Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

CMD 18-H6.35

File / dossier: 6.01.07
Date: 2018-05-07
Edocs: 5528801

Oral Presentation

Submission from Jerry Cuttler

In the Matter of

Ontario Power Generation Inc., Pickering Nuclear Generating Station

Request for a ten-year renewal of its Nuclear Power Reactor Operating Licence for the Pickering Nuclear Generating Station

Commission Public Hearing – Part 2

June 2018

Exposé oral

Mémoire de Jerry Cuttler

À l’égard de

Ontario Power Generation Inc., centrale nucléaire de Pickering

Demande de renouvellement, pour une période de dix ans, de son permis d’exploitation d’un réacteur nucléaire de puissance à la centrale nucléaire de Pickering

Audience publique de la Commission – Partie 2

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Canada

Original

CNSC Commission Member Document (CMD)

CMD: PFP 2017 PNGS01CA Cuttler

Date Submitted: 07 May 2018

Reference CMDs: 18-H6.1 and 18-H6

Ontario Power Generation Inc.

Pickering Nuclear Generating Station

Two-Part Commission Public Hearing – Part 2

Scheduled for:
26–28 June 2018

Request for a Licensing Decision:

Regarding Renewal of Operating Licence for Pickering NGS

Report submitted by intervenor

Part A:
Review of Pickering NGS Licence Renewal Documents

Part B:
Health Effects of Radiation Exposures

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Executive Summary

Section 2.2 of the PFP contribution agreement *PFP 2017 PNGS01 CA Cuttler* requires:

1) participation as an intervenor in the proceedings of the Public Hearing on the OPG application to renew its licence to operate Pickering NGS,
2) review of the OPG licence application, the two Commission Member Documents (CMDs) and the April 4th Public Hearing in Ottawa (a webinar),
3) submission of a written report summarizing intervenor comments, and
4) a presentation at the June 26-28th Public Hearing in Courtice, Ontario.

The focus is to be on the potential for a plant failure that releases radioactive materials and the expected health effects on nearby residents as a result of their exposures to ionizing radiation.

The OPG license application and the CMDs exceeded the reviewer's expectations in terms of their detailed content. The material was familiar to the reviewer, who has more than 40 years of experience in the design, procurement, construction, licensing and operation of CANDU reactors. He is impressed and very confident in the capabilities of OPG to maintain and operate the Pickering reactors in compliance with all of the requirements and in the capabilities of the CNSC staff to review OPG's performance.

Based on the intervenor's experience with and studies on nuclear (ionizing) radiation since 1964 and on nuclear reactors and their failures, he is confident in the safety of operating Pickering NGS for the period specified in the licence application. A failure that would release radioactive materials is very unlikely. An event that did would not harm any of the residents. Absorbed doses would be below the known thresholds for harm and would likely stimulate their inherent protection systems *against* toxins, pathogens, cancer and injuries. Overall, health benefits are expected to occur.

The intervenor recommends CNSC approval of the OPG application. If economic conditions become favourable, OPG should consider applying for a licence to operate Pickering NGS beyond 2024.

This report presents some of the extensive evidence of the beneficial health effects of low-dose or low-level exposures. The intervenor urges the CNSC to examine more of the evidence, from over 120 years of human experience, and discard the ideologically-driven linear no-threshold (LNT) model that was recommended in 1956 to assess risk of radiation-induced mutations and cancer mortality. Regulatory acceptance of the LNT model at that time is the basis for the public fear of nuclear energy and exposures to low doses of X-rays that are used in medical diagnostic imaging. The scientific evidence should be communicated to all Canadians in plain language. Very important changes should be made to our nuclear safety policies, laws and regulations.

The intervenor urges the CNSC to organized an international conference that would establish a new consensus on science-based, dose-response models, including new limits for radiation protection. These limits would be based on measured radiobiological and human data for different types of ionizing radiation.

In 1987, the Engineering Centennial Board recognized the CANDU Nuclear Reactor System among the 10 outstanding Canadian achievements of the previous century. It set Canada on the path towards establishing a sound nuclear electric generating system and becoming a major player in the medical and industrial applications of nuclear knowledge. This vision is now in jeopardy because of extreme social fear of radiation.

The Canadian government should develop a method of communicating to Canadians the health effects of radiation and reverse the growing fear that blocks opportunities for new medical treatments and further development of nuclear energy.

1.0 Introduction

This document was produced to fulfill a requirement in Section 2.2 of PFP agreement *PFP 2017 PNGS01 CA Cuttler*. The intervenor reviewed: the OPG application to renew its licence to operate Pickering [1] and two Commission Member Documents (CMDs) [2,3] and he attended the April 4th Public Hearing Part 1 in Ottawa [4] by webinar.

Part A of this report contains the intervenor's comments on the OPG application, the CMDs and Part 1 of the Public Hearing. Part B of this report examines the potential for a failure that releases radioactive materials and assesses the expected health effects on nearby residents as a result of their exposures to ionizing radiation. It presents evidence from the Chernobyl and the Fukushima radiation exposures and discusses the health effects observed.

2.0 Part A – Review of Pickering NGS Licence Renewal Documents

2.1. Comments on OPG Application

The August 28th 2017 OPG letter to the CNSC Secretary requested a 10-year licence renewal to operate the Pickering NGS. It also sought approval to operate the Pickering 5-8 fuel channels beyond the current approved limit of 247,000 effective full power hours (EFPH) up to the 295,000 EFPH limit, which corresponds to the intended end of commercial operation of the six operating reactors on December 31 2024 [1].

The 197-page package appeared to be complete. It provided evidence to demonstrate that OPG is very qualified and capable of operating and maintaining Pickering NGS. Its nuclear management system meets the requirements of the excellent CSA 286-12 standard, and its employees are well trained and motivated to deliver high performance from these vintage reactors. OPG has in place all of the documents needed. It commits that it will continue to comply with all laws and regulations that pertain to the operation of this Class I nuclear facility. It has substantial resources to address all eventualities.

In the mid-1970s, I led the team that designed and procured the nuclear instrumentation for the reactor control system and the safety systems for the Pickering B reactors. My review of the OPG application indicates the condition of these reactors has been assessed repeatedly, upgraded and maintained to achieve fitness for service at the required level of safety and performance.

I recall when Pickering A was designed in the 1960s. I received a detailed tour of the whole plant in the summer of 1971, during the construction of the four reactors. They were built from 1966 until 1973, at a cost of about $500 million. As expected, technical problems were encountered during initial operation and were remedied. Operation over 47 years, with upgrades and refurbishments, has demonstrated it to be a very safe and reliable plant. The licence application indicates that OPG intends to continue inspecting and assessing the condition of these reactors, including their pressure tubes, to provide a high level of assurance that the occurrence of failures would be unlikely—that failures would not jeopardize safety. The consequences of the following plant events illustrate the resilience of this plant and its ability to accommodate fuel channel failures or a pipe break.

In August 1974, Pickering Unit 3 was shut down for a period of time due to cracks in 17 of the 390 pressure tubes. The cracks were a result of incorrect installation procedures during construction. The improper positioning of the rolling tool, to join the pressure tube to the end fitting, resulted in very high residual stresses. The defective tubes were replaced using improved tools and procedures [5].

On August 1, 1983 while operating at full power, Pickering Unit 2 experienced a sudden pressure tube failure in fuel channel G16—a 2-metre-long crack, 20 mm wide, from the rolled joint in the outlet end-fitting inwards. It terminated one-third of the way along the pressure tube with a 120^{o} circumferential crack. This failure resulted in a 17 kg/s leak from the heat transport system. A controlled shutdown and cool-down were performed by the operator using normal system controls. Automatic safety system action was not required. The G16 pressure tube failure demonstrated that the calandria tube can withstand full heat transport system pressure. Ontario Hydro replaced all the Zircaloy-2 pressure tubes with zirconium-niobium tubes for long-life performance. It also installed modified spacer rings that maintain the required gap between the pressure tube and the calandria tube. Design and operating analyses have confirmed that pressure tube failures, such as occurred on 1983 August 1, present no public safety or worker safety concerns. The actual safety consequences were zero [6].

On December 10, 1994 the fracture of a rubber diaphragm in a liquid relief valve (LRV) initiated a loss of coolant incident in Pickering Unit 2 while it was operating at full power. The LRV failed open, filling the bleed condenser. The reactor shut itself down. When pressure recovered, two spring-loaded relief valves opened and one of them chattered. The pulsations cracked the 3-inch inlet pipe to the chattering relief valve. This loss of coolant triggered the emergency core cooling system. No radioactive materials were released as a result of this incident. Improvements were made to the design of the heat transport system and the maintenance program was strengthened before the Pickering A reactors restarted [7].

The fact that the 1983 sudden G16 pressure tube fracture, a 2-metre-long crack, had no safety consequences raises the question: Why is there a requirement to shut down the Pickering NGS when the 295,000 EFPH pressure tube milestone is reached? Because OPG 1) maintains these safe reactors in very good condition, 2) monitors the condition of its pressure tubes, and 3) can replace one or more leaking or ruptured tubes with no public or worker safety concerns, it may be concluded that it is acceptable from a safety point of view to license operation of the Pickering reactors for the full 10-year period. Economic considerations should be the deciding factor for any decision to terminate reactor operation sooner. If economically justified, OPG should reconsider refurbishing Units 2 and 3. Shut down of the station would be a very costly decision.

2.2. Comments on OPG CMD

OPG's written submission of March 5th 2018 to the CNSC requested a 10-year renewal of its Nuclear Power Reactor Operating Licence for Pickering NGS, from Sep 1, 2018 until Aug 31, 2028 [2]. This 376-page document was designated Commission Member Document CMD 18-H6.1 for the Public Hearing Part 1, held on April 4th 2018 in Ottawa.

This submission is very comprehensive. It presents the evidence that Pickering NGS and OPG meet all the legal requirements of the Nuclear Safety and Control Act and the associated regulations. It shows that OPG is qualified to perform the licensed activities. The executive summary says it all succinctly.

Reflecting back to the start up of the first reactor of Pickering A in 1971, I note that the design of this 515 MWe reactor was based on the design of the 22 MWe Nuclear Power Demonstration prototype reactor that started operation in 1962 and the design of the 200 MWe Douglas Point full-scale reactor that started operation in 1967. Those reactors were safe. They were designed, constructed, operated and maintained safely by very qualified people, and the costs of those plants were affordable. The evidence that was required to license those plants for operation in the 1960s and 1970s was far less than what is required today. It is important to understand what has changed and why.

It is clear that the radiation scare that began to be disseminated in 1956 was the most important reason. This scare linked any exposure to nuclear (ionizing) radiation to an elevated risk of *health effects* (cancer mortality).

The great advances in science, technology and mathematical analysis since the 1960s were important, to improve reactor design for better performance and reliability than the early nuclear plants. Enormous efforts have been made to reduce the likelihood of any release of radioactive materials and to minimize radiation exposures to employees and to nearby residents due to operation of the plant and to management of the used fuel and the radioactive wastes. The radiation levels from releases are many orders of magnitude below the radiation levels due to natural radioactivity in the environment. Because of ongoing public fear of radiation, the nuclear regulatory authorities continue to issue more and more restrictive laws and regulations.

2.3. Comments on CNSC Staff CMD

The March 5th 2018 submission by CNSC Staff to the CNSC [3] presented information about the following matters of regulatory interest with respect to OPG's application.

- Renewal of the Power Reactor Operating Licence (PROL) for Pickering NGS
- The periodic safety review that was conducted in support of licence renewal
- The planned end of commercial operation of Pickering NGS
- Compliance with the safety and control areas for safe operation.

The submission requested the following actions by the CNSC.

- Issue a PROL authorizing OPG to carry the activities in Part IV of the PROL
- Accept 4 new station-specific conditions listed in the PROL
- Authorize OPG to operate Pickering 5-8 fuel channels up to 295,000 EFPH
- Authorize the delegation of authority as per section 6.11 of this submission.

This 472-page document designated Commission Member Document CMD 18-H6.1 [3] was issued for the Public Hearing Part 1 that was held on April 4th 2018 in Ottawa. It includes the following items as attachments.

- The proposed licence changes and the proposed PROL 48.00/2028
- The draft Licence Conditions Handbook
- The current PROL 48.04/2018
- The 2017 Environmental Assessment.

The executive summary is a clear description of the matters under consideration and their resolutions. Parts one and two of this BMD are very detailed and comprehensive. They seem a bit much for a nuclear plant that is so very safe.

2.4. Comments on CNSC's April 4th Public Hearing (webinar)

Revision 1 of the Notice of Public Hearing was issued on March 16th [4]. Part 1 of the hearing was held in Ottawa on April 4th. The presentations delivered by the OPG and CNSC speakers were very effective and convincing. OPG appears to be managing Pickering NGS very competently, and the CNSC staff is carefully tracking OPGs compliance with the regulatory requirements. The members of the CNSC asked good questions, and no significant issues were identified in Part 1 of this hearing.

2.5. Conclusions

The OPG licence application and the CMDs are of very high quality and very detailed. The presentations at the April 4th Public Hearing Part 1 were effective and convincing.

Pickering NGS is in good condition, is well managed and is carefully regulated. It is a very safe facility. This intervenor supports the CNSC Staff recommendation to approve the OPG application to renew its operating licence for 10 years.

The intervenor identified Pickering A failures in 1974, 1983 and 1994 that provide strong evidence that the plant is robust. The 1983 pressure tube fracture demonstrated that the calandria tube can withstand full heat transport system pressure. Pressure tube failures present no public safety or worker safety concerns.

Maintaining the Pickering reactors in good working order and monitoring the condition of their pressure tubes would allow Pickering NGS to remain in operation beyond 2024.

2.6. Recommendations

The intervenor recommends that:

- the CNSC approve the OPG application for a 10-year licence renewal
- OPG consider applying for a licence to operate Pickering NGS beyond 2024, if economic conditions become favourable.

3.0 Part B – Health Effects of Radiation Exposures

3.1. Early history of health effects of ionizing radiation

Immediately after the discoveries of X-rays in 1895 and radioactivity in 1896, X-ray devices and radioactive materials were applied in physics, chemistry, and medicine. Medical practitioners have employed ionizing radiation for imaging and treatment of patients. Low doses of ionizing radiation were used to treat many illnesses extensively until about the late 1950s when a radiation scare was created in the United States for the political purpose of stopping the testing, development and production of atomic bombs. The U.S. National Academy of Sciences recommended that radiation-induced mutation risk be assessed using a linear no-threshold dose-response model.

Practitioners learned very early that low doses produced important beneficial effects, but did not understand how the patient's protective systems were stimulated. They developed and used many therapies, based on observations of successful outcomes. They treated and cured cancers, inflammations, and many kinds of infections, wounds, asthma and other illnesses. Many thousands of articles appeared in radiology journals and in other medical publications [8,9]. However, after the radiation scare set in, most of these treatments ceased and were replaced by antibiotics and other pharmaceuticals that were being developed.

In the very early days, the users were unaware that a large X-ray dose could cause serious harmful effects. They also had no instruments to measure the radiation. The calibration of X-ray tubes was based on the amount of skin reddening (erythema) when the operator placed a hand directly into the X-ray beam. The dose needed to produce erythema is high—if the skin is exposed to 200 kilovolt X-rays at a high dose rate of 300 mGy per minute, then erythema appears after about 20 minutes or 6 Gy of exposure. A third-degree burn occurs after about 110 minutes or about 20 Gy of exposure [10]. [For X-rays, the equivalent dose in sieverts (Sv) equals absorbed dose in gray (Gy). 1 gray equals 1 joule/kg of tissue.] Ignorance of the hazards resulted in many injuries. A severe case of radiation burn was published in 1896. The first dose limit (in 1902) ~ 100 mGy per day, was based on the lowest dose detectable by a photographic plate. By 1903, animal studies had shown that X-rays could produce cancer. Most vulnerable were skin tissue and blood-forming bone marrow [10].

In 1924, Mutscheller was the first to recommend (to American Roentgen Ray Society) a "tolerance" dose rate for radiation workers that could be tolerated indefinitely. He observed workers in shielded work areas and estimated that they had received about 1/10 of an erythema dose or 600 mSv per month. He also observed that none of them had shown any signs of injury. While concluding that this was acceptable, he applied a safety factor of 10, thus setting the limit at 1/100 of an erythema dose per month (2 mSv per day) 700 mSv per year. A tolerance dose was "assumed to be a radiation dose to which the body can be subjected without production of harmful effects." His paper, Physical Standards of Protection against Roentgen Ray Dangers, was published in 1925. Sievert's limit was about the same, using a similar approach [10].

Subsequent concerns in committee meetings about potential genetic effects of ionizing radiation and risk of cancer resulted in a stepwise reduction in the recommended annual occupational dose limit from 700 to 10 mSv in 1993. A recommended annual public limit of 5 mSv was introduced in 1960 that was reduced in 1990 to 1 mSv. Figure 1 in Inkret et al (1995) shows the changes [10]. Note that 1 rem = 10 mSv.

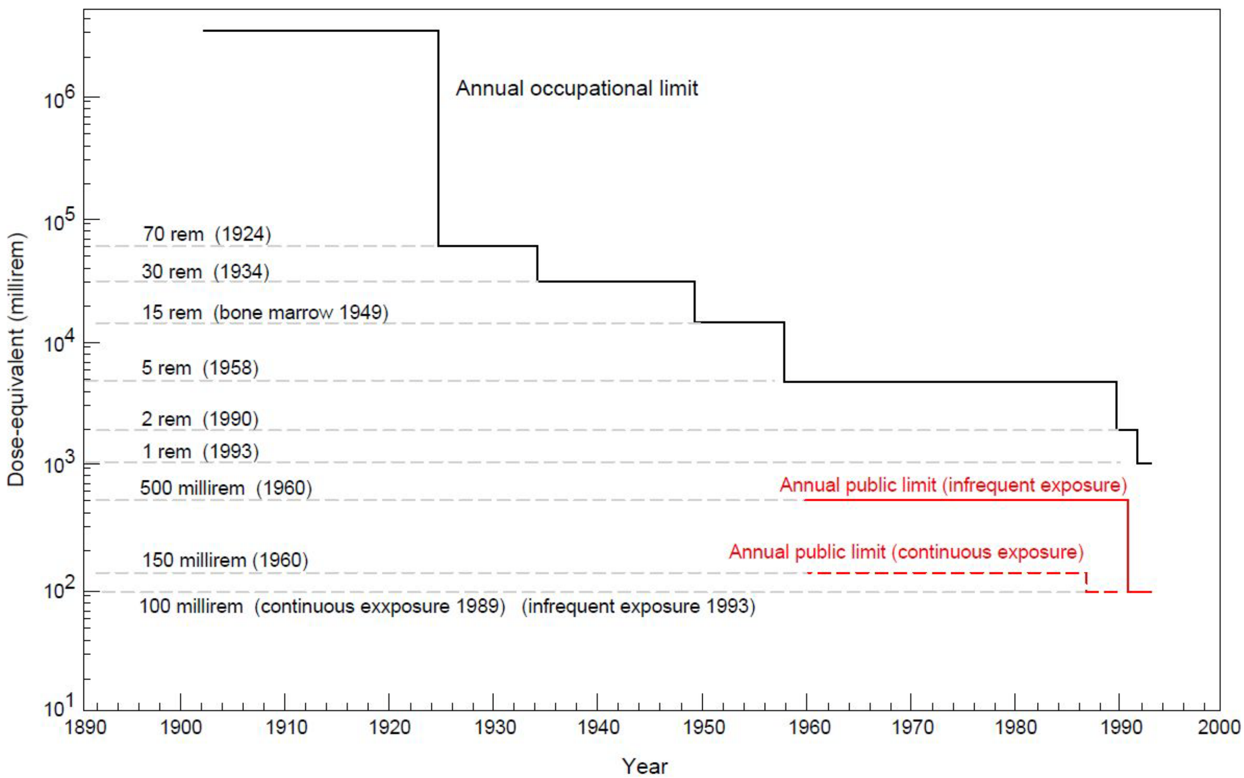


Figure 1. Changing radiation dose limits over the 20th century [10]. 1 rem = 10 mSv.

Early geneticists began to study the effects of X-rays on organisms. Muller, a eugenicist who was impatient with the slow pace of natural evolution, lamented about "the extreme infrequency of mutation occurrence under ordinary conditions, and by the general unsuccessfullness of attempts to modify decidedly, and in a sure and detectable way, this sluggish natural mutation rate. … for more directly utilitarian purposes … [11]" He irradiated fruit flies, with very large doses of X-rays at a very high dose rate, and he measured high germ cell mutation rates. The mutation rate was related to the square root of the X-ray energy absorbed. Further studies by geneticists and analysts led to this data being fitted to a linear no-threshold model, which raised concerns about risks of low-dose “health effects”, namely genetic mutations and cancers. A study that showed, for a low dose rate, a dose threshold at about 500 mSv [12] was sidelined.

Based on more than 50 years of human evidence, renowned MIT scientist and health physicist Evans calculated the radiation-induced mutation rate in humans. He concluded in 1949 that “From the appropriate mathematical theory, and the experimental data now available, it seems safe enough to conclude that no detectable increase in hereditary abnormalities is likely to result, even after many generations, if a small fraction of the population receives daily radiation doses up to 0.1 roentgens (r) per day.” Since 0.1 r is about 1 mGy, this “tolerance dose” rate corresponds to a limit of about 300 mGy per (working) year. The evidence contradicts the notion that such doses have a cumulative effect. R.D. Evans acknowledged that his manuscript [13] was reviewed by University of Rochester geneticist D. R. Charles and Hammersmith Hospital, London physicist and radiobiologist L. H. Gray.

The use of atomic bombs in the Second World War followed by intensive testing, development and production of nuclear weapons led to strong antinuclear political activity by many scientists. Without any evidence, they linked exposure to radioactive “fallout” or any ionizing radiation, no matter how small, to a risk of “health effects”. This radiation scare continues to this day.

The U.S. National Academy of Sciences (NAS) Biological Effects of Atomic Radiation (BEAR) I Committee Genetics Panel started the pervasive fear of radiogenic mutations by issuing a recommendation in 1956 to use a linear no-threshold (LNT) dose-response model to assess the risk of radiation-induced mutations instead of the standard threshold model [14]. The entire world was misled by deliberate falsifications.

Many, many thousands of studies have been carried out over the past 120 years and much has been learned. In 1980, Lauriston Taylor, founder and past president of the National Council on Radiation Protection and Measurements stated, *Collectively, there exists a vast array of facts and general knowledge about ionizing radiation effects on animal and man. It cannot be disputed that the depth and extent of this knowledge is unmatched by that for most of the myriads of other toxic agents known to man* [15]. *No one has been identifiably injured by radiation while working within the first numerical standards first set by the NCRP and then the ICRP in 1934* [15]. *The LNT is a deeply immoral use of our scientific heritage* [15]. However, intense controversy continues to this day about the risk of low-dose radiation-induced “health effects”, mainly for economic and political reasons.

Two articles by Calabrese give very detailed descriptions of why and how linearity at low doses became the basis for carcinogen risk assessment in 1956 and the origin of the LNT dose-response concept [16,17]. In another article, he describes how the NAS misled the world community on cancer risk assessment by not providing a scientific assessment [18]. A later article points out that all of the regulatory agencies did not review any scientific record. They improperly adopted LNT for cancer risk assessment

[19]. More recently Calabrese provided newly uncovered evidence of scientific misconduct by the NAS Genetic Panel for deliberately misrepresenting or falsifying the research record in order to advance an ideological agenda. This led to all governments adopting the LNT model for cancer risk assessment [20]. A further article summarized the ideological history of cancer risk assessment [21].

3.2. Modern understanding of the effects of radiation

From the 1970s until the present, many important discoveries were made on how low doses of ionizing radiation stimulate the immune system and other protection systems, to cure cancer or lower its risk [22]. During the 1980s, biologists became aware of the very high rate of spontaneous DNA damage being caused by the high concentration reactive oxygen species (ROS) in all aerobic organisms [23]. They breathe air, and the blood flow brings oxygen and glucose to all of the cells to react and produce energy. But the oxygen species react with and damage all biomolecules including DNA. Organisms produce large amounts of antioxidants to prevent most of the oxidative damage, but the average rate of human DNA alterations (single-strand breaks) per average cell per day is about 1 million, compared with 10^{-2} due to 1 mGy of background γ-radiation, a ratio of 100 million to 1. The number of double-strand breaks per cell per day is about 10^{-1}, compared with 10^{-4} due to background radiation, a ratio of 1000:1. It became apparent that the rate of cell damage caused by low-level radiation is negligible compared with rate of damage caused by internally-produced ROS and toxins and pathogens [24]. To survive, organisms have many very powerful protection systems that repair damaged DNA and other molecules, scavenge and destroy unrepaired cells. Mutated cells that become malignant are destroyed by the immune system [24].

A small dose of a stressor usually stimulates the activities of the protection systems, which overcompensate for the perturbation. A low dose of radiation produces a burst of *hits* and ROS that damage biomolecules. This sends signals to up-regulate many of the biological protection systems (>150 genes) against aerobic ROS, toxins, pathogens and all damage events. Such stimulation produces a range of beneficial effects, including a lower risk of cancer [25]. However, a dose above known threshold dose levels inhibits protection systems resulting in harmful effects, including radiation illness [26].

Large amounts of evidence—thousands of references—appear in two books by Luckey demonstrating that low doses or low levels of radiation stimulate many biopositive responses while high doses or high levels inhibit them [27,28]. He termed this effect "radiation hormesis" from the Greek word to excite, as in hormone. An article by Cuttler and Pollycove reviews the impact of this phenomenon on nuclear energy [29]. A chapter by Feinendegen et al. covers radiation-induced cancer risk modeling, pointing out that it must recognize low-dose up-regulation of protection [25]. Much evidence of radiation hormesis is presented and discussed in two recent books by Sanders [30,31].

Figure 2 is the hormetic and the LNT dose-response models for ionizing radiation-induced effects. The NOAEL level is the threshold dose (or dose rate) at which net harmful effects begin to be observed. The threshold model is a special case of the hormetic model in which no beneficial effects are apparent. There is essentially no evidence in support of LNT model use in the low dose range. The LNT model is tool that safety analysts employ to predict the risk of radiation-induced cancer death at a low dose where there actually may be no risk at all, or even a health benefit of lower cancer incidence. Figure 3 shows evidence of a threshold dose at about 0.5 Sv for the onset of leukemia among 96,800 Hiroshima atomic bomb survivors during the period 1950-57, after the acute exposures they received on August 6, 1945. Below this threshold dose, the incidence of cancer was at or below the actual incidence of leukemia in unexposed people. Since bone marrow is most sensitive to radiation, it is reasonable to expect that the threshold doses for initiation of other radiation-induced cancer types are higher [26].

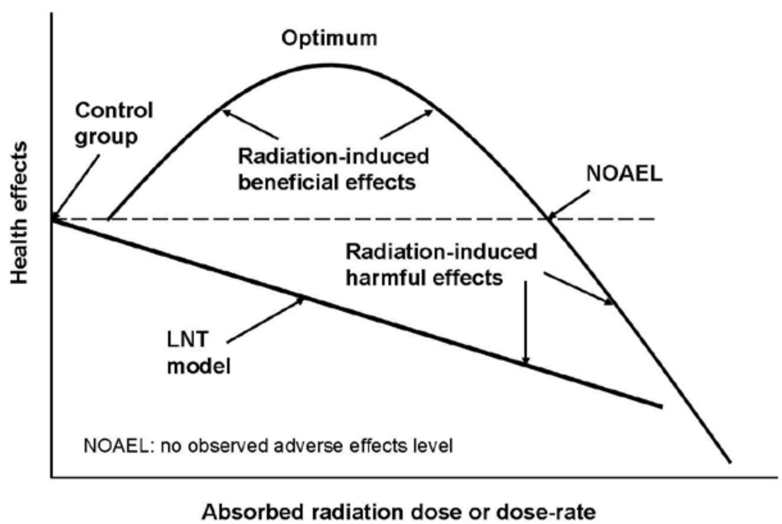


Figure 2. Hormetic and LNT dose-response models for radiation-induced health effects

Most concerns are raised about long-term or chronic exposures to a continuous level of radiation that is above the world average level of natural background radiation, which is about 2.4 mSv per year. It is impossible to measure directly the risk of radiation-induced cancer in humans because the natural incidence of cancer is high, about 1 in 3, which results in a high statistical uncertainty. There are many causes of cancer and they are not well understood. Some cases are causes by a genetic problem. In most, it develops because the immune system, which kills most cancer cells, becomes weak in old age. Cancer is dreaded by everyone—an ideal choice for a radiation scare.

A proper study would require a *control* population that is exposed to normal background radiation and many *experimental* groups, each exposed to different fixed radiation levels for their entire lives, up to 100 years. All confounding factors that affect cancer would be controlled to be the same for each person. This study cannot be performed on humans, but many studies were performed on carefully bred dogs. Dogs model humans better than mice. Since cancer is not well understood, overall mortality (or longevity) is a better indicator of the health effects of radiation than cancer mortality. A recent analysis of two studies on dogs revealed a threshold dose rate for lifelong gamma-ray exposure and a threshold body burden for inhaled plutonium aerosols [32], shown in figures 4 and 5.

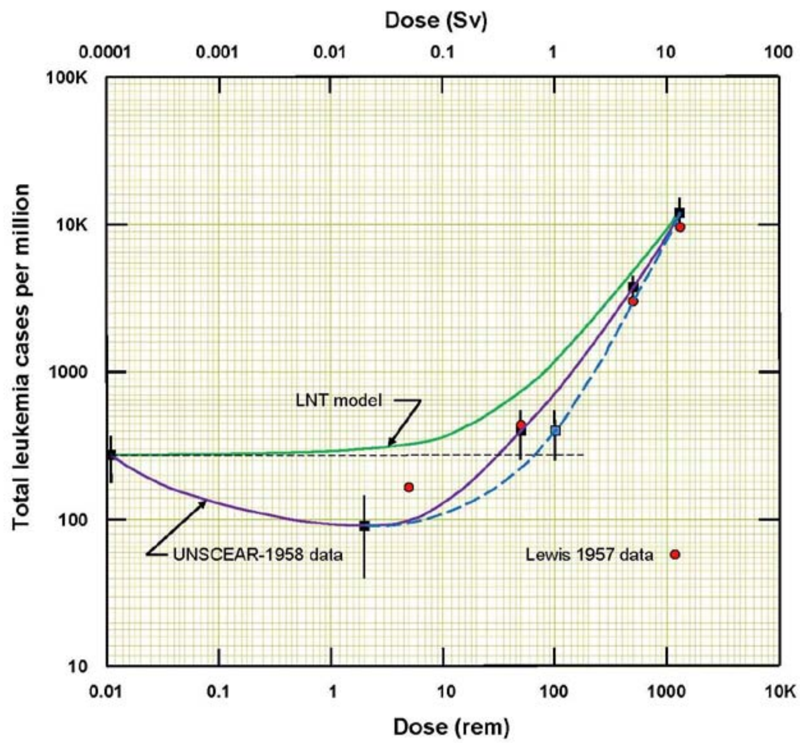


Figure 3. Leukemia 0.5 Sv threshold for 96,800 Hiroshima atomic bomb survivors [26].

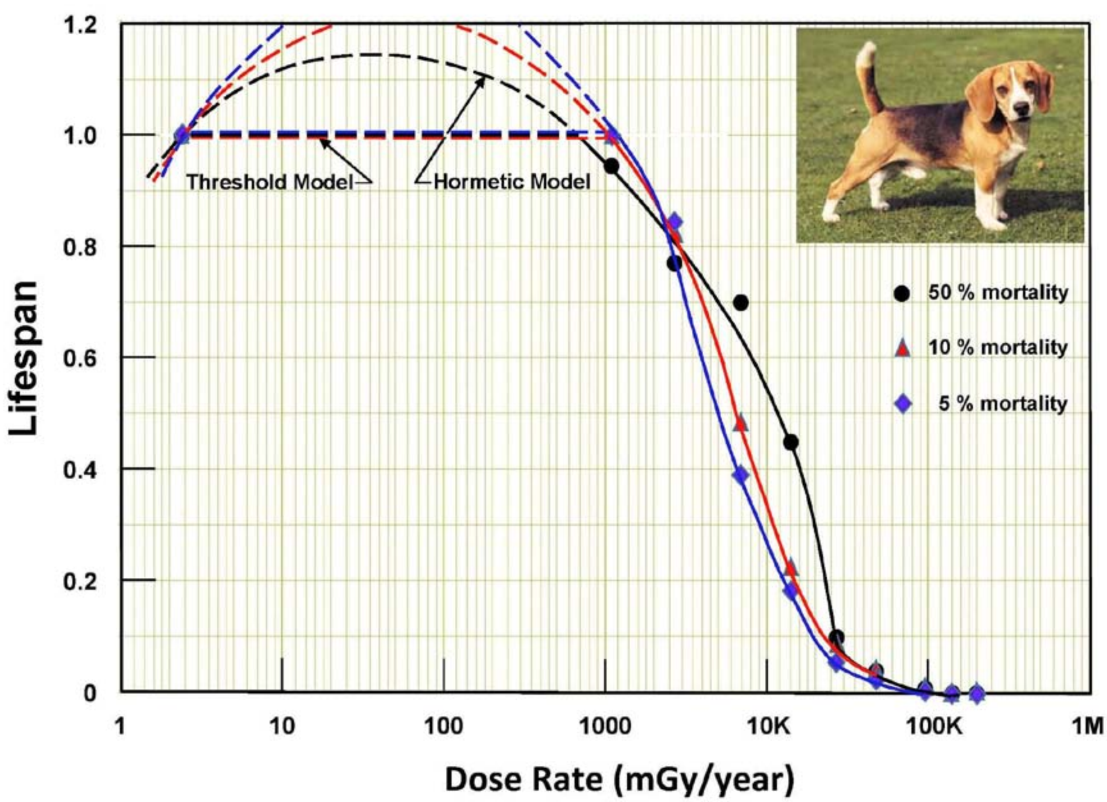


Figure 4. Gamma radiation threshold at 700 mGy per year for beagle dogs [32]

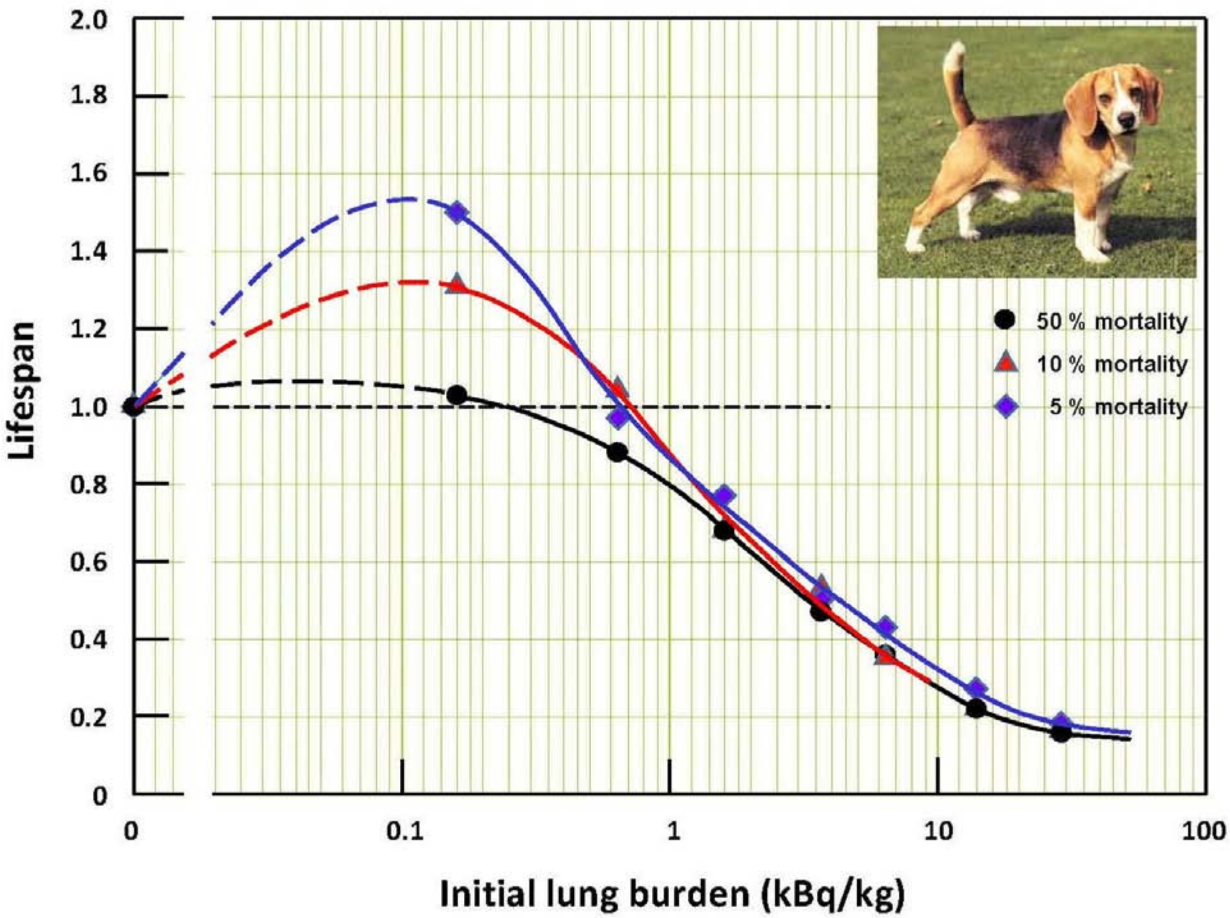


Figure 5. Inhaled plutonium threshold lung dose rate for beagle dogs [32]

Figures 4 and 5 present strong evidence that contradicts the ideological-driven LNT model, which should not be used to assess risk for radiation-induced health effects. The U.S. Department of Energy and its predecessor agencies have been studying radiation-induced health effects since the 1950s. Figure 6 is a 2010 picture of the known health effects over many orders on magnitude of dose and dose rate [33]. DOE studies on beneficial health effects have been carried out in the 0 to 100 mSv range; however, many early treatments to cure illnesses by stimulating the patient's adaptive protective systems employed doses in the 100 to 1000 mSv range.

It is very important to note that all government radiation protection laws, regulations and guidelines are still based on the 1956 NAS recommendation to use the LNT model to assess radiation-induced risk. The policy has been to keep exposures as low as reasonably achievable (ALARA). The regulatory limits are thousands of times below the levels at which stimulatory (beneficial) health effects have been observed for the past 120 years. This policy has produced enormous social fear and resistance against every application of ionizing radiation, such as medical diagnostic imaging, treatments with low doses of radiation, generation of nuclear electricity and management of radioactive materials (used nuclear fuel and waste).

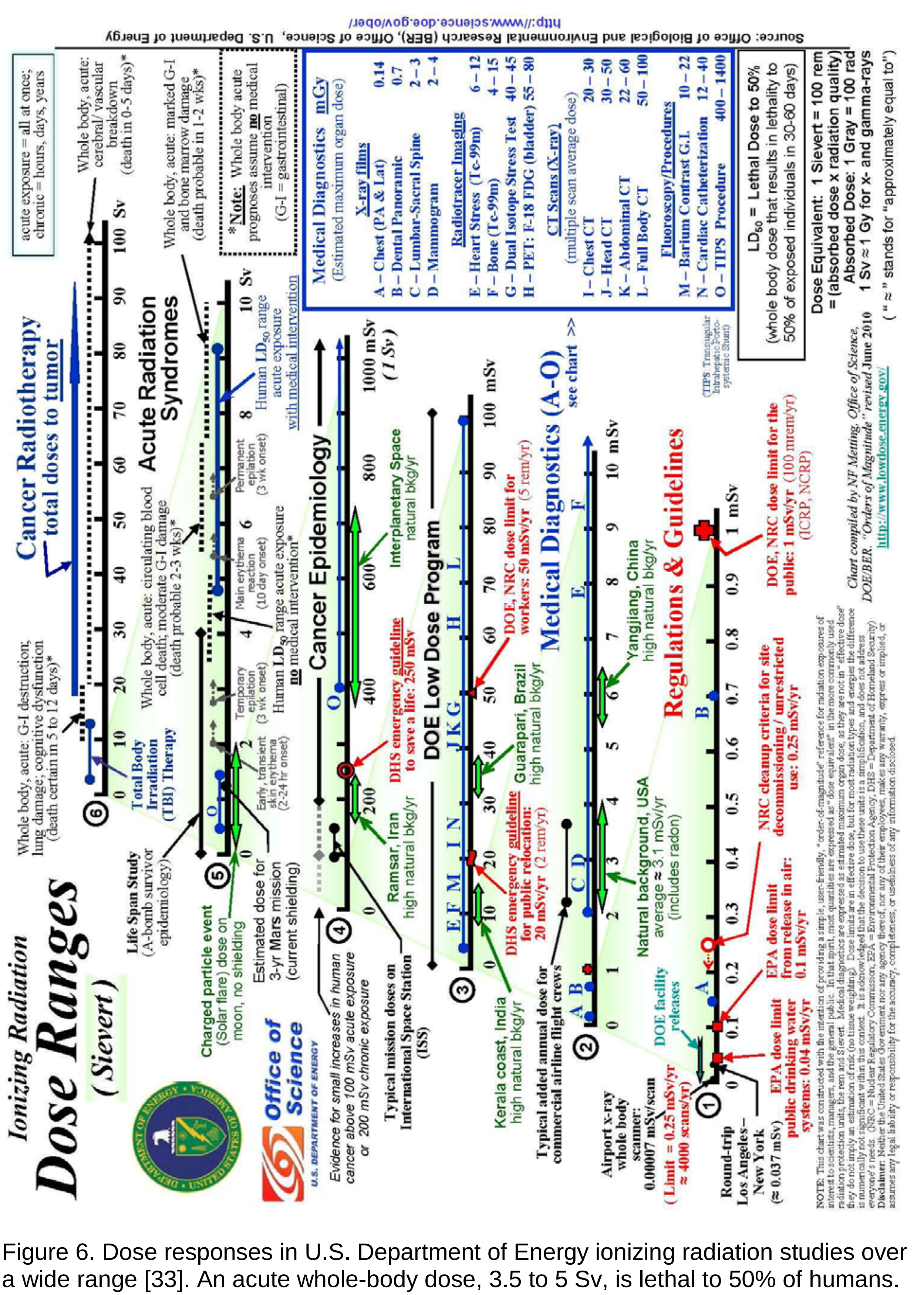


Figure 6. Dose responses in U.S. Department of Energy ionizing radiation studies over a wide range [33]. An acute whole-body dose, 3.5 to 5 Sv, is lethal to 50% of humans.

3.3. Regulatory omissions

All regulators have apparently omitted considering the following important fundamental scientific discoveries and facts that should be affecting policy, laws and regulations.

- DNA molecules are very unstable—single- and double-strand breaks occur spontaneously at very high rates due to natural, internal causes, mostly the oxidative stress of the aerobic metabolism.
- Organisms have very powerful protection systems that act both immediately and with adaptive delay to prevent damage to biomolecules (DNA), to repair actual damage and to remove damaged molecules, cells and tissues that were not adequately repaired. These protection systems actively neutralize and remove the internal and external toxins and pathogens, repair injuries and restore health.
- The amount of DNA damage caused directly by a low dose of radiation is negligible when compared to the endogenous damage rate due to normal oxidative stress.
- However, many of the very powerful protection systems (>150 genes in humans), including the immune system, are affected (modulated) by the signaling of a small dose of ionizing radiation. Each event produces direct hits and a small burst of ROS (ionized water molecules). A low acute dose or low chronic dose rate causes/signals stimulation, and beneficial health effects are observed. On the other hand, a high dose or high dose rate signals inhibition and damages protection systems.
- Every individual is affected by radiation in a similar manner. The threshold dose, the amount of stimulation and the NOAEL dose depend on the individual's genetic make-up and health condition.
- Much evidence has been and is now being published that seems to be disregarded.

On April 30th 2018, the U.S. Environmental Protection Agency (EPA) started to strengthen the transparency of EPA regulatory science. It issued for comment [34] by May 31 a proposed regulation that "provides that when EPA develops regulations, including regulations for which the public is likely to bear the cost of compliance, with regard to those scientific studies that are pivotal to the action being taken, EPA should ensure that the data underlying those are publically available in a manner sufficient for independent validation." This regulation [35] p. 18770 includes the following paragraph:

"In addition, this proposed regulation is designed to increase transparency of the assumptions underlying dose response models. As a case in point, there is growing empirical evidence of non-linearity in the concentration-response function for specific pollutants and health effects. The use of default models, without consideration of alternatives or model uncertainty, can obscure the scientific justification for EPA actions. To be even more transparent about these complex relationships, EPA should give appropriate consideration to high quality studies that explore: a broad class of parametric concentration-response models with a robust set of potential confounding variables; nonparametric models that incorporate fewer assumptions; various threshold models across the exposure range; and spatial heterogeneity. EPA should also incorporate the concept of model uncertainty when needed as a default to optimize low dose risk estimation based on major competing models, including linear, threshold, and U-shaped, J-shaped, and bell-shaped models."

3.4. Assessment of the health effects of the Chernobyl radiation exposures

The Chernobyl reactor core was destroyed within seconds in a reactivity excursion to more than 100 times full power. The highly radioactive materials in the core were widely dispersed. The releases continued for about 10 days [36]. It was the worst nuclear accident imaginable. The pattern of contamination was very uneven. About 116,000 people were evacuated, mostly from the 30-km radius area around the plant.

The radiation dose to the whole body depended on their positions around the site and the delays in evacuating them. The range of the estimated doses was wide, but the average was 17 mSv. Such doses were well below the threshold for radiation-induced harmful effects, shown in Figure 3 or 4. However, there was much traumatic stress and many premature deaths due to the fear of delayed *health effects* due to radiation [36].

The average dose to the thyroid gland of the evacuees from Pripyat was 1.4 Gy for the 2,400 who were born from 1983 to 1986. The average was 0.3 Gy for the 8,100 born from 1971 to 1982 and 0.07 Gy for 38,900 born in 1970 or earlier [36]. This may be compared against the therapeutic dose of iodine-131 administered to a hyperthyroid patient: Mean (SD) = 308 (232) MBq, which would deliver 1 Gy per MBq to the thyroid [29]. Screening for thyroid cancer has been shown to result in a large overdiagnosis of naturally-occurring (occult) thyroid cancer (incidence) with no rise in mortality. It can result in unnecessary thyroidectomies and is potentially harmful [37,38].

Many emergency workers responded to the disaster, and 134 of them were treated for acute radiation syndrome. Of these, 28 died within weeks of having received doses in the range from 2 to 16 Gy [36]. Of the 106 highly irradiated Chernobyl workers who fully recovered, 22 died over the next 19 years, a mortality rate of 1.09 percent per year. This rate is lower than the average local mortality rate, about 1.4 percent per year in 2000 [39]. In 2001, the group’s mortality structure was 26 percent cancer deaths among all causes of death, which is not much different from the normal ratio in Central Europe [39]. So there appears to have been no significant delayed effects following their very high exposures. This important human evidence should not be overlooked.

3.5. Assessment of the health effects of the Fukushima radiation exposures

In March 2011, the fuel in three Fukushima Dai-chi reactors melted after the 14 m high tsunami caused the loss of decay heat removal. Radioactive material escaped from the reactors, and Figure 7 shows the radiation levels measured on April 29th 2011 [40]. The radiation level in the red zone ranged from 19 to 91 microSv per hour, which is 0.5 to 2.2 mSv *per day*. This is about the tolerance dose limit of 2 mSv *per day* for radiologists, which was acceptable to the authorities in 1924, as discussed in Section 3.1.

The plant worker radiation doses (upper range) during the first year of the accident are shown in Table 1 [41]. Interestingly, their doses did not exceed the 700 mSv per year “tolerance” limit [10] for the early radiologists, described in Section 3.1.

Table 1. Fukushima worker radiation doses from March 11 until December 31, 2011 [41]

Number of Workers	Dose (mSv)
135	100 - 150
23	150 - 200
3	200 - 250
6	250 - 678
167	

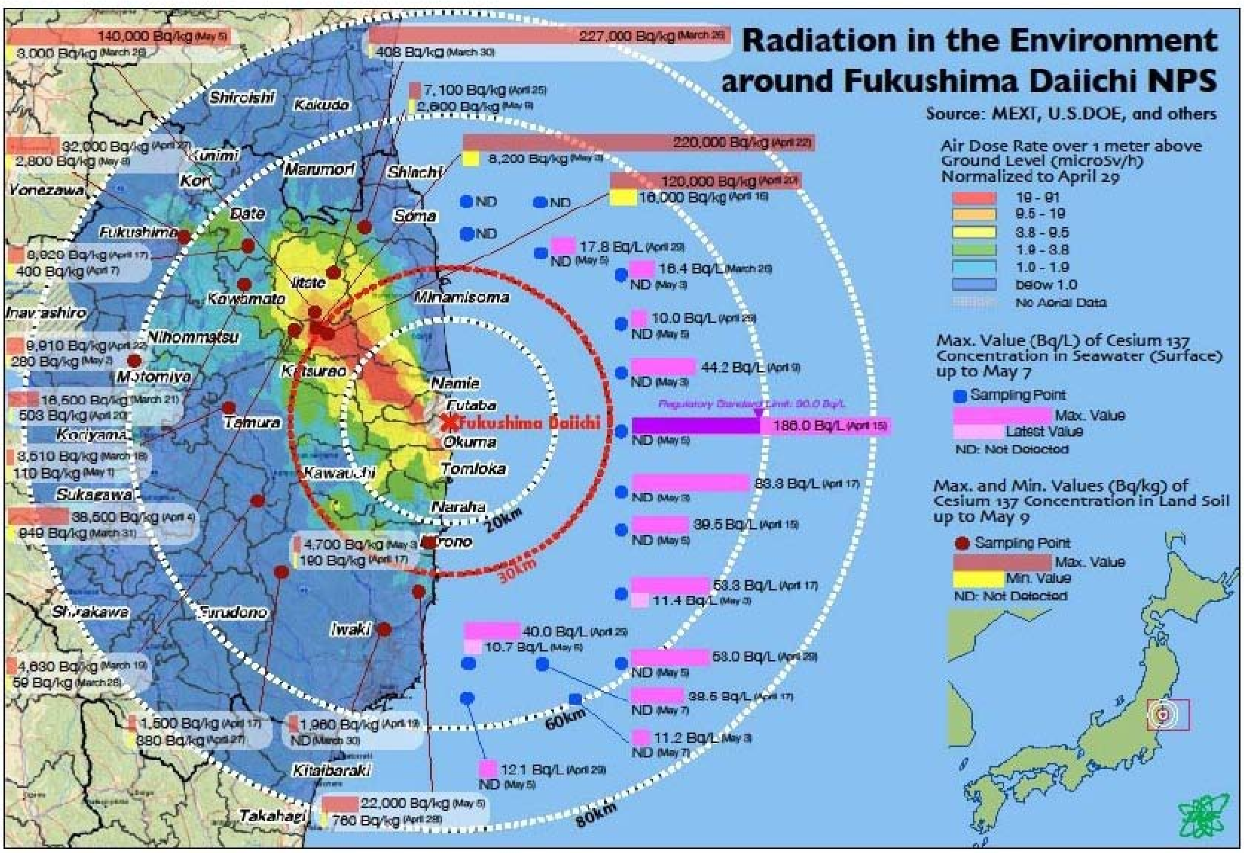
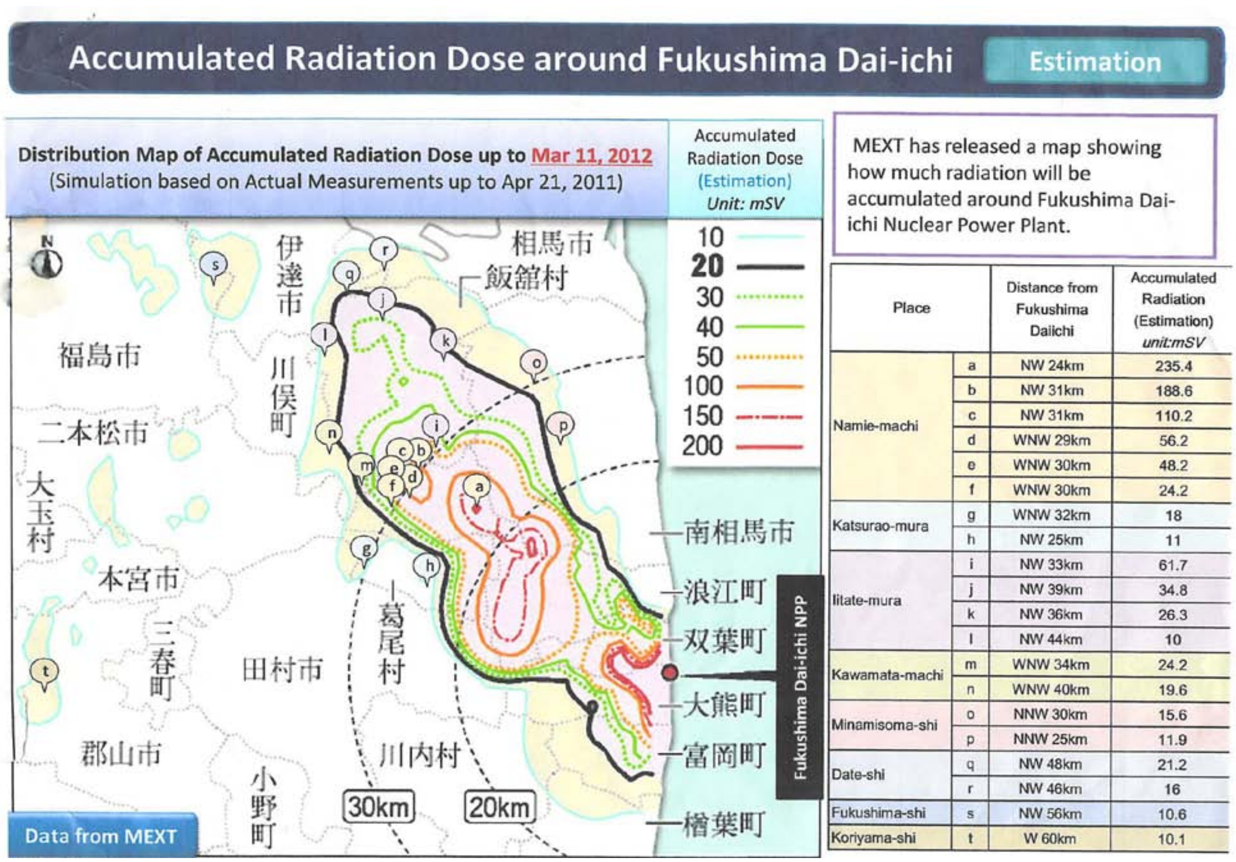


Figure 7. Radiation in the environment around Fukushima Daiichi in April 2011 [40].

For the protection of the public during emergencies, the ICRP continues to recommend setting "reference levels for the highest planned residual dose in the band of 20 to 100 mSv." "When the radiation source is under control, contaminated areas may remain. Authorities will often implement all necessary protective measures to allow people to continue to live there." The ICRP continues to recommend reference levels in the band of 1 to 20 mSv *per year*, with the long term goal of 1 mSv *per year* [42].

The Japanese authorities ordered evacuation as a precautionary measure against the risk of *health effects*. Some 300,000 people eventually evacuated their homes in the Fukushima prefecture. According to the 2012 Reconstruction Agency report, 1632 people who had survived the earthquake and tsunami were confirmed dead as of March 31, 2012. The cause of their deaths is listed as “disaster-related”, which means not as a result of the tragedy itself, but of disaster-induced fatigue, psychological trauma or the aggravation of existing chronic diseases. More than 95% (1206) of the victims were aged 60 years or older. The most common cause of death was physical or mental fatigue from life at evacuation shelters [43].

The highest accumulated radiation dose in the first year was at place “a” in Figure 8. The total dose from April 21, 2011 until March 11, 2012 was 235.4 mSv [44]. So the radiation levels around the Fukushima Nuclear Power Station during this period did not exceed the natural background levels, up to 260 mSv per year, in Ramsar, Iran, a city of about 35,000 people. It is reasonable to conclude that the precautionary evacuation did not avoid a health risk from radiation; however, it really caused extreme hardship for the residents.



Place		Distance from Fukushima Daiichi	Accumulated Radiation (Estimation) unit:mSV
Namie-machi	a	NW 24km	235.4
	b	NW 31km	188.6
	c	NW 31km	110.2
	d	WNW 29km	56.2
	e	WNW 30km	48.2
	f	WNW 30km	24.2
Katsurao-mura	g	WNW 32km	18
	h	NW 25km	11
Iitate-mura	i	NW 33km	61.7
	j	NW 39km	34.8
	k	NW 36km	26.3
	l	NW 44km	10
Kawamata-machi	m	WNW 34km	24.2
	n	WNW 40km	19.6
Minamisoma-shi	o	NNW 30km	15.6
	p	NNW 25km	11.9
Date-shi	q	NW 48km	21.2
	r	NW 46km	16
Fukushima-shi	s	NW 56km	10.6
Koriyama-shi	t	W 60km	10.1

Figure 8. Accumulated radiation dose from April 21, 2011 until March 11, 2012 [44]

Seven years after the earthquake, many residents still hesitate to return to their home-towns. One important reason is anxiety regarding the health effects of radiation exposure. There is a gap between residents' risk perception and their actual risk of health effects. A recent survey revealed a marked polarization of the risk perception after the accident that could have a major impact on social well-being. They do not understand the difference between radiation protection policy (ALARA) and the actual health effects [45]. There has been a failure to communicate, and this should change.

The important lessons that should have been learned from the accidents at Chernobyl and Fukushima are [46]:

- Severe accidents release radioactive materials that result mainly in low radiation levels in surrounding residential areas.
- Long-term evacuation of residents from such areas would not be appropriate because the low radiation levels would not be harmful. The dose-rate level for evacuation should be based on the known threshold for harm.
- In areas where the radiation level is low, precautionary measures (evacuation or iodine blocking pills) should be avoided because great fear would be induced that would cause severe psychological stress and result in many premature deaths. In any case, it is essential to communicate in plain language to the public what the expected health effects will be from exposures to the radiation (none or positive).

3.6. Regulating the management of radioactive waste

About 21 years ago, nuclear pioneer Theodore Rockwell stated [47] that the cost of trying to reduce harmless radiation exposures is exorbitant, and "predicting" casualties from such exposures generates groundless fear and distorts public policy. It is time to bring radiation protection policy into line with the data. When you press them, many regulators will admit there is really no science to support the notion that any amount of radiation, no matter how small, can be harmful. They say, "We're not really saying it is harmful; just that it might be." But then they ask: "What's wrong with being cautious? We tell people it might hurt them, and perhaps it won't. Can that do any harm?"

The answer: PLENTY OF HARM—five different kinds of harm: billions of dollars wasted, ridiculous regulations imposed that degrade the credibility of science and government, destructive fear generated, detrimental health effects created, and environmental degradation accelerated. Current regulations define as "radioactively contaminated" material that gives off less radiation than the natural background where people have lived happy and healthy for many generations. Storing even low-level radioactive waste requires multimillion-dollar studies with grotesque scenarios of atoms migrating through miles of desert soil to "contaminate" a possible water source in the distant future—water whose natural radioactivity would already be far above that of the mythical contaminant.

3.7. Canada's nuclear technology at risk

In 1987, the Engineering Centennial Board recognized the CANDU Nuclear Reactor System among the 10 outstanding Canadian achievements of the 20th century. It set Canada on the path towards establishing a sound nuclear electric generating system and becoming a major player in the medical and industrial applications of nuclear knowledge [48]. This vision is in jeopardy because of extreme social fear of radiation.

The environmental revolution started in the late 1960s and 1970s after the publication of Rachel Carson's 1962 book, Silent Spring. It has had a strong antinuclear component. Her book was influenced by Muller's work on X-ray induced gene mutations. Muller also wrote a powerfully supportive review of Silent Spring in the New York Herald Tribune [49]. Environmental organizations have been campaigning for decades to "phase out" nuclear energy in Canada. Fear of radiation was increased by the media scare stories about the Three Mile Island nuclear accident in 1979, the 1986 Chernobyl accident and the 2011 Fukushima accident. (The train derailment accident that happened, in 1979, in Mississauga, Ontario, Canada seems to have been forgotten. That accident opened a tanker car filled with 90 tonnes of chlorine and also exploded a tanker car of propane, causing the immediate evacuation of 250,000 nearby residents. It lasted for one week.)

Ongoing fear mongering and antinuclear activity resulted in rising costs and expanding project schedules to comply with regulatory requirements that are intended to minimize the likelihood of any release of radioactive materials. The cost and schedule of a new nuclear project are very different from the Pickering experience. NuScale (incorporated 2007) filed a design certification application to the U.S. NRC in 2017 for a small modular light water reactor. It expects approval in 2021 and delivery of the first reactor in 2026 [50]. Likewise, the cost of nuclear-generated electricity has changed. The production cost at Darlington in 1995 was 1.05 cents per kWh, including corporate overhead. The fuel component was 0.26 cents per kWh, including provision of 0.09 cents per kWh for permanent disposal of the used fuel [51]. The cost in 2017 was 6.9 cents per kWh [52].

3.8. Low-dose medical treatments and diagnostic X-ray imaging are avoided

Important medical treatments were performed with low doses of radiation, starting 120 years ago, until the 1960s. Cancers, inflammations and many types of serious infections were cured by stimulating the patient's protection systems with low doses. The evidence in recent case reports [53,54,55] on Alzheimer's dementia, Parkinson's disease, cancer, inflammations and rheumatoid arthritis [56] suggest the need for follow up clinical trials; however, there is a reluctance by medical scientists (and a lack of funding) to perform studies that use low doses of ionizing radiation to produce beneficial effects.

3.9. Change of regulatory policy, laws, regulations and radiation dose limits?

It is likely difficult to change the opinions of the public and the people who are employed in radiation protection or nuclear safety analysis. Having being misled for many years, they may have a strong resistance to even looking at evidence or other information that contradicts their long-held beliefs or discredits their work. Nevertheless, it is essential that our regulatory authorities examine the evidence, read the scientific papers and become familiar with the biological phenomena. Canadians deserve science-based regulations for ionizing radiation and radioactive materials. It is important for their safety, for their health and to preserve their nuclear technologies. CANDU reactors provide a sustainable, low-polluting supply of electricity to many Canadians.

The actual health effects of ionizing radiation have never been communicated to the Canadian people. This message should come from respected Canadian authorities or it will not be accepted. It will also be necessary to speak with the nuclear regulatory authorities in other countries and share factual information.

3.10. Conclusions

- Medical practitioners have been using low doses of X-rays and nuclear radiation for more than 120 years to cure important illnesses and diseases. These treatments stimulated the patient’s normal protection systems.
- In 1924, a “tolerance” dose rate of 20 mSv per day for radiologists was proposed. This limit, which may be received indefinitely, was accepted by the international radiation protection community.
- In the 1920s, geneticist Muller tried to accelerate the slow pace of natural evolution by irradiating fruit flies using high doses of X-rays at a very high dose rate. A high mutation frequency was measured, and he promoted his Proportionality Rule that it was linear with dose. Evidence of a threshold, when dose rate is low, was sidelined.
- To address concerns about potential genetic effects, committee meetings cut the annual occupational dose limit, in steps, from 700 mSv in 1924 to 10 mSv in 1993.
- A strong antinuclear movement started after atomic bombs were used to end World War II. Scientists linked exposure to radiation from bomb “fallout” to a risk of health effects (genetic mutations, cancer). This started an on-going radiation scare.
- In 1956, the U.S. National Academy of Sciences issued a recommendation to use the linear no-threshold (LNT) model to assess risk of radiation-induced mutations. The entire world was misled by this deliberate falsification (no supporting evidence).
- Lauriston Taylor stated, “The LNT is a deeply immoral use of our scientific heritage.”
- In the 1980s, biologists discovered the very high rate of biomolecular (DNA) damage being caused naturally by the high concentration of reactive oxygen species (ROS) in all air-breathing organisms.
- All organisms have very powerful protection systems that produce antioxidants to prevent damage. The protection systems also repair damaged DNA and remove the damaged molecules, cells and tissues that were not repaired. They restore health.
- The protection systems are very sensitive and react to small disturbances. A small dose of ionizing radiation produces a burst of “hits” and ROS. This burst sends many signals that stimulate many protection systems (>150 genes) against naturally-occurring ROS, internal and external toxins, pathogens and damage.
- Stimulation produces a range of beneficial effects including a lower risk of cancer. However, a large dose, above known thresholds, will inhibit or damage protection systems. This will result in harmful effects, including radiation illness.
- A study of leukemia incidence in 96,800 atomic bomb survivors provides evidence of a threshold at the dose 0.5 Sv for acute radiation-induced leukemia. This suggests that the dose thresholds for other types of cancer may be higher.

- An analysis of a study on dogs exposed to different dose rates of gamma radiation for their entire lives suggests a threshold at about 700 mSv per year for the onset of harmful effects.
- U.S. Department of Energy information (a published chart) shows responses to ionizing radiations over a wide range of dose. This chart shows limits for radiation protection regulations and guidelines that are about a factor of 1000 lower than the levels where harmful effects are expected. The limits should be raised much higher.
- Nuclear regulators appear to be ignoring the fundamental scientific discoveries on the effects of ionizing radiation on health, especially the stimulatory effects of low doses and the thresholds for onset of harmful effects.
- The Chernobyl accident led to the evacuation of about 116,000 residents. They received radiation doses that averaged only 17 mGy. However, there was much traumatic stress and many premature deaths due to fear of radiation-induced health effects.
- The average dose to the thyroid gland was only 1.4 Gy for 2,400 children who were born from 1983 to 1986. Screening for thyroid cancer has been shown to result in a large overdiagnosis of naturally-occurring thyroid cancer, with no rise in mortality.
- Of the 134 emergency workers who were treated for acute radiation syndrome, 28 died within weeks. Their doses ranged from 2 to 16 Gy. The 106 who recovered showed no evidence of delayed effects after 19 years.
- After the Fukushima accident, 300,000 residents were evacuated as a precaution against radiation-induced health effects. The radiation did not reach harmful levels; however, the 2012 Reconstruction Agency report listed 1632 disaster-related deaths due to fatigue, psychological trauma or the aggravation of existing diseases.
- The plant worker radiation doses during the first year did not exceed harmful levels.
- Lessons that should be learned from the Chernobyl and Fukushima accidents are:
  - Radioactive materials released in severe accidents result in low-radiation levels.
  - Long-term evacuations from low-radiation areas are not appropriate.
  - Precautionary evacuations induce fear; stress leads to many premature deaths.
- Radiation protection for managing radioactive waste should be changed to be in-line with the data.
- Since the 1970s, Canada’s nuclear technology has been at increasing risk due to the opposition of antinuclear activists, who exploit public fear of radiation.
- Rising regulatory requirements, to lower the likelihood of any release of radioactive materials, have greatly increased the cost and lengthened the schedule of a nuclear reactor project. They have also increased reactor operating costs.
- Diagnostic imaging and medical treatments with low doses of radiation are inhibited due to public fear of health effects.
- Because the public has been misled for many years, it will likely be very difficult to change the current opinions about the health effects of a low dose of radiation. Furthermore, those who are employed in radiation protection and in nuclear safety analysis will likely resist any proposed changes to existing regulations, radiation dose limits and the concept of as low as reasonably achievable, known as ALARA.

3.11. Recommendations

Part B of this report identifies several very important problems for Canada that the Government of Canada should address.

Unfortunately, these problems exist also in the international community. There is an international consensus, deeply rooted in the original ideological agenda that resists any change from the status quo. It urges additional government-funded research programs.

The intervenor has no recommendations for the CNSC on solutions. It may be difficult to identify scientists who have an “open mind” on this subject because of misconceptions that have become embedded.

The scientific evidence of actual effects of ionizing radiation on health, presented in this report, has not been communicated to the Canadian people. This Public Hearing is an opportunity to do. To be accepted, such information should also be disseminated by respected Canadian authorities.

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