CHAPTER 11

RADIOLOGICAL COMPLIANCE

Contents

11.1 INTRODUCTION

This chapter provides information on the sources and occurrence of the radiological determinands covered by the *Drinking-water Standards for New Zealand 2005* (DWSNZ, Ministry of Health), and discusses the current and potential risks of contamination of water supplies.

It explains the methods used to derive the Maximum Acceptable Values (MAVs) for determinands of health significance and provides information on how to apply the DWSNZ to these determinands.

The MAV of a determinand is the maximum concentration of that determinand which does not result in any significant risk to the health of a 70 kg consumer over a lifetime of consumption of two litres of the water a day.

11.2 RADIOLOGICAL DETERMINANDS

11.2.1 OVERVIEW

Radioactivity in drinking-water is principally derived from two sources:

- the leaching of radionuclides from rocks and soils
- the deposition of radionuclides from the atmosphere.

Naturally occurring radionuclides from both these sources account for almost the entire radioactivity present in New Zealand drinking-water. Traces of artificial radioactive fallout from above ground nuclear weapons tests (conducted up to 1980) are detectable in the environment but their contribution to drinking-water radioactivity is negligible.

The naturally occurring radionuclides originate in the Earth's crust where uranium, thorium and potassium are widely distributed and detectable in all soils and rocks.

Uranium and thorium are radioactive, and each decays through a series of radionuclides to stable isotopes of lead, as shown in the decay schemes below.

Only a very small percentage (0.0118%) of all potassium is the radioactive isotope potassium-40. It is not considered to be of radiological significance because potassium is an essential metabolic element and its levels in the body are in a state of equilibrium, and therefore do not vary significantly with dietary potassium levels.

<u>Uranium series</u>:

$^{238}U \rightarrow {}^{234}Th \rightarrow {}^{234}Pa \rightarrow {}^{234}U \rightarrow {}^{230}Th \rightarrow {}^{226}Ra \rightarrow {}^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214}Pb \rightarrow {}^{214}Bi \rightarrow {}^{214}Po \rightarrow$
$^{210}Pb \rightarrow {}^{210}Bi \rightarrow {}^{210}Po \rightarrow {}^{206}Pb$

<u>Thorium series</u>:

$^{232}Th \rightarrow {}^{228}Ra \rightarrow {}^{228}Ac \rightarrow {}^{228}Th \rightarrow {}^{224}Ra \rightarrow {}^{220}Rn \rightarrow {}^{216}Po \rightarrow {}^{212}Pb \rightarrow {}^{212}Bi \rightarrow {}^{212}Po$ or $^{208}Tl \rightarrow$
^{208}Pb

where the symbols represent elements as follows:

Ac, actinium; Bi, bismuth; Pa, protactinium; Pb, lead; Po, polonium; Ra, radium; Rn, radon; Th, thorium; Tl, thallium; U, uranium.

The radionuclides in these decay series display a great range of radioactive half-lives from approximately 10^{10} years for ^{232}Th to 0.0001 seconds for ^{214}Po. Every radionuclide emits either alpha or beta radiation but their radiological significance varies. The solubility of thorium, for example, is so low, that it is only found in water as a component of suspended mineral particles. The natural radionuclides primarily regarded as being of radiological interest in drinking water appear in Table 11.1.

Table 11.1: The natural radionuclides that may be found in drinking-water

Radionuclide	**Radiation**	**Half-life**
uranium - 238	alpha	4.5×10^9 y
uranium - 234	alpha	2.5×10^5 y
radium - 226	alpha	1600 y
radium - 228	beta	6.7 y
radon - 222	alpha*	3.8 d

* Radon decay products emit both alpha and beta radiation

Only water supplies from groundwater sources are likely to contain significant concentrations of these radionuclides, and the concentrations are as variable as the nature of the soils and rocks themselves.

While groundwaters may contain natural uranium and thorium series radionuclides, surface waters may contain radioactive material deposited from the atmosphere, including both natural radionuclides and materials from artificial sources such as nuclear weapons tests and satellite debris. Although the present levels of contamination from these sources are negligible the DWSNZ applies to radioactivity from all sources, artificial and natural.

Because all radionuclides of interest emit alpha or beta radiation, their levels in drinking water may be assessed by measurement of the total alpha and beta activities. Such total-activity measurements can be performed rapidly and cost-effectively, and it is only if the total-activity MAVs were exceeded that detailed isotopic analysis would need to be performed. Radon levels are assessed separately because radon is a gas and cannot be analysed in routine alpha activity measurements.

Water supplies in New Zealand servicing population groups of 5000 or more were surveyed for radioactivity levels in 1980 (Gregory, 1980). Samples representing 102 water sources were analysed for total alpha and beta radioactivity and radon concentration, and the results are summarised in Table 11.2.

Table 11.2: Radioactivity in New Zealand waters

Determinand	**Range Bq/L**	**Mean Bq/L ± SD**
Total alpha activity, excluding radon	0 - 0.07	0.01 ± 0.01
Total beta activity, including potassium	0 - 0.2	0.05 ± 0.04
Radon concentration: surface waters	0 - 2	0.9 ± 1.1
groundwaters	2 - 54	16 ± 11

Bq = becquerel; SD = standard deviation

11.2.2 DERIVATION OF RADIOLOGICAL MAVS

All life on earth is exposed to radiation from natural sources including cosmic radiation; external radiation from natural radionuclides present in soils, rocks and building materials; and internal radiation due to potassium-40 and inhaled radionuclides, particularly radon decay products. Natural radiation exposure varies regionally as the compositions of soils and rocks change, and increases with altitude as cosmic radiation intensity increases. Radon is a radioactive gas, which emanates from the ground and can concentrate in buildings. Use of water can increase the indoor radon concentration, if radon is present in the water supply.

The risk associated with the presence of radionuclides in drinking-water is an increase in cancer rate. The aim of the DWSNZ is to set limits for radiological determinands, so that the radiation exposure resulting from the presence of radionuclides in water represents only a small part of the total radiation exposure from natural sources.

Radionuclides in drinking water enter the human body through two pathways leading to radiation exposure:

1. internal radiation exposure from ingested radionuclides
2. exposure from inhalation of radon gas and its daughter nuclides.

The DWSNZ adopts MAVs that ensure that the committed effective dose from ingested radionuclides is less than 0.1 millisievert per year (5% of total average for natural sources). The MAV for radon was chosen to limit the contribution of radon in water to the indoor radon concentration to a level typical for outdoor radon levels (10 Bq/m^3).

Different radionuclides have a different radio-toxicity and for an accurate determination of the exposure a detailed radioanalytical assessment would be required. However, an upper limit to the exposure can be derived from a measurement of total alpha, total beta and radon concentration.

Dose conversion factors linking concentrations in water to resulting radiation dose, recommended by the International Commission on Radiological Protection (ICRP 1996) were used in deriving the MAV concentrations. This approach is consistent with that of other organisations such as the World Health Organisation (2004). The MAVs are deliberately conservative. If the natural radionuclides radium-226 and radium-228 were present in drinking-water at the MAV level (worst case scenario), the annual radiation dose would still be less than 5 percent of the total annual natural dose.

The MAVs for radiological determinands are:

- total alpha concentration: 0.10 becquerel per litre, excluding radon-222
- total beta concentration: 0.50 becquerel per litre, excluding potassium-40
- radon-222 concentration: 100 becquerel per litre.

In the radiological context, the MAV is intended to indicate a level above which the radioactive content of the water should be investigated further and an assessment of all relevant radiological issues undertaken. Radiation protection issues are often complex and many factors would have to be taken into account before a water supply could be classified as unacceptable even though a radiological MAV might have been exceeded. The DWSNZ therefore emphasise that further assessment by the National Radiation Laboratory of the Ministry of Health is required in such cases. The MAV is thus more of a guideline than necessarily an absolute maximum. It is also intended to be clear however, that at levels below the MAV, there is no need for further assessment.

11.3 MONITORING PROGRAMME DESIGN

Natural radioactivity levels in water show seasonal variations, and might change over long periods.

Water from new underground sources should be tested before connection to public supplies, and further testing is required every ten years. Testing of water from other sources is discretionary.

11.4 SAMPLING PROCEDURES AND TECHNIQUES

A Drinking Water Assessor should be contacted before sampling. General guidance follows:

Alpha and beta activity: generally a one litre sample of water representative of the source should be collected in a polyethylene bottle. A small quantity of acid should be added as a preservative; approximately 5 mL of 1 M nitric acid is suitable. The sample should be despatched to the analytical laboratory as soon as possible after collection.

Radon: expert advice should be sought on appropriate sampling techniques. Radon measurements must be performed promptly after collection so it is essential to make prior arrangements with the analytical laboratory.

11.5 ANALYTICAL DETAILS

Total Alpha and Beta Radioactivity Measurement:
United States Environmental Protection Agency. Standard drinking water method for gross alpha by co-precipitation (EPA 520/5-84-006, method 00-02).

United States Environmental Protection Agency. Environmental Monitoring and Support Laboratory. Prescribed procedures for measurements of radioactivity in drinking water. Gross alpha and gross beta radioactivity in drinking water (Method 900.0, August 1980).

Additional methods such as pre-concentration and liquid scintillation counting can be employed if the method is documented and validated for this purpose.

Radiochemical Analysis:
If the total-alpha or total-beta activity MAV is exceeded radiochemical procedures are required for analysis of uranium and radium isotopes and any other radionuclides that may be present. A wide range of techniques may be applied depending on the nature of the sample and the determinand in question. Details of particular techniques may be obtained from the National Radiation Laboratory.

Radon Determination:
Radon concentrations in water are determined either by extraction and measurement of the bismuth-214 decay product by beta measurement, or by liquid scintillation counting. Details of particular techniques may be obtained from the National Radiation Laboratory.

11.6 RECORDS AND ASSESSMENT OF COMPLIANCE

Radiological compliance should be assessed by the National Radiation Laboratory of the Ministry of Health.

Records should be kept for future reference, see section 12 of DWSNZ.

11.7 RESPONSE TO TRANSGRESSIONS

If the radioactivity of a drinking-water supply exceeds the MAV, the supply is to be analysed for contributing radioactive materials and an assessment made of their radiological significance by the National Radiation Laboratory of the Ministry of Health.

If the alpha-radioactivity exceeds the MAV, the water should be analysed for uranium-238, uranium-234 and radium-226.

If the beta-radioactivity exceeds the MAV, the water should be analysed for radium-228 and any artificial radionuclides that may be present.

If the measured levels of these radionuclides do not account for the measured total-activity levels, the water should be analysed for any other radionuclides that may be present such as lead-210 and artificial radionuclides, until a complete assessment can be made.

Remedial action is necessary if the committed effective dose from ingestion exceeds 0.1 mSv/year, or the radon concentration exceeds 100 Bq/L.

The National Radiation Laboratory will advise on necessary remedial action.

REFERENCES

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ICRP (1996). *Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients.* Publication 72, International Commission on Radiological Protection. Pergamon Press.

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