



DPC: 25/30467459 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 29 January 2025

Origin: International

Latest date for receipt of comments: 24 March 2025

Project No. 2022/02958

Responsible committee: NCE/2 Radiation protection and measurement

Interested committees:

Title: Draft BS ISO 18990 Measurement of radioactivity in urine-238Pu, 239Pu and 240Pu-Test method using alpha spectrometry and ICP-MS.

Please notify admin.start@bsigroup.com if you are aware of any keywords that might assist in clarifying or identifying the standard or of the content of this standard:

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD. THIS DRAFT IS NOT CURRENT BEYOND 24 March 2025

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop <http://shop.bsigroup.com> or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from <https://standardsdevelopment.bsigroup.com/>.

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 18990

Measurement of radioactivity in urine- ^{238}Pu , ^{239}Pu and ^{240}Pu -Test method using alpha spectrometry and ICP-MS

ICS: 17.240

ISO/TC 85/SC 2

Secretariat: **AFNOR**

Voting begins on:
2025-01-29

Voting terminates on:
2025-04-23

This document is circulated as received from the committee secretariat.

THIS DOCUMENT IS A DRAFT CIRCULATED FOR COMMENTS AND APPROVAL. IT IS THEREFORE SUBJECT TO CHANGE AND MAY NOT BE REFERRED TO AS AN INTERNATIONAL STANDARD UNTIL PUBLISHED AS SUCH.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

Reference number
ISO/DIS 18990:2025(en)

Full document details: 25/30467459 DC

© ISO 2025  **Documents**
Document Sharing Hub



COPYRIGHT PROTECTED DOCUMENT

© ISO 2025

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Principle	2
5 Chemical reagents and apparatus	3
5.1 Chemical reagents	3
5.2 Apparatus	3
6 Sampling	4
7 Sample preparation procedure	5
7.1 General	5
7.2 Sample pre-concentration	5
7.3 Organics decomposition	5
7.4 Chemical separation	5
7.5 Sample preparation for measurement	6
7.5.1 Preparation for alpha spectrometry measurement	6
7.5.2 Preparation for ICP-MS measurement	6
8 Measurement	6
8.1 Alpha spectrometer measurement	6
8.2 ICP-MS measurement	6
9 Expression of results	6
10 Test report	7
11 Quality assurance and quality control program	7
11.1 General	7
11.2 Variables that can influence the measurement	8
11.3 Instrument verification	8
11.4 Contamination	8
11.5 Interference control	8
11.6 Method verification	8
11.7 Demonstration of analyst capability	9
Annex A (Informative) Chemical separation of plutonium from 20 ml of urine sample	10
Annex B (Informative) Chemical separation of plutonium from 100 ml of urine sample	12
Annex C (Informative) Chemical separation of plutonium from a 24-hour excretion urine sample	14
Annex D (Informative) Preparation of the source by electrodeposition	17
Annex E (Informative) Preparation of the alpha source by lanthanide fluoride co-precipitation	20
Annex F (Informative) Measurement and results expression when using the alpha spectrometry method	22
Annex G (Informative) Measurement and results expression when using the ICP-MS method	30
Bibliography	36

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In the course of employment, individuals might work with radioactive materials that, under certain circumstances, could be taken into the body. Protecting workers against risks of incorporated radionuclides requires the monitoring of intakes and exposures. Part of the monitoring is the measurement of the activity of the radionuclides in the body (in vivo measurement) and/or biological samples, e.g., urine or faeces (in vitro measurement).

Analytical methods for plutonium urine bioassay are addressed in this document because of:

- the convenience of urine sampling and relatively easy sample processing. Urine bioassay is the most commonly used in-vitro measurement method for accurately assessing the magnitude of internal contamination;
- the high radiotoxicity of Pu isotopes (e.g. ^{238}Pu , ^{239}Pu and ^{240}Pu) due to their long half-lives, highly energetic alpha emission and ability to accumulate into bone and organs;
- one of the main contributions of Pu isotopes to the internal contamination in many situations, with relatively lower detection limits of Pu isotopes compared to the other highly radiotoxic actinides.

For routine individual monitoring, the detection of all annual exposures that can lead to doses exceeding 1 mSv shall be ensured according to ISO 20553. In emergency situations, the urine bioassay techniques should be sufficiently sensitive to meet the maximum value for reference level of 0,1 Sv recommended by the International Commission on Radiological Protection (ICRP)^{[1][2][3]}.

This document offers general requirements for sample processing and measurement of the activity concentration of Pu isotopes in urine samples. Examples of detailed procedures are given in the annexes for different monitoring situations.

Measurement of radioactivity in urine- ^{238}Pu , ^{239}Pu and ^{240}Pu -Test method using alpha spectrometry and ICP-MS

1 Scope

This document specifies approaches for the determination of plutonium isotopes (^{238}Pu , ^{239}Pu and ^{240}Pu) in urine using alpha spectrometry and inductively coupled plasma mass spectrometry (ICP-MS).

It is applicable to the measurement of plutonium isotopes at levels which are appropriate to:

- workers handling plutonium in occupational settings, where detection limits should be sufficient to determine compliance with dose limits
- workers, members of the public and emergency responders in accident situations, where required detection limits may be much higher, and results should be reported in a short timescale.

This document does not provide information on when monitoring should be carried out or the interpretation of the results in terms of dose or biological effects.

This document specifies requirements used to the analysis of plutonium (^{238}Pu , ^{239}Pu , and ^{240}Pu) contents in urine samples of occupational and rescue workers under emergencies. The mass concentrations obtained can be converted into activity concentrations of the different isotopes.

The detection limit depends on the efficiency of chemical separation and the performance of the measurement device.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 28218, *Radiation protection — Performance criteria for radiobioassay*

ISO 20553, *Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material*

ISO 24434, *Radiological protection — Radiological monitoring for emergency workers and population following nuclear/radiological incidents — General principles*

ISO 20899, *Water quality — Plutonium and neptunium — Test method using ICP-MS*

ISO 17294-1, *Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS) — Part 1: General requirements*

ISO 17294-2, *Water quality — Application of inductively coupled plasma mass spectrometry (ICP-MS) — Part 2: Determination of selected elements including uranium isotopes*

ISO 13167, *Water quality — Plutonium, americium, curium and neptunium — Test method using alpha spectrometry*

ISO 23548, *Measurement of radioactivity — Alpha emitting radionuclides — Generic test method using alpha spectrometry*

ISO 11929, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation — Fundamentals and application*

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 28218, ISO 20553, ISO 80000-10, ISO 11929, ISO 17924-1, ISO 20899 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org>

3.1

reference level

level of dose, risk or activity concentration for an emergency exposure situation or an existing exposure situation above which it is not appropriate to plan to allow exposures to occur and below which optimization of protection and safety would continue to be implemented

3.2

spot urine sample

urine sample that the collection duration is shorter than 24 h

3.3

sample turn-around time

total time for sample processing and measurement

4 Principle

This document introduces the methods for determining of plutonium (^{238}Pu , ^{239}Pu and ^{240}Pu) in urine by alpha spectrometry or inductively coupled plasma mass spectrometry (ICP-MS). The sample preparation volume and measurement method can be selected according to the required detection limit, sample turn-around time and isotopes need to be determined.

Based on the reference level of 100 mSv (effective dose, in the first year following contamination) in accident emergencies recommended by the ICRP,^{[1][2][3]} the derived daily urinary excretions of the ^{238}Pu , ^{239}Pu and ^{240}Pu on the third day after the intake could be 1×10^{-2} Bq/l or lower. And based on the recording level of 1 mSv (5 % of the annual dose limit of 20 mSv, 50-year committed effective dose) in the routine monitoring,^[4] the derived daily urinary excretions of the ^{238}Pu , ^{239}Pu and ^{240}Pu could be 1×10^{-5} Bq/l or lower with an annual monitoring frequency (365 days $\pm$ 30 days monitoring interval).

NOTE 1 Assuming the form of Pu is Type S, and 5 μm activity median aerodynamic diameter aerosols inhaled by a reference worker.

NOTE 2 Assuming 1,6 l daily urine excretion for a Reference Man.

In case exposure to more than one radionuclide cannot be ruled out, the detection limit of methods for ^{238}Pu , ^{239}Pu and ^{240}Pu are recommended to be 10 % urinary excretions or lower, and the requirement of measurement frequency shall be adjusted accordingly to ensure reliable assay results.

With a sample volume of 0,02 l to 1 l, the detection limits of the two measurement methods:

- for ^{239}Pu and ^{240}Pu by ICP-MS measurement are 5×10^{-4} Bq/l to 1×10^{-5} Bq/l;
- for ^{238}Pu and $^{239+240}\text{Pu}$ by alpha spectrometry measurement are $1,5 \times 10^{-2}$ Bq/l to 3×10^{-4} Bq/l with a counting time of two days.

Since internal dose calculations with biokinetic models use 24-h urine excretion as an input parameter to estimate the committed effective dose, normalization of spot urine samples to 24-h sample collection is required. The method for urinary output normalization can refer to the creatinine (CRE) test recommended by ICRP (1968)^[5] and IAEA (1999),^[6] or the specific gravity test^[7].

The urine sample needs to be measured after specific chemical separation procedures to eliminate potential interferences, including

- the salt content of the urine sample, in order to prepare a thin α counting source and achieve the desired energy resolution and counting efficiency for alpha spectrometry, or to avoid signal suppression for ICP-MS measurement.
- other potential α -emitters radionuclides, such as ^{241}Am (5,44–5,49) MeV and ^{228}Th (5,35–5,42) MeV, whose emissions can overlap with ^{238}Pu (5,46–5,50) MeV.
- the organic matrix in urine, which can seriously suppress the detection sensitivity of Pu isotopes in both alpha spectrometry and ICP-MS measurement.
- the interferences at m/z 239, 240 from U^+ peak tailing, UH^+ , UH_2^+ and other isobaric or polyatomic ions when measuring plutonium isotopes with ICP-MS.

Due to its relatively short half-life and the isobaric interference of ^{238}U , the ^{238}Pu measurement by ICP-MS would not be practically meet the required detection limits, and alpha spectrometer measurement is recommended.

Given the alpha ray energies of ^{239}Pu (5,11–5,16) MeV and ^{240}Pu (5,12–5,17) MeV are similar, and their spectral peaks overlap significantly, the alpha spectrometry method is only applicable to the analysis of $^{239+240}\text{Pu}$ activity. In this case, the alpha spectrometry measurement method described in ISO 13167 shall be selected. If individual contents of ^{239}Pu and ^{240}Pu are required, the ICP-MS measurement method described in ISO 17294-1 and ISO 17294-2 shall be selected.

5 Chemical reagents and apparatus

5.1 Chemical reagents

The chemical reagents are described in [Annexes A](#), [B](#) and [C](#) for the specific chemical separation and in [Annexes D](#) and [E](#) for the preparation of the deposited source, and in [Annexes F](#) and [G](#) for the alpha spectrometry measurement and the ICP-MS measurement.

5.1.1 Tracer, ^{242}Pu is commonly used, but ^{236}Pu and ^{244}Pu can also be chosen. The tracer solution should be traceable to national or international measurement certified standards and can be obtained from a number of commercial suppliers and national measurement institutes.

5.1.2 Ultrapure water, resistivity $> 18,2 \Omega\cdot\text{cm}$.

5.2 Apparatus

Usual laboratory apparatus and in particular the following equipment.

5.2.1 Alpha spectrometer, semiconductor detector equipped with vacuum pump shall be used. For obtaining a well-resolved spectrum, the chamber should be maintained at a pressure $< 10 \text{ Pa}$ during the measurement, and the distance between the detector and the source should be appropriate.

5.2.2 ICP-MS apparatus with associated software, installed in an air-conditioned room with Ar gas supply.

5.2.3 Balance, accurate to 0,1 mg.

5.2.4 Vacuum filtration system.

5.2.5 Filters, of pore size 0,45 um or smaller.

5.2.6 Metal discs with a sticky side.

5.2.7 Centrifuge.

5.2.8 Multi-hole vacuum box, for example, 12 positions. (optional)

5.2.9 Centrifuge tubes/bottles, for example, 50 ml and 500 ml in volume.

5.2.10 Hot plate.

5.2.11 Magnetic stirring plate.

5.2.12 Magnetic stirrer bars.

In addition, the apparatuses for specific chemical separation and sample measurement are listed in [Annexes A, B, C, D](#) and [E](#).

6 Sampling

Urine samples shall be collected in appropriate test containers free of contamination.

In accident situations, a large number of workers, members of the public and emergency responders may need to be assessed in a short timescale. In that case, spot urine samples can be collected and processed to quickly estimate the intake, and to provide information for the initiation and support of any appropriate health surveillance. And sampling should not be done too early to prevent internal contamination of nuclides that have not yet been excreted.

In the individual occupationally monitoring (e.g. routine monitoring, special monitoring, confirmatory monitoring, and task-related monitoring), 24-h urine excretion shall be collected.

When collecting 24-h urine, discard the first urine void (on the day of collection) and collect all urine voids for the next 24 h. The final collection should be at the end of the 24-hour time period.

Both the spot urine sample and the collected 24-h urine sample should be analysed for 24-h urinary output normalization as soon as possible. The method for urinary output normalization can refer to the creatinine (CRE) test recommended by ICRP (1968)^[5] and IAEA (1999)^[6] or the specific gravity test^[7].

For each sample, a unique identifier shall appear on the label of the sample container, which can be traceable to:

- date and time of sampling;
- duration of urine collection;
- sample number;
- name of sampling personnel;
- information of the tested person (e.g. gender, height, weight, the dietary history and the medical history)
- details of sample preservation and storage used;

The urine sample shall be acidified to ensure that the pH is less than 2, and shall be analysed as soon as possible or stored in the refrigerator at (0-4) °C.

Specimens should be handled in a safe manner and according to applicable legal requirements or guidance.

7 Sample preparation procedure

7.1 General

The volume of urine sample preparation can be chosen based on the monitoring situations (e.g. accident and incident emergency situations, individual occupationally monitoring situations), the requirements of detection limits and sample turn-around time.

In the emergency situations, the small volume of urine (<50 ml) can be analysed to quickly identify individuals with significant Pu internal contamination and determine the magnitude of likely exposures. And the spot urine sample can be prepared for Pu concentration measurement for an early estimation of internal dose so that physicians can determine whether or not a medical intervention is needed. Two examples of sample preparation procedures for emergency monitoring using urine volumes of 20 mL and 100 mL are described in [Annex A](#) and [Annex B](#), respectively.

In the individual occupationally monitoring (routine monitoring, special monitoring, confirmatory monitoring, and task-related monitoring), 24-h urine shall be prepared. An example sample preparation method for routine monitoring using 24-h urine sample (approximately 1,6 l) is shown in [Annex C](#).

7.2 Sample pre-concentration

The chemical recovery tracer is added during this initial sample pre-treatment phase.

The sample should be well mixed, and the isotopic equilibrium between the analyte radionuclides and the tracer should be ensured.

For small-volume urine samples (<50 ml), pre-concentration may not be necessary.

For the large-volume samples (>50 ml), pre-concentration steps are necessary, which can be carried out through evaporation or co-precipitation. If an evaporation step is performed, the resultant residue is dissolved with an acidic solution. If a co-precipitation is performed, it is often useful to add a carrier to the sample to aid collection of the precipitate. After centrifugation or filtration, the precipitate is dissolved with an acidic solution.

Among these, co-precipitation is a rapid, effective and frequent method for processing large-volume samples. For example, calcium phosphates ($\text{Ca}_3(\text{PO}_4)_2$), bismuth phosphate (BiPO_4), iron hydroxide ($\text{Fe}(\text{OH})_2$ or $\text{Fe}(\text{OH})_3$), calcium oxalate (CaC_2O_4), titanium hydroxide ($\text{Ti}(\text{OH})_3$), manganese oxide (MnO_2), and fluorides can be added to co-precipitate the plutonium isotopes. One example of co-precipitation with titanium hydroxide for different volumes of urine samples is described in [Annex B](#) and [Annex C](#).

7.3 Organics decomposition

A step of organics decomposition is necessary for large volume (>100 ml) urine samples to achieve a good chemical recovery and method performance. This step is recommended to be performed after sample pre-concentration, which can reduce reagent usage and shorten sample preparation time.

Acid digestion methods are commonly used for decomposing organics in urine, such as Fenton's reaction using H_2O_2 and a Fe^{2+} catalyst or by heating urine with HNO_3 or $\text{HNO}_3+\text{H}_2\text{O}_2$. An example of organics decomposition by heating with $\text{HNO}_3+\text{H}_2\text{O}_2$ is described in [Annex C](#).

7.4 Chemical separation

To achieve identical chemical behavior for the tracer and the target nuclides, a valence adjustment step is necessary to bring the Pu isotopes to a suitable oxidation state. Various reagents, such as H_2O_2 , NaNO_2 , hydroxylamine hydrochloride ($\text{NH}_2\text{OH}\cdot\text{HCl}$), silver oxide (AgO), ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$), titanium chloride (TiCl_3), sodium sulphite (Na_2SO_3), potassium metabisulfite ($\text{K}_2\text{S}_2\text{O}_5$), ferrous sulphate (FeSO_4), ferrous sulfamate ($\text{Fe}(\text{NH}_2\text{SO}_3)_2$), and ammonium persulfate ($(\text{NH}_4)_2\text{S}_2\text{O}_8$), have been used to convert Pu to a suitable oxidation state, e.g. the (+IV) oxidation state or the (+III) oxidation state.

The subsequent chemical separation of plutonium is usually conducted by chromatography using either anion exchange resins or solid-phase extraction (SPE) resins. The separation/purification processes using anion exchange and extraction chromatography resins are presented in [Annexes A, B and C](#) for examples.

For large-volume urine samples (>1 l), multiple column separation/purification steps are necessary to remove the interferences for plutonium measurement. An example of the separation process is given in [Annex C](#).

7.5 Sample preparation for measurement

7.5.1 Preparation for alpha spectrometry measurement

The thin-layer alpha counting sources are usually prepared by electro-deposition or co-precipitation method. The electro-deposition method is presented in [Annex D](#), and the co-precipitation method is presented in [Annex E](#).

7.5.2 Preparation for ICP-MS measurement

The sample solution can be filtered by a membrane filter ([5.2.5](#)) to prevent blockage of the ICP-MS injection tube.

8 Measurement

Alpha spectrometry and ICP-MS are commonly used for measuring Pu isotopes. The measurement methods can be selected according to the requirements of detection limit, sample turn-around time and nuclides need to be determined.

8.1 Alpha spectrometer measurement

The alpha spectrometry method is recommended for the measurement of ^{238}Pu and $^{239+240}\text{Pu}$.

In the situations with a lower detection limit required, such as in routine monitoring, it may be necessary to extend the measurement time to a few days.

The measurement method of alpha spectrometry is given in [Annex F](#).

8.2 ICP-MS measurement

When the individual concentrations of ^{239}Pu and ^{240}Pu are required, the ICP-MS measurement method shall be selected.

ICP-MS method is recommended for a large number of samples need to be measured in a short timescale, and for the monitoring programme with a requirement of lower detection limit.

The measurement method of ICP-MS is given in [Annex G](#).

9 Expression of results

Measurement results are expressed as activity concentrations in Bq/l with associated uncertainties,^[8] presented in a test report. The coverage factor for the expanded uncertainty is specified in the presentation of results.

The results measured by alpha spectrometry are given in [Annex F](#).

The results measured by ICP-MS are given in [Annex G](#).