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# RATIONALE DOCUMENT FOR THE DEVELOPMENT

# OF AN INTERIM ONTARIO DRINKING WATER OBJECTIVE

# FOR TRITIUM

PREPARED BY

Standards Development Branch
Ministry of Environment and Energy

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Ontario
Ministry of Environment and Energy
Ministère de l'Environnement et de l'Énergie

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## EXECUTIVE SUMMARY

In response to the recommendations of the Environmental Assessment Advisory Committee on the need for an individual environmental assessment on the proposed Pickering/Ajax Water Supply Plant, the Ministry of Environment and Energy requested that the Advisory Committee on Environmental Standards (ACES) carry out a public review and advise the Minister on an appropriate standard for tritium in drinking water.

In order to assist in the public review of the Ontario Drinking Water Objective (ODWO) for tritium, this document has been prepared by the Standards Development Branch of the Ministry. The report summarizes the process by which the current ODWO for tritium of 40,000 becquerels per litre (Bq/L) was established, gives an overview of the pertinent information that has become available since the ODWO was established and provides the rationale for recommending an interim Ontario Drinking Water Objective of 7,000 Bq/L for tritium. The interim objective will be applied as a health-related maximum acceptable concentration. It is recommended that the interim ODWO of 7,000 Bq/L replace the current ODWO and that it be reexamined once the review of the Canadian Drinking Water Guideline for tritium is complete.

Monitoring data collected under the Ontario Drinking Water Surveillance Program and surveillance programs in the vicinity of nuclear generating stations in Ontario demonstrate that the concentrations of tritium in raw and treated drinking water rarely exceed 100 Bq/L.

A reassessment of the human health effects of ionizing radiation has been conducted by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the Committee on the Biological Effects of Ionizing Radiation (BEIR) of the United States National Research Council, the International Commission on Radiological Protection (ICRP) and the United States National Council on Radiation Protection and Measurements (NCRP). These scientific criteria documents are available for public review as a separate attachment to this report.

## 1.0 BACKGROUND

In order to address the need for additional water supply to the Pickering/Ajax area of Ontario, the Region of Durham in 1990 approved a recommendation to build a new, larger water treatment plant at the same location as the existing water supply plant.

In 1992 the Minister of the Environment asked the Environmental Assessment Advisory Committee for its advice on whether an individual environmental assessment should be required for the proposed water supply plant.

In its report to the Minister, the Environmental Assessment Advisory Committee recommended against an individual environmental assessment for the proposed plant provided that certain recommendations were appropriately addressed.

With respect to concerns raised about radionuclide concentrations in drinking water, the Committee recommended that the Minister "request her Advisory Committee on Environmental Standards (ACES) to carry out a public review and advise the Minister by the end of 1993 on an appropriate standard for tritium in drinking water". In addition, "the effects of long-term exposure to low levels of radionuclides and of short-term exposure to sudden elevated levels in drinking water" should also be addressed.

The following documentation is provided by the Ministry of Environment and Energy in order to assist in the public review of the current Ontario Drinking Water Objective for tritium.

## 2.0 INTRODUCTION

The current Ontario Drinking Water Objectives (ODWOs) for radionuclides, including tritium, were adopted from the Canadian Drinking Water Guidelines (CDWGs). The CDWGs are developed through a formal Federal-Provincial process involving representatives from each of the Provinces and Territories, in addition to representatives from Health & Welfare Canada and Environment Canada.

The current CDWGs and ODWOs for radionuclides were based upon the findings and recommendations of the International Commission on Radiological Protection (ICRP) that were published in 1977.

The recommendations from the ICRP, which are primarily based upon the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), have recently been revised to reflect the most up to date information on the effects of ionizing radiation (ICRP, 1990). The UNSCEAR and ICRP reports indicate that earlier reports underestimate the risk associated with radiation exposure. Most information on the effects of ionizing radiation on humans comes from the continuing assessment of the effects of the nuclear explosions at Nagasaki and Hiroshima, as well as from nuclear incidents such as the one at Chernobyl. In light of the revised recommendations from the ICRP, the World Health Organization (WHO) is currently revising its drinking water guidelines for radionuclides, and Canada is currently in the process of revising its CDWGs for radionuclides, including tritium.

This report summarizes the available information that is pertinent to revision of the Ontario Drinking Water Objective for tritium and proposes an interim ODWO for tritium. The rationale for the interim ODWO is based primarily on the information and recommendations provided by UNSCEAR, the ICRP, the WHO and the U.S. National Research Council's Committee on the Biological Effects of Ionizing Radiations (BEIR). A glossary of radiological terms has been included in Appendix A.

## 3.0 THE PROPERTIES OF TRITIUM

Tritium is a radioactive isotope of hydrogen and has one proton and two neutrons. Through the process of beta decay, tritium emits ionizing radiation in the form of a beta particle, or electron. All ionizing radiation is considered to be carcinogenic to humans, with the risk of developing cancer being proportional to the dose to the individual.

Tritiated and non-tritiated (i.e., normal) water have similar chemical and physical properties, and the human senses of smell, touch and taste are unable to distinguish tritiated from normal water.

Tritium is a naturally occurring radionuclide and may also be produced as a by-product in water-cooled nuclear reactors. Tritium undergoes beta decay with a physical half-life of 12.3 years. The beta particles are emitted in a continuous spectrum of energy, with the maximum energy being 18.6 kiloelectron volts (keV) and the average energy being 5.7 keV. The beta particle emitted has a range of approximately 6 millimetres (mm) in air and 0.0052 mm in a unit density material, which means, for example, that it is incapable of penetrating the outer layer of human skin.

Tritium may be taken into the body by inhalation or absorption through the skin. Once taken in, it is assumed that tritiated water is uniformly distributed among all the soft tissues in the body.

Ingested, tritiated water is believed to be completely and immediately absorbed from the gastrointestinal tract, mixing rapidly with the total body water. Once absorbed, the retention of tritiated water in the body is related to the natural turnover of body water, which is related to water intake, etc. Typically, the retention half-life is estimated to be ten days, but considerable variation can occur due to factors such as ambient temperature and personal habits.

In the natural environment and in drinking water treatment plants, tritiated water cannot be readily distinguished from other water. Consequently, conventional water treatment is unlikely to reduce tritium levels that are present in raw water supplies (see Appendix C).

## 4.0 TRITIUM: SOURCES AND OCCURRENCE

Tritium may be produced naturally in the upper atmosphere through the bombardment of nitrogen with neutrons from cosmic rays. Consequently, low levels of naturally-formed tritium exist in rainwater and surface waters. It is estimated that $10^{15}$ Bq of tritium are produced annually by natural processes (UNSCEAR, 1988).

Tritium is also produced in nuclear explosions, and nuclear weapons testing is the source of most of the tritium in the global environment. Tritium may also be released into the environment in emissions from nuclear energy production facilities, in particular from CANDU type water-cooled reactors.

## 5.0 EXPOSURE TO IONIZING RADIATION

The most comprehensive source of information on the overall exposure of the population to ionizing radiation is the United Nations Scientific Committee on the

Effects of Atomic Radiation (UNSCEAR). The 1988 UNSCEAR Report on Sources, Effects and Risks of Ionizing Radiation summarizes current knowledge on exposure to ionizing radiation.

## 5.1 Natural Sources of Radiation

Natural sources of radiation are, by far, the largest contributor to the overall exposure of the global population to ionizing radiation. Cosmic rays, gamma rays and naturally occurring radionuclides, such as the uranium-238 and thorium-232 decay series including radon, are believed to contribute more than 98% of the annual radiation dose (excluding medical exposure) to the population. UNSCEAR has estimated that the global average exposure to ionizing radiation from natural sources is 2.4 millisieverts (mSv) per year (see Appendix A for definitions of radiological terms).

A recent assessment of the average exposure of the U.S. population to ionizing radiation was made by the National Council on Radiation Protection and Measurements (NCRP, 1987). The NCRP estimated that annual exposure to natural background radiation in the U.S. exceeded the global average and totalled approximately 3 mSv per year. The increased exposure estimate is primarily due to exposure in homes to radon from natural geological sources.

## 5.2 Other Sources of Radiation

In addition to the natural sources of ionizing radiation, humans may also be exposed to radiation through medical procedures (e.g. diagnostic x-rays), occupational sources, environmental releases from nuclear power production etc.

Estimated annual radiation exposures from various sources are summarized in Table 1. Radon, a naturally occurring radioactive gas, is the principal source of radiation exposure, whereas tritium in drinking water comprises less than .1% of the total annual exposure to radiation (BEIR, 1990). Drinking water sources of radiation exposure are included under "consumer products" in this table.

Table 1 : Radiation Exposure from Various Sources

| Source | Estimated Annual Exposure | |
|---|---|---|
| | mSv | % of Total Annual Exposure |
| Natural Sources | 2.4[1] - 3.0[2] | 82% |
| Medical Exposures<br>a) x-rays<br>b) Nuclear Medicine | <br>0.4<br>0.14 | <br>11%<br>4% |
| Consumer Products (including food and drinking water) | 0.10 | 3% |
| 1 UNSCEAR, 1988<br>2 NCRP, 1987 | | |

## 6.0 HEALTH EFFECTS OF IONIZING RADIATION

Current knowledge on the health effects of ionizing radiation is summarized in the 1990 Report of the Committee on the Biological Effects of Ionizing Radiations (BEIR V, 1990). This Committee was established by the National Research Council in the United States to update the assessment on radiation effects published in 1980 (BEIR III, 1980).

Acute exposure to high levels of ionizing radiation may cause severe damage to bone marrow, gastrointestinal mucosa and other rapidly proliferating tissue. The degree of damage is dependent upon the magnitude of the dose and the duration of exposure. Acute radiation exposure is associated with nuclear accidents or explosions and is not relevant to the issue of long-term exposure to low levels of radionuclides in water.

Low doses of radiation may cause adverse effects in the genes and chromosomes of living cells. Where reproductive cells are affected by radiation, mutations may occur and adverse effects may be manifested in offspring. Adverse heritable effects from radiation exposure have been demonstrated in the mouse, but have not as yet been clearly demonstrated in humans.

Exposure to radiation may also result in the development of cancer. The carcinogenic potential of ionizing radiation is affected by such factors as the duration of exposure, the type of radiation, and the sensitivity of the tissue or organ irradiated. Some radionuclides concentrate in certain tissues (e.g., radioiodine in the thyroid gland), while other radionuclides, such as tritium, have no specific target tissue and are distributed throughout the body.

In general, it is assumed that the risk of cancer is proportional to the effective dose, and there is no "threshold" dose below which a cancer may not occur.

## 6.1 Assessing the Effective Dose of Radiation

Different types of radiation differ in their ability to cause adverse biological effects, and body tissues and organs have varying sensitivities to radiation. Consequently, in order to assess the relative impact of radiation on various biological receptors, the international scientific community has developed a system of radiation and tissue weighting factors in order that different radiation exposures may be readily compared and assessed. Through this approach, the effective dose of different radiation exposure scenarios can be estimated.

In this report, the effective dose is expressed in sieverts or millisieverts (1 Sv = 1000 mSv) and the amount of radioactivity is measured in becquerels in accordance with the current international system of units.

## 6.2 Estimation of the Risk Associated with Exposure to Ionizing Radiation

Assessment of the risk associated with exposure to radiation is an ongoing international effort. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and, in the United States, the National Research Council's Committee on the Biological Effects of Ionizing Radiations have prepared several comprehensive reports on the sources, effects and risks of ionizing radiation (UNSCEAR, 1988; UNSCEAR, 1986; UNSCEAR, 1982; BEIR V, 1990; BEIR III, 1980).

Both the UNSCEAR and BEIR reports focus primarily on information obtained from follow-up studies on the survivors of the Hiroshima and Nagasaki atomic explosions, as well as on studies of workers and patients exposed to ionizing radiation. Information available in the 1980s made it apparent that the radiation risk estimates that were available for the UNSCEAR, 1982 and BEIR III reports underestimated the risk associated with radiation exposure and required extensive revision. The UNSCEAR 1988 and BEIR V reports reflect this updated risk assessment.

The findings of the UNSCEAR and BEIR committees are used by international and national agencies as the basis for recommendations for radiation protection.

The International Commission on Radiological Protection (ICRP), and the National Council on Radiation Protection and Measurements (NCRP) in the United States, for example, provide recommendations to regulatory authorities based on the information in the UNSCEAR and BEIR reports.

In 1990, the ICRP issued its revised recommendations for radiation protection (ICRP, 1990). Based upon available information, the ICRP has estimated that the risk of developing a fatal cancer for the general population from radiation exposure is $5 \times 10^{-2}$ per sievert.

## 7.0 DRINKING WATER GUIDELINES FOR RADIONUCLIDES

### 7.1 World Health Organization Guidelines

In light of the additional information and recommendations that have been provided by the ICRP and UNSCEAR, the World Health Organization (WHO) is currently revising its recommendations with regard to radionuclides in drinking water.

In its new guidelines, the WHO recommends a reference level committed effective dose of 0.1 mSv from one year's consumption of drinking water, and notes that this dose represents less than 5% of the average annual effective dose attributable to natural background radiation (WHO Draft Guidelines). In calculating the reference level of dose, a water consumption estimate of 2 L per day for a year was assumed and the calculation was based on an adult's metabolism. The WHO states that the influence of age on metabolism, and variations in the consumption of drinking water, do not require modification of the reference level of dose as an appropriate margin of safety is provided in the calculations and the dose is based on a lifetime exposure.

For practical purposes, the reference level of dose needs to be expressed as an activity concentration of radionuclides in drinking water. Metabolic and dosimetric factors were considered in the development of dose conversion factors which relate a dose (in Sv) to the amount of radionuclide (in Bq) ingested.

The reference concentration of tritium that would correspond to the reference level of dose of 0.1 mSv was estimated by the WHO to be 7,800 Bq per litre(WHO, 1993, in press). The WHO applied dose-conversion factors that had been used by the National Radiological Protection Board of the United Kingdom (NRPB, 1991) in deriving the reference concentration for tritium. This reference concentration of 7,800 Bq/L for tritium is based upon the cancer risk associated with radiation exposure. The calculated cancer risk associated with the committed effective dose of 0.1 mSv is approximately $5 \times 10^{-6}$ (i.e., 5 fatal cancers per million people exposed). At this level of exposure, any cancers that may result from radionuclides in drinking water are not detectable or distinguishable from the normal cancer incidence. Cancers due to background radiation cannot be distinguished from other cancers and, since exposure to natural background radiation cannot be avoided, they are simply part of the natural cancer incidence.

## 7.2 Canadian Drinking Water Guidelines

The current Canadian Drinking Water Guidelines (CDWGs) for radionuclides, including tritium, are based primarily upon the information available in the 1970's from international sources including the ICRP and WHO.

The current CDWG for tritium is 40,000 Bq/L. Through Health & Welfare Canada, Canada has played an active role in the revision of the WHO guidelines. In light of the new information on radionuclides and the revision of the ICRP and

WHO recommendations, the CDWGs for radionuclides are currently being reviewed and revised through a formal federal-provincial process and are expected to be finalized in 1994. The new CDWGs are expected to reflect the WHO's recommendation of a reference level committed effective dose of 0.1 mSv from one year's consumption of drinking water.

7.3 Ontario Drinking Water Objectives

Ontario participates in the formal federal-provincial process that establishes the CDWGs and normally adopts new and revised CDWGs as Ontario Drinking Water Objective (ODWO).

The current ODWO of 40,000 Bq per litre is based upon the current CDWG for tritium. In effect, the ODWO for tritium and other radionuclides is being formally reviewed and revised through the federal-provincial process at this time. Revision of the CDWGs and ODWOs for radionuclides is expected to be completed in 1994.

Ontario has the perogative to establish ODWOs independently, where appropriate, and this document is in response to the Ministry of the Environment and Energy's commitment to review the current tritium guideline by the end of 1993.

7.4 United States Environmental Protection Agency Limits

The EPA has proposed the establishment of a maximum contaminant level (MCL) of 4 millirems effective dose equivalent per year for beta-emitting radionuclides. This would be equivalent to approximately 2300 Bq per litre of tritium. This proposed MCL is currently being reviewed and assessed.

An assessment of the rationale and policies supporting the proposed EPA standard for tritium is beyond the scope of this document.

7.5 Calculation of an Interim Ontario Drinking Water Objective for Tritium

Based upon the recommendations of the ICRP and WHO, an interim drinking water objective for tritium may be calculated as follows:

$$\text{Interim Objective Concentration} = \frac{0.1\ \text{mSv/yr}}{730\ \text{L/yr} \times \text{dose conversion factor (Sv/Bq)}}$$

where 730 L/yr is the annual consumption of drinking water (assuming 2.0 L/day)

0.1 mSv/yr is the permissible exposure to radionuclides from drinking water

dose conversion factor, as provided by the National Radiological Protection Board (NRPB, 1991) and by the WHO for tritium, = $1.8 \times 10^{-11}$ (Sv/Bq)

Based upon the above, the interim objective concentration for tritium that would result in 0.1 mSv exposure per year from drinking water is approximately 7,600 Bq/L.

In its most recent publication (Publication 61), the ICRP applies a different dose conversion factor for tritium that, if substituted into the above calculation, would result in an interim objective concentration for tritium of approximately 6,850 Bq/L (ICRP, 1991). Since an evaluation of the different dose conversion factors is beyond the scope of this document, and taking into account the appropriateness of using just one significant digit when dealing with scientific estimates of this nature, it is proposed that the interim Ontario Drinking Water Objective for tritium be established at 7,000 Bq per litre.

Where more than one radionuclide is present in a drinking water supply, drinking water objective concentrations may need to be adjusted such that the total exposure from all radionuclides in a drinking water supply does not result in an average annual exposure in excess of the committed effective dose of 0.1 mSv/yr. The testing of drinking water supplies for radionuclides includes, in addition to testing for tritium, an assessment of the gross alpha and beta emissions from various radionuclides. Where significant alpha and/or beta activity is detected, it is necessary to identify the specific radionuclides involved, to measure their individual activity concentrations, and to determine the effective dose from each of these radionuclides by applying the appropriate dose conversion factors.

The committed effective dose from all radionuclides in drinking water should not exceed 0.1 mSv per year.

## 8.0 THE NATURE AND APPLICATION OF DRINKING WATER GUIDELINES

### 8.1 WHO Guidelines

The World Health Organization (WHO) first published Guidelines for Drinking Water Quality in 1984 (WHO, 1984). The guidelines were developed by the WHO to describe the quality of water that is suitable for drinking purposes under all circumstances. As such, the WHO described the derived guideline values as follows:

a) A guideline value represents the concentration of a constituent that ensures an aesthetically pleasing water and does not result in any significant risk to the health of the consumer;

b) The quality of water defined by the WHO guidelines is such that it is suitable for human consumption and for all normal domestic purposes;

c) Exceedence of a guideline value should be considered a signal to investigate the course of the exceedence with the purpose of determining the appropriate remedial action, and to consult with public health authorities for advice;

d) The guidelines were derived to describe a quality of water that would be acceptable for, and would safeguard health during, lifelong consumption;

e) Short-term deviations above the guideline values do not necessarily mean the water is unfit for consumption. The amount by which, and the duration that, any guideline value can be exceeded without affecting public health depends upon the specific substance involved;

f) In the case of radioactive substances, the term guideline value is used in the sense of a "reference level", as defined by the ICRP, where a reference level is not specifically a limit but is a signal to pursue certain courses of action, such as investigation of the cause or implications of the elevated level; and

g) A value in excess of the guideline value does not in itself imply that the water is unsuitable for consumption.

## 8.2 Canadian Drinking Water Guideline (CDWGs)

The Guidelines for Canadian Drinking Water Quality (Health and Welfare, Canada, 1993(b)) indicate that the CDWGs are to be applied in a similar fashion to the WHO guidelines.

Similarly to the WHO, the CDWGs are intended to provide guidance as to the acceptability of drinking water supplies. The judicious use of the guidelines e.g., investigating exceedences, taking remedial action where appropriate, will result in drinking water that is protective of public health.

## 8.3 Ontario Drinking Water Objectives (ODWOs)

Ontario Drinking Water Objectives are applied in a similar fashion to the Canadian Drinking Water Guidelines. They provide guidance as to the acceptability of public drinking water supplies and water supplies that meet these objectives are protective of human health.

It should be noted that the assessment of the acceptability of a water supply during a specific nuclear emergency (e.g., a large spill of tritium) that may lead to significantly elevated tritium levels in drinking water supplies, is primarily the responsibility of the local Medical Officer of Health and the Ministry of the Solicitor General. Through Ontario's Nuclear Emergency Response Plan, the Ministry of the Solicitor General, in cooperation with public health authorities and other agencies, would coordinate the appropriate response to any nuclear accident.

## 9.0 TRITIUM IN DRINKING WATER IN ONTARIO

Through its Drinking Water Surveillance Program (DWSP), the Ontario Ministry of Environment and Energy now surveys more than 100 water supply systems annually for radionuclides and other contaminants in water. Both raw and treated water are analyzed. Tritium data from the DWSP are summarized in Appendix E.1.

In addition to DWSP, the MOEE also runs surveillance programs in the vicinity of nuclear generating stations in Ontario. Part of this nuclear surveillance program involves regular testing of water supplies at nearby water treatment plants. Drinking water data for tritium from this program, for 1991, are summarized in Appendix E.2.

All radionuclide analysis is conducted by the Ontario Ministry of Labour's Radiation Protection Laboratory. A brief description of the analytical method is given in Appendix D.

## 10.0 SOCIO-ECONOMIC IMPACT OF REVISED DRINKING WATER OBJECTIVE FOR TRITIUM

As summarized in Section 9.0 and Appendix E, the levels of tritium in drinking water supplies in Ontario rarely exceed 100 Bq/L. Consequently, revision of the current ODWO of 40,000 Bq/L to an interim ODWO of 7,000 Bq/L would not be anticipated to have any major socio-economic impact in normal situations.

In emergency situations (e.g., spill of nuclear material), the provincial response would be directed by the Ministry of the Solicitor General under its Nuclear

Emergency Plan for Ontario. Under this plan, the response of various Ministries (e.g., Ministry of Environment and Energy, Ministry of Labour, Ministry of Agriculture and Food, Ministry of Health) would be coordinated by the Ministry of the Solicitor General. Additional support and advice would be sought from Federal Departments such as Health & Welfare Canada, and guidance as to the acceptability of water supplies would be provided by the appropriate medical officer of health for the affected area. During an emergency situation, it may be necessary to consider other sources of exposure (e.g., contaminated food) in addition to drinking water, and the duration of exposure would also need to be considered. Consequently, emergency response guidance would be provided on a case-by-case basis, and assessment of the socio-economic impact of such an event is beyond the scope of this document.

## 11.0 PROPOSED INTERIM DRINKING WATER OBJECTIVE FOR TRITIUM

For the reasons provided in this report, it is recommended that the current ODWO of 40,000 becquerels/litre for tritium be replaced by an interim ODWO for tritium of 7,000 becquerels per litre. This interim objective is a health-related maximum acceptable concentration and should be applied as such until the CDWGs for radionuclides, including tritium, are revised. Once the CDWGs for radionuclides are revised, this interim objective should be reviewed.

# APPENDIX A : GLOSSARY

Absorbed Dose

The mean energy imparted by ionizing radiation to an irradiated medium per unit mass. The international unit for absorbed dose is the gray (Gy). Absorbed dose was previously expressed in rads (Radiation Absorbed Dose) where 1 rad equals 0.01 Gy.

Activity

The rate of decay (i.e., number of disintegrations or transformations per unit time) of a radioactive nuclide. The international unit of activity is the becquerel (Bq).

Alpha Particles

Fast moving helium nuclei (consisting of two protons and two neutrons) that are emitted from certain radioactive isotopes during decay or disintegration. Alpha particles are densely ionizing with little penetrating power.

Background Radiation

The amount of radiation to which a member of the population is exposed from natural sources including terrestrial radiation due to naturally occurring radionuclides in the soil and cosmic radiation originating in outer space.

Beta Particles

Fast moving electrons ejected from the nuclei of certain unstable radioactive atoms (e.g. tritium). Beta particles are not densely ionizing.

BEIR

The U.S. National Research Council's Committee on Biological Effects of Ionizing Radiation.

Becquerel (Bq)

International unit of measurement of the activity of a radioactive nuclide. One becquerel corresponds to one atomic transformation or disintegration per second and is equivalent to $2.7 \times 10^{-11}$ Curies.

Carcinogen

An agent that may cause cancer. Ionizing radiation is a carcinogen.

Committed Effective Dose

The time integral of the effective dose, where the integration time is usually 50 years.

Curie (Ci)

A unit of activity equal to $3.7 \times 10^{10}$ disintegrations per second.

Dose Equivalent

A measurement that relates absorbed dose with the biological effectiveness (i.e. probability of causing biological damage) of all kinds of ionizing radiation. Dose equivalents are calculated by multiplying the absorbed dose by a quality factor that accounts for differences between different types of radiation. The international unit of dose equivalents is the sievert (Sv).

Effective Dose Equivalent

A measurement that relates the absorbed dose and dose equivalent to the risk of biological damage, taking into account the varying degrees of sensitivity of particular tissues and organs to radiation damage. In order to assess effective dose equivalents, tissue weighting factors have been developed by organizations such as the ICRP.

Gamma Rays

Short-wave electromagnetic radiation that is not densely ionizing but possesses high penetrating ability. It can easily penetrate and pass through a human body. Used in certain medical procedures (e.g. cancer therapy), they are more energetic than x-rays.

Gray

The international unit of absorbed dose where one gray equals one joule per kilogram, and one gray equals 100 rad.

ICRP

International Commission on Radiation Protection

Ionizing Radiation

Radiation that is capable of producing ions (particles with an electric charge) by dislodging electrons from an atom.

Maximum Acceptable Concentration (MAC)

A MAC is a type of Drinking Water Objective that is established for certain substances that are known or suspected to cause adverse effects on health. Each MAC has been derived to safeguard health assuming lifelong consumption of drinking water containing the substance at that concentration.

Drinking water that continually contains a substance at a level greater than its MAC will contribute significantly to consumers' exposure to the substance and may, in some instances, induce deleterious effects on health. However, short-term excursions above the MAC do not necessarily mean that the water constitutes an undue risk to health. The amount by which, and the period for which, the MAC can be exceeded without posing a health risk must be assessed by taking into account the toxicity of the substance involved.

Neutron Radiation

Neutrons are uncharged subatomic particles that are capable of producing ionization in matter by collision with charged particles. One of the sources of neutron radiation is the fission process in nuclear reactors and this is often used to create radioactive isotopes.

Rad

A unit of absorbed dose, now replaced in international units by the gray, where one rad equals 100 erg/g, which equals 0.01 gray.

Radioactivity

The spontaneous emission of radiation, in the form of alpha particles, beta particles etc.

Relative Biological Effectiveness

The biological potency of one type of radiation as compared with another to produce equivalent biological damage.

Rem

A measure of dose equivalent (1 rem = 0.01 Sv).

Sievert

The international unit of dose equivalents, equal to 100 rem or 1000 millisieverts.

UNSCEAR

United Nations Scientific Committee on the Effects of Atomic Radiation. UNSCEAR publishes periodic reports on sources and effects of ionizing radiation.

X-Rays

Penetrating electromagnetic radiation that is artificially produced by specific devices. X-rays resemble gamma rays but are less energetic.

## APPENDIX B : LONG-TERM VS SHORT-TERM EXPOSURE TO RADIONUCLIDES

As part of the recommendation from the Environmental Assessment Advisory Board to the Minister of Environment (and Energy) to review the guideline for tritium in drinking water, the Ministry was also requested to address the issue of the effects of long-term exposure to low levels of radionuclides and of short-term exposure to sudden elevated levels in drinking water.

The proposed interim drinking water objective for tritium of 7000 Bq/L addresses the issue of long-term exposure to low levels of radionuclides. Drinking water containing 7000 Bq/L of tritium would lead to an annual exposure of 0.1 mSv, approximately 4% of the annual background exposure to radiation in Ontario. Exposure to 1000 mSv of radiation at one time might result in nausea and vomiting in the short term, but such exposures would not be encountered in drinking water supplies, (i.e., in order to be exposed to 1000 mSv of radiation from tritium in a day, assuming 2 L of water is consumed, the tritium concentration in the drinking water would need to be approximately $2.8 \times 10^{10}$ Bq/L (or 28 billion becquerels/L).

# APPENDIX C : REMOVAL OF TRITIUM FROM DRINKING WATER: TREATMENT OPTIONS

Very little information is available on the efficacy of various water treatment processes with regard to the removal of tritium from water supplies.

Conventional treatment (e.g., coagulation/sedimentation) is believed to be of limited effectiveness for the removal of tritium from water (Health & Welfare Canada, 1993(a)).

While air stripping, adsorption and ion exchange technologies may be effective technologies for the removal of tritium, these technologies have not been adequately assessed with respect to tritium removal (Health & Welfare Canada, 1993(a)). Consequently, the U.S. Environmental Protection Agency recommends the use of alternate water supplies (including bottled water) when drinking water supplies are excessively contaminated with tritium (Federal Register, V.56, No. 138; July 18, 1991).

## APPENDIX D : ANALYSIS OF TRITIUM IN DRINKING WATER

The analysis of tritium in drinking water is conducted by the Radiation Protection Service Laboratory (RPSL) of the Ontario Ministry of Labour.

The procedure used for the determination of tritium in water begins with the distillation of the samples. The middle fraction of the distillate is combined with a liquid scintillation cocktail and counted in a Liquid Scintillation Counter. Normal reported detection limits are approximately 7 Bq per litre.

# APPENDIX E : TRITIUM IN ONTARIO DRINKING WATER

## APPENDIX E.1 : Drinking Water Surveillance Program - Tritium Results (Bq/l)

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| AJAX WTP | 12-Mar-91 | 130 | 30 |
| | 12-May-92 | 16 | 12 |
| ALEXANDRIA WTP | 28-Sep-92 | < 7 (a) | < 7 |
| ALVINSTON WTP | 18-Feb-91 | < 9 | < 9 |
| | 19-Aug-91 | <10 | <10 |
| | 21-Oct-91 | < 9 | < 9 |
| | 22-Jun-92 | < 7 | < 7 |
| AMHERSTBURG WSS | 18-Mar-91 | < 9 | |
| | 20-Mar-91 | | 10 |
| | 16-Sep-91 | <10 | <10 |
| | 16-Mar-92 | < 9 | |
| | 18-Mar-92 | | < 9 |
| | 22-Sep-92 | < 7 | |
| | 24-Sep-92 | | < 7 |
| ATIKOKAN WTP | 26-Mar-91 | <11 | <11 |
| | 23-Sep-91 | 8 | 10 |
| | 23-Mar-92 | < 9 | < 9 |
| | 25-May-92 | < 6 | 7 |
| BEAVERTON WTP | 18-Feb-92 | < 9 | < 9 |
| BELLE RIVER WTP | 18-Feb-91 | < 9 | < 9 |
| | 16-Sep-91 | <10 | <10 |
| | 21-Apr-92 | 55 | < 8 |
| BELLEVILLE WTP | 02-Jul-91 | <10 | <10 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| | 04-Nov-91 | < 9 | < 9 |
| | 06-Apr-92 | < 9 | < 9 |
| BRACEBRIDGE LEADER SPRING | 23-Sep-91 | 14 | 10 |
| BRACEBRIDGE WTP | 23-Sep-91 | < 8 | 8 |
| | 24-Feb-92 | < 9 | < 9 |
| | 25-May-92 | | 7 |
| BRANTFORD WTP | 25-Feb-91 | 11 | 9 |
| | 26-Aug-91 | | <20 |
| | 23-Sep-91 | | < 8 |
| | 25-May-92 | 9 | 7 |
| BROCKVILLE WTP | 19-Feb-91 | 9 | < 9 |
| | 17-Sep-91 | <10 | <10 |
| | 21-Apr-92 | 22 | 12 |
| BURLINGTON WTP | 04-Feb-91 | 11 | 15 |
| | 06-Aug-91 | <10 | 13 |
| | 07-Oct-91 | 12 | 15 |
| | 01-Jun-92 | 15 | 12 |
| CAMBRIDGE WELL SUPPLY(G3,MIDDLETON ST) | 21-Jan-92 | < 9 | 10 |
| CASSELMAN WTP | 04-Feb-91 | 18 | <16 |
| | 03-Sep-91 | <10 | <10 |
| | 06-Apr-92 | < 9 | < 9 |
| CAYUGA WTP | 04-Mar-91 | < 9 | < 9 |
| | 05-Sep-91 | 9 | < 8 |
| | 04-May-92 | < 8 | < 8 |

| PLANT | DATE | RAW WATER | TREATED WATER |
| --- | --- | --- | --- |
| CHAPLEAU WTP | 18-Apr-91 | <11 | <11 |
| | 23-Sep-91 | < 8 | < 8 |
| | 03-Dec-91 | < 8 | |
| | 24-Feb-92 | < 9 | < 9 |
| | 28-Sep-92 | < 7 | < 7 |
| CHARLOTTENBURG WTP | 19-Jun-91 | 15 | <10 |
| | 22-Oct-91 | < 9 | < 9 |
| | 21-Jan-92 | < 9 | < 9 |
| | 18-Aug-92 | 9 | 11 |
| CHATHAM WTP | 04-Feb-91 | <12 | |
| | 05-Feb-91 | | 12 |
| | 06-Aug-91 | <11 | |
| | 07-Aug-91 | | <11 |
| COBOURG WTP | 21-Oct-91 | < 9 | < 9 |
| CORNWALL WTP | 18-Mar-91 | 10 | 10 |
| | 23-Sep-91 | 8 | 11 |
| | 21-Sep-92 | < 7 | < 7 |
| DELHI SPRING SUPPLY | 04-Mar-91 | < 9 | < 9 |
| | 07-Oct-91 | < 8 | |
| | 06-Jan-92 | < 8 | < 8 |
| | 08-Sep-92 | < 7 | < 7 |
| DELHI WTP | 04-Mar-91 | < 8 | < 8 |
| | 07-Oct-91 | < 8 | < 8 |
| | 06-Jan-92 | < 8 | < 8 |
| | 06-Jul-92 | < 7 | < 7 |
| DESERONTO WTP | 06-Aug-91 | 11 | <11 |
| | 04-Nov-91 | 9 | < 9 |
| | 02-Mar-92 | 9 | < 9 |

| PLANT | DATE | RAW WATER | TREATED WATER |
| --- | --- | --- | --- |
| DRESDEN WTP | 11-Feb-91 | 9 | 9 |
| | 10-Jun-91 | 10 | <10 |
| | 12-Aug-91 | <11 | 12 |
| | 04-May-92 | < 8 | < 8 |
| DRYDEN WTP | 25-Mar-91 | <11 | <11 |
| | 27-Jan-92 | < 8 | < 8 |
| DUNNVILLE WSS (INDUSTRIAL WATER) | 12-Aug-91 | <10 | |
| | 08-Jun-92 | 10 | |
| DUNNVILLE WTP | 11-Feb-91 | <16 | 16 |
| | 12-Aug-91 | <10 | <10 |
| | 08-Jun-92 | 6 | < 6 |
| EMO WTP | 10-Jun-91 | <10 | <10 |
| | 16-Jul-91 | <11 | <11 |
| | 12-Nov-91 | < 8 | |
| | 13-Nov-91 | | < 8 |
| | 10-Feb-92 | < 9 | |
| | 11-Feb-92 | | < 9 |
| | 13-Oct-92 | < 7 | |
| | 14-Oct-92 | | < 7 |
| FORT ERIE (ROSEHILL) WTP | 10-Jun-91 | <10 | <10 |
| | 07-Oct-91 | 10 | 10 |
| | 09-Mar-92 | < 9 | < 9 |
| FORT FRANCES WTP | 25-Feb-91 | < 8 | < 8 |
| | 28-Sep-92 | < 7 | < 7 |
| GODERICH WTP | 06-Apr-92 | < 8 | < 9 |
| | 08-Sep-92 | < 7 | < 7 |
| GRAVENHURST WTP | 18-Mar-91 | 10 | 9 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| | 16-Sep-91 | <10 | <10 |
| | 21-Oct-91 | < 9 | < 9 |
| | 17-Feb-92 | < 9 | < 9 |
| GRIMSBY WTP | 18-Nov-91 | < 8 | 11 |
| | 21-Apr-92 | 12 | < 8 |
| HALDIMAND/NORFOLK WSS | 04-Feb-91 | 11 | |
| | 06-Feb-91 | | < 8 |
| | 03-Sep-91 | <10 | <10 |
| | 06-Apr-92 | < 9 | |
| | 08-Apr-92 | | < 9 |
| HAMILTON WSS | 25-Nov-91 | < 8 | < 8 |
| | 22-Jun-92 | 12 | 9 |
| HARROW-COLCHESTER WSS | 25-Mar-91 | 11 | |
| | 26-Mar-91 | | < 9 |
| | 27-Jan-92 | 9 | |
| | 28-Jan-92 | | < 8 |
| HAWKESBURY WTP | 11-Feb-91 | <18 | <18 |
| | 12-Nov-91 | 9 | 9 |
| | 13-Apr-92 | 9 | < 8 |
| JOHNSON ST WELL, BARRIE | 10-Mar-92 | <18 | |
| KENORA WTP | 25-Feb-91 | < 9 | < 9 |
| | 26-Aug-91 | <10 | <10 |
| | 22-Jun-92 | < 7 | < 7 |
| KINGSTON WTP | 10-Jun-91 | 11 | 11 |
| | 04-Nov-91 | < 9 | < 9 |
| | 06-Apr-92 | 13 | < 9 |
| | 06-Jul-92 | < 7 | < 7 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| KITCHENER (STRANGE STREET RESERVOIR) | 16-Jul-91 | | <11 |
| KITCHENER WELL SUPPLY | 16-Jul-91 | <11 | <11 |
| LINDSAY WTP | 25-Feb-91 | 16 | 14 |
| | 09-Sep-91 | <10 | <10 |
| | 28-Oct-91 | < 9 | 9 |
| | 25-May-92 | 15 | 16 |
| LONDON (LAKE HURON) WSS | 18-Nov-91 | 9 | 9 |
| | 15-Jun-92 | 10 | 15 |
| MANITOUWADGE WELL SUPPLY(WELL1,3,RES) | 28-May-91 | 11 | <10 |
| | 28-Jan-92 | < 8 | < 8 |
| MARATHON WELL SUPPLY | 22-May-91 | <10 | <10 |
| METRO TORONTO (F.J. HORGAN) WSS | 17-Jun-91 | <10 | <10 |
| | 15-Jun-92 | 12 | < 6 |
| METRO TORONTO (R. L. CLARK) WTP | 17-Jun-91 | 12 | 17 |
| | 19-May-92 | 17 | 15 |
| METRO TORONTO (ISLAND) WTP | 19-May-92 | 14 | 17 |
| MITCHELLS BAY WTP | 19-Aug-91 | <10 | <10 |
| | 17-Feb-92 | < 9 | |
| | 19-Feb-92 | | < 9 |
| | 17-Aug-92 | 11 | 8 |
| NAPANEE WTP | 27-May-91 | <11 | <11 |
| | 22-Jun-92 | < 7 | 12 |
| NIAGARA FALLS WTP | 13-May-91 | <10 | <10 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| | 09-Sep-91 | <10 | <10 |
| | 11-May-92 | < 9 | < 9 |
| NIPIGON WTP | 27-May-91 | <10 | <10 |
| | 24-Feb-92 | < 9 | < 9 |
| | 27-Jul-92 | < 6 | 7 |
| NORTH BAY WTP | 18-Jun-91 | <10 | <10 |
| | 28-Oct-91 | < 9 | < 9 |
| | 22-Jun-92 | < 7 | < 7 |
| OAKVILLE WTP | 13-May-91 | <10 | <10 |
| | 09-Sep-91 | <10 | <10 |
| | 13-Jan-92 | < 9 | < 9 |
| | 13-Oct-92 | < 7 | < 7 |
| ODESSA WTP | 22-Apr-91 | <11 | <11 |
| | 26-Aug-91 | <10 | <10 |
| | 28-Oct-91 | < 9 | < 9 |
| | 28-Apr-92 | < 8 | < 8 |
| ORANGEVILLE WELL SUPPLY | 05-Oct-92 | < 7 | < 7 |
| OSHAWA WSS | 12-Mar-91 | 28 | 17 |
| | 09-Jul-91 | 19 | 14 |
| | 14-Jan-92 | 14 | 13 |
| | 13-Oct-92 | 9 | 7 |
| OTTAWA (BRITANNIA) WSS | 26-Aug-91 | 13 | 14 |
| | 24-Feb-92 | < 9 | |
| OTTAWA (LEMIEUX ISLAND) WSS | 24-Jun-91 | 37 | 37 |
| | 26-Nov-91 | < 8 | < 8 |
| | 23-Mar-92 | < 9 | < 9 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| OWEN SOUND (RICHARD H. NEATH) WTP | 24-Jun-91 | <10 | <10 |
| | 28-Apr-92 | < 8 | 11 |
| PEMBROKE WTP | 09-Mar-92 | < 9 | < 9 |
| | 14-Sep-92 | 13 | 13 |
| PERTH WTP | 04-May-92 | < 8 | 17 |
| PETERBOROUGH WSS | 10-Jun-91 | <10 | <10 |
| | 15-Oct-91 | 9 | < 8 |
| | 08-Jun-92 | 7 | 7 |
| | 10-Aug-92 | < 6 | 8 |
| PICTON WTP | 13-Jan-92 | < 9 | < 9 |
| | 13-Oct-92 | < 7 | < 7 |
| PLANTAGENET WTP | 13-May-91 | <10 | |
| | 09-Sep-91 | <10 | <10 |
| | 27-Apr-92 | < 8 | < 8 |
| | 08-Jun-92 | < 6 | < 6 |
| PORT COLBORNE WTP | 04-Mar-91 | < 8 | 10 |
| | 05-Aug-91 | <10 | |
| | 06-Aug-91 | | <10 |
| | 13-Jul-92 | < 7 | < 7 |
| PORT DOVER (DOANS HOLLOW) SPRING SUPPLY | 22-Jul-91 | <11 | 12 |
| PORT DOVER WSS | 22-Jul-91 | 13 | 11 |
| PORT ELGIN WTP | 04-May-92 | 16 | 17 |
| | 05-Aug-92 | 14 | 16 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| PORT HOPE WTP | 04-Mar-91 | < 8 | 13 |
| | 28-Oct-91 | < 9 | < 9 |
| | 23-Mar-92 | 10 | 12 |
| PORT STANLEY WTP | 24-Jun-91 | <10 | <10 |
| | 23-Mar-92 | < 9 | < 9 |
| PRESCOTT WTP | 19-Aug-91 | <10 | <10 |
| | 16-Mar-92 | < 9 | |
| RAINY RIVER WTP | 10-Jun-91 | <10 | |
| | 11-Jun-91 | | <10 |
| | 13-Nov-91 | < 8 | < 8 |
| | 13-Apr-92 | < 8 | |
| | 14-Apr-92 | | < 8 |
| RED ROCK | 18-Jun-91 | <10 | <10 |
| | 24-Mar-92 | < 9 | < 9 |
| RENFREW WTP | 08-Apr-91 | <11 | 11 |
| | 15-Oct-91 | < 8 | < 8 |
| | 13-Apr-92 | 9 | < 8 |
| ROCKLAND WTP | 11-Feb-91 | 18 | <18 |
| | 12-Aug-91 | 16 | 15 |
| | 13-Jan-92 | < 9 | 10 |
| SARNIA (LAMBTON COUNTY) WTP | 03-Jul-91 | | <10 |
| | 04-Nov-91 | < 9 | |
| | 05-Nov-91 | | < 9 |
| | 03-Feb-92 | < 9 | |
| | 04-Feb-92 | | < 9 |
| | 04-Aug-92 | 8 | 10 |
| SAULT STE MARIE (GOULAIS WELL) | 10-Feb-92 | < 9 | < 9 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| SAULT STE MARIE (LORNA WELL) | 08-Jul-91 | <11 | <11 |
| | 11-May-92 | < 9 | < 9 |
| SAULT STE MARIE (SHANNON WELL) | 11-May-92 | < 9 | < 9 |
| SAULT STE MARIE (STEELTON WELL) | 08-Jul-91 | <11 | <11 |
| SAULT STE MARIE WTP | 08-Jul-91 | <11 | <11 |
| SMITH FALLS WTP | 15-Oct-91 | < 8 | < 8 |
| | 13-Jan-92 | < 9 | < 9 |
| | 14-Sep-92 | < 6 | < 6 |
| SOUTH PEEL (LAKEVIEW) WSS | 02-Jul-91 | <10 | <10 |
| SOUTH PEEL (LORNE PARK) WSS | 12-Aug-91 | <11 | |
| ST CATHARINES (DE CEW) WSS | 18-Mar-91 | 9 | < 9 |
| | 16-Sep-91 | <10 | <10 |
| | 20-Jan-92 | < 9 | < 9 |
| ST THOMAS (ELGIN) WSS | 02-Jul-91 | <10 | <10 |
| | 04-Nov-91 | < 9 | < 9 |
| | 06-Jan-92 | < 8 | 9 |
| | 06-Jul-92 | < 7 | < 7 |
| STONEY POINT (TILBURY NORTH) WSS | 22-Jul-91 | 11 | 11 |
| | 27-Apr-92 | < 8 | < 8 |
| STOUFFVILLE WELL SUPPLY | 20-Aug-91 | <10 | <10 |
| STRATFORD WELL SUPPLY | 13-Jul-92 | <42 | < 7 |
| SUDBURY (DAVID ST) WTP | 05-Jun-91 | <11 | <11 |
| | 06-Jan-92 | < 8 | < 8 |
| | 08-Jul-92 | < 7 | < 7 |
| SUDBURY (WANAPITEI) WSS | 04-Jun-91 | <11 | |
| | 05-Jun-91 | | <11 |
| | 06-Jan-92 | < 8 | < 8 |
| | 08-Jul-92 | < 7 | < 7 |
| TECUMSEH WTP | 19-Aug-91 | <10 | <10 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| | 20-Jul-92 | 7 | < 6 |
| TERRACE BAY | 21-May-91 | <10 | <10 |
| | 23-Apr-92 | < 8 | < 8 |
| THAMESVILLE WELL SUPPLY | 16-Apr-91 | <11 | <11 |
| | 21-Oct-91 | < 9 | < 9 |
| | 20-Jul-92 | < 6 | < 6 |
| THUNDER BAY (BARE POINT) WTP | 08-Apr-91 | <11 | <22 |
| | 15-Oct-91 | < 8 | < 8 |
| THUNDER BAY (LOCH LOMOND) WTP | 08-Apr-91 | <11 | <11 |
| TILBURY WTP | 15-Jul-91 | <11 | <11 |
| | 17-Feb-92 | < 9 | < 9 |
| | 17-Aug-92 | 11 | 8 |
| TRENTON (CHESTER ROAD) WTP | 03-Jun-91 | <11 | <11 |
| TRENTON SPRING SUPPLY | 03-Jun-91 | <11 | <11 |
| UNION WSS | 06-Aug-91 | <10 | <10 |
| | 07-Oct-91 | 10 | |
| | 08-Oct-91 | | 10 |
| WALLACEBURG WTP | 13-May-91 | <10 | |
| | 14-May-91 | | <10 |
| | 09-Sep-91 | <10 | <10 |
| | 08-Jun-92 | 7 | 8 |
| | 17-Aug-92 | 11 | 8 |
| WALPOLE ISLAND WTP | 02-Jul-91 | <11 | 15 |
| | 03-Sep-91 | <10 | <10 |
| | 07-Jul-92 | 8 | |
| | 08-Jul-92 | | < 7 |
| WATERLOO WELL SUPPLY (W7,ERB ST RES) | 16-Jul-91 | | <11 |

| PLANT | DATE | RAW WATER | TREATED WATER |
|---|---|---|---|
| | 22-Jul-92 | < 6 | < 6 |
| WATERLOO WELL SUPPLY(W2,WILLIAM ST RES) | 16-Jul-91 | <11 | <11 |
| | 21-Jul-92 | < 6 | 10 |
| WELLAND WSS | 02-Sep-91 | <10 | <10 |
| | 03-Feb-92 | < 9 | < 9 |
| | 04-Aug-92 | 6 | < 6 |
| WINDSOR WSS | 17-Jun-91 | <10 | |
| | 18-Jun-91 | | <10 |
| | 12-Nov-91 | <10 | |
| | 13-Nov-91 | | < 8 |
| | 08-Jun-92 | 8 | 9 |
| | 10-Aug-92 | 7 | |
| | 11-Aug-92 | | 9 |

(a) < = less than

APPENDIX E.2 : 1991 TRITIUM DATA - NUCLEAR SURVEILLANCE PROGRAM

| PLANT | Range (Bq/l) in Treated Water |
|---|---|
| AJAX WTP | < 9 - 50 |
| AMHERSTBURG WTP | < 8 - 34 |
| BOWMANVILLE WTP | < 9 - 27 |
| DEEP RIVER | < 8 - 12 |
| HARROW-COLCHESTER | < 8 - 12 |
| KINCARDINE PUC | < 8 - 25 |
| NEWCASTLE | < 8 - 24 |
| OSHAWA WTP | < 9 - 36 |
| PETAWAWA | < 9 - 370 |
| PEMBROKE | < 9 - 270 |
| PICKERING | 17 - 21 |
| TORONTO | < 8 - 57 |
| WARKWORTH | < 9 |
| WHEATLEY WTP | < 9 - 11 |
| WHITBY WTP | < 8 - 36 |
| VERNEER WTP | < 10 |

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