NRRC Specific Regulations

Radiological Safety of Treated Underground Drinking Water for Public Consumption

NRRC-R-01-SR07

2023

هيئة الرقابة النووية والإشعاعية

Nuclear and Radiological Regulatory Commission

Specific Regulation

Radiological Safety of Treated Underground Drinking Water for Public Consumption

2023

NRRC-R-01-SR07

Preamble

In accordance with the provisions of the Radiation Safety Regulation (NRRC-R-01), approved by the NRRC's Board of Directors in resolution No. (R/1/1/2022), dated 20 April 2022, in chapter (16), section (105), article (287(b)), this specific regulation provides detailed requirements for the radiological safety of the drinking water that mentioned in the Radiation Safety Regulation (NRRC-R-01).

This specific regulation has been prepared on the basis of International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) standards, as well as the international best practices and the experiences of similar international regulatory bodies, and in accordance with the Kingdom's international commitments, and it has been approved by the NRRC's CEO resolution No. 1339 dated 22/06/2023.

Table of Contents

Chapter 1: Objective, Scope, and Definitions

Section 1: Objective

1. This specific regulation sets the control and risk management strategies necessary to ensure radiologically safe water for drinking. It outlines the practical requirements for taking appropriate action related to radioactivity in drinking water that occurs during normal situations. These situations are where there could be consumption of drinking water containing radionuclides over extended periods of time leading to prolonged radiation exposure of individuals. The duration of exposure could continue for many years or even over a lifetime.

Section 2: Scope

2. This specific regulation applies relevant national drinking water standards and implementation activities to the ground water treated by various physical and chemical technologies, particularly when reference levels are exceeded.

3. This specific regulation's target audience consists of individuals and organizations responsible for managing radiological risks in industries supplying drinking water.

4. This specific regulation shall not apply to the case of nuclear and radiological emergency resulting in radioactive contamination of drinking water.

Section 3: Definitions

Activity concentration

The activity per unit mass or volume of the material in which the radionuclides are essentially uniformly distributed.

The guidance levels

The guidance levels are activity concentrations in drinking water that can be measured at an operational level by water suppliers as part of drinking water monitoring and assessment.

The individual dose criterion (IDC)

The individual dose criterion (IDC) of 0.1 mSv y^{-1} is established for assessing health risks to an individual from prolonged exposure to radionuclides in drinking water. The guidance levels have been developed as practical operational criteria to be used to assess if the IDC is exceeded.

The screening levels

The screening levels are activity concentrations that can be used to demonstrate if the IDC may be exceeded. If either of the screening levels are exceeded, the activity concentrations of individual radionuclides should be determined and compared with the guidance levels.

Chapter 2: Background

5. Activity concentrations of radionuclides in drinking water are most likely to result from radionuclides which occur naturally in the ground, such as radionuclides of the thorium and uranium decay series.

6. Radionuclides in drinking water can arise from natural or artificial (i.e. anthropogenic) sources. Many radionuclides occur in nature, including in rocks and soil and thus concentrations of radionuclides in drinking water are most likely to result from groundwater sources. Of particular significance for human radiation exposure from drinking water are the natural radionuclides that originate from the elements of the thorium and uranium decay series, for example radium-226, radium-228, polonium-210, lead-210 and radon. These radionuclides can arise in water from natural processes in the ground or technological processes involving naturally occurring radioactive materials (NORM), such as mining. Radon is an inert gas abundant in the ground and is soluble in water. Radon gas is liberated (degassed) from the water to the air during water extraction or use.

7. Artificial radionuclides may be present in water from several sources, such as incidental or regular discharges from nuclear facilities, discharges of radionuclides produced for and used in medicine or industryand global dispersion of nuclear weapons fallout. The most common artificial radionuclides found in drinking water are caesium-134, caesium-137, strontium-90 and iodine-131.The levels of artificial radionuclides in drinking water are generally very low.

8. The ground water treatment plants are the major providers of drinking water and should be held primarily accountable for the radiological safety of that water. Other water quality control authorities also shall have a role in this aspect of drinking water quality.

Chapter 3: Approach Adopted for Assessing Public Health Risk from Radionuclides in Drinking Water

Section 4: The individual Dose Criterion

9. The individual dose criterion (IDC) shall be equal to 0.1 mSv y^{-1} for assessing public health risks from prolonged exposure to radionuclides in drinking water.

10. The IDC of 0.1 mSv from one year's consumption of drinking water shall be used for all radionuclides, regardless of whether they are of natural or artificial origin. The exposure to radionuclides in drinking water, particularly for natural occurring radionuclides is likely to occur over a prolonged period and possibly a lifetime. In order to keep the doses at a level where the risks from this exposure pathway are very low, maintaining the doses below the IDC shall be viewed as a long-term goal.

Section 5: Guidance Levels

11. The screening levels are activity concentrations that can be used to determine if the IDC may be exceeded. If any of the screening levels are exceeded, the activity concentrations of individual radionuclides should be determined and compared with the guidance levels as shown in Table 1.

12. The guidance levels for radionuclide concentration in drinking water shall be established as listed in Table 1.

13. The guidance levels are for individual radionuclides and are the concentration that, if present in the drinking water consumed throughout a year at a rate of 2 liters per day, would result in an individual dose of 0.1 mSv being received.

Table 1 Guidance Levels for Radionuclides in Drinking Water

Radionuclide		Half-life	Guidance Level $Bq\ L^{-1}$**
Tritium	^{3}H	12.33 y	2690
Carbon-14	^{14}C	5730 y	240
Strontium-90	^{90}Sr	29.12 y	4.9
Iodine-131	^{131}I	8.04 d	6.2
Caesium-134	^{134}Cs	2.062 y	7.2
Caesium-137	^{137}Cs	30 y	11.0
Lead-210	^{210}Pb	22.3 y	0.2
Polonium-210	^{210}Po	138.38 d	0.1
Radium-226	^{226}Ra	1600 y	0.5
Radium-228	^{228}Ra	5.75 y	0.2
Uranium-234	^{234}U*	244500 y	2.8
Uranium-238	^{238}U*	$4.468\ 10^{9}$ y	3.0
Thorium-228	^{228}Th	1.913 y	0.6
Thorium-232	^{232}Th	$1.405\ 10^{10}$ y	3.0
Plutonium-239 or 240	^{239}Pu or ^{240}Pu	$2.41\ 10^{4}$ y / 6537 y	0.6
Americium-241	^{241}Am	432.2 y	0.7

* Uranium is normally controlled on the basis of its chemical toxicity; the guideline value for total content of uranium in drinking water is 30 µg/L. 30 µg/L is equivalent to 0.37 Bq/L of ^{238}U or ^{234}U.
** For other radionuclides, values can be found in Annex I.

Section 6: Application of Guidance Levels

14. The process for applying the guidance levels shall be established as shown in Figure 1.

    a. The screening levels are the total radioactivity present in the form of alpha and beta radiation in drinking water. They represent activity concentrations below which no further action is required and are based on the IDC of 0.1 mSv y^{-1}.

    b. The gross alpha and gross beta screening methods rely on the detection of emitted alpha or beta particles during radioactive decay of the radionuclides. They are appropriate for most situations in which radionuclides in drinking water are likely to be found, as they detect naturally occurring radionuclides.

    c. The guidance levels shall be used as a trigger for further investigation and not be interpreted as a limit indicating that the drinking water is unsafe.

    d. The guidance levels shall not be applied in emergency exposure.

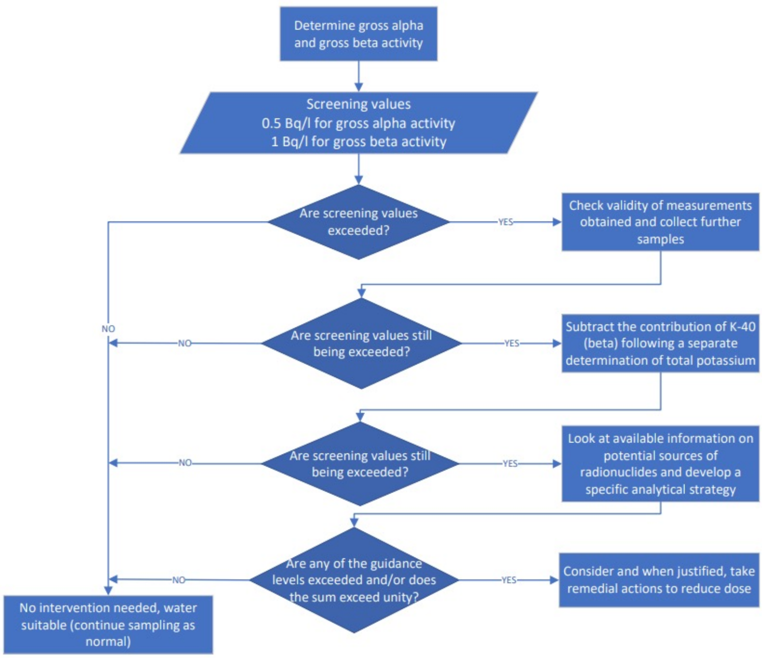

Figure 1 The process of applying the guidance levels in drinking water.

Section 7: The Radon Reference Level

15. A level of 300 Bq m^{-3} of radon in tap water shall be established as a reference level.

16. Levels of radon in surface water or in water that has been stored are extremely low, and dissolved radon in water is readily degassed once it is released from the tap. If there is a groundwater supply close to and directly linked to the drinking water supply, with little or no opportunity for agitation or storage before the domestic tap is opened, it shall be relevant to take account of radon in drinking water in dwellings with high radon concentrations in indoor air from the ground.

Section 8: Measurements of Radionuclide Concentrations in Drinking Water

17. Prior to the design and construction of new water supplies, samples must be taken and analyzed for radionuclides to determine their suitability for drinking.

18. For a new drinking water supply, measurements of radionuclides in the water shall be made at the source as part of characterizing the source and determining its suitability for drinking water. The extent of treatment that will be carried out shall also be taken into account.

19. The frequency of measuring activity concentrations of radionuclides in drinking water shall be developed based on the available resources, the potential for a public health risk from radionuclides in drinking water, and other priorities for providing safe drinking water.

Section 9: The Excess Above Screening Levels

20. If neither the gross alpha nor gross beta screening levels are not exceeded, the individual dose criterion (IDC) of 0.1 mSv per year shall also not be exceeded, except under exceptional circumstances. Monitoring of drinking water shall continue at the locations and frequency that has been agreed upon with the water quality regulator for radiological parameters.

    a. If it is suspected that the water may contain a radionuclide that will not be detected by the screening methods. Annex I provides information on the main radionuclides that will not be detected by the gross alpha and beta screening methods. Different sources of information may indicate that radionuclides in drinking water could be present but would not be detected e.g. other environmental monitoring data in the area and the catchment that the water is drawn from, knowledge of sites that could have led to discharges of radionuclides to the catchment and local geology. In this case, radionuclide-specific measurements should be made and compared with the relevant guidance values.

b. There are a few naturally occurring radionuclides (notably Ra-228 and Po-210) where the IDC of 0.1 mSv per year could be exceeded, even if the screening levels are not exceeded, in the exceptional situation where these radionuclides are the only significant contributors to the total activity concentration.

Section 10: The Excess of Radionuclide-specific Activity Concentration(s) above Guidance Level(s)

21. If only a single radionuclide has been identified in the drinking water, the activity concentration shall be compared with the guidance level for that radionuclide.

22. If the guidance level is exceeded, it shall be assumed that the individual dose criterion (IDC) of 0.1 mSv y^{-1} has been exceeded until further investigation has been undertaken.

23. If several radionuclides have been identified, then the sum across radionuclides shall be considered to check that it does not exceed unity, i.e. to check if the IDC has been exceeded.

The equation to use is:

$$\sum_i \frac{C_i}{GL_i} \leq 1$$

Where:

C_i = the measured activity concentration of radionuclide i,

GL_i = the guidance level for radionuclide i, calculated using the default assumptions (adult, 2 litres per day for one year)

If the summation greater than or equal to 1, then the IDC is very likely to have been exceeded and further investigation is required.

The example of calculation for radionuclide mixture is provided in Annex II.

24. A water supply shall not automatically be shut down if the annual dose is around the reference level of 1 mSv y^{-1}, particularly if no other source is available or alternative sources are not suitable and affordable.

25. Consuming water that is with an estimated radiation dose of between 0.1 and 1 mSv y^{-1} shall not be considered a radiological health risk. However, if the individual dose criterion (IDC) of 0.1 mSv y^{-1} is exceeded, several steps must be taken, and it is necessary to apply optimization to reduce the prolonged exposure to the source of the drinking water as much as is reasonable.

26. The concentration of radionuclide activity in the drinking water shall be measured using the approved standard methods of measurement can be used to determine whether or not the reference level has been exceeded.

Annex I: Guidance Levels for Radionuclides in Drinking Water

The Table I.1 provides values of guidaline levels for radionuclides other than radionuclides given in Table 1.

The guidance levels are calculated according to the following equation:

$$GL = IDC/(DC * q)$$

Where :

GL is a guidance level, (Bq/L),

IDC is an individual dose criterion, (equal to 0.1 mSv per year),

DC is the dose coefficient for ingestion by adults (mSv/Bq); and

q is the annual ingested volume of drinking water, assumed to be 730 litres in a year (equivalent to the standard WHO drinking water consumption rate of 2 litres per day).

Table I.1 Guidance Levels for Radionuclides in Drinking Water

Element	Radionuclide	Dose Coefficient, DC, mSv/Bq	Guidance Level, Bq/L
P	^{32}P	1.70×10^{-6}	8.06×10^{1}
P	^{33}P	2.70×10^{-7}	5.07×10^{2}
S	^{35}S	3.10×10^{-9}	4.42×10^{4}
Ca	^{45}Ca	2.70×10^{-7}	5.07×10^{2}
Ca	^{47}Ca	6.90×10^{-7}	1.99×10^{2}
Fe	^{55}Fe	2.90×10^{-7}	4.72×10^{2}
Fe	^{59}Fe	1.70×10^{-6}	8.06×10^{1}
Co	^{56}Co	1.90×10^{-6}	7.21×10^{1}
Co	^{57}Co	1.20×10^{-7}	1.14×10^{3}
Co	^{58}Co	5.40×10^{-7}	2.54×10^{2}
Co	^{60}Co	3.20×10^{-6}	4.28×10^{1}
Zn	^{65}Zn	4.30×10^{-6}	3.19×10^{1}
Sr	^{85}Sr	2.10×10^{-7}	6.52×10^{2}
Sr	^{89}Sr	4.00×10^{-7}	3.42×10^{2}
Y	^{90}Y	5.60×10^{-7}	2.45×10^{2}
Y	^{91}Y	4.00×10^{-7}	3.42×10^{2}
Zr	^{93}Zr	5.00×10^{-8}	2.74×10^{3}
Zr	^{95}Zr	3.20×10^{-7}	4.28×10^{2}
Nb	^{93m}Nb	2.70×10^{-8}	5.07×10^{3}
Nb	^{94}Nb	2.30×10^{-6}	5.96×10^{1}
Nb	^{95}Nb	3.00×10^{-7}	4.57×10^{2}
Mo	^{93}Mo	2.60×10^{-8}	5.27×10^{3}
Mo	^{99}Mo	2.60×10^{-7}	5.27×10^{2}
Tc	^{96}Tc	8.90×10^{-7}	1.54×10^{2}
Tc	^{97}Tc	4.40×10^{-8}	3.11×10^{3}
Tc	^{97m}Tc	2.20×10^{-7}	6.23×10^{2}

Element	Radionuclide	Dose Coefficient, DC, mSv/Bq	Guidance Level, Bq/L
Tc	^{99}Tc	2.70 x 10^{-7}	5.07 x 10^{2}
Tc	^{99m} Tc	1.40 x 10^{-8}	9.78 x 10^{3}
Ru	^{97}Ru	9.00 x 10^{-8}	1.52 x 10^{3}
Ru	^{103}Ru	2.60 x 10^{-7}	5.27 x 10^{2}
Ru	^{106}Ru	2.60 x 10^{-6}	5.27 x 10^{1}
Sb	^{122}Sb	4.50 x 10^{-7}	3.04 x 10^{2}
Sb	^{124}Sb	1.10 x 10^{-6}	1.25 x 10^{2}
Sb	^{125}Sb	3.70 x 10^{-7}	3.70 x 10^{2}
Te	^{123m}Te	2.60 x 10^{-7}	5.27 x 10^{2}
Te	^{127}Te	4.60 x 10^{-8}	2.98 x 10^{3}
Te	^{127m}Te	4.50 x 10^{-7}	3.04 x 10^{2}
Te	^{129}Te	6.10 x 10^{-8}	2.25 x 10^{3}
Te	^{129m}Te	8.90 x 10^{-7}	1.54 x 10^{2}
Te	^{131}Te	8.30 x 10^{-8}	1.65 x 10^{3}
Te	^{131m}Te	1.10 x 10^{-6}	1.25 x 10^{2}
Te	^{132}Te	1.90 x 10^{-6}	7.21 x 10^{1}
I	^{125}I	1.30 x 10^{-5}	1.05 x 10^{1}
I	^{126}I	2.10 x 10^{-5}	6.52 x 10^{0}
I	^{129}I	9.40 x 10^{-5}	1.46 x 10^{0}
Cs	^{129}Cs	8.70 x 10^{-8}	1.57 x 10^{3}
Cs	^{131}Cs	2.80 x 10^{-8}	4.89 x 10^{3}
Cs	^{132}Cs	2.90 x 10^{-7}	4.72 x 10^{2}
Cs	^{135}Cs	1.30 x 10^{-7}	1.05 x 10^{3}
Cs	^{136}Cs	9.70 x 10^{-7}	1.41 x 10^{2}
Ba	^{131}Ba	2.10 x 10^{-7}	6.52 x 10^{2}
Ba	^{140}Ba	5.30 x 10^{-7}	2.58 x 10^{2}
La	^{140}La	7.90 x 10^{-7}	1.73 x 10^{2}

Element	Radionuclide	Dose Coefficient, DC, mSv/Bq	Guidance Level, Bq/L
Ce	^{139}Ce	8.80×10^{-8}	1.56×10^{3}
Ce	^{141}Ce	6.20×10^{-8}	2.21×10^{3}
Ce	^{143}Ce	2.40×10^{-7}	5.71×10^{2}
Ce	^{144}Ce	9.80×10^{-7}	1.40×10^{2}
Pr	^{143}Pr	1.40×10^{-7}	9.78×10^{2}
Nd	^{147}Nd	1.50×10^{-7}	9.13×10^{2}
Pm	^{147}Pm	8.40×10^{-9}	1.63×10^{4}
Pm	^{149}Pm	1.50×10^{-7}	9.13×10^{2}
Sm	^{151}Sm	1.20×10^{-8}	1.14×10^{4}
Sm	^{153}Sm	8.70×10^{-8}	1.57×10^{3}
Eu	^{152}Eu	6.50×10^{-7}	2.11×10^{2}
Eu	^{154}Eu	7.20×10^{-7}	1.90×10^{2}
Eu	^{155}Eu	4.40×10^{-8}	3.11×10^{3}
Gd	^{153}Gd	7.00×10^{-8}	1.96×10^{3}
Tb	^{160}Tb	4.90×10^{-7}	2.80×10^{2}
Er	^{169}Er	8.40×10^{-9}	1.63×10^{4}
Tm	^{171}Tm	2.00×10^{-9}	6.85×10^{4}
Yb	^{175}Yb	3.30×10^{-8}	4.15×10^{3}
Ir	^{190}Ir	5.90×10^{-7}	2.32×10^{2}
Ir	$^{19}2Ir$	4.50×10^{-7}	3.04×10^{2}
Pb	^{203}Pb	1.20×10^{-7}	1.14×10^{3}
Bi	^{206}Bi	1.20×10^{-6}	1.14×10^{2}
Bi	^{207}Bi	8.30×10^{-7}	1.65×10^{2}
Bi	^{210}Bi	1.10×10^{-6}	1.25×10^{2}
Ra	^{223}Ra	4.10×10^{-5}	3.34×10^{0}
Ra	^{224}Ra	2.90×10^{-5}	4.72×10^{0}
Ra	^{225}Ra	4.50×10^{-5}	3.04×10^{0}

Element	Radionuclide	Dose Coefficient, DC, mSv/Bq	Guidance Level, Bq/L
Th	^{227}Th	1.30×10^{-6}	1.05×10^{2}
Th	^{228}Th	3.10×10^{-5}	4.42×10^{0}
Th	^{229}Th	2.10 x 10-4	6.52×10^{-1}
Th	^{230}Th	6.00×10^{-5}	2.28×10^{0}
Th	^{231}Th	1.70×10^{-8}	8.06×10^{3}
Th	^{234}Th	5.90×10^{-7}	2.32×10^{2}
Pa	^{230}Pa	3.20×10^{-7}	4.28×10^{2}
Pa	^{231}Pa	1.80×10^{-4}	7.61×10^{-1}
Pa	^{233}Pa	1.20×10^{-7}	1.14×10^{3}
U*	^{230}U	1.30×10^{-5}	1.05×10^{1}
U*	^{231}U	4.90×10^{-8}	2.80×10^{3}
U*	^{232}U	1.80×10^{-4}	7.61×10^{-1}
U*	^{233}U	3.50×10^{-5}	3.91×10^{0}
U*	^{235}U	3.20×10^{-5}	4.28×10^{0}
U*	^{236}U	3.20×10^{-5}	4.28×10^{0}
U*	^{237}U	7.60×10^{-8}	1.80×10^{3}
Np	^{237}Np	3.00×10^{-5}	4.57×10^{0}
Np	^{239}Np	8.50×10^{-8}	1.61×10^{3}
Pu	^{236}Pu	4.60×10^{-7}	2.98×10^{2}
Pu	^{237}Pu	3.00×10^{-8}	4.57×10^{3}
Pu	^{238}Pu	2.20×10^{-6}	6.23×10^{1}
Pu	^{241}Pu	2.30×10^{-8}	5.96×10^{3}
Pu	^{242}Pu	2.30×10^{-6}	5.96×10^{1}
Pu	^{244}Pu	2.70×10^{-6}	5.07×10^{1}
Am	^{242}Am	4.50×10^{-8}	3.04×10^{3}
Am	^{242m}Am	6.00×10^{-5}	2.28×10^{0}
Am	^{243}Am	5.80×10^{-5}	2.36×10^{0}

Element	Radionuclide	Dose Coefficient, DC, mSv/Bq	Guidance Level, Bq/L
Cm	^{242}Cm	3.50×10^{-6}	3.91×10^{1}
Cm	^{243}Cm	4.60×10^{-5}	2.98×10^{0}
Cm	^{244}Cm	3.90×10^{-5}	3.51×10^{0}
Cm	^{245}Cm	6.00×10^{-5}	2.28×10^{0}
Cm	^{246}Cm	6.00×10^{-5}	2.28×10^{0}
Cm	^{247}Cm	5.50×10^{-5}	2.49×10^{0}
Cm	^{248}Cm	2.30×10^{-4}	5.96×10^{-1}
Bk	^{249}Bk	1.20×10^{-7}	1.14×10^{3}
Cf	^{246}Cf	5.50×10^{-8}	2.49×10^{3}
Cf	^{248}Cf	6.20×10^{-6}	2.21×10^{1}
Cf	^{249}Cf	5.20×10^{-5}	2.63×10^{0}
Cf	^{250}Cf	2.90×10^{-5}	4.72×10^{0}
Cf	^{251}Cf	5.30×10^{-5}	2.58×10^{0}
Cf	^{252}Cf	2.50×10^{-5}	5.48×10^{0}
Cf	^{253}Cf	3.20×10^{-7}	4.28×10^{2}
Cf	^{254}Cf	$1.80 \times 1^{0-4}$	7.61×10^{-1}
Es	^{253}Es	3.50×10^{-7}	3.91×10^{2}
Es	^{254}Es	5.90×10^{-6}	2.32×10^{1}
Es	^{254m}Es	3.10×10^{-7}	4.42×10^{2}

* The provisional guideline value for uranium in drinking water is 30 µg/L based on its chemical toxicity for the kidney.

Annex II: Theoretical Example to Illustrate the Evaluation of Activity Concentrations in a Drinking Water Sample against the IDC

Measured activity concentrations are:

Radium-226 = 0.1 Bq L^{-1}

Radium-228 = < LOD (below Limit of Detection)

Lead-210 = 0.05 Bq L^{-1}

Polonium-210 = 0.03 Bq L^{-1}

Summation equation = 0.1/0.5 + 0.05/0.2 + 0.03/0.1 = 0.75

As the summation is less than 1 in this case, the IDC of 0.1 mSv y^{-1} is not exceeded.

Care should be taken if the measurements being used to compare with the guidance levels are reported as less than the LOD. These measurements are not actual activity concentrations but are a feature of the detection capability of the equipment used. Using measurements reported as below LOD as actual activity concentrations in the drinking-water sample will be conservative; the radionuclide may be present in the sample but the equipment used is unable to quantify the amount.

King Fahd National Library Cataloging-in-Publication Data

L.D. no. 1444/11098
ISBN: 978-603-92052-0-3

هيئة الرقابة النووية والإشعاعية
Nuclear and Radiological Regulatory Commission

Kingdom of Saudi Arabia

@saudinrrc

nrrc.gov.sa