Summary of Environmental Risk Assessment for Gentilly-2 Facilities (2024)

CALIAN

Hydro Québec

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1. Background and Study Objectives

Since the beginning of operations at Gentilly-2[1], Hydro-Québec has carried out environmental monitoring of physical, chemical and radiological parameters throughout the operating and decommissioning phases. Sampling and radiological surveys are carried out in the environment on the facility site, as well as in surrounding areas. All this data is used to document radioactivity levels, confirm compliance with applicable regulations, and assess the public's degree of exposure to ionizing radiation.

In 2020, Canadian Nuclear Safety Commission (CNSC) staff notified Hydro-Québec of the integration of regulatory document REGDOC 2.9.1 *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (2017 edition) to its licence conditions handbook. According to this new edition, licensees must carry out an environmental risk assessment at each change in phase in the lifecycle of a nuclear facility, in accordance with CSA standard N288.6 E*nvironmental risk assessments at Class I nuclear facilities and uranium mines and mills*.

Hydro-Québec therefore submitted the first version of its environmental risk assessment for the storage with surveillance phase to the CNSC in May 2022, which was revised and subsequently accepted in June 2024. The environmental risk assessment (ERA) will now be updated every five (5) years, in compliance with REGDOC 2.9.1.

Gentilly-2 nuclear generating station, equipped with a CANDU®,[2] reactor, operated from October 1983 to December 2012. The generating station had an installed capacity of 675 MW and generated around 5 TWh of electricity per year throughout its operation. Since its definitive shutdown on December 28, 2012, Hydro-Québec has been carrying out decommissioning activities.

The decommissioning process is divided into five phases:

- **Phase 1: Stabilization** (completed in 2014)
- **Phase 2: Storage with surveillance** (2014–2057)
  - Phase 2a: Preparation for storage with surveillance
  - Phase 2b: Storage with surveillance
- **Phase 3: Dismantling** (2057–2062)
  - Phase 3a: Preparation of dismantling
  - Phase 3b: Dismantling
- **Phase 4: Site restoration** (2063–2064)
- **Phase 5: Environmental follow-up** (2064–2074)

1. In 2016, the Commission de toponymie du Québec issued a favourable opinion following Hydro-Québec's request to change the toponym of "Gentilly-2 nuclear generating station" to "Gentilly-2 facilities." "Gentilly-2 facilities" refers to the Gentilly-2 nuclear facility and radioactive waste facilities. The radioactive waste facilities include the solid Radioactive Waste Storage Area (RWSA), the Irradiated Fuel Dry Storage Area (IFDSA) and the Solid Radioactive Waste Management Facility (SRWMF). The term "nuclear generating station" is retained only when referring to the past.
2. CANDU (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited (AECL).

A number of energy generation or support systems were shut down, i.e., stopped, emptied and any energy sources removed. Removal activities generated radioactive waste that is now stored in special bunkers or has been shipped off-site for treatment or recovery by third parties:

- The reactor core was emptied of fuel. All irradiated fuel is now in dry storage, in each of the 11 different CANSTOR modules of the Irradiated Fuel Dry Storage Area (IFDSA) or the Solid Radioactive Waste Management Facility (SRWMF).
- The tanks containing spent resins were emptied and the resins transferred to the SRWMF's spent resin storage bunkers (SRSBs).
- All heavy water system (heat transport and moderator) filters were transferred to a specific concrete vault in the Radioactive Waste Storage Area (RWSA).
- The heat transport and moderator systems were drained. The heavy water from the heat transport system was recovered by another licensee, while that from the moderator system is stored at another licensee's site.
- Compactable waste from the RWSA and SRWMF was treated to reduce its volume. Treatment residues were compacted and placed in metal containers, which are stored in one of the SRWMF's concrete vaults.

This transition leads to an overall reduction in risks and potential environmental impacts:

- Reduced risks arising from the presence of irradiated fuel or heavy (tritiated) water
- Decrease in radioactivity quantified in liquid or atmospheric releases
- Changes affecting facilities and their functions (reduction in site activities)

The ERA updates the environmental risks associated with the Gentilly-2 facilities. It deals first and foremost with human health risks (HHRA) and ecological risks (EcoRA) associated with radioactive contaminants, as well as those associated with physical and chemical contaminants and physical stress factors. The main objectives of the ERA are as follows:

- Assess the risks to people, wildlife and plant life in the current state of the Gentilly-2 facilities.
- Predict potential risks, given that the facilities are in the process of transitioning to the storage with surveillance phase, during which activities involving radiological risk will be more limited.
- Make recommendations for adapting environmental monitoring.

2. Description of Gentilly-2 Facilities

The Gentilly-2 facilities are located on the south shore of the Fleuve Saint-Laurent (St. Lawrence River), in the municipality of Bécancour, about 15 km east of the city of Trois-Rivières (located in Québec, Canada).

The specific facilities covered by the ERA are shown in Figure 1 and include:

- The Gentilly-2 nuclear facilities, formerly known as “Gentilly-2 nuclear generating station”
- Outbuildings, such as turbine, service and administrative buildings, etc.
- Solid Radioactive Waste Management Facility (SRWMF)
- Irradiated Fuel Dry Storage Area (IFDSA)
- Radioactive Waste Storage Area (RWSA)

However, the ERA for the Gentilly-2 facilities does not cover the switching substation, SF_6-insulated equipment building, Bécancour generating station or water demineralization plant, all of which are under the jurisdiction of other Hydro-Québec authorities, nor does it cover the Gentilly-1 facilities, which belong to Canadian Nuclear Laboratories (CNL).

Figure 1: Gentilly-2 Facilities

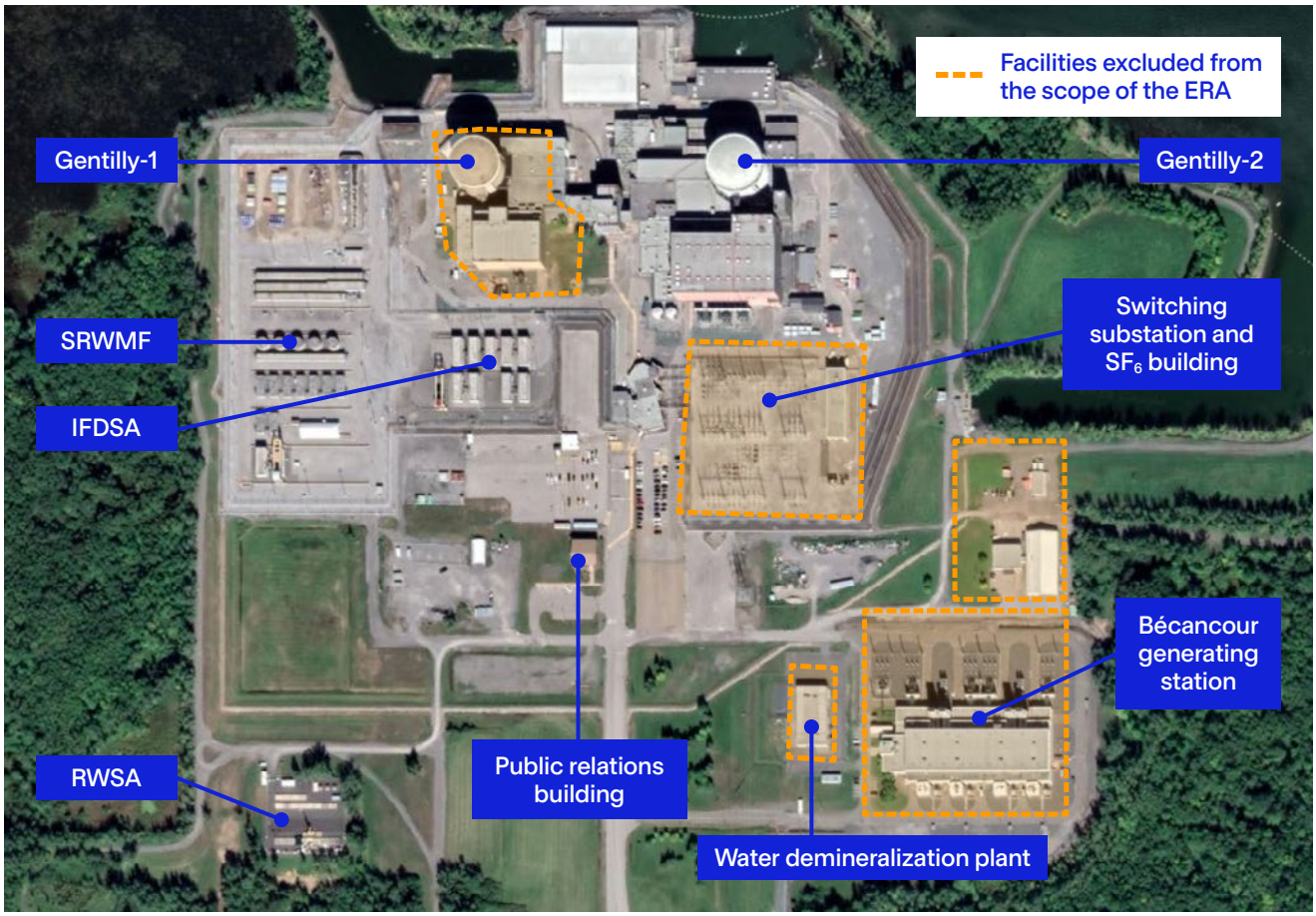
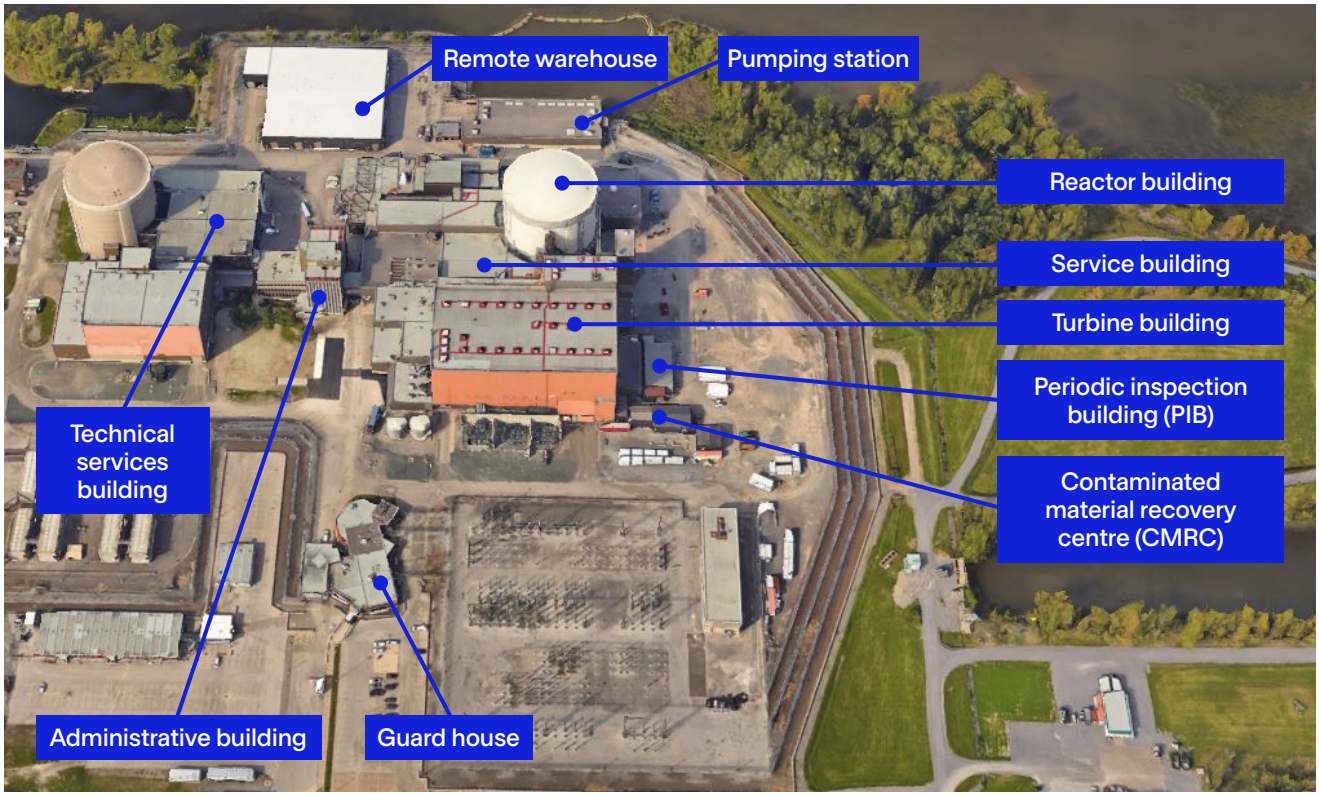


Figure 2: Main Buildings Associated with Gentilly-2 Facilities



2.1.1 Irradiated Fuel Dry Storage Area (IFDSA)

The IFDSA is a storage area dedicated to CANSTOR (CANDU STORage) modules used for dry storage of irradiated fuel. A CANSTOR module is a reinforced concrete bunker in which 20 sealed carbon steel cylinders are positioned vertically. Each sealed cylinder stacks 10 storage baskets. Each cylinder is sealed with a welded shielding plug. The stainless steel baskets each contain 60 spent fuel bundles. In addition, the last three baskets have been modified, and contain defective fuel bundles. Each of them has been individually encapsulated to recreate a first safety barrier, once again ensuring the containment of fission products.

2.1.2 Solid Radioactive Waste Management Facility (SRWMF)

The SRWMF also includes reinforced concrete structures, which are used to store low- or medium-level waste, such as used filters or spent resins. Part of the irradiated fuel is also stored in two CANSTOR modules to the far west of the SRWMF.

2.1.3 Radioactive Waste Storage Area (RWSA)

The RWSA is located in the northwestern part of the site and consists of compacted, impermeable backfill, completely covered by a layer of asphalt. The RWSA was also designed to store low- and medium-level radioactive waste, such as used filters from the primary system, as well as several other waste matrices, compacted or not.

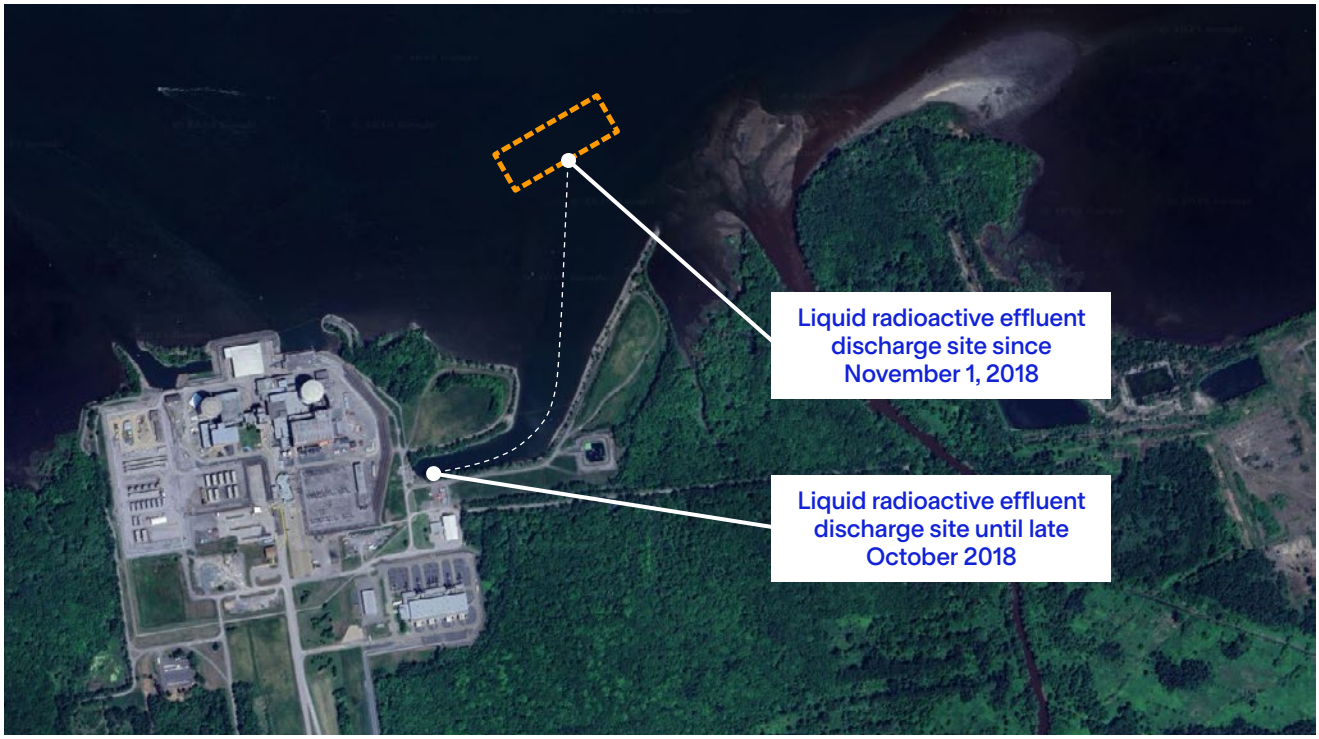
All the waste present at the RWSA was treated as part of a recent project, with the exception of that present in the used filter pit. As a result, the treatment residues were, for the most part, re-compacted and placed in metal containers, which were then stored in one of the SRWMF pits. Eventually, used filters stored at the RWSA could also be repatriated to one of the SRWMF's used filter storage bunkers (UFSBs). As a result, the RWSA may no longer contain radioactive waste in the medium term.

2.1.4 Sources of Radioactive Effluents

The main sources of radioactive effluents are:

- The ventilation system of the reactor building, via its main chimney
- The ventilation system of the service building, via its chimney
- The authorized liquid radioactive effluent management system

Figure 3: Liquid Radioactive Effluent Discharge Sites



3. Environmental Risk Assessment

The environmental risk assessment (ERA) of the Gentilly-2 facilities is a systematic process used to identify, quantify and characterize the risk posed by contaminants and physical stressors on biological receptors, including the magnitude and scope of potential associated effects. “Receptors” includes humans as well as flora and fauna. Human receptors are covered by a human health risk assessment (HHRA), while flora and fauna are covered by an ecological risk assessment (EcoRA).

Generally speaking, risk assessment aims to quantitatively estimate the level of risk to the environment and human health associated with exposure to radionuclides, chemical substances or physical stressors. This approach is based on knowledge of environmental releases and the components of the biophysical and human environments likely to be affected by exposure to these substances and factors. The risk assessment process comprises four distinct steps:

- Problem formulation
- Exposure assessment
- Assessment of toxicity or effects
- Risk characterization

Following these steps, conclusions are drawn and recommendations for environmental monitoring are formulated.

The ERA complies with the methodology described in CSA standard N288.6 *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills*.

The ERA was developed in two steps. The first is the baseline ERA, based on real data recorded between 2015 and 2020. The second is the predictive ERA, which aims to assess the environmental risks for the future storage with surveillance phase.

3.1 Problem Formulation

The goal of the initial problem formulation step is to identify potential receptors, contaminants of potential concern (COPCs) and exposure pathways. These three elements form the basis of a conceptual site model illustrating contaminant exposure pathways, from the source to receptors of interest in relevant environmental media. The problem formulation examines these three elements (receptors, contaminants and exposure pathways) in detail to identify realistic combinations where all three elements are present, corresponding to complete exposure pathways. Incomplete pathways are eliminated from further consideration. In addition, complete exposure pathways are also assessed in terms of their importance in relation to overall exposure. In some cases, exposure pathways may be complete, but still considered insignificant contributors to overall exposure and therefore not reported for the ERA.

3.1.1 Receptor Identification

The ERA considers human receptors for the HHRA and ecological receptors for the EcoRA. Human receptors were selected on the basis of potential exposure to liquid and atmospheric releases from Gentilly-2 facilities. They include the following representative groups:

- Residents of neighbouring municipalities
- Farm residents
- Workers from surrounding areas
- Local hunters and fishers

Residents of neighbouring municipalities belong to three different age groups, from infancy to adulthood.

Farm residents are also represented by individuals in the same age groups, with the difference that they live on the region's farmland.

Workers are represented by adult individuals. The workers are Gentilly-2 site employees, working inside or outside the various buildings, as well as industrial workers from neighbouring municipalities.

Hunters and fishers are people who are presumed to frequent the area around the Gentilly-2 site. They hunt, fish and eat their own catch (game or fish) in greater proportion than the rest of the population. As with the first two groups, their age ranges from infancy to adulthood.

A functional ecosystem implies the interaction of multiple species, each reacting differently to COPCs and/or physical stressors. As it is not possible to assess risk directly for each species, the ecosystem has been divided into several components (e.g., plants, invertebrates, birds, mammals, fish). For birds, mammals and fish, a limited number of species were selected from each component to be representative of the whole. For plants and invertebrates, individual species were not selected, as these receptors were defined at the component level (e.g., terrestrial plants, soil invertebrates, aquatic plants, phytoplankton, zooplankton and benthic invertebrates)..

Photo taken as part of environmental monitoring of the Gentilly-2 facilities. Technicians are shown here in a boat traveling along the Fleuve Saint-Laurent (St. Lawrence River) to sample water, sediment dynamics, algae, mollusks and fish near the site.

The EcoRA considers receptors that live on and in the earth, air, and on and in the water:

- Terrestrial ecological receptors:
  - Terrestrial plants
  - Soil invertebrates
  - Mammals
  - Birds
  - Reptiles and amphibians
- Aquatic ecological receptors:
  - Aquatic plants
  - Zooplankton
  - Benthic invertebrates
  - Various fish species

3.1.2 Identification of Contaminants of Potential Concern and Physical Stressors

Since the early 1990s, more than 50 environmental studies have been carried out specifically on the Gentilly-2 site. The scope of these studies varies, with some focusing on the physical and chemical characterization of soil, groundwater and surface water, as part of environmental monitoring, or following specific events such as the accidental discharge of contaminants or the removal of underground infrastructure. Others were more ecologically oriented, aimed at identifying the habitat or wildlife species present. The majority of environmental quality data focused on radiological contaminants; however, some studies detail non-radiological data that were deemed relevant to support the risk assessment objectives and approach. Radiological and non-radiological COPCs were identified in the following matrices, based on historical studies and measurements:

- Soil
- Groundwater
- Surface water
- Liquid effluents
- Atmospheric effluents

As the Gentilly-2 reactor was permanently shut down in late 2012, several radioelements that were once considered are no longer of interest today, due to radioactive decay or the cessation of activation or even fission processes, or because some equipment or waste has since been stored in completely enclosed systems, or disposed of off-site. The radioelements they contained no longer pose an immediate problem.

Also, given that radionuclides with half-lives of less than a year are no longer present, tritium (H-3), carbon-14 (C-14), cobalt-60 (Co-60) and cesium-137 (Cs-137) are automatically considered to be the limiting COPCs for the HHRA and EcoRA.

The data review did not identify any non-radioactive COPCs for the purposes of the HHRA or EcoRA. The analytical results were all below the respective screening criteria, or the concentrations would result in minimal incidental exposure of the receptors. For example, diesel generators at the Gentilly-2 site are tested periodically; however, given the infrequency and very short duration of these tests, exposure to airborne particles is considered negligible.

Identified physical stressors include:

- Motor vehicle traffic
- Industrial noise
- Dust generated by work or traffic on the site
- Collisions with various animals on the access road
- The dissipation of a thermal plume in the Fleuve Saint-Laurent
- Fish capture at the pumping station
- Site lighting

With the exception of lighting, which has been fully maintained at the site for the time being, all other stress factors are either decreasing, given the lower number of workers at the Gentilly-2 site, or no longer apply at all (e.g., thermal plume and fish capture), since the systems that generated them have been completely shut down and retired.

3.1.3 Identification of Exposure Pathways

Exposure pathways are the means by which a receptor comes into contact with a COPC. Exposure pathways depend on both the receptors and the nature of the contaminants.

For human exposure to non-radioactive contaminants, numerous pathways were considered when identifying COPCs from soil and groundwater, including direct contact with soil (i.e., accidental ingestion, skin contact and inhalation of soil particles), direct contact with groundwater (i.e., accidental ingestion and skin contact by a worker assigned to excavations or trenches) and inhalation of vapours.

For the exposure of flora and fauna to non-radioactive contaminants, the following terrestrial exposure pathways were considered complete:

- Plants: direct contact with the soil and absorption by the roots
- Soil invertebrates
- Mammals and birds: accidental ingestion of soil and varied dietary exposure (ingestion of plants, invertebrates or small mammals that have accumulated COPCs)

The IMPACT model ("Integrated Model for the Probabilistic Assessment of Contamination Transport") was used to model and calculate the radiation dose to humans for each radionuclide as a result of the following exposure pathways:

- Air inhalation
- External radiation from air immersion
- Water ingestion
- External radiation from water immersion
- Soil ingestion (incidental)
- External radiation from ground deposits
- Terrestrial animal ingestion
- Terrestrial plant ingestion
- Aquatic animal ingestion
- Aquatic plant ingestion
- Sediment ingestion (incidental)
- External radiation from sediment deposits

Exposure of flora and fauna to radionuclides is classified into two types of exposure pathways: external and internal.

External exposure pathways for terrestrial flora and fauna include:

- Air immersion (exposure to gaseous radionuclides present in the air)
- External irradiation from ground deposits (exposure to radioactive aerosols on the ground, mainly of the beta/gamma type)

External exposure pathways for aquatic flora and fauna include:

- Water immersion (exposure to radioactive particles in water)
- External irradiation from sediments (exposure to radioactive particles on or in sediments)

3.2 Exposure Assessment

The second step of the ERA aims to quantitatively assess the contact between a chemical substance or radionuclide present in the environment and a living organism. For each of the targeted ecological and human receptors, exposure doses are calculated for the radionuclides or for each of the chemical substances of interest, taking into account their presence in the various environmental matrices (air, soil, water, food) and the different routes of entry into the body (e.g., inhalation, skin contact, ingestion). Calculations are based on data measured directly in the environment and on the results of mathematical models that consider the dispersion of substances in air, water and soil.

3.3 Assessment of Toxicity or Effects

The third step of the ERA is the assessment of toxicity or effects. This involves classifying the potential effects of COPCs and estimating the concentrations of chemical and radioactive substances to which receptors could be exposed without suffering adverse health effects. Toxicity is assessed for all COPCs, taking into account the possible modes of toxicity associated with the various pathways, the duration of exposure, and receptor sensitivity. Toxicity assessment provides an estimate of the maximum acceptable doses that can be incurred over a lifetime (or significant part thereof) without unacceptable health effects. It also provides a basis for interpreting anticipated exposure rates.

For the assessment of radiological toxicity, the legal effective dose limit for the public (i.e., one millisievert or 1 mSv/year) was used as the limit below which exposure is considered to have no significant effect on human health. Although there is inherent variability in each individual's sensitivity to radiation exposure, this annual dose value represents a well-established regulated dose limit, incorporating a safety margin to cover uncertainties in the toxicity assessment process.

For the exposure of flora and fauna to radioactive contaminants, reference values for assessing radiological effects are based on the recommendations of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR):

- *Chronic dose rates of less than 100 µGy/h to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities.*
- *A maximum dose rate of 400 µGy/h to any individual in aquatic populations would be unlikely to have any detrimental effects at the population level.*

If these reference values are exceeded, there is a potential for adverse effects.

For the exposure of terrestrial plants and soil invertebrates to chemical contaminants, this is an acceptable concentration in the exposure medium (soil or groundwater), known as the "toxicity benchmark." For mammals and birds, this value is expressed as an acceptable daily intake and is known as the "toxicological reference value." These values are used as thresholds for comparison with exposure concentrations (for terrestrial plants, soil invertebrates and aquatic life) and total doses (for mammals and birds) at the risk characterization stage.

Photo taken as part of environmental monitoring at the Gentilly-2 facility. Here, a lab technician collects a groundwater sample from one of the many piezometers installed on site.

3.4 Risk Characterization

The fourth and final step of the ERA is to assess the risk potential associated with a radionuclide or chemical of interest, by comparing the estimated exposure doses for each ecological or human receptor with recognized reference values or dose limits.

For radioactive contaminants, the ERA concludes that there is no radiological risk to human receptors or flora and fauna from activities related to the transition to storage with surveillance at the Gentilly-2 site. For humans, doses are estimated to be less than 1 µSv[1]/year, which represents less than 0.1% of the regulated annual dose limit (1 mSv/year) for the public. For all the ecological receptors, the ratio of total dose rate to the reference value is well below 1.

The ERA also concludes that there are no non-radiological COPCs contributing to a risk to human receptors or fauna and flora. It is estimated that there will be even fewer potential sources of contaminants present on the site once the storage with surveillance phase has been decreed, and that risks will therefore still be negligible.

1. Sievert or Gray: Units of measurement in the international system used to measure the dose received by a human (sievert) or by a plant or animal (gray) and to assess its biological effects.

3.5 Conclusions and Recommendations

3.5.1 Conclusions for the Baseline ERA

The baseline ERA for the Gentilly-2 facilities provides a quantitative and conservative risk assessment, i.e., an assessment based on models recognized as prudent. It is based on historical data from 2015–2020, while considering the most recent data to be more representative of the current state of the facilities.

3.5.1.1 HHRA due to radioactive contaminants

The HHRA assessed the risk potential for workers at the Gentilly-2 site, as well as for workers in surrounding areas, residents of neighbouring municipalities, farm residents, hunters and fishers, assuming continued industrial use of the site.

Radiation doses to representative members of the public around Gentilly-2 facilities were assessed for the years 2015–2020. These dose values are falling. Annual doses are now estimated to be less than 1 µSv/year, which represents less than 0.1% of the regulated annual dose limit (1 mSv/year) for the public.

3.5.1.2 EcoRA due to radioactive contaminants

The radiological risk assessment for fauna and flora shows that there are no risks associated with the current transition phase to storage with surveillance. The estimated risks are all below the respective reference values.

3.5.1.3 HHRA due to chemical contaminants and physical stressors

Based on previous environmental studies, all specific to the Gentilly-2 site, no non-radiological COPCs were identified in the soil, groundwater or effluents. Consequently, risks are considered negligible for all identified human receptors with regard to exposure to non-radioactive contaminants released as a result of historical, current and future (storage with surveillance phase) activities.

3.5.1.4 EcoRA due to chemical contaminants and physical stressors

The EcoRA assessed the risk to terrestrial and aquatic ecological receptors, assuming continued industrial use of the site. Based on a thorough review of previous studies, all specific to the Gentilly-2 site, no non-radiological COPCs were identified in the soil, groundwater or effluents. Consequently, risks are considered negligible for all identified non-human receptors with regard to exposure to non-radioactive contaminants released as a result of historical, current and future (storage with surveillance phase) activities.

3.5.2 Conclusions for the Predictive ERA

The predictive ERA provides a qualitative assessment of future risks compared to those of the baseline ERA. Most of the activities in the storage with surveillance phase are a continuation of the transition activities that have been underway for several years. As such, they should have no impacts other than those already documented in the baseline ERA.

The only activity that could represent a significant change in the composition of liquid discharges is the draining of water from fuel storage pools. Estimates of the radiological activity of the water contained therein show that it will be of the same order of magnitude as that quantified in the annual discharges of recent years. Given the conservative nature of the risk assessment and the margins in relation to dose limits, the risks are still considered insignificant. In any case, this activity is subject to rigorous supervision by CNSC staff, and all necessary authorizations will have been obtained before any discharge takes place.

3.5.3 Recommendations

The ERA contributes to the effort to revise the environmental monitoring procedures for the Gentilly-2 facilities, by adding or deducting, as needed, the monitoring of certain chemical substances or radionuclides that may be present in the environment.

The ERA carried out at the Gentilly-2 facilities leads to the following recommendations:

- Radiological monitoring of the environment could be adapted immediately, as several results have been equivalent to the natural background level or below the detection limit of laboratory equipment for many years. Other parameters have also been identified for possible easing, after confirmation of a significant drop in discharge rates. For example, it was recommended to discontinue analyses in the surface water of the discharge channel, in the absence of any discharge at this point since 2018. Concentrations are now below the detection limit or at the natural background level.
- It was recommended to maintain sediment monitoring at the bottom of the discharge channel until concentrations approach the natural background level, as this is the limiting location for exposure of aquatic biota.
- It was recommended that the sampling point for surface water, sediment, aquatic plants, shellfish and mollusc meat be moved downstream of the radioactive discharge outlet to better quantify the potential impact of the discharges.
- It was recommended that Hydro-Québec's internal procedures for groundwater sampling be updated to include filtration of samples for metal analysis, since groundwater screening criteria are based on filtered samples (dissolved metals).

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