. Water influx into the mine was also a known problem, but this was not publicly disclosed until the 1990s.[101] This meant that the structural stability of this mine was severely compromised, and it was unsafe from the outset, let alone for storing radioactive waste.

It is not known what effects this repository has had and may continue to have on local residents or on other forms of life, due to radioactive exposure via air and water. But when 13,000 people file objections at a hearing, that is certainly an indication of significant public concern.

ii) The Asse II Salt Mine

Deep in the abandoned salt mine known as Asse II, in the region of Lower Saxony in Germany, barrels of nuclear waste lie in a jumbled heap, untouched since the 1970s, surrounded by puddles of radioactively contaminated salty water.[102]

First built in 1906 to a depth of 750 metres, the abandoned salt mine was selected as a test case for the development of a deep geological repository to permanently store nuclear waste. The underlying assumption for using rock salt as the host geological formation was that salt would prevent water from contacting the storage barrels. But it turned out to be an experiment gone terribly wrong. The Asse II waste dump has earned the dubious honour of being the most contaminated legacy of Germany's nuclear power industry.

Between 1967 and 1978, approximately 125,000 barrels of low-level and 1,300 barrels of medium-level radioactive waste, 90 percent of it from nuclear power plants, were dumped inside the abandoned salt mine. Just ten years later, water was found to be seeping into the mine chambers (at a rate of about 12, 000 litres a day), eroding layers of salt and causing cracks in the salt rock.

Inevitably, the metal barrels of radioactive waste were covered with rock salt and saline solutions. Since the barrels were not designed to withstand contact with water, the influx of water into the mine resulted in radioactive wastes being flushed out from the corroding barrels. This radioactive waste has been leaking into the surrounding environment, contaminating the earth and groundwater in the region and well beyond. An underground pond of briny radioactively-contaminated water (including for example, Caesium-137, plutonium and

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[101] Nuclear Heritage Info Flyer: http://www.nuclear-heritage.net/images/5/53/NuclearHeritage_Infoflyer_Morsleben_150dpi.pdf

[102] Nuclear-Waste Pileup - Leaking Nuclear Waste Fills Former Salt Mine: http://news.nationalgeographic.com/news/2010/07/photogalleries/100708-radioactive-nuclear-waste-science-salt-mine-dump-pictures-asse-ii-germany/#/salt-mine-nuclear-waste-asse-germany-waste-barrels_23159_600x450.jpg Photographs by Emory Kristof, National Geographic

strontium) has formed below the mine, threatening to destroy the geological barrier below the sealed storage chambers. Some 12,000 litres of salt-saturated water have to be pumped daily from the mine to stop it from mingling with the leaked radioactive waste.

The mine is unstable and could collapse, releasing radon gas into the atmosphere. This would lead to a far greater disaster than has ever been contemplated, and one which would be beyond control, especially given the nature of this waste.

The inflow of water into the mine was first detected and reported in 1988, but not made public until 2008. This inordinate delay in releasing information on the status of the mine provoked widespread anger among local residents and in Germany as a whole. After all, how long has the inflow of water into the mine really been going on? What effect has this already had, and what effect will it ultimately have, on the local population, the farmlands, the forests, and the water? What effect will it have downstream from the mine? How, can this be remedied in any way? What, if anything, can be done to prevent any further disaster?

Data from the Lower Saxony Oncological Disease Registry point to elevated cancer incidence rates more than double the national average in Germany. Some of the local population who have developed cancer may have been workers at Asse II and been involved in managing the waste, or else members of their families. If these illnesses are due to leaking radionuclides from the dump, then given the long half-lives that some of them have (e.g., plutonium, 24,100 years), the residents, the farm animals, and the wildlife will continue to be exposed to cancer-causing radionuclides from contaminated food, water and air for generations and centuries.[103]

In January 2010, the German authorities (the Federal Office for Radiation Protection Control (BfS)) decided that all the waste from Asse II needed to be retrieved, following tests for radiation, toxicity, and explosive gases, and repackaged, including the saline water that had leaked into the chambers of the mine.

However, retrieval of this waste poses very serious problems. "What we have to do now is find out if it's possible to remove the waste," said agency spokesperson Werner Nording. "This work has never been done anywhere in the world up until now." "We have to guarantee the safety of the public with respect to radiation.” "Then we have to build a big interim storage area, where we can store it for some years until we find a place where we can leave it."

iii) The Konrad Mine - Germany’s DGR Solution for L&ILW

With the closure of the Asse II mine, Germany sought another site for a DGR to store the L&ILW from its reactors. Despite public opposition, it is now constructing a DGR at a depth of 800 metres at a former iron mine (Konrad mine) located near Salzgitter, in Lower Saxony.

The studies on the possibility of locating a disposal site for radioactive waste at the abandoned Konrad mine began in 1975. On May 22, 2002, the license was approved for the deep geological storage of up to 303,000 m³ of L&ILW.

[103] Bellona – Increased cancer incidence in Germany’s Lower Saxony linked to old radwaste storage facility http://www.bellona.org/articles/articles_2010/1293064792.18

For years there was growing public opposition to this disposal site that lasted for years, with citizens filing several complaints against granting a license for this facility. Key issues were out-of-date long-term safety studies, insufficiently based on current facts; the potential for accidents; the transportation of radioactive waste; radioactive exposure to the population in the area; possible terrorist attacks; and the lack of a comparative assessment with other locations.

In October 1992, a public hearing was held on this plan. The presentation by the Nuclear Guardianship Network, "No Final Solution", stated that the solution to the problem (i.e., nuclear waste) was not limited to "finding a site for the final disposal that is as safe as possible. There is no site like this on the planet." [104]

Instead of burying the waste deep underground, the Network proposed "indefinite storage" of this waste at ground-level. In this way, the waste would be regularly tested for radiation, the containers could be retrieved if needed for repair or replacement, and the population would be kept informed and educated as to the dangers of radiation and the sites where this waste was stored. In other words, they were advocating a continual guardianship or rolling stewardship, which would keep affected future generations aware of this waste and the danger it posed.

In response to this proposal, government officials stated that guarded, ground-level storage was out of the question because of the radiation danger to personnel. In other words, the risks to the ecosystem of wider, long-term contamination from leaking, inaccessible containers were found preferable to that of a rolling stewardship to monitor the waste from generation to generation.

At public hearings on the Konrad repository plan, held in 2006, the issues and concerns by individuals and organizations presented were dismissed as unfounded, and the plan was subsequently approved. The conversion of the mine to a repository is now underway.[105]

Currently, 3,500 steel, cast iron and concrete containers of mildly and moderately contaminated waste, such as cleaning rags, radioactive sludge and moderately radioactive scrap metal, are being stored in one of two above-ground buildings in the village of Gorleben, which is located in a thinly populated area near the border of the former German Democratic Republic. This waste is scheduled to be buried in the Konrad Repository.

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[104] *Testimony at Konrad Mine Radioactive Waste Disposal Hearings* - NO FINAL SOLUTION http://www.ratical.org/radiation/NGP/NoFinalSolu.html

[105] http://www.endlager-konrad.de/cln_228/nn_1273016/EN/News/ProjectKonrad/umbau__schacht__konrad.html

C. United States - The Waste Isolation Pilot Plant (WIPP)

Overview of WIPP

The Waste Isolation Pilot Plant (WIPP), located in the Delaware Basin salt basin, approximately 40 kilometres east of Carlsbad in New Mexico, is a U.S. Department of Energy (DOE) facility designed to permanently dispose of defence-related transuranic radioactive waste (TRU). These wastes contain material such as protective gear, tools, residue, debris and machinery from weapons research and production that are contaminated with transuranic elements, mainly plutonium, as well as americium, curium and neptunium.[106]

WIPP is regulated by the US Environmental Protection Agency (EPA) and licensed for 10,000 years. It has the capacity to store approximately 176,000 cubic metres (6.2 million cubic feet) of transuranic weapons-related waste.

The most common transuranic element in TRU waste is Plutonium-239, which has a half life of 24,100 years. These elements are alpha-emitters, and have very long half-lives with lengthy decay-chains of elements, many of which also have very long half-lives.

For years, this waste has been temporarily stored at federal sites around the United States. Since WIPP began waste disposal operations in 1999, the waste is being shipped to this facility by train or truck to be “permanently disposed of” in rooms mined out of an ancient salt formation approximately 650 metres below the surface.

The Use of Salt Beds for Storing Radioactive Waste

The Delaware Basin salt beds were formed during the Permian Era approximately 250 million years ago from the evaporation of an ancient sea once covering the area, leaving behind a “nearly impermeable” layer of salt that over time was covered by 300 meters of soil and rock.

In 1957, the National Academy of Sciences (NAS) recommended salt rock as a perfect geologic medium for the eternal entombment of radioactive waste. At depth under pressure, salt plastically deforms, and flows like slow-moving silly putty, a motion called "salt creep". It is expected to close in on the waste, crush it, and seal any cracks and fissures in the repository, thus making it completely impermeable. No water would be able to seep into the repository, and mingle with the waste, and no radiation would be able to escape. Another attribute of salt rock is that it is considered to be nearly impervious to seismic activity.

The giant salt licks in the Delaware Basin were considered advantageous over alternative rock formations for storing radioactive waste, such as underground deposits of shale and granite, which can be brittle and can fracture under stress, creating cracks through which radioactive waste could seep into the surrounding environment and groundwater supplies.

As noted in this submission, experiences with abandoned salt mines used in Germany as repositories for radioactive waste has demonstrated very serious problems with salt rock for storing radioactive waste. Both the Asse II salt mine and the repository at Morsleben, closed for

[106] Transuranic elements (elements with atomic numbers greater than that uranium) are not naturally occurring, but are produced from man-made nuclear reactions. All TRUs are radioactive.

several years, experienced severe problems such as the influx of water into the mines, the corrosion of barrels of radioactive waste, and cave-ins, and have failed to retain the radioactive wastes.

In 1970, the Carey salt mine in Lyons, Kansas was selected as the first full-scale national repository for nuclear waste. At the same time, political opposition to constructing this repository was mounting. Criticism of the project pointed to insufficient knowledge about repository design, the primitive nature of heat-flow models, and large gaps in the understanding of waste-rock interactions and rock mechanics. In just over a year, technical difficulties developed, including the unexpected disappearance of water from a nearby mining operation, which raised questions regarding the geologic integrity of the salt domes for storing liquid nuclear waste. In February 1972, the Atomic Energy Commission (AEC) withdrew from further operations at the Lyons site, citing technical uncertainties and problems with political and public acceptance. The mine shaft was permanently sealed in December 1994.

The Beginnings of WIPP

After the site in Lyons, Kansas was abandoned in 1973, the Department of Energy (DOE), the successor to AEC, selected the Delaware Basin salt beds in New Mexico for a DGR. However, the geology of the basin proved to be more complex than anticipated. Hollowed-out caverns were found to be unstable. Brine (salt solution in water) deposits below the salt deposits in the Delaware Basin posed a potential safety problem. Constructing the plant near one of these deposits could compromise the facility's safety as the brine could leak into the repository and either dissolve radioactive materials or entrain particulate matter with radioactive waste to the surface. The contaminated brine would then need to be cleaned and properly disposed of. The exact placement of the construction site in the Delaware Basin changed multiple times due to safety concerns.

In 1979, the US Congress authorized WIPP to demonstrate the safe disposal of radioactive waste resulting from defence operations, not from commercial reactors. The first extensive testing to verify the integrity of the facility was to begin in 1988, but was delayed by opposition from various external organizations. Attempts at testing were resumed in October 1991, with the anticipation that transportation of waste to the WIPP would begin shortly after.

WIPP began accepting shipments of nuclear wastes in 1999, which were limited to transuranic waste resulting from the production of nuclear weapons, and excluded spent nuclear fuel from nuclear reactors.[107] The process from siting to first shipment took over twenty-five years.

Status of WIPP – Present and Future

Shipments of TRU Waste: The first nuclear waste (TRU) to arrive at the plant on March 26, 1999 was from Los Alamos National Laboratory, a major nuclear weapons research and development facility located north of Albuquerque, New Mexico. As of January 2012, over 10,000 shipments (79,385 cubic meters) of waste were transported to WIPP via railroad or

[107] http://en.wikipedia.org/wiki/Waste_Isolation_Pilot_Plant

truck for disposal. This is about 45% of the capacity of WIPP. The plant expects to continue accepting waste until 2035.

In addition to TRU waste, WIPP accepts Mixed TRU waste (MRTU) waste that contains both radioactive and other hazardous constituents, such as carbon tetrachloride, lead, toluene, and xylene. Approximately 55% of DOE's TRU waste is mixed-waste. [108] WIPP can handle both Contact-Handled (CH) and Remote-Handled (RH) TRU. [109]

Planned Closure of Facility: Following the interment of waste, the storage caverns will be collapsed and sealed with 13 layers of concrete and soil. Expectations are that salt would slowly creep into WIPP's caverns of nuclear waste to eventually seal them. Once the salt walls close in around the barrels and drums, fractures and openings would be sealed, leaving no pathway for water to enter or for waste to escape. After approximately 75 years, the waste would be completely isolated from the environment.

Alerting Future Generations: The EPA requires that a system of markers and other controls be put in place, referred to as Passive Institutional Controls (PICs), to indicate dangers and locations of waste. Experts from a variety of disciplines, including scientists, anthropologists, and linguists, have worked on developing a conceptual design to communicate the location, contents and design of the WIPP during the regulatory frame of 10,000 years. The system of markers and warnings is designed to tell future generations that the WIPP site location is not in a natural state. Stay-out signs warn against possible intrusion.[110]

Issues of Concern

- **Acceptance Criteria:** The acceptance criteria for TRU waste are limited in a number of ways. For example, TRU waste that does not meet both the defined criteria, that is the half-life and the activity, are not being dealt with. Furthermore, the criteria apply only to TRU waste generated after 1970. TRU waste prior to that time was "managed' as low-level radioactive waste and generally disposed of by shallow land burial. Given the half-lives of the radioactive elements in this waste, the sites where they are buried will remain contaminated for thousands of years, and could potentially contaminate groundwater. There does not seem to be a plan to address these matters.

- **Handling and Transport of TRU Wastes:** While the volume of RH-TRU is about 4% of the total TRU, it is much more radioactive, and thus more hazardous. The maximum external radiation dose rate set for CH-TRU is 200 mrem/hr (equivalent to 2 mSv/hr) and for RH-TRU it ranges from 200mrem/hr to 1000 mrem/hr (10 mSv/hr).[111] As the radioactive components of this waste are mainly alpha-emitters, special caution is needed for the

[108] MTRU is jointly regulated by the EPA and the New Mexico Environment Department. Refer to http://www.epa.gov/rpdweb00/mixed-waste/about.html and http://www.nmenv.state.nm.us/wipp/

[109] The criteria by which WIPP accepts TRU waste generated from DOE activities is based on the definition of TRU waste under U.S regulations (that is, " waste containing more than 100 nCi (nanocuries) of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years". Note: 100nCi/gram is equivalent to 3.7 MBq/kg (Megabecquerels/kilogram http://www.epa.gov/radiation/docs/wipp/wcpip_rev_od_final.pdf p. 19

[110] http://www.gema.ga.gov/content/atts/prepare/Radiological%20Preparedness/WIPP/PICs.pdf

[111] http://www.wipp.energy.gov/library/rhwaste/rhsec3.htm#RH-TRU

containment, shielding and transport of this waste, to avoid any possibility of internal exposure. The potential for occupational exposure to radiation and radionuclides is particularly disconcerting, especially in the case of any accidents, which are inevitable over time. These concerns have been raised by the public, but have not resonated with the authorities of WIPP.

A portion of the waste in containers is liquid. The energy released from radioactive materials will dissociate water into hydrogen and oxygen, which could potentially create an explosion inside the container. While venting the containers may deter this from happening, it may not necessarily prevent it. It could also allow radionuclides to escape into the atmosphere.

- **Closure of facility:** The facility is supposed to be sealed and isolated from the environment in less than 100 years. This assumption is dependent on the hypothesis that the salt will prevent any seepage from the repository, an assumption that may not only be overly optimistic but even completely unfounded.

  According to EPA (40 CFR Part 1), the WIPP facility must be designed to provide a reasonable expectation that for 10,000 years after disposal, no member of the public should be exposed to more than 15 mrems (0.15 mSv) per year.[112] One has to question how meaningful this requirement is 10,000 years from now.

  Given the very long half-lives of plutonium and other long-living isotopes, the uncertainties in predicting geological processes, and chemical behaviour, the length of time that a radioactive waste storage facility must remain impenetrable to prevent the migration of radioactive waste into the biosphere runs into hundreds of thousands to millions of years. This timeframe defies the durability of every material and structure conceivable by humankind.

There is absolutely no guarantee that there will be continual institutional control for 10, 000 years to regulate this facility. Nor can one guarantee that a system of markers would survive that long and be understandable to those living at that time. Natural events, such earthquakes, glaciation and climate change, will play havoc with such expectations.

[112] EPA 40 CFR part 191 www.epa.gov/envrio/facts/radinfo/cfr_191_194.html

D. Repository for L&ILW in Sweden (SKB)

The Swedish Final Repository (SFR) for radioactive waste has been in operation since 1988. It was designed for short-lived L&ILW from the operation of all of Sweden's ten nuclear power plants, and other producers of similar wastes (e.g., medical care) in Sweden.

It is owned and operated by the Swedish Nuclear Fuel and Waste Management Company (SKB), which is the nuclear industry in Sweden.

The SFR is located adjacent to the nuclear power plant at Forsmark, in crystalline rock, 60 metres beneath the bottom of the Baltic Sea. It has four vaults and one silo for the disposal of different kinds of waste. The most active ILW waste is disposed of in the concrete silo surrounded by a clay buffer. LLW is deposited in one of the four rock vaults. It consists of such items as used protective clothing. The three remaining rock vaults are used to dispose of the less active ILW. The radioactivity is so high that radiation shielding is required.[113]

In 1980, at the start of construction, the predicted volume of operational waste was about 90,000 m^3. The first stage was constructed to accommodate 63,000 m^3 of wastes for a preliminary operational period. Currently, approximately half the space has been utilized. Approximately 1,000 m^3 of wastes are disposed of each year in the repository, which is much less than anticipated. This is due to practices that result in greater minimization of waste, and the disposal of very LLW in surface disposal areas at power plants.[114]

It is not clear what this minimization entails, and what its effects might be or how much very low LLW is disposed of at reactor sites.

A major problem identified at the repository is the corrosion of metal parts and some waste packages, as a result of high humidity conditions, particularly in the late summer when the humidity is 100%.

Most of the incidents reported at the repository were in the years 1993-95, and were related to waste packages. This was also the period when the repository received the greatest volume of waste. Some of these incidents include:

- <u>High levels of radiation exposure:</u> Poor closure methods caused the highest radiation (collective) doses to workers (6 mmanSv) in the repository. For example, in one of the vaults, drums grouted with concrete containing ashes were exposed. Closure methods have been modified and the doses have been reduced to about 2 mmanSv.
- <u>Contaminated transport containers:</u> Contamination of transport containers was caused by contaminated water from corroded steel drums in the waste packages. This was due to a fault in the drier equipment. Also, some containers used for LLW had been previously used and were in bad condition (holes, broken lids).
- <u>Contamination in drainage water:</u> Due to corrosion in the steel drums, the drainage water that passed through the disposal compartments in the cavern where ILW was stored showed elevated levels of radioactivity. This was rectified by extra construction.

[113] http://www.skb.se/upload/publications/pdf/SFR_Final_repository_en.pdf
[114] Skosberg M., Ingvarsson R.; Operational experience from SFR

The decommissioning and dismantling of all the nuclear power plants will result in about 150,000 cubic metres of L&ILW. This waste is planned to be disposed of in SFR. This will require significant expansion of the facility. It is expected to take about seven years, and will require a special permit.

The conditions of this repository (size, rock and depth) are not comparable with the proposed DGR. The one similarity with OPG's proposed DGR at Bruce noted by CNSC was that there was local support for the repository. The means by which the local level of support was assessed is highly questionable in both cases.

Most importantly, issues have been identified, with corrosion in particular, at very early stages in the SFR. This should raise very serious concerns with OPG's proposed Project.

E. Concluding Remarks

While a number of physical aspects of the repositories were included in the tour of these facilities by the JRP, a very important component missing was an investigation into long-standing social and political issues regarding DGRs.

For many years, very serious concerns were raised by local communities in close proximity to the sites proposed for DGRs, and also by the broader public. These concerns included the nature of this waste, its transportation through communities, its effects on human health and the environment, the long-term safety of DGRs, public engagement, and political approval processes. These issues are very serious, and deserve very significant consideration.

Another aspect missing from this tour was an exploration of those sites which have already stored "L&ILW", and the experiences with those DGRs. This would have included, for example, the repositories in the Morsleben and Asse II salt mines in Germany, where very serious problems developed very early on in their operations.

Clearly the complexity and uniqueness of each DGR make comparisons of these facilities to OPG's proposed DGR at the Bruce nuclear site difficult, if not even impossible. But it is very serious that all the operating DGRs to date have had very serious problems.

In conclusion, the tour by the JRP cannot be used as a basis to factor into their decision to allow the DGR proposed by OPG to proceed.

CONCLUSION

Any DGR for any level or amount of nuclear waste is an experiment, and a unique one at that. Much may depend on the geology of the specific site itself. But unlike experiments conducted under controlled conditions over a limited time period, OPG proposes to abandon its DGR and leave it uncontrolled for millions of years.

There is no assurance that this waste could be safely contained over hundreds of thousands or even millions of years in a DGR. No computer models can accurately take into account all the complexities that would be encountered by burying this deadly waste deep underground, or guarantee that over a million years, no radioactivity would be released. Natural systems are far too complex and ever-changing for a complete, accurate model to be valid, or even possible.

Nothing is immutable, not even rocks. Containers of this waste will inevitably corrode. Cracks and fissures will develop in the rock formations and widen over time. Water and gas contaminated with radionuclides will flow through the cracks and penetrate the barriers in the repository. Chemical and microbial processes and interactions will occur that could further erode the barriers. Climate change, glaciation, and earthquakes could severely destabilize the repository. And then, there is the possibility of accidental and even intentional intrusion into the repository.

Any and all of these factors, acting singly, cumulatively and synergistically, could lead to the migration of these radionuclides and their escape to the biosphere. No material has yet been discovered that is impervious to all chemical and radiological assaults for a million years.

Based on logic and all our experience to date, it is an absolute scientific guarantee that over this time period anything and everything that can go wrong will go wrong, and the radioactive waste will escape well before a million years has passed. This is equivalent to accepting that this deadly material will be dispersed everywhere.

DGRs really only serve as a construct to hide the waste, under the misguided hope by the nuclear industry that when it out of sight, it will be out of the public's mind. Arguably, there is no safe place on the planet to permanently store this waste with no human monitoring or intervention.

This waste is the legacy that we of the nuclear age leave for future generations. To presume that burying this waste would take the burden off future generations to deal with this nuclear legacy is simplistic and totally wrong. Future generations do not deserve to inherit this nuclear legacy. But future generations will still have to be the guardians of these wastes, and these wastes must be stored in a way that will make it possible to keep them securely under control. It comes down to an ethical decision as to whether those who inherit our waste will be able to keep it under control, monitor it and re-package it as needed, or whether it is buried deep in the earth in the vain hope that nothing will ever go wrong that will result in its dispersal into the biosphere.

Our best hope is to permanently store this waste on the site of the nuclear stations, and ensure that full information about its contents and the danger it poses is kept alive for future generations, that nuclear storage sites are routinely monitored for any leakages, that the waste is retrievable from storage when leaks need to be repaired, and that transportation of this waste is minimized or even avoided completely.

Quoting Rosalie Bertell, the founder of IICPH:

> *"There is really no such thing as "disposal" in our closed earth system. One can only isolate these wastes from the environment for a finite time".*

Wisdom and common sense tell us that we need to stop producing this waste. That reality must be accepted by all.

Therefore, because the proposed means of storing this highly hazardous material has not been conclusively proven to fully protect human health and the environment against it for as long as it remains harmful, and because OPG has stated that current storage methods are safe for another fifty years, IICPH urges the Joint Review Panel reject OPG's proposed DGR Project to allow extensive further study of the safest possible way to securely isolate these materials from the biosphere.

APPENDICES

Appendix A: Potential Adverse Health Consequences of OPG's DGR Project

Joseph Mangano MPH MBA
Radiation and Public Health Project

1. <u>How Radioactive Isotopes Damage Human Health</u>.

Nuclear fission, or creation of high energy by splitting uranium atoms, is used in nuclear reactors to generate electricity. It also generates hundreds of radioactive isotopes that are waste products. Most are not found in nature, and all are similar to those found in the large clouds of fallout after above-ground atomic bomb tests. These radioactive isotopes are highly unstable atoms which emit alpha particles, beta particles, or gamma rays.

Radioactive isotopes can enter the body by breathing, the food chain, water, and dermally (e.g., through open skin wounds). Each of these affects various organs. Cesium seeks out the muscles (including the heart and reproductive organs), iodine attacks the thyroid gland, and strontium attaches to bone. Exposure to radioactive chemicals can either kill or damage a cell. After breaking through the cell membrane and damaging DNA in the cell nucleus, radioactive isotopes can cause mutations, which can lead to cancer and other conditions. DNA damage caused by radioactivity includes adverse effects on the sperm and ova, and thus can be passed down to future generations. A particular dose of radiation from radioactive exposures is far more harmful to the fetus, infant, and child, the elderly with declining immune systems, and persons who are immune compromised, than it is to healthy adults.

Some radionuclides decay quickly; Iodine-131 has a half life of 8 days (a half life is the period needed for half of a given amount of the isotope to disappear). Others remain for longer periods (Strontium-90 has a half life of 29 years). Some will literally last forever; plutonium-239/240 has a half life of 24,400 years.

Some of these radionuclides decay into other radioactive products, known as "daughter products." For example, Strontium-90 (bone seeker) decays into Yttrium-90 (pituitary gland seeker), before decaying into the stable, non-radioactive Zirconium-90. Others have a longer list of daughter products. For example, Uranium-238 (which would be part of the inventory of radioactive chemicals in the DGR) begins a chain of 14 daughter products, some of which also would be in the inventory. The final, stable decay product in this chain is Lead-206, a heavy metal which has its own hazards. (1)

2. <u>Exposures from a Catastrophic Event/Large-Scale Release</u>.

The worst-case scenario would be a large-scale release of radioactivity. While the wastes are non-fissile, and thus there is no chance for criticality, it would still be possible for large amounts of radioactivity to be released into the environment. This could occur through an act of sabotage and deliberate release by terrorists; an extreme weather or geological event; or mechanical/structural failures of the facility. The radioactivity would spread for many miles and enter people's bodies through breathing, water, and the food chain.

Resulting adverse health consequences after a large-scale release of radioactivity would include (short term) acute radiation poisoning and (long term) cancer, among other conditions. The fact that any repository such as the DGR must be secured for thousands of years makes a catastrophic event of great concern.

The fact that the DGR would be located at a large nuclear power plant like Bruce presents another problem, if a meltdown to a reactor core or spent fuel pool occurred. The resulting chaos while evacuating the plant would present security problems – not just to the power plant, but all facilities, including the DGR.

3. Background on Health Risk from Low-Dose Exposures.

Exposures from the proposed DGR that represent relatively low doses also pose a health threat to humans. It is imperative to recognize the many health studies on humans exposed to relatively low doses of radioactivity. The DGR can expose both workers (occupationally) and the population at large.

Many studies have identified health risk from low-dose exposures, countering an initial assumption that a "safe" level of radiation existed. In the 1950s, British physician Alice Stewart showed that a pelvic X-ray to a pregnant woman nearly doubled the chance the baby would die of cancer before age 10. (2) Subsequent reports documented elevated thyroid cancer cases to Americans from exposure to atom bomb test fallout (3) and high cancer rates among workers at U.S. nuclear weapons plants. (4) The Committee on the Biological Effects of Ionizing Radiation (BEIR V) report and the more recent BEIR VII report concluded that a linear no-threshold dose-response relationship exists between radiation and health, i.e. all exposures inflict harm on humans. (5) (6)

Studies of low-dose exposures often focus on cancer in children. Radioactive chemicals are known to be more harmful to the young, particularly the developing fetus and infant. Body growth and cell division is most rapid early in life, and thus a damaged cell is most likely to cause harm. Many medical journal articles identify elevated child cancer rates near different nuclear plants, mostly power plants. The greatest number of studies focused on British nuclear plants. The most recent and most recognized analyses are case-control studies near all nuclear plants in Germany (7) and France (8), which identified elevated risk for childhood cancer.

4. Occupational Exposures.

Several types of occupational exposures would pose health risks to workers at a repository such as the DGR. One of these would occur during construction of the facility, which would involve a large-scale excavation into the earth. This process would expose workers to radioactive products found in nature, including radon, a gas that resides in soil and rocks. Radon-222 decays quickly (half life of 4 days). But its "daughter products" including radioactive polonium-210 have been found to enter the lungs and disrupt cell DNA, increasing the risk of cancer. While much study has been conducted on the experience of coal miners, any exposure to radon is considered a lung cancer risk. (9)

Other routes of exposure to radioactivity would result from routine emissions from the eight Bruce reactors on site, and work carried out during maintenance and repairs of the reactors, and the planned refurbishment of the four Bruce B units.

5. Other Deep Repositories - WIPP.

Other deep repositories are used to store radioactivity. In the USA the Waste Isolation Pilot Plant (WIPP), which stores transuranic nuclear waste from U.S. nuclear weapons production and research plants, has been in operation since 1999. (The term transuranic refers to those isotopes with an atomic weight greater than uranium, which is the 92nd heaviest of 118 elements). WIPP is located in the desert of southeastern New Mexico.

By February 28, 2013, WIPP had stored 85,815 cubic meters of radioactive waste in rooms the size the size of seven football fields, stored 2100 feet below ground level. While 25-35 years of additional waste are expected before the facility reaches capacity, plans are being made to expand the site for other nuclear waste storage purposes. (10)

Even before a 1979 law authorized construction of WIPP as a transuranic storage site, many health concerns were raised. Geological shifts over thousands of years were cited as potentially hazardous because they could cause leaks of water into the storage units and eventually into the environment. Acts of sabotage were among the concerns of storing an enormous amount of radioactive waste in one single location. Many of the transuranic elements stored at WIPP have long half-lives, and will still be hazardous long after the initial 10,000 year period planned.

To date, no studies of health risk to the local public near WIPP or to workers at the site have been published in the peer-reviewed medical literature. The modest number of articles addressing WIPP thus far has focused on measuring environmental spatial and temporal radioactivity levels near WIPP, especially as a baseline before the site began accepting transuranic waste. (11) (12) (13)

In recent years, the Carlsbad Environmental Monitoring and Research Center has examined trends and patterns in environmental radioactivity close to WIPP. (The Center is part of New Mexico State University, is staffed by engineers, and has partnered with Sandia National Laboratory and Los Alamos National Laboratory, both of which send waste to WIPP). One journal article by the Center examined unfiltered exhaust air from the underground repository for daily total alpha and beta concentrations, which it termed “the most important effluent” of WIPP, at a site used for releasing aerosol effluents from underground. Daily levels of gross alpha and beta varied 800- to 1000-fold over the study period. (14) Another recent study by the Center reviewed airborne concentrations of Plutonium-239/240 in the period 1998 to 2010. After finding typical seasonal variations (highest levels in the spring, when "strong and gusty winds frequently give rise to blowing dust," but no unusual inter-annual patterns), the authors concluded that “there is no evidence of any release from the WIPP contributing to radionuclide concentrations in the environment.” (15)

No health records or studies of WIPP workers have been made available to the public. Even if such records were available for study, a relatively small number of workers (approximately 1,000, many of whom are young adults, an age when disease and death rates are low) could only be tracked over a relatively short period of time (14 years maximum, as not all worked there for all years since operations began in 1999). Thus, it would be difficult to generate significant results for any studies of cancer and other immune-related disorders.

However, morbidity and mortality data exist for the local population. WIPP is situated within 30 miles of nearly all 120,000 residents of Eddy and Lea (New Mexico) counties, which flank the site. A cursory examination of infant death trends is given below; as mentioned, the fetus and infant are much more sensitive to a given dose of radiation than adults.

Period	Eddy/Lea Cos. Deaths <1 Yr.	Eddy/Lea Cos. Live Births	Deaths/ 100,000	Vs. Other New Mexico
1996-2000	62	8,444	734.25	+10.62%
2001-2005	46	8,542	561.93	- 10.75%
2006-2010	73	9,935	734.78	+28.64%

The death rate for infants in the two counties in the most recent five years was 28.64% higher than in other New Mexico counties. (16) Naturally, many factors can account for infant mortality changes, and no firm conclusions can be drawn from these data. However, the unexpectedly high rate in the areas closest to WIPP suggests that exposure levels to workers and the public and certain local health indicators should be tracked – as they should be near all waste repositories.

6. Other Deep Repositories - Germany.

Aside from WIPP, the only other deep underground repositories for low- and intermediate-level waste are located in Germany. Both of these – the Asse II Salt Mine and Morsleben – have been permanently closed.

Asse II received waste from 1967 to 1978. A former salt mine in the Lower Saxony province of Germany, Asse II was also used for research until 1995. A total of 126,000 drums and containers that contain the waste are buried at the site. Health concerns have been raised since 1988, when ground water began penetrating the repository pit at a rate of 12,000 litres per day, as the amount of salt covering the pit proved insufficient to prevent seepage. The water penetrated the metal drums and containers, allowing radioactive waste to escape. (17)

Similar to all other radioactive waste facilities, no peer-reviewed journal articles on the health of workers or local residents exist. But in late 2010, reports of an excess number of cancers in the town of Wolfenbuettel (where Asse II is located) surfaced. According to the German national cancer registry, 18 residents of the town were diagnosed with cancer in the eight-year period 2002-2009, compared to 8 expected (if local rates corresponded to national ones). While 18 cancer cases is a relatively small number, it still raised the possibility that radioactive exposure from the Asse II facility was one factor that contributed to the elevated number of cancers. (18) (19)

German authorities were quick to deny any potential connection between radioactive leaks from Asse II and high local cancer rates, citing analyses of radioactivity concentrations in local soil and vegetation. But no explanations for the unusually high cancer rate exist, meaning Asse II must be considered as a possible factor. The experience at Asse II provides a lesson for all current and proposed underground waste facilities, including the DGR.

The 3rd (and last) deep repository for nuclear waste in the world is Morsleben, a former salt mining site in the former East Germany. Morsleben also stored low- and intermediate-level nuclear waste, from 1971 to 1998. The site was closed to new waste after a request from the local environmental ministry. Since then, concerns over the salt covering the waste pit prompted the German government to pump large amounts of salt over the site. Similar to other waste repositories, no health studies have been conducted in the area near the Morsleben facility.

7. Other Low-Level Nuclear Waste Repositories.

In several nations, low- and intermediate-level radioactive waste has been stored at sites that are not deep below ground level. In the U.S., which operates a large program of nuclear sites with civilian and military applications, there are four such facilities (aside from WIPP), i.e. in Barnwell, South Carolina; Richland, Washington; Clive, Utah; and Andrews, Texas.

The Barnwell Low Level Radioactive Waste Disposal Facility, which is about seven miles from the eastern boundary of the sprawling Savannah River Site nuclear weapons complex, has the greatest amount of waste of any U.S. facility as it has been accepting waste since 1971. Barnwell is 90% full and sharply cut back on the amount of waste it accepts in 2008.

The state of South Carolina operates a groundwater monitoring site, and collects quarterly samples of radioactivity from wells close to the Barnwell site. A summary table prepared by the state of trends in tritium concentrations from 2007 to 2012 indicated that of 31 wells, the 2007-2012 trend was higher in 7 wells; lower in 11 wells; and neither higher or lower in the other 13 wells. (20)

But a graph generated by the state of South Carolina of quarterly measurements of tritium concentrations from 2007 to 2012 showed disturbing results in several wells, as indicated below.

Numbers are approximate, since they are indicated in graph form only. Each of these represented generally steady increases over the period, as opposed to an unusual single year. (19)

	Average Tritium*		
Well	2007	2012	Change
WM0055	20,000	45,000	More than 2x
WM0073	5,000	23,000	More than 4x
WM0115	35,000	80,000	More than 2x
WM0100	700	2,000	More than 2x

* in picocuries of tritium per litre of water (1 picocurie [pci] = 0.037 Becquerel [Bq**]**)

While tritium exists in nature, and quarterly samples can fluctuate randomly, steady increases over a long period of five years indicate that a current source of radioactivity is affecting results. While the nearby Savannah River Site (formerly nuclear weapons production) and the Alvin Vogtle nuclear power plant may be affecting these numbers, leaks from the Barnwell facility should be considered as a potential factor in these large increases.

While no studies of health status indicators near the facility have been published, official statistics from the U.S. Centers for Disease Control and Prevention can be used to analyze infant mortality rates for Barnwell County, compared to other counties in the state, before and after the facility began operating. (15)

	Barnwell Co.	Barnwell Co.	Deaths/	vs. Other
Period	Deaths <1 Yr.	Live Births	100,000	S. Carolina
1968-1971	28	1,280	2187.50	- 8.56%
1972-1998	147	9,317	1577.76	+10.13%
1999-2010	44	3,692	1191.77	+37.07%

In 1968-1971, before the Barnwell facility began operations, the Barnwell county infant death rate was 8.56% below the rest of the state. But after it opened, the rate exceeded the state, most sharply in the most recent years, 1999-2010 (+37.07%). Many factors can affect the risk of an infant dying, but the increasing amounts of radioactivity in a number of local wells means that emissions from Barnwell should be considered as one potential cause.

8. <u>Health Threats From Ecosystems Linked to DGR Sites</u>.

The experience at existing repositories, especially Asse II, presents concerns for the Canadian/Bruce DGR site. If radioactive leaks were to occur at the DGR in its expected lifetime (i.e. thousands of years), exposures to local residents and workers would pose a public health threat.

Approximately 65,000 persons live in Bruce County. The population density of the county is greater than that near WIPP, but lower than near other existing and proposed deep geological repositories for low and intermediate-level radioactive waste (below).

Nation	Repository	County	Population	Sq Mi	Pop/Sq. Mi.
Existing:					
U.S.	WIPP	Eddy/Lea	119,000	8,592	14
Germany	Asse II	Wolfenbuettel	120,000	279	432
Germany	Morsleben	Borde	177,000	914	190
Finland	Onkalo	Satakunta	227,000	3,248	70
Sweden	Forsmark	Uppland	1,433,000	4,947	290
Proposed:					
Germany	Konrad	Hannover*	3,900,000	7,200	500
Canada	DGR	Bruce	65,000	1,538	42

*Hannover- et al Braunschweig- Goettingen-Wolfsburg

But the threat extends far beyond the 65,000 residents of Bruce County. The proposed DGR location on a large fresh water body like Lake Huron poses health threats to other residents who live along the lake, and consume its water or aquatic life. If radioactivity from the DGR were to enter Lake Huron, currents could transport the radioactivity for great distances. Bodies of water downstream from Lake Huron include the St. Clair River, Lake St. Clair, the Detroit River, Lake Erie, the Niagara River, Lake Ontario, and the St. Lawrence River (which empties into the Atlantic Ocean).

About 8,000,000 persons live to the southeast (downwind during the colder months) within 165 kilometres of the DGR, including lower Ontario County, and parts of Michigan. Thus, potential exposure to these persons constitutes an issue not addressed in the EIS.

9. Conclusion - Failure of EIS to Adequately Address Health Issues.

The EIS consistently failed to consider or minimized potential health hazards of the proposed DGR. Low- and intermediate-level radioactive waste consists of multiple isotopes, each capable of increasing risk of cancer and other disorders in humans. Aggregating an enormous amount of these isotopes in a single location like the DGR, which must not come into contact with humans for thousands of years, presents a major public health hazard to a great many people. The experience with permanent nuclear waste storage in nations outside of Canada, including in deep repositories like the DGR, has confirmed these health concerns.

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Appendix B: Critique of the RADICON Study

Dr. Linda Harvey B.Sc., M.Sc., M.D
President, Physicians for Global Survival
May 2013

The stated purpose of the RADICON Study, by the Canadian Nuclear Safety Commission (CNSC) was "to determine the radiation doses to members of the public living within 25 km of the Pickering, Darlington and Bruce NPPs and to compare cancer cases among these people with the general population of Ontario from 1990-2008."

The RADICON Study is a very lengthy summary (50+ pages) which is being critiqued as they have refused to release the "Study" itself to the public.

Design of Study:

As an ecological study, a design which can give no information about causation of any effects found, it will be of limited usefulness in answering the question "are there health effects caused by radiation doses to the public from nuclear power plants." In lumping together the population within 25 km of each nuclear power plant (Pickering, Darlington and Bruce) into a single category, it lacks the definition of the more skilfully executed studies already in existence, such as the German KiKK study on childhood leukemia.

Unsurprisingly, it finds "no evidence" of increased childhood leukemia, or cancers in general, around Canadian nuclear power plants.

No evidence of harm is NOT the equivalent of evidence of no harm.

One good quality, robustly designed and meticulously executed study which finds a clear positive result is worth any number of weak studies that "fail" (and in this context it is a failure) to find anything.

To achieve their stated goal, the authors used the following:

Mathematical Models:

Mathematical models were used to recreate the atmospheric plume and to estimate dispersion into the environment of "each nuclear substance". The models were not described in detail, actually at all, nor were the "nuclear substances" in question itemized and named. The data used to develop these models were supposedly recorded releases into the atmosphere from each of the plants for each substance. The data were never shown. Monitoring techniques, frequency, and calibration or other validation procedures were not described.

The statement on p. 12 that, "Radioactive iodine, which is the primary cause of radiation-related thyroid cancer, was below detection limits of the in-stack sampling monitors at all three NPPs for the entire study period ", does not fill one with confidence that their sampling was adequately done.

Nor does the recent situation surrounding tritium sampling at the SSI plant in Peterborough, in which the stack sensor was found, after 18 years of operation and several CNSC inspections, to be under-reporting by close to a factor of 10.

Emissions to water were not considered at all in this paper. No information was given on substances monitored, techniques or frequency of sampling. No data were presented.

From their environmental models, supposedly based on measured releases, further modeling was done to derive human exposure patterns. Exposures were modeled for various “critical groups” around each nuclear power plant. Details of these models were not given. Models in this situation can be quite complex, as the human body is complex, and so are its interactions with the environment around it. The results of such modeling are only as good as the thoughtfulness and care that go into constructing the model. Small errors in assigning values can have quite a profound effect on the outcome of the modeling. We are left guessing in this situation.

Some of the human doses derived from these models are presented in Table 1 on p. 6. Without the explanatory material necessary to clearly understand where they came from and what they represent, they are essentially meaningless. Are the authors asking us to “trust” them…? While this position has been quite a typical stance for the nuclear industry over the years, it is not how science is done.

<u>Statistical Databases:</u>

As a source of cancer statistics for the time period under consideration, they used the Ontario Cancer Registry and Canadian Cancer Registry, and for population data, the Census of Canada.

In comparing cancer rates between populations, it is important to remember that cancer is multifactorial in origin, that is a large number of agents or insults to the body can cause it to arise, and that each population, indeed each individual, has its own pattern of exposures. To compare a population exposed to radiation with one exposed to pesticides, for instance, and to find no difference in cancer rates is meaningless. This most certainly does not justify allowing either of these exposures to continue on the grounds that there is “no effect”.

The fact that background levels of cancer are very high in the Canadian population currently means that it will be more difficult to tease out an effect caused by any particular agent. This does not mean it isn’t happening and it does not mean that it is acceptable to go ahead and keep causing it because it doesn’t show up in a given study.

The population base in each of the study areas is rather small, and in a small population it is rather difficult to achieve statistical significance. In addition, for individual cancer types with an incidence of less than 6, an SIR is not calculated as it is deemed to be too variable in such a tiny sample. While statistically valid, this manoeuvre effectively removes rare cancers from the full statistical analysis, and care is needed to make sure this data is not lost. It is not clear what steps the authors took in this situation.

<u>Analysis and Comment:</u>

As a regulatory agency, mandated to protect the health and safety of Canadians, the CNSC should properly be exercising the **Precautionary Principle,** which stipulates that where there is a suggestion, or serious suspicion of harm to any segment of the human population by a given action or process or substance, the burden of proof must be on those wanting to continue the exposure to prove that it is safe, and that the exposure should cease until this is done.

The second last paragraph on p. 5 of the their document begins, “Interpreting SIRs must be done with a great deal of caution…” and goes on to state, “Thus a high cancer rate in a given region is not sufficient evidence to implicate specific risk factors or require more epidemiological investigation to assess the relative importance of various factors.” (!) (if not, what is?) This passage very deftly absolves them of any and all responsibility to take seriously any effect, no matter how positive or statistically significant. This they proceed to do for the balance of the paper.

On p. 12 of the document they discuss first thyroid cancer and then leukemia, discounting the relevance of increases found, and flatly denying and implication of the nuclear industry. Nor do they recommend further, more definitive studies.

This is not the stance of a well motivated and responsible regulator.

At no point do they discuss the fact that foetuses and young children are well known to be far more sensitive to ionizing radiation than adults, and that most or all of our standards for allowable exposure are based on adult data. The adult data also fail to take into account any transgenerational or hereditary effects of radiation, including subtle decreases in fertility and increases in defective recessive genes which can accumulate in exposed populations. Both of these are extremely difficult to detect, and have not been considered in the creation of standards.

Foetuses and young children, in forming their internal organs and growing in a coordinated manner to maturity, use parts of their genome that they will never call on again in their lifetime. Damage to these genes at this stage will cause deleterious effects that would not occur from the same damage happening later in life. Damage to germ cells will not become apparent until the next generation, and may not be visible even then, but may carry silently forward to succeeding generations, accumulating as long term exposures continue. Indeed, childhood leukemia may be the tip of the iceberg in terms of genetic harm being caused to our children and grandchildren.

Nor is background radiation innocuous. It gives us ongoing background rates of cancer, miscarriage and of genetic or inheritable disease. We have evolved DNA repair mechanisms that allow us to be in equilibrium with this level of radiation. All human-made radiation is superimposed on background radiation, it does not replace it. Not quite 60 years after the inception of the Atomic Age, we are still experiencing exposures from the longer-lived isotopes released by the Hiroshima and Nagasaki bombs, all of the atomic testing on several continents, all of the operating and defunct nuclear reactors ever used, and the disasters at Three Mile Island, Chernobyl, and Fukushima. It seems unsurprising that thyroid cancers are increasing worldwide, as stated in this study on p. 12. It also seems untenable to totally dismiss the idea that the nuclear industry could be contributory to this.

All of the above, and more, should have been discussed in a sincere and responsible manner in a paper dedicated to furthering our understanding of the connections between the nuclear industry and the health of the Canadian public, both in the short and the long term.

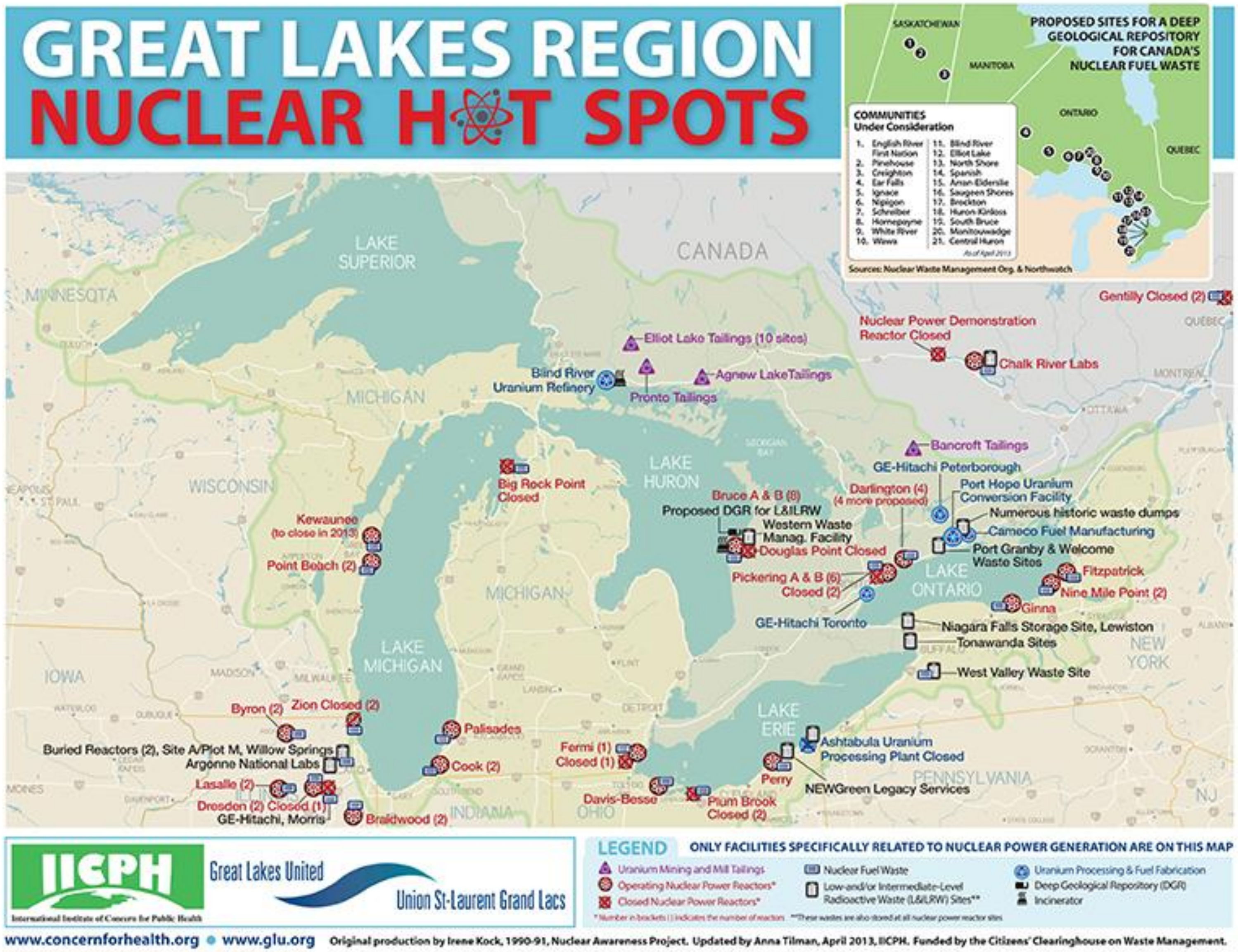
One almost gets the impression that the authors, as spokespersons for the nuclear industry, want to obscure, rather than clarify, these matters.

This is consistent with the stance taken by the mentor organization for the nuclear industry, the International Atomic Energy Agency, which has been given, and has exercised, a gag order over the World Health Organization since 1959. Research into the effects of radiation on human populations is 60 years behind where it should be, and we are making decisions about our future and long-term exposures based on outdated information.

This is dangerous.

Our regulator needs to regulate.

Appendix C: Great Lakes Region Nuclear Hotspots Map



Appendix D: Affidavit of Dr. David Hoel

IN THE FEDERAL COURT OF CANADA
TRIAL DIVISION

Between:

INVERHURON & DISTRICT RATEPAYERS' ASSOCIATION
Applicant

and

THE MINISTER OF THE ENVIRONMENT,
THE ATOMIC ENERGY CONTROL BOARD AND
MINISTER OF FISHERIES AND OCEANS

And

ONTARIO POWER GENERATION INCORPORATED
Respondent

Court File Number: T-906-99

IN THE FEDERAL COURT OF CANADA
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Between:

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THE MINISTER OF THE ENVIRONMENT,
THE ATOMIC ENERGY CONTROL BOARD and
MINISTER OF FISHERIES AND OCEANS
and
ONTARIO POWER GENERATION INCORPORATED
Respondents

AFFIDAVIT OF DR. DAVID HOEL

I, DAVID G. HOEL, of the City of Charleston, South Carolina, AFFIRM THAT:

1. I am a presently employed as a Distinguished University Professor at the Medical University of South Carolina and have been in this position since 1997. My teaching responsibilities include developing and teaching three courses in epidemiology to medical and graduate students. From 1992 to 1997, I was a Professor and Chairman of the Department of Biometry and Epidemiology and Associate Director for Epidemiology at the Hollings Cancer Center, also at the Medical University of South Carolina.

2. For over 20 years, I was a researcher and a research director at the National Institutes of Health, with particular emphasis on the cancer effects of chemicals and ionizing radiation. As a research director, I supervised research into epidemiology, biostatistics, and risk assessment. These fields are not mutually exclusive: biostatistics, for example, is the study of statistical methods for the design, analysis and interpretation of biomedical and epidemiological studies. In turn, risk assessment uses epidemiological, toxicological and biostatistical methods to quantitatively assess risks to human populations.

3. Over this period of time, I have carried out research into numerous cancer-related topics on both chemical and radiation effects.

4. My research into radiation topics includes two periods of employment (1979-80 and 1984-86) in Japan at the Radiation Effects Research Foundation in Hiroshima, Japan.

5. Since 1976, I have been a member of committees of the United States National Academy of Sciences. From 1986 to 1989, this included membership on the Committee on the Biological Effects of Ionizing Radiation (BEIR V). I have been and continue to be a

Affidavit of Dr. David Hoel (T-906-99)
(December 9, 1999)

Council Member of the National Council on Radiation Protection and Measurements (NCRP) for two terms, 1993-1999 and 1999-2000.

6. My research has resulted in over 150 published papers, and includes specific consideration of risk estimating models for chemicals and radiation. Attached as Exhibit "A" to my affidavit is a true copy of my *curriculum vitae*.

7. For this affidavit, I have reviewed the following documents:

   - affidavit of Suzana Fraser, dated October 5, 1999;

   - the Atomic Energy Control Board (AECB) studies, "Childhood Leukemia around Canadian Nuclear Facilities" - Phases 1 and 2 (1989 and 1991) ("AECB child leukemia studies") (attached as Exhibits "B" and "C" to my affidavit are true copies of the Phase I and Phase II AECB studies, respectively); and

   - "Childhood leukemia in the vicinity of Canadian nuclear facilities" (1993), 4 Cancer Causes and Control 51-58, found as Ex.49 to the affidavit of Normand de la Chevrotiere (hereafter, "Ex.49");

AECB child leukemia studies for areas around the Bruce and Pickering nuclear generating stations

8. The AECB child leukemia studies consist of two phases: the Phase I study considers leukemia deaths in children 0-4 years of age nearby to selected nuclear facilities; and the Phase II study considers child leukemia deaths in children 0-14 years of age nearby to the same selected nuclear facilities.

9. Both studies focus on five nuclear facilities: two nuclear stations; a research facility; and a uranium mine and a uranium refinery. The AECB study authors identify "diversity in the nature of the three general types of facilities" and note that "each would result in different potential exposures" (Phase I, p.7). On this basis, the authors concluded it was "not appropriate to pool the results across all facility types" (*ibid.*). However, the authors did pool results for the two nuclear stations. It is these findings which I believe merit specific attention.

10. The two nuclear stations show elevated levels of cancer within 25 km of the two stations studied.

11. Ms. Fraser offers two opinions about the results of these AECB studies for nuclear power stations (para.14):

> (a) "Statistically significant differences between childhood leukemia rates in the 25 kilometre region of BNPD/Pickering and Ontario were not evident...";
>
> (b) "No consistent, statistically significant, temporal pattern of risk was evident to suggest increasing rates over time."

12. I disagree with the first opinion and say that the second opinion is misleading because the data were not adequate to assess trends over time.

(a) Statistical significance

13. In statistical work such as the AECB study, a central issue is whether a finding is statistically significant. Thus, for the AECB study, a central issue is whether the 40% increase rate of childhood leukemia deaths compared to expected rates is statistically significant.

Statistical significance is determined on the basis of two related issues:

- the starting hypothesis for the study; and
- the confidence interval associated with a specific study result.

<u>Starting hypothesis</u>

15. It has long been clear that radiation of the type emitted by nuclear stations - ionizing radiation - can cause childhood leukemia. In fact, in the study of radiation-induced cancers, childhood leukemia cancers appear to be one of the single greatest detectable adverse health effects of ionizing radiation. Thus, epidemiologically, childhood leukemia cancers are one of the most obvious indicators of radiation effects.

16. Additionally, as noted in the AECB study, a number of studies in other countries have found an increased risk of childhood leukemia around nuclear plants (Introduction, page 1).

In this context, the issue for the AECB study is whether there was an increased risk of childhood leukemia around Canadian nuclear facilities. As stated by the authors in the Phase I study:

> "The general objective of this study was to investigate whether or not there exist clusters of leukemia among children born to mothers resident in the vicinity of nuclear facilities in Canada. The specific objectives of the study were to determine (a) whether or not there have been elevated frequencies of leukemia in children who were born to mothers residing in the vicinity of nuclear facilities in

Ontario, and (b) whether frequencies have been greater by residence at time of birth than by residence at time of death." (p.2)

18. This situation of examining whether there is an increased risk of leukemia contrasts with a situation of initial neutrality. A situation of neutrality exists where one has equal reason to expect that nuclear facilities may decrease leukemia risks as increase such risks.

19. The starting point for the AECB study was appropriately not neutrality. As stated clearly in its objectives, the focus was on whether or not there was an increase in leukemia deaths.

20. In statistical terms, the difference in starting hypotheses is critical. Where one has a starting hypothesis of, for example, increased risk, the study is oriented towards establishing whether or not there is statistically significant increased risk. As there is a single orientation to the study, the test for significance is termed a single-tail test.

21. By contrast, where one has no data to support any hypothesis, one starts with a position of neutrality. In this situation, the study is oriented to establishing whether there is any departure - increased risk or decreased risk - from what is normally the case. As this kind of study gives equal weight to two opposite orientations - an increased occurrence or a decreased occurrence- its test for significance is termed a two-tail test.

22. Having regard for these accepted statistical principles, the AECB study should use a one-tailed test for significance, not a two-tailed test. The authors of the AECB study explicitly recognize this point at page 7 of their Phase I Report:

> "It should be noted...that the existence of the prior hypothesis of increased risk in the vicinity of nuclear facilities calls for the use of a one-tailed, rather than a two-tailed test of statistical significance."

Confidence intervals

23. In radiation cancer epidemiology, a one-tail test is coupled with a 90% confidence interval to determine statistical significance. This approach is illustrated in two international studies that are among the most important radiation cancer studies to appear in the last several years:

> (1) The leading international study of cancer in radiation workers is the study by E. Cardis and others, *Combined Analyses of Cancer Mortality Among Nuclear Industry Workers in Canada, the United Kingdom and the United States of America* (World Health Organization, IARC Technical Report No.25 (1995); also *Radiation Research 142*, pp.117-32) [Attached as Exhibit "D" to my affidavit is a

true copy of this *Radiation Research* article.]

(2) The most recent and important study for radiation risk assessment is the A-bomb survivors cohort study by Pierce, DA, and others, *Studies of the Mortality of Atomic Bomb Survivors* Report 12, Part 1. Cancer: 1950-1990; summarized in (1996), Vol.146 *Radiation Research* 1-27. These findings provide the basis for radiation standards around the world. [Attached as Exhibit "E" to my affidavit is a true copy of this *Radiation Research* article.]

24. By contrast, a 'neutral' hypothesis uses a two-tailed test and a 95% confidence interval to determine statistical significance.

25. Thus, depending on whether the starting hypothesis involves use of s single-tailed or double-tailed test, one uses a different confidence interval.

26. In para.10 of her affidavit, Ms. Fraser comments that the "established scientific statistical criteria" for this study was to use a 95% confidence interval. I disagree with this statement. The appropriate statistical standard for studies like this is a 90% confidence interval because the study's starting hypothesis involved a one-tailed test of statistical significance.

Conclusion on statistical significance

27. In my opinion, the AECB study fails to follow appropriate statistical methods for analyzing radiation cancer epidemiology data. This results in understating the statistical significance of the 40% observed increase in childhood leukemia rates around the Pickering and Bruce nuclear power plants. The AECB study fails in the following ways

(1) the Phase I study used a single-tail hypothesis test for some nuclear facilities, but inappropriately failed to use this hypothesis for the nuclear power plants;

(2) the Phase I study inappropriately used the 95% confidence interval for the nuclear power plants;

(3) the Phase II study inappropriately used a two-tail hypothesis test, when the context called for a single-tailed hypothesis test, as set out in the Phase I study; and

(4) the Phase II study inappropriately used the 95% confidence interval for the nuclear power plants.

28. When the AECB data is considered appropriately (i.e., a single-tail hypothesis and a 90%

confidence interval), the study shows a statistically significant excess leukemia rate in the vicinity of the two nuclear stations studied. The AECB's use of the 95% confidence interval, which is inappropriate in my opinion, has the effect of denying a statistically significant increased risk.

29. In sum, if the AECB study had used the internationally-accepted method for studying radiation induced cancers, of a single-tailed test and a 90% confidence interval, the present excess rates of childhood leukemia deaths near the Bruce and Pickering nuclear power plants would be considered statistically significant.

30. The conclusion that the AECB study provides statistically significant results for the nuclear power plants appears to have been communicated to the AECB as early as 1991. In 1991, a Canadian organization - Energy Probe - appears to have submitted a technical analysis on this point to the AECB. Further, it appears that the AECB subsequently retained two outside reviewers to examine this conclusion. Each reviewer came to different conclusions, with one reviewer Professor Park Reilly, agreeing with the Energy Probe analysis and the conclusion of statistical significance (Reilly, p.5). Attached as Exhibit "F" to my affidavit is a true copy of a package received by me that was assembled by Energy Probe documenting these communications to and from the AECB.

31. I disagree with Ms. Fraser's conclusion in para.22 that the observed 40% excess in childhood leukemias found in the AECB study was "in fact, most likely due to chance." In my view, the AECB study clearly indicates a statistically significant excess of leukemia mortality among children 0-14 years of age within 25 km of the two nuclear facilities. Further, in my view, it is simply incorrect to conclude that a situation which has less than a 5% probability of being due to chance is "most likely" due to chance.

(b) Trends over time

32. One important means of assessing trends over time is to compare leukemia deaths before nuclear power plant operation with deaths after. The authors of the AECB study carried out this work for the Pickering nuclear station, but not the Bruce station. I have two comments:

(a) Factually, the data is incomplete as this before and after comparison was not done around the Bruce station. The authors of the AECB study suggest that the rationale for not doing this work is that the population around the Bruce area was "relatively small" (Phase II Report, p.12). I believe that the absence of this before and after data for Bruce is unfortunate and not justified by reference to a small population.

(b) For the comparison that was done, that around the Pickering station, the leukemia rate before operations was essentially the same as expected.

33. Thus, there is no evidence of an increase in childhood leukemia rates before the activation of the two plants. However, the study data shows a significant excess in childhood leukemias after operations began.

Follow up studies

34. Ms. Fraser suggests that the AECB followed up its child leukemia studies with a further AECB study. In my opinion this follow-up study is inadequate. I believe that at least four follow-up studies should be conducted:

(1) Follow-up on the specific issue of leukemia around these sites. The first study ended with 1987 data. It is now 1999. There are thus several years of data to follow-up on.

(2) Follow-up on other reactors. I understand that all Canadian domestic reactors use the same basic technology - CANDU technology developed by Canada. In addition to the Bruce and Pickering reactor complexes, I understand that there are other CANDU reactor complexes in Canada, including a reactor complex in Darlington Ontario and other CANDU reactors in the provinces of Quebec and New Brunswick (AECB Phase I, p.2). The first study was restricted to the Pickering and Bruce reactors. There is no identified study of the other reactors.

(3) Follow-up on the location of cancers. The first study states that its parameters allowed no differentiation of cancer locations inside a 25 km radius of the power stations. It would be important to assess where the leukemia risk is higher at closer distances.

(4) Follow-up on exposure levels. The AECB study provides no exposure data for people nearby the nuclear power facilities. I understand the proposed project is expected to release neutrons as well as gamma radiation. I would note that there is very interesting German work being done on the issue of neutron exposures and their relative biological effectiveness (RBE) which suggest that neutron exposure may be more effective than current RBE estimates of 10 to 15 at low dose exposures. The German work suggests that the current multiplier may need to be greatly increased. Attached as Exhibit "G" to my affidavit is a true copy of a recent article discussing these issues.

35. I would rate any of these four follow-up studies as more directly relevant to the AECB leukemia study than the one follow-up study done by the AECB identified by Ms. Fraser. I have reached this conclusion, in part, because the authors of the first study suggested that their data did not support the hypothesis examined in more depth in this single follow up study (Ex.49, p.55: "Unlike the large difference between the mortality ratios obtained by Gardner *et al*... for the birth cohort and the school cohort in the vicinity of the Sellafield facility, in Ontario there was no consistent pattern of higher mortality ratios based on residence at birth rather than death."). There is, by contrast, no indication in the AECB study of what the answers are to the four matters set out above by me as deserving further study.

36. I also believe that it is inappropriate for Ms. Fraser to rely on the population mixing hypothesis, as she does in para.23. Ms. Fraser's thesis is based on a British study asserting that population mixing is a cause of cancer clusters near the Sellafield nuclear reprocessing plant in the United Kingdom. In my opinion, it is inappropriate to assert that population mixing is responsible for cancer clusters around Canadian nuclear reactors absent Canadian data relating to population mixing in the vicinity of these nuclear plants. In my view, this hypothesis would require a further Canadian follow-up study using Canadian data on this topic before it may be judged applicable in Canada.

37. Further, as concerns the British situation, it is simply not true that the British hypothesis has been 'demonstrated' as she sets out in para.23. The fact that population mixing can be <u>a</u> cause of childhood leukemia does not demonstrate that it was <u>the</u> cause of the childhood leukemias near the British reprocessing stations. For example, I note that the authors of the British study and Dr. Richard Doll, upon whom Ms. Fraser appears to rely (see her paras.19-23), both recognize that the population mixing hypothesis most likely appears to account for some <u>but not all</u> of the elevated levels of leukemia around the British nuclear reprocessing facilities: see her Ex.5, pp.144 (Summary), 149; also, Ex.6, p.4.

Other studies in other countries

38. Ms. Fraser appears to place considerable reliance upon studies of different nuclear facilities in other countries, especially Sellafield in England - which has been extensively studied. Yet it is not clear from her affidavit or other studies that the British fuel processing facilities (such as at Sellafield or Dounreay, Scotland) emit the same type and quantity of radiation emissions as the Canadian nuclear reactors. This makes epidemiological extrapolation difficult.

39. I also note that the area around the German Krummel site - which is a nuclear power plant - has been subject to unexplained excesses of childhood leukemias within 10 km of the site arising since its establishment. Whether these increases are due to radiation, or chemicals, or possibly some other cause, is not yet known. Further, unlike the British

areas, this German site has not received extensive population mixing. This indicates that the British "infectious agent" hypothesis is not a complete explanation for observed increases around other countries' nuclear facilities.

40. Thus, there are a number of issues which point away from using other countries' studies for the Canadian context:

(1) Technologies. The Canadian study compares two reactors using CANDU technology. For reasons indicated above, it is not clear to me that other nuclear facilities - such as the English nuclear reprocessing facilities - will have the same effects as these reactors. Indeed, it is not clear to me that other non-CANDU nuclear reactors should be presumed to have the same effects.

(2) Emissions. The Canadian studies compare two reactors at a range of 25 km. Yet the AECB study provides no information on the radiation emissions from the nuclear power plants (e.g., beta, gamma, and neutron). Further, the emissions data from other studies cited by Fraser is also incomplete. For example, the German study cited by her (Ex.3), provides no emissions data on the Krummel situation or the other German nuclear plants. Absent such information, it is difficult to compare the results of studies in other countries with the AECB study results.

(3) Radiation dose. Other studies have sought to relate dose to cancer findings. Absent specific numbers suggesting similar radiation dosages (in total or in specific forms of radiation - alpha, beta, gamma, neutron), it is not clear to me that other studies are comparable.

(4) Populations. A basic population question is whether the populations around Canadian nuclear sites resemble those around nuclear facilities subject to other epidemiological studies. The British studies cited by Ms. Fraser suggest that population mixing is a particularly important matter to appreciate in comparing populations; the German situation suggests population mixing is not central to its leukemia excesses. Absent facts on population showing similar populations, it is not clear to me that other studies are comparable.

41. In sum, I believe that the best approach to the Canadian studies is to use Canadian data and Canadian follow-up studies. Studies in other countries are relevant, particularly in identifying hypotheses meriting further study in Canada, but I do not believe studies in other countries may be presumed to "demonstrate" answers to Canadian data.

Increased prostate cancer rates in Bruce County

42. At paragraph 28 of her affidavit, Ms. Fraser responds to the incidence of increased prostate cancer in Bruce and Grey counties. I understand that the Bruce reactor is located

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in Bruce county and is proximate to Grey county. Ms. Fraser states that "existing occupational studies do not provide convincing evidence to suggest that nuclear workers as a group exhibit excess prostate cancer attributable to radiation exposure." It is unclear from this choice of words whether Ms. Fraser was aware of British studies showing elevated rates of prostate cancer in its nuclear workers. Attached as Exhibit "H" to my affidavit is a true copy of four papers on this topic:

- Beral et al., (1985), 291 British Medical Journal 440-447;
- Beral et al., (1988), 297 British Medical Journal 757-770;
- Fraser et al., (1992), 67 British Journal of Cancer 615-624; and
- Rooney et al., (1993), 307 British Medical Journal 1391-1397.

43. Having regard for these British studies, the Canadian data would appear to merit further study for its potential relationship to radiation exposure.

I make this affidavit in support of an application by the Inverhuron & District Ratepayers' Association for certain relief in respect of the Bruce Used Fuel Dry Storage Facility Environmental Assessment and for no other purpose.

DR. DAVID HOEL

Sworn before me this 9th day of December, 1999
at the City of Charleston, in the State of South Carolina,
in the United States of America

Notary/ Commissioner **for taking affidavits**

Jamie M. Williams
Commission Expires: 09/23/02