Radiation Protection Authority

Zambia

SAFETY GUIDE

RPA SG 24

Guidelines for Monitoring of Radioactivity in Drinking Water

2025

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Abbreviations and Acronyms

RPA: Radiation Protection Authority

RPAB: Radiation Protection Authority Board

IAEA: International Atomic Energy Agency

GSG: General Safety Guide

QA/QC: Quality Assurance/Quality Control

ALARA: As Low As Reasonably Achievable

RPO: Radiation Protection Officer

RPSP: Radiation Protection and Safety Program

SI: Statutory Instrument

ICRP: International Commissioning on Radiological Protection

ICP-MS: Inductively Coupled Plasma Mass Spectrometry

WHO: World Health Organisation

FOREWORD

Access to safe drinking water is fundamental to public health and sustainable development. As the Republic of Zambia continues to enhance its environmental and public health safeguards, it is increasingly important to address potential sources of radiological contamination in water supplies.

Radioactivity in drinking water whether from natural or anthropogenic sources can pose health risks when levels exceed recommended limits. Recognizing this, the Radiation Protection Authority (RPA), in collaboration with relevant stakeholders, has developed these **Guidelines for Monitoring Radioactivity in Drinking Water** to provide a standardized approach for the detection, evaluation, and management of radioactive substances in water intended for human consumption.

These guidelines are informed by the Ionising Radiation Protection Act No. 16 of 2005 and are aligned with international safety standards, including those from the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and publications from the International Commissioning on Radiological Protection (ICRP). They offer practical guidance to water utilities, regulators, laboratories, and public health authorities to ensure that drinking water sources are regularly monitored and that any radiological risks are promptly addressed.

The implementation of these guidelines will strengthen national capacity to protect public health, support evidence-based decision-making, and enhance Zambia's compliance with global best practices in radiological safety. We commend the efforts of all contributors to this important document and urge all stakeholders to apply these guidelines diligently and consistently.

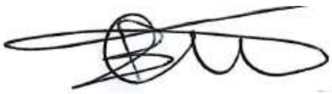
Christabel Jinja Ngongola-Reinke
RPA Board Chairperson

ACKNOWLEDGEMENT

The Radiation Protection Authority (RPA) of Zambia extends its sincere gratitude to the dedicated professionals and stakeholders whose expertise and collaboration were instrumental in the development of this safety guide.

We acknowledge the foundational standards and advisory materials provided by the International Atomic Energy Agency (IAEA), World Health Organisation (WHO) and International Commissioning on Radiological Protection (ICRP), which form the technical backbone of this document. The contributions of water utilities, public health officials, environmental scientists, laboratory specialists, local and international stakeholders who have played a crucial role in customizing these standards to fit the specific operational context of Zambia.

Special thanks are extended to the Radiation Protection Authority Board, Management and technical staff, who are committed to ensure public and environmental safety through monitoring radioactivity in drinking water. Their commitment ensures that the people and the environment are protected from the effects that may arise from ionizing radiation.



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1.0. Introduction

Drinking water contains naturally occurring radionuclides such as such as Uranium–Radium (238U–226Ra) and Thorium (232Th) decay series, their decay products and potassium (40K) and artificial radionuclides (137Cs, 134Cs, 90Sr, etc.) coming from the fallout from atmospheric nuclear weapons testing and the accidents at nuclear reactors. These radionuclides could present a risk to human health (WHO, 2011). Low doses caused by ingestion of these radionuclides in drinking water can increase the radiological risk of longer-term effects.

Radium isotopes (226Ra and 228Ra) are the most radiotoxic and dangerous element once ingested, behaves chemically like calcium and, therefore, deposits in significant quantities in bone mineral, where it is retained for a very long time. Being an alpha-emitting radionuclide, the radium irradiates bone surface-lining cells and has resulted in an excess incidence of osteogenic sarcomas. The 226Ra (T1/2 = 1600 y) and 228Ra (T1/2 = 5.75 y) can dissolve easily in water and travel within the aquifer. The most common source of them in drinking water is from radiological decay of naturally occurring 238U and 232Th found in the earth's crust. 40K is present as a very small fraction of naturally occurring potassium (39K), which is an element found in the earth's crust, oceans, and all organic material. Once taken in, 40K in the body behaves in the same manner as other potassium isotopes. Humans require potassium to sustain biological processes, with most (including 40K) being almost completely absorbed upon ingestion, moving quickly from the gastro intestinal tract to the bloodstream. The 40K that enters the bloodstream after ingestion or inhalation is quickly distributed to all organs and tissues. It can present both an external and an internal health hazard. The health hazard of 40K is associated with cell damage caused by the ionizing radiation that results from radioactive decay, with the general potential for subsequent cancer induction (ANL, 2005). Cesium (137Cs) reacts with water producing a water-soluble compound. After drinking 137Cs contaminated water, it gets more or less uniformly distributed throughout the body, with the highest concentrations in soft tissue, where it would expose living tissue to gamma and beta radiation. Therefore, determining of the concentration levels of the natural and artificial radionuclides in drinking water is an important factor for public health studies, which allow the assessment of population exposure to radiation by the consumption of water.

This guideline provides a systematic approach for the monitoring of radioactivity in drinking water to ensure public health protection and compliance with national and international safety standards.

2.0. **Objectives**

2.1. Establish a comprehensive and scientifically sound framework for monitoring and managing radioactivity in drinking water.

2.2. Protect public health by ensuring drinking water adheres to radiological safety standards set by international (WHO, IAEA) and national authorities.

2.3. Ensure compliance with legal and regulatory requirements, including the Ionising Radiation Protection Act No. 16 of 2005, and current best practices.

2.4. Facilitate early detection of radionuclide exceedances, thereby reducing health risks from internal exposure.

2.5. Promote capacity building within water supply systems and laboratories for effective detection, analysis, and response.

2.6. Encourage transparency and public awareness regarding radiological quality of drinking water.

3.0. Scope and Applicability

3.1. This guideline applies to:

3.1.1. Drinking water suppliers (public and private).

3.1.2. Regulatory bodies involved in water quality and radiation safety.

3.1.3. Laboratories conducting radiological analyses.

3.1.4. Water sources used for public consumption, including boreholes, wells, and surface water supplies.

4.0. Regulatory Framework

4.1. This guideline is grounded in the following:

4.1.1. The Ionising Radiation Protection Act No. 16 of 2005

4.1.2. The Water Resources Management Act No. 21 of 2011

4.1.3. The Environmental Management Act (No. 12 of 2011

4.1.4. The Local Government Act (No. 2 of 2019

4.1.5. Public Health Act

4.1.6. WHO Guidelines for Drinking-water Quality

4.1.7. IAEA Safety Standards (e.g., GSG-8)

4.1.8. IAEA Publications

5.0. Roles and Responsibilities

5.1. Radiation Protection Authority (RPA):

5.1.1. Develop and enforce regulatory requirements.

5.1.2. Monitor drinking water and food for radioactivity

5.1.3. Establish national safety standards for drinking water and food

5.1.4. Provide technical support and training

5.1.5. Maintain a national database on water radioactivity

5.2. Water Utilities and Suppliers:

5.2.1. Regulate the provision of water supply and sanitation services for efficiency and sustainability

5.2.2. Conduct routine monitoring and ensure compliance

5.2.3. Report results to RPA

5.3. Laboratories:

5.3.1. Conduct reliable analysis and maintain quality control.

5.3.2. Submit results and retain records as required.

6.0. Key Radionuclides of Concern

6.1. Naturally Occurring Radionuclides:

6.1.1. Uranium-238 and Uranium-234

6.1.2. Radium-226 and Radium-228

6.1.3. Thorium-232

6.1.4. Radon-222

6.2. Artificial Radionuclides (if applicable):

6.2.1. Cesium-137

6.2.2. Cesium-134

6.2.3. Strontium-90

6.2.4. Iodine-131

7.0. Monitoring Requirements

7.1. Gross Alpha and Beta Activity: Initial screening should include gross alpha and beta measurements.

7.2. Radionuclide-Specific Analysis: Required if gross alpha > 0.5 Bq/L or gross beta > 1.0 Bq/L.

7.3. Guidance levels for radionuclides in drinking water for infants and pregnant women are typically lower than for those for the general population due to their increased sensitivity to radiation. These guidance levels are set to limit the annual effective dose, to 1 mSv/year or less, with additional precaution for sensitive subgroups.

7.3.1. The World Health Organisation (WHO) Guidance Levels (2017 Guidelines for Drinking-water Quality) provides screening levels and reference doses for radionuclides. The calculated guidance levels for individual radionuclides are based on an assumption of:

7.3.1.1. 2 liters/day consumption for adults

7.3.1.2. 1 liter/day for infants

7.3.1.3. Dose criterion: 0.1 mSv/year for routine situations

7.3.2. For infants and pregnant women, WHO recommends stricter controls, especially for radionuclides that accumulate in sensitive tissues (e.g., iodine, strontium, cesium, plutonium). Refer to Appendix I.

7.4. Frequency:

7.4.1. Urban water supplies: Annually

7.4.2. Rural water supplies: Every 2 years

7.4.3. Suspected contaminated areas: As needed

7.5. Frequency of Monitoring in an Emergency

7.5.1. In a radiological emergency, monitoring radioactivity in water is critical for protecting public health. The frequency and scope of monitoring depend on several factors, including the type and scale of the event, the radionuclides released, and the population at risk. Below is the frequency of radioactivity monitoring in an emergency;

7.5.1.1. Initial Phase (First 24–72 Hours):

7.5.1.1.1. Frequent sampling (every few hours to daily) near the contamination source (e.g., nuclear plant, accident site).

7.5.1.1.2. Continuous monitoring if online radiation sensors are available.

7.5.1.1.3. Focus on drinking water sources, surface water (rivers, lakes), and groundwater used for consumption.

7.5.1.2. Stabilization Phase (Days to Weeks): Monitoring frequency may shift to daily or every few days, based on trends and decay rates.

7.5.1.2.1. Adjust frequency based on:

7.5.1.2.1.1. Detection of key radionuclides (e.g., iodine-131, cesium-137).

7.5.1.2.1.2. Water use (drinking vs. irrigation vs. recreation).

7.5.1.3. Recovery Phase (Weeks to Months)

7.5.1.3.1. Frequency may reduce to weekly or monthly, depending on:

7.5.1.3.1.1. Residual contamination.

7.5.1.3.1.2. Effectiveness of remediation.

7.5.1.3.1.3. Radionuclide half-lives (e.g., cesium-137: ~30 years).

8.0. Sampling Procedures

8.1. Use clean, pre-labelled, leak-proof polyethylene bottles

8.2. Avoid contamination; sample at point of use

8.3. Preserve samples appropriately (e.g., acidification for uranium analysis)

8.4. Record GPS coordinates, sample date/time, and source type

8.5. Sampling should be conducted in accordance with the RPA sampling procedures

9.0. Analytical Methods

9.1. Gross Alpha/Beta: Evaporation and proportional counting

9.2. Radon-222: Liquid scintillation counting

9.3. Uranium, Radium: Alpha spectrometry, ICP-MS

9.4. Quality Control: Use certified reference materials

9.5. Laboratories analyzing water for radioactivity must be accredited by the IAEA, WHO, FAO, ISO (e.g., ISO/IEC 17025), local and other international standards.

9.6. They must participate in inter-laboratory comparisons and proficiency test to align with the international protocols.

10.0. Interpretation of Results

10.1. Guideline Levels (based on WHO):

10.1.1. Gross Alpha: 0.5 Bq/L

10.1.2. Gross Beta: 1.0 Bq/L

10.1.3. Radon-222: 100 Bq/L

10.1.4. Uranium: 30 µg/L (chemical toxicity); 0.04 Bq/L (radiological)

10.1.5. Conduct dose assessment if levels exceed guidance

11.0. Exposure Assessment

Exposure assessment will be conducted in order to evaluate the extent to which people are exposed to radioactive substances in water. It will involve identifying sources, pathways, and receptors.

12.0. Risk Management and Remediation

12.1. Risk management will involve mitigation of the health risks posed by radionuclides in water, based on assessment findings. This will be done through the following;

12.1.1. National regulatory limits and international Guidelines

12.1.2. Implementation of Monitoring Programs through regular testing of drinking water sources and emergency monitoring during nuclear events

12.1.3. Apply Treatment and Remediation Techniques e.g. Ion exchange, reverse osmosis, coagulation/filtration. Removal of radionuclides in water depends on the specific radionuclides.

12.1.4. Communication and Public Protection: Informing the public and providing guidance and provide alternative safe water supplies if needed

12.1.5. Long-term surveillance and health risk assessment

13.0. Response to Exceedances and Public Communication

13.1. Immediate notification to RPA

13.2. Confirmatory sampling and analysis

13.3. Public notification if levels pose a health risk

13.4. Implement corrective actions (e.g., treatment, alternative sources)

14.0. Reporting and Recordkeeping

14.1. Submit results to RPA within 30 days of analysis

14.2. Maintain records for at least 10 years

14.3. Annual summary reports to be submitted by water suppliers

15.0. Quality Assurance and Control

15.1. Develop and implement QA/QC procedures

15.2. Use trained personnel and calibrated equipment

15.3. Participate in national/international proficiency tests

16.0. Review and Revision of Guidelines

These guidelines shall be reviewed every five years or earlier as needed based on scientific advances, regulatory updates, or identified gaps and to incorporate emerging scientific data and technology advancements.

17.0. APPENDIX I: SELECTED WHO GUIDANCE LEVELS IN DRINKING WATER (BASED ON 0.1 MSV/YEAR)

Radionuclide	Guidance Level for Adults (Bq/L)	Notes for Infants/Pregnancy
Iodine-131	10	Reduce further due to thyroid sensitivity
Cesium-137	10	Similar to adults, but lower intake assumed
Strontium-90	4	Lower due to bone uptake risk in infants
Tritium	10,000	Generally lower risk; same or slightly reduced level
Plutonium-239	0.1	Much stricter controls for pregnant women
Radium-226	1	Stricter for infants due to bone deposition

18.0. REFERENCES

THE REPUBLIC OF ZAMBIA, The Ionising Radiation Protection Act, No. 16 of 2005, Government Printer, Lusaka (2005).

THE REPUBLIC OF ZAMBIA, The Ionising Radiation Protection (Amendment) Act, No. 19 of 2011, Government Printer, Lusaka (2011).

THE REPUBLIC OF ZAMBIA, The Ionising Radiation Protection (General) Regulations, Statutory Instrument No. 98 of 2011, Government Printer, Lusaka (2011).

The World Health Organisation (WHO) Guidelines for Drinking-water Quality (2017).

International Atomic Energy Agency (IAEA) Radiation Protection of the Public and the Environment (GSG-8), (2020).

ICRP Publication 72 (1995): Age-dependent Doses to Members of the Public from Intake of Radionuclides

ZABS (Zambia Bureau of Standards) drinking water standards