Chemistry - PI 24

ENVIRONMENTAL MONITORING - RADIOLOGICAL EMISSIONS

Objectives:

1. In your own words define or describe the term "Derived Emission Limit". This description should centre on:

   (i) Types of releases, eg, controlled or failure.
   (ii) Pathways to man.
   (iii) Basis for limits, ie, dose received by the critical group.

2. State that the monitored radiological emissions fall in the following categories:

   (a) Airborne - Tritium
   - Noble Gases
   - Iodine-131
   - Particulate.

   (b) Liquid - Tritium
   - gross β, γ.

   and that the NGD target is 1% of the DEL in each case.

3. Given access to suitable data (reference #2), prepare a worksheet showing the DEL for each of the items for objective #2 above, for the station to which the trainee has been deployed. Note the target and performance and briefly discuss any highlights or abnormalities.

References:

1. Basis for the Derived Limits for the Release of Radionuclides in Gaseous and Liquid Effluents from Ontario Hydro's Nuclear Stations. K.W. Wong, H.P.D.-73-6 August 1974.

2. NGD Annual Environmental Summary, 1980 (or current); Environmental Protection Section, RMEP.

3. Provided as a text for this module is a summary of reference #1 prepared by Health and Safety Division.

Here's What To Do:

1. Peruse the references paying particular attention to the station to which you have been deployed.

2. Do the practice exercises on worksheet #1. Check your results with a colleage.

3. Fill in the data plus comments on worksheet #2 for the station to which you have been deployed. (If not deployed to a station, choose Pickering or Bruce). Explain this worksheet to the course manager and have him initial the sheet.

DERIVED EMISSION LIMITS

1. Introduction

The operation of a nuclear power station may result in small amounts of radioactive materials, in the form of activation and fission products, being dispersed to the environment. The Atomic Energy Control Board prescribes, in the operating license of a station, maximum limits for the radioactivity that may be released in the station effluents.

In practice, the very small doses from nuclear plants are barely measurable, so the regulations are translated into derived emission limits (DEL's) for specific radionuclides. The quantities of radionuclides released must be monitored to ensure that they remain within these limits.

This lesson summarizes the basis for the derived limits for the release of radionuclides in gaseous and liquid effluents. These Derived Emission Limits (DEL's) apply to the total release resulting from controlled short-term releases; and from short-term releases resulting from failures of process equipment.

The emission limits are derived from the maximum radiation doses permitted to members of the public as recommended by the International Commission on Radiological Protection. For gaseous emissions, the limits are such that if the release were continued for the whole year, the dose received by someone spending the full year at the station boundary would not exceed the dose limit. Any circumstances which could concentrate the radioactive material or increase the dose are taken into account. The limits for liquid effluents are based on a person not only drinking the undiluted effluent, but also eating 18 kilograms of fish raised in the effluent. Fish and other edible aquatic life can concentrate radionuclides, so this is taken into account in deriving emission limits.

2. Dose Limits

The annual dose limits for <u>individual</u> members of the public, comply with the regulations of the AECB, are summarized in Table 1.

TABLE 1

Dose Limits for Members of the Public

Organ	Annual Dose Limit
Whole Body Gonads Red-bone marrow	0.5 rem
Skin, bone	3.0 rem
Thyroid	3.0 rem (Adults) 1.5 rem (Children up to 16 years)
Other single organs	1.5 rem
Extremities	7.5 rem

The AECB further limits the population dose by stipulating the following population dose limits:

10^4 man-rems per year to whole body.

10^4 man-rems per year to thyroid.

The integration area extends over all areas, outside the exclusion area, in which individual dose exceeds 1% of the individual dose at the boundary.

The population density around a given site and local meteorological conditions determine whether the population dose or dose to the individual is limiting.

If dose to the population is found to be limiting, permissible individual doses at the station boundary will be reduced proportionately to ensure that the AECB population dose limits are not exceeded.

3. Pathways to Man

Radioactivity released into the environment may lead to external exposure of the public or internal exposure via food chains and through direct inhalation. These pathways are summarized in Figure 1.

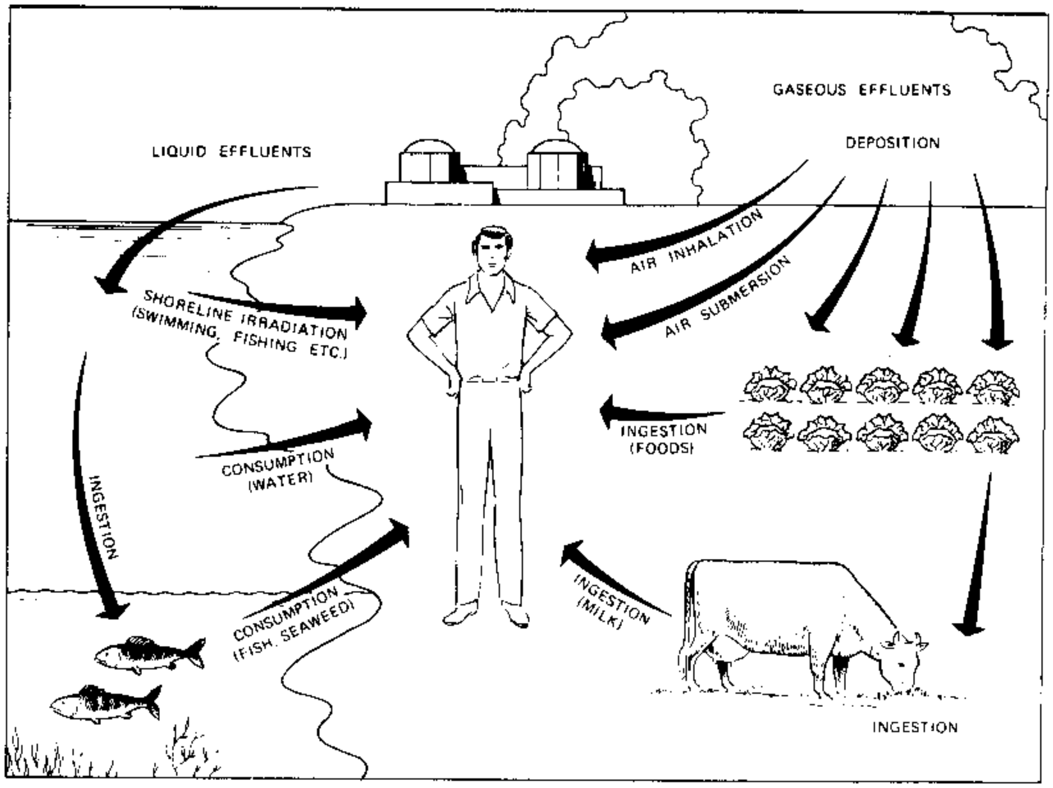

Figure 1

Pathways to Man

The radionuclides released in the gaseous effluent are tritium, radioiodines, noble gases and particulates. The various pathways from the stack to man are:

Tritium

There is no known mechanism whereby tritiated water can be significantly concentrated in the biosphere; the important routes of entry into the human body for this radionuclide from airborne releases are inhalation and absorption through the skin.

A continuous airborne concentration (MPC_a) of 3×10^{-7} Ci/m^3 at the station boundary would give a person residing there a whole body dose of 500 mrem per year.

A combination of factors makes the Atmosphere → Pasture → Cow → Milk → Man chain the most important food chain leading to internal exposure. Milk is the major component of diet for the infant, whose small organ masses cause him to receive doses significantly higher than that to an adult.

The most important radionuclides transmitted through food chains from airborne releases are generally considered to be I-131 and Sr-90 with I-131 being the dominant cause of radiation exposure. These radionuclides are rapidly transmitted to milk, and dairy cattle may graze over large areas of contaminated pasture land. If other food chains are operative, the resulting doses are considerably lower.

Maximum permissible concentrations for these radionuclides in air over pasture land are derived assuming the pathway to be Atmosphere → Pasture → Cow → Milk → Child.

Radionuclide	MPC(Ci/m^3)
I-131	6×10^{-13}
Sr-90	1.5×10^{-12}
Unidentified Particulate*	1.5×10^{-12}

*the lowest MPC value for "particulates" is used for unidentified particulate.

Noble Gases

Fission product noble gases consist of isotopes of xenon and krypton. Ar-41 is produced by neutron activation of Ar-40 in air.

Noble gases are considered external whole body irradiators (from the gamma). Using the semi-infinite cloud approximation, the dose rate is given by

$$DR = 0.25\ \bar{E}C \text{ rem/sec} \qquad (1)$$

where C is the air concentration in Ci/m^3 and $\bar{E}$ is the effective gamma energy per disintegration. Some of the important noble gas radionuclides are summarized on the following Table.

TABLE 2

Radionuclide	Half-Life	$\bar{E}$(MeV)
Ar-41	1.83 h	1.29
Kr-88 (Rb-88)	2.8 h (17.8 min)	2.82
Xe-133	5.27 d	0.03
Xe-138 (Cs-138)	17.5 min (32.2 min)	2.81

The external immersion dose delivered by noble gases is determined by the energy released per unit volume, ie, $\bar{E}$. The unit Ci-MeV is a measure of the effective gamma energy and hence the maximum permissible air concentrations are quoted in terms of Ci-MeV/m^3.

The maximum permissible dose rate for the whole body is 0.5 rem/year or 1.6×10^{-8} rem/sec. From equation (1):

$$MPC = \frac{1.6 \times 10^{-8}}{0.25} = 6.4 \times 10^{-8} \frac{\text{Ci-MeV}}{m^3} \qquad (2)$$

4. Dispersion of Airborne Activity

The dilution of gaseous emissions by the atmosphere is given by the relationship:

$$C = KQ \qquad (3)$$

where Q is the stack release rate (Ci/sec), C is the concentration at the point of interest (Ci/m^3), and K, the dilution factor (sec/m^3), is a function of the distance from the stack, the effective height of release, the weather, and the averaging time, ie, the time over which it is measured.

5. Derived Emission Limits for Airborne Activity

The permissible continuous emission rate for a single radionuclide is:

$$Q = \frac{MPCa}{K} \qquad (4)$$

Values for MPCa were given earlier, K for various effective stack heights have been established.

Maximum permissible daily intakes are calculated directly from the permissible limits and the dosimetric data for the various radionuclides.

TABLE 3

Radionuclide	MPDI	MPC_w
I-131	2.6×10^{-4}	3×10^{-7}
H-3	4.5	5.5×10^{-3}
Sr-90	8.8×10^{-4}	4×10^{-7}

Maximum permissible concentrations in drinking water (MPC_w) are given by:

$$MPC_w = \frac{MPDI}{\text{Daily Water Intake}} \qquad (6)$$

The daily water intake for the adult and the infant are 2200 ml and 800 ml respectively.

The effects of radionuclide concentration in fish are described by the biological concentration factor, b.

$$b = \frac{\mu Ci/g \text{ fish}}{\mu Ci/ml \text{ water}} \qquad (7)$$

The average daily fish consumption for the adult is taken at 50 grams. Radionuclide intake from fish consumption by the adult is equivalent to drinking an additional 50 x b ml of contaminated water a day. The maximum permissible concentrations in fresh water which supports fish life, MPC_{fw}, are given by:

$$MPC_{fw} = \frac{MPDI}{50\ b + 2200} \qquad (8)$$

TABLE 4

Radionuclide	MPC_{fw}
I-131	3×10^{-7}*
H-3	5.5×10^{-3}*
Sr-90	3×10^{-7}

*Critical group for I-131 and H-3 is the infant; critical pathway is drinking water.

10. Derived Emission Limits for Liquid Effluents

The average radionuclide concentrations in the station effluent must not exceed the MPD_{fw}'s. The period of averaging is one month. Since liquid wastes are discharged into the condenser cooling water, permissible monthly releases are given by:

$$\frac{\text{Total Activity Released into ccw in 1 month}}{\text{ccw Flow in 1 Month}} \leq MPC_{fw} \quad (9)$$

11. Releases of Several Radionuclides; MPC_{fw} for Gross-Beta Gamma Activity

Constraints similar to equation 5 will be used if necessary to limit the releases of several radionuclides in liquid effluents so that the dose limit for any given organ is not exceeded.

In practice, since detailed radiochemical analysis of the liquid effluent is seldom performed, the MPC_{fw} for the most restrictive radionuclide (Sr-90), 3×10^{-7} µCi/ml, is used for gross beta-gamma activity

12. Exposure from Combined Gaseous and Liquid Emissions

Although permissible emission levels have been set separately for gaseous and for liquid releases, the possibility of combined exposure from these two release routes cannot be excluded. That the dose limit for any organ is not exceeded is generally accomplished if equation (10) is not violated for any group of N radionuclides which irradiate a common critical organ.

$$\sum_{i=1}^{N} \frac{Q_i}{Q_{i\,LIM}} + \sum_{i=1}^{N} \frac{(\text{Liquid Effluent Concentration})\ i}{(MPC_{fw})\ i} \leq 1.0$$

13. Actual Emissions

The emission limits are derived from the maximum dose permitted to a member of the general public. In practice, Ontario Hydro works to less than one-hundredth of this.

Since releases of radioactivity can easily be limited to less than 1% of the DEL's it is reasonable to ask whether the official AECB standards should be tightened. This suggestion is rejected by the AECB on the grounds that it is unnecessary and would undermine the international uniformity of standards.

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WORKSHEET #1

1. Define or describe "Derived Emission Limit".

2. List the categories or items for which there are radiological DEL's.

WORKSHEET #2

Station: ______________ Reference Year: ______________

CATEGORY		DEL	TARGET	PERFORMANCE
Airborne				
	Tritium			
	Noble Gases			
	I-131			
	Particulates			
Liquid				
	Tritium			
	gross β,γ			

Highlights or Abnormalities:

Date: ______________

Course Manager: ______________