Ecological Risk Assessment for Radiological and Chemical Contaminants at a Site with Historical Contamination

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Abstract

An Ecological Risk Assessment was carried out for a uranium conversion facility in Ontario, located on a site with a history of contamination. The ERA assessed risk to aquatic and terrestrial biota from exposure to radionuclides and non-radionuclides in soil and groundwater associated with the site. The results indicated no undue risk to aquatic biota from radionuclides. Small potential risks were identified for terrestrial biota at limited locations associated with this industrial site. Recommendations are provided for follow-up risk-informed activities.

1. Introduction

This paper summarizes an ecological risk assessment (ERA) carried out as part of a larger series of studies for Cameco Corporation's Port Hope Conversion Facility (PHCF) in Port Hope, Ontario. The PHCF is a uranium conversion facility located on a site with a history of industrial use by multiple users, starting in the mid-to-late 1800s. The site is shown in Figure 1.

Figure 1 Cameco Corporation's Port Hope Conversion Facility Site, Port Hope, Ontario

2. Background

The Port Hope Conversion Facility (PHCF) receives uranium trioxide for conversion to either uranium hexafluoride (UF_6) or uranium dioxide (UO_2). Cameco routinely monitors releases of radioactive and non-radioactive chemicals to the environment (to air, water and waste) to ensure that they are within regulatory requirements. Cameco also monitors concentrations in the environment (air, soil, water and sediment).

The historic operations on the site were recognized to have resulted in surface and sub-surface contamination on the site and in the surrounding environment at the time Cameco was formed in 1988. A legal agreement exists between the federal government and the municipalities of Port Hope and Clarington for the clean up and long-term safe management of historic low-level radioactive waste. The Port Hope Area Initiative (PHAI) led by Atomic Energy of Canada Limited (AECL) and Cameco's Vision 2010 project are being developed to address this historic contamination in the municipality, including the Port Hope Harbour (Harbour) and site, respectively. The Vision 2010 project involves the removal of several old or under-utilized buildings, the removal of contaminated soils, building materials and stored historical wastes, and the construction of some new buildings where necessary to improve the efficiency of the facility.

Cameco retained SENES Consultants Limited (SENES) to carry out a Site-Wide Risk Assessment (SWRA) based on information readily available as of December 2008 [1]. The SWRA addressed regulatory expectations provided at the start of the project by the Canadian Nuclear Safety Commission (CNSC) and the Ontario Ministry of the Environment (MOE). The SWRA was submitted to the CNSC in June 2009. The SWRA included the fundamental elements of a risk assessment, such as:

- Screening for Contaminants of Potential Concern (COPCs);
- Site Characterization;
- Conceptual Site Model;
- Hazard Assessment and Exposure Assessment; and
- Risk Characterization, etc.

In addition, the SWRA included unique features such as a site-specific hydrodynamic and contaminant transport model and the derivation of Risk-Based Performance Objectives for the site.

The SWRA addressed risks from both radiological and chemical contaminants associated with the PHCF operations. They included scenarios for both present-day soil conditions and post-Vision 2010 soil conditions.

The results of the SWRA were used to provide risk-informed feedback on risk-sensitive information gaps as well as information on the potential need for mitigative and preventative measures to ensure that there is no undue risk associated with PHCF operations.

The SWRA also developed site-specific risk-based performance objectives for groundwater. This was done by performing inverse calculations to determine groundwater loadings to surface water at which the receptors will not be adversely affected.

After the June 2009 SWRA, Cameco and SENES made a number of refinements. Many of these refinements were based on a discussion of uncertainties in the SWRA. The refinements were incorporated into a SWRA Update [2], which was submitted to the CNSC in December 2009. The SWRA Update included the following:

- Collection and analysis of several additional surface water samples in the Harbour;
- Re-screening for COPCs based on additional data and screening criteria;
- Refined hydrodynamic and contaminant transport modelling and verification, in order to derive more realistic dilution factors from groundwater to the Harbour and Lake Ontario surface water. Simulation of contaminant plumes taking cooling water flow into account;
- Development of scenarios for hypothetical pump-and-treat failure or maintenance outage scenarios (A pump-and-treat system has been installed to protect the present and future quality of groundwater seeping into the Harbour);
- Update of ecological and human health Toxicological Reference Values (TRVs);
- Update of Human Health Risk Assessment (HHRA) calculations and documentation;
- Update of Ecological Risk Assessment (ERA) calculations and documentation;
- Updated derivation of Performance Objectives; and
- Vapour Intrusion Modelling from Groundwater and Soil to Indoor Workers and associated Risk Assessment calculations.

For the remainder of this paper, the term SWRA refers to the June 2009 SWRA and the December 2009 SWRA Update. The SWRA included Human Health and Ecological Risk Assessments. This paper discusses the ERA process and results. A companion paper on the Human Health Risk Assessment (HHRA) is also being presented at this conference [3].

3. Ecological Risk Assessment (ERA) objectives and scope

The main objectives of the ERA were to address the following questions:

Q1. What are the potential net effects on biota resulting from current site groundwater loadings to the Harbour and Lake Ontario? This is assessed in the “Incremental” scenarios, where environmental concentrations are calculated from the estimated loadings of the PHCF into the Harbour and the lake (SWEIR, Golder 2008a). Current loadings take implementation of the current updated EMP into account. (This item addresses the potential issue of Harbour recontamination following sediment cleanup by PHAI).

Q2. What are the potential total effects on biota resulting from several sources, including current contamination levels in the Port Hope Harbour and current site soil levels and groundwater loadings? This is assessed in the “Total” scenarios, where environmental concentrations are based on monitoring data.

The ERA addressed the above questions Q1 and Q2 for both radioactive and chemical contaminants, for representative ecological receptors present at the site and its vicinity. The PHCF is an industrial site and as such does not provide a good habitat for biota. Ecological receptors were selected for the ERA based on knowledge of the site (including accessibility) and previous Port Hope ERA studies. A land use survey carried out for the site was referred to in the selection of receptor locations. Ecological receptors considered in the SWRA include:

- Aquatic biota, such as: aquatic plants, benthic invertebrates, benthic and pelagic fish, as well as aquatic birds such as scaup and grebe; and
- Terrestrial biota, such as: earthworms, terrestrial plants, meadow voles, cotton-tail rabbits, great-horned owls, red foxes, yellow warblers and American robins.

The selected receptors cover a variety of trophic levels and are assumed to be representative of the biota expected to be found in the study area, including species at risk. Figure 2 shows the ecological receptor locations across the site, as assumed for the ERA.

The ERA took into consideration receptor characteristics, exposure pathways and mitigating circumstances. Risk was evaluated using toxicological information associated with the particular contaminants of concern, physical site conditions and characteristics of the receptors using the site (e.g., intakes).

The ERA investigated soil at and groundwater below the PHCF site as well as surface water and sediment in the Port Hope Harbour. The focus of the ERA was risk from soil and groundwater pathways, including the loadings from on-site groundwater to the surface water environment (Port Hope Harbour or Lake Ontario). Storm water loadings from the site were also included in the scope of the ERA.

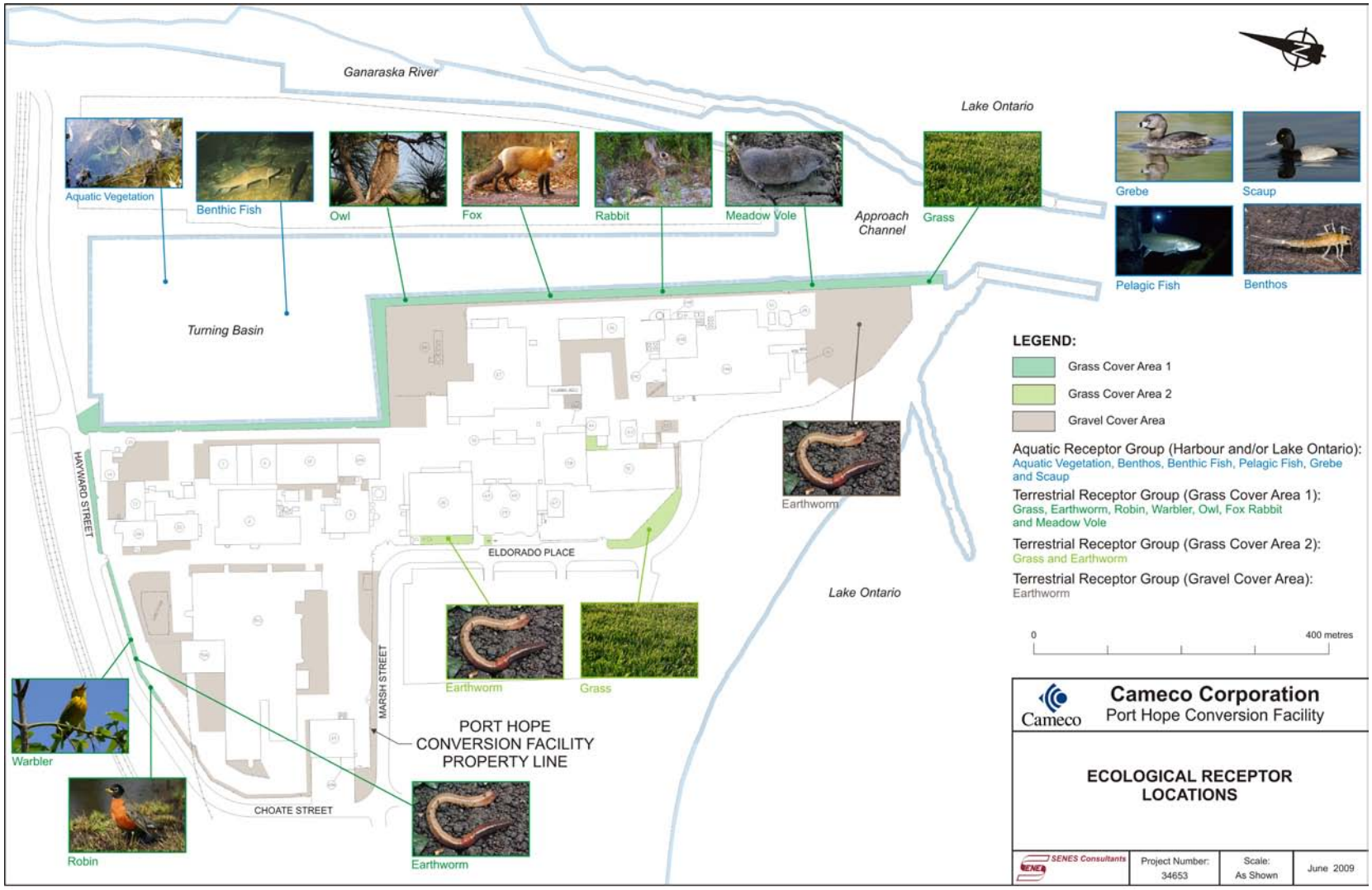

Figure 2 Ecological Receptor Locations

4. ERA calculations

A screening-level (also called Tier 1) ERA was carried out for all of the biota included in the SWRA. This involved conservative assumptions about environmental concentrations, ecological receptor exposure time and hazard assessment parameters. A Tier 2 ERA was carried out for selected biota in selected media. The Tier 2 ERA involved the use of more realistic parameters, such as 95% Upper Confidence Limit (UCL) of the mean measured concentrations, and Canadian or site-specific transfer factors where available.

Details of the ERA calculations are provided in the SWRA [1],[2]. A brief summary of the methodology is provided in the following sub-sections.

4.1 Conceptual model

Information on the site conditions (including the nature, extent and distribution of the radiological and chemical hazards) and potential exposure pathways were integrated into a Conceptual Site Model (CSM). The CSM for this study is shown in Figure 3.

4.2 Exposure assessment

The ERA exposure models used measured and estimated media concentrations as well as receptor characteristics, in order to estimate the doses and intakes to biota from radionuclides and non-radionuclides associated with the facility.

4.3 Hazard assessment

The toxicity assessment for aquatic species and wildlife determines the concentrations or levels of the individual non-radioactive and radioactive constituents that can cause harm in ecological species. The radiological benchmarks used in the ERA are based on Estimated-No-Effect-Values (ENEVs), from literature. ENEVs are used in ERAs as benchmarks for population-level impacts. The non-radiological benchmarks were Toxicological Reference Values (TRVs), based on a variety of toxicity studies, also found in literature. It should be noted that an exposure level above a criterion does not mean that an effect will occur, but instead means that there is an increased risk of an adverse effect occurring. These benchmarks were compared to the estimated biota doses and intakes in order to characterize risk.

Radiological weighting factors (also referred to as relative biological effectiveness, RBE) were applied, in order to account for the different biological effects produced from different types of radiation. Although we acknowledge the uncertainty in this value, in this ERA a conservative RBE value of 40 was applied to doses from alpha-emitting radionuclides, based on Environment Canada and Health Canada (2003) [5].

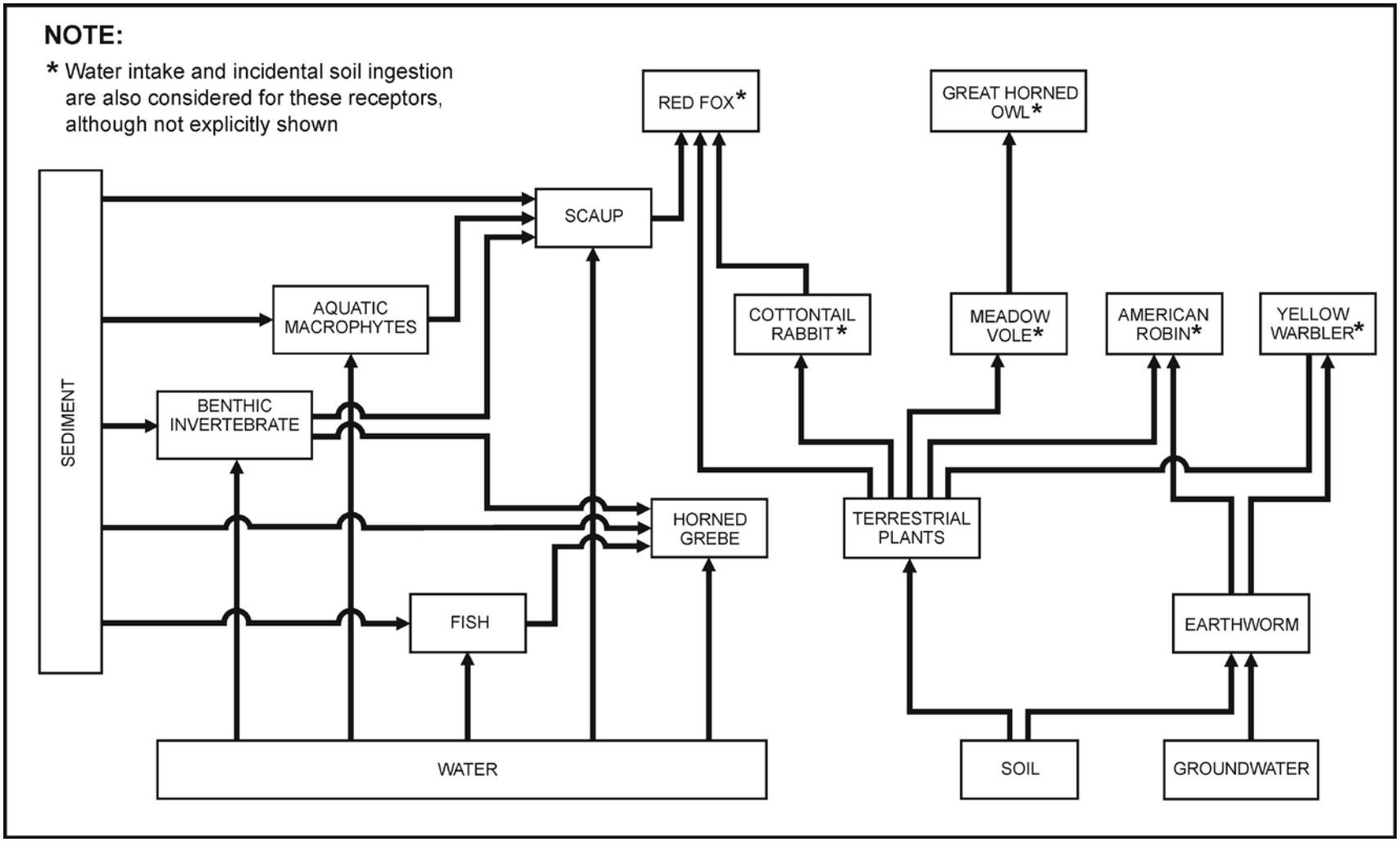

Figure 3 ERA conceptual site model

5. ERA results

The main conclusions from the ERA were:

- There are a small number of locations on-site with potential undue risk to biota (notably earthworms) which are not addressed by the Vision 2010 project, based on the Vision 2010 excavation maps (August 2007) considered in the SWRA. It should be emphasized that the excavation plans for Vision 2010 are still being refined by Cameco. Further, it should be recognized that there is a limited spatial extent within the PHCF that is accessible to biota and therefore no population-level effects on earthworms in the overall Port Hope area are expected. This addresses Question Q2 ("Total") of the Problem Formulation.
- Potential ecological risk to terrestrial biota was also identified in the off-site grass strip between the fence and the Harbour wall (from fluoride, in particular). Recommendations for addressing soil contamination in this strip are discussed in the SWRA. This addresses Question Q2 ("Total") of the Problem Formulation.
- There is no undue ecological risk to aquatic biota expected due to chemicals associated with PHCF operations. This addresses Questions Q1 ("Incremental") and Question Q2 ("Total") of the Problem Formulation.
- The preliminary assessment of aquatic impacts also identified a potential radiological issue related to aquatic plants (for both the "Total Case" and the "Incremental Case") for some water flow conditions. However, there is no such undue risk from radionuclides associated with PHCF operations (i.e., uranium isotopes). Furthermore, a field survey has not identified such an effect. This addresses both Questions Q1 ("Incremental") and Question Q2 ("Total") of the Problem Formulation.
- No other undue risks were identified which are potentially associated with the PHCF operations.

Toxicity testing and the results of field surveys were used to support the ERA calculations.

In order to reduce residual uncertainties in the ERA, it is suggested that the following gaps be filled:

(i) Storm water data: Data on radionuclides in storm water were not available. In the absence of this data, the amounts of some radionuclides in storm water were estimated based on the measured uranium levels. Cameco has initiated a storm water study in order to provide this information. The data were not available at the time of preparation of the SWRA Update. The results from the storm water study can be used to refine the estimates of all COPC loadings into the Harbour. They may also clarify the contribution of upstream sources to storm water, in which case the associated risks may also be delineated.

(ii) Sediment transport modelling.

(iii) Assessment of the risk of hypothetical failure or maintenance outage of the pump-and-treat system under various 'what-if' scenarios.

(iv) Temperature and pH measurements in the Harbour are currently limited. Because of the stakeholder interest in the potential effect of ammonia on fish, additional temperature and pH measurements are recommended to support the ERA results.

Work to fill these gaps is underway or planned for 2010.

6. ERA summary

Table 1 provides a simplified representation of the overall results of the ERA. Results are presented as one of the following:

- ✓ Indicates no adverse effect expected from COPCs associated with PHCF operations (see additional notes such as requirement for use of PPE).
- ✕ Indicates the potential for adverse effects from COPCs associated with PHCF operations. Mitigation measures to address these issues will be included in the Site-Wide Environmental Management Plan if warranted.

Question	Aquatic Biota	Terrestrial Biota
Q1 (Incremental)	✓	N/A
Q2 (Total)	✓	✕ In limited locations on-site (with limited accessibility) and in the grass patch along Harbour wall

N/A – Not assessed.

Table 1 Summary of ERA results for radioactive and chemical contaminants

The results shown in Table 1 are supported by extensive site characterization data and a multi-source multi pathways-risk assessment. The results are also supported by toxicity testing and field observations.

Performance Objectives were also provided in the SWRA. However, it is important to note that the PHCF Performance Objectives alone cannot ensure Harbour water quality, because of potential loadings from other non-PHCF sources. Ideally, therefore, the derivation of Performance Objectives for PHCF groundwater would be integrated with the overall water-quality management of the Harbour and near-shore Lake Ontario.

7. References

[1] SENES Consultants Limited, "Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 June.

[2] SENES Consultants Limited, "Update: Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 December.

[3] Garisto, N.C., F. Cooper and R. Peters, "Human Health Risk Assessment for Radiological and Chemical Contaminants at Site with Historical Contamination", Technical Paper submitted to Canadian Nuclear Society 2010 Annual Conference, Montreal, Quebec, Canada, 2010 January.

[4] Canadian Standards Association, "CSA Guideline N288.1-08 - Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities", 2008 September.

[5] Environment Canada/Health Canada (EC/HC), "Priority Substances List Assessment Report: Releases of Radionuclides from Nuclear Facilities (Impact on Non-Human Biota)", Canadian Environmental Protection Act, 2003.