# Nuclearelectrica – Building a sustainable future for tomorrow's generations

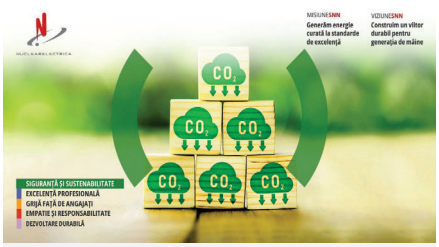

Simona Zaharov

Radioprotection Department, Cernavodă Nuclear Power Plant



SNNMISSION - We generate clean energy at standards of excellence| SNNVISION - We build a sustainable future for tomorrow's generation

## Romania's experience in nuclear industry



**Experience: Nearly 30 years of experience** in operations, at the highest level of safety and productivity

**Recognised excellence:** CNE Cernavodă operates **2 of the best-performing units** among +440 nuclear power plants worldwide, considering on the capacity factor; Romania – the first place worldwide with regards to **Lifetime Unit Capability Factor – UCF: 92.2%**

**Supply chain:** +50 years - experience in the nuclear field, with a well-established local nuclear industry

**Experienced Industry Regulatory Commission – CNCAN (National Commission for Nuclear Activities' Control):** We have a strong, independent, experienced nuclear regulatory commission, highly appreciated worldwide

**Engineering education system:** Network of universities, such as the National University of Science and Technology Politehnica in Bucharest (the 1st SMR Simulator to train students), Ovidius University in Constanța (Dual education partnership), Pitești University Centre, Valahia University in Târgoviște or Cluj Technical University.

## Nuclear Energy in Romania presently

| | |
|---|---|
| Decrease $CO_2$ emissions in Romania since the commissioning of Units 1 and 2 | 225 milion Tones |
| Annual reduction of $CO_2$ emissions due to the operation of Cernavodă NPP | 10 milion Tones |
| Nuclear energy in Romania now – 1,400 MWe, production - 235,500,000 MWh, Average Capacity Factor: 92.00% | 18-20% |
| Nuclear contribution to clean electricity | 33% |
| Jobs in the industry | 11,000 |
| Investments estimated at the level 2030 decade | EUR 12 bln |

SNNMISSION - We generate clean energy at standards of excellence| SNNVISION - We build a sustainable future for tomorrow's generation

## Nuclear energy in Romania in 2031/2032

| | |
|---|---|
| Annual decrease of $CO_2$ emissions with 4 units in operation + SMR power plant | 24 mil. Tones |
| Contribution of nuclear energy in Romania | 36% |
| Contribution of nuclear energy in total $CO_2$-free energy | 66% |
| Jobs in industry | 20,000 |

# Nuclearelectrica

**S. N. Nuclearelectrica S.A.**
**(HQ in Bucharest)**

**RoPower**

## Cernavoda Nuclear Power Plant

- Safe & efficient operation of Units 1&2 - CANDU 6
- Town heating supplier

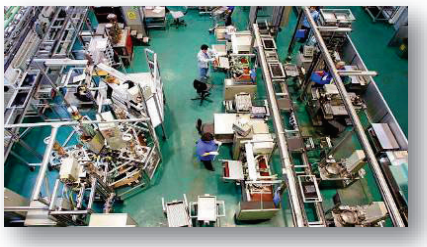
**Energonuclear**
**(Units 3&4 project, including preservation of U3&4)**

**Nuclearelectrica Serv**

**Feldioara uranium octoxide processing line**

## Pitești Nuclear Fuel Facility

- Nuclear fuel fabrication for two units



### Shareholders structure

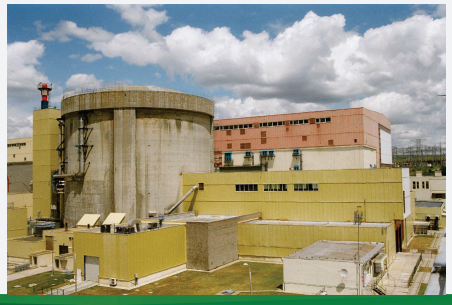
- Ministry of Energy 82.4981%
- Others 17.5019%



# CERNAVODĂ NUCLEAR POWER PLANT

**1979**
Start of Cernavodă NPP Construction

**1996**
Unit 1



**2007**
Unit 2

# CERNAVODĂ NUCLEAR POWER PLANT

CANDU technology – Canadian Deuterium Uranium

~700 MWh/ Unit

Both units CANDU6: U2 is more advanced U1

Uses natural uranium as fuel and heavy water as moderator and cooling agent

Management processes developed based on international safety and security standards





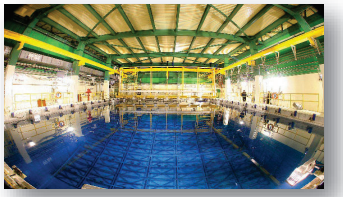
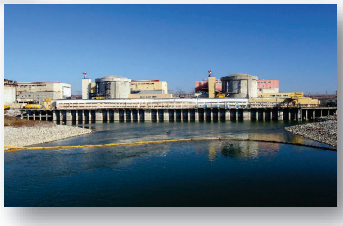
# PITEȘTI FUEL FACTORY

FCN Pitești is **the only nuclear fuel factory in South-East Europe** and the **only CANDU nuclear bundle factory in Europe.** Each year, FCN Pitești produces approx. 11,000 fuel bundles.

In 2024, **FCN celebrated 32 years of continuous operation** and the production of over **250,000 fuel bundles.**

During the life-cycle of a fuel bundle in the reactor, approx. 1 year, a 1 bundle generates 1,115 MWh.

# Fuel Cycle in Romania


- The power plant uses the **fuel bundles manufactured at its FCN Pitești.**

- The **spent nuclear fuel is stored in the spent fuel bay for 6 years** and then it is transferred to the **Interim Dry Storage Facility** (DICA). **DICA** is a modular structure, gradually built to accommodate the spent fuel resulted from the operation of 4 nuclear units (the two operating ones and future Units 3&4).



SNNMISSION - We generate clean energy at standards of excellence| SNNVISION - We build a sustainable future for tomorrow's generation

## Nuclearelectrica Projects for Repowering Romania

Refurbishment / Life Extension of Unit 1

2 new CANDU Units – timespan: 2031/2032


SMR Development

Cernavodă Tritium Removal Facility (CTRF)

Integrated Nuclear Fuel Cycle

Medical Isotopes

# Validation Method for Organically-Bound Tritium (OBT) Analysis of Reference Materials through Interlaboratory Comparison Exercises

**Simona Zaharov**

**Radioprotection Department, Cernavodă Nuclear Power Plant**



## Contents

OBT International Group: Workshops & ILC exercises, 2012 – 2025

The 7th OBT Inter-laboratory comparison exercise

1. Preliminary activities
2. TFWT analysis
3. Matrix preparation
4. Sample preparation and measurement
5. Registration of the participants and schedule
6. Evaluation of the results

Conclusions

# OBT International Group

- In the environmental samples, tritium is often associated with the free water fraction, but may be included in the organic form. Organically-bound tritium **is formed in living systems through natural or biological processes from HTO**.
- The measurement of tritium in its various forms is an important key step in evaluating **health and environmental risks** and finally to estimate more accurately **doses for the public.**
- For this purpose, the Environmental Control Laboratory – Radioprotection Department of Nuclearelectrica – Cernavoda NPP implemented different combustion methods and validated through international intercomparison exercises for OBT analysis, as a member of the **OBT International Group**.
- The main purpose of the OBT International Group is to elaborate and validate, through **interlaboratory comparison (ILC) exercises**, **OBT analysing methods** suitable for international community because there were no certified reference materials and no standard analytical methods through the international organization related to OBT.

# OBT International Group

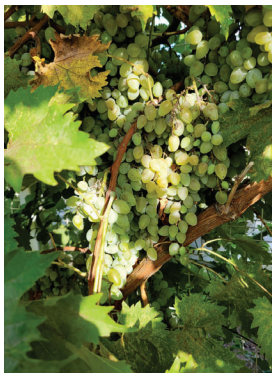
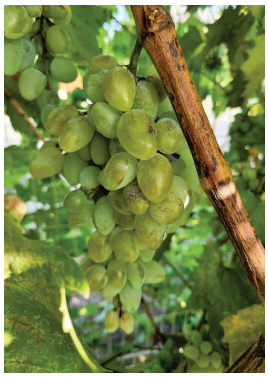
| Year | Event | Organizer, Country |
|---|---|---|
| 2012 | 1st OBT Workshop | CEA, France and AECL, Canada |
| 2013 | 1st OBT Ex. potato | AECL, Canada |
| | 2nd OBT Workshop | University of Southampton & GAU, UK |
| 2014 | 2nd OBT Ex. sediment | GAU Radioanalytical Laboratories, UK |
| | 3rd OBT Workshop | AECL, Canada |
| **2015** | 3rd OBT Ex. wheat | CEA, France |
| | **4th OBT Workshop** | **SNN-Cernavodă NPP, Romania** |
| **2016** | **4th OBT Ex. grass** | **SNN-Cernavodă NPP, Romania** |
| | 5th OBT Workshop | CEA, France |
| 2017 | 6th OBT Workshop | University of Southampton & GAU, UK |
| 2018 | 6th OBT Ex. fish | CNL, Canada |
| | 7th OBT Workshop | CNL, Canada |
| **2019** | **6th OBT Ex. quince** | **SNN-Cernavodă NPP, Romania** |
| | **8th OBT Workshop** | **SNN-Cernavodă NPP, Romania** |
| 2023 | 9th OBT Workshop | SCK-CEN, Belgium |
| **2024** | **7th OBT Ex. grapes** | **SNN-Cernavodă NPP, Romania** |
| **2025** | **10th OBT Workshop** | **SNN-Cernavodă NPP, Romania** |

# OBT Inter-laboratory comparison exercises 2013 – 2025

| # OBT Exercise | Year | Matrix | Organizer, Country |
|---|---|---|---|
| 1st | 2013 | potato | AECL, Canada |
| 2nd | 2014 | sediment | GAU Radioanalytical Laboratories, UK |
| 3rd | 2015 | wheat | CEA, France |
| 4th | 2016 | grass | SNN-Cernavodă NPP, Romania |
| 5th | 2018 | fish | CNL, Canada |
| 6th | 2019 | quince | SNN-Cernavodă NPP, Romania |
| 7th | 2024 | grapes | SNN-Cernavodă NPP, Romania |

# The 7th OBT Intercomparison exercise

1. **Preliminary activities:**
   - Type of sample: **fruits – grapes (Vitis vinifera L.)** from its yard – was chosen in September 2023;
   - Sampling location: Environmental Control Laboratory yard – **Cernavoda town** (2 km from the Cernavodă NPP);
   - Reference date: **18 September 2023**.

# The 7th OBT Intercomparison exercise

## 2. Tissue-Free Water Tritium analysis:

- Sample preparation: extraction of free water by azeotropic distillation with toluene; mixing **8 ml TFWT : 12 ml of Ultima Gold LLT cocktail** in **20 ml PE vials**;
- Analysing systems: Tri-Carb 3180 TR/SL and Quantulus GCT 6220;
- Fresh to dry mass ratio: **84% dehydration water**;
  **16% dry mass**;
- Hydrogen percentage in dehydrated sample (H%):
- **m ± 2s = 6.09 ± 0.22 %**, k=2 (ICSI-Rm. Valcea)
- TFWT activity in free water**:** **115 ± 4 Bq/L** (k=2)
- TFWT activity in fresh sample: **96 ± 3 Bq/kg** (k=2)

# The 7th OBT Intercomparison exercise

## 3. Matrix preparation:

- Quantity: about 15 kg grapes; 12.2 kg net fresh sample; 2 kg of dehydrated matrix; 50 g-75 g sample/ lab;
- Oven drying; blender cutting; coffee-grinding; homogenization; determination of Hydrogen % on dehydrated matrix; sealing subsamples.

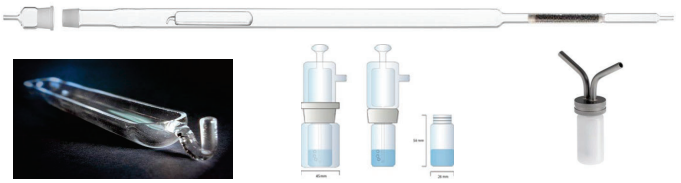
# The 7th OBT Intercomparison exercise

## 4. Sample preparation and measurement:

### A. Combustion for OBT analysis:

Pyrolyser-6 Trio System from Raddec:

- 6-tubeTri-zone, Eurotherm 3504 and Nanodac controllers, AGS (automated gas changing);
- Pt-alumina catalyst (10g/tube), Quartz wool;
- Heating profile: from 20°C – 800°C in 6 steps; air and Oxygen;
- 5 g of dehydrated sample/ Quartz boat;
- 1.8 g – 2.2 g of combustion water trapped directly into 20 ml PE vials (Y – shape cap on vial; vial into glass bubbler with anti-back suction);
- 12 ml Ultima Gold LLT cocktail/ vial.


# The 7th OBT Intercomparison exercise


### B. Measurements for OBT analysis:

- LSC analysers: **Tri-Carb 3180TR/SL**; **Quantulus GCT 6220TR**;
- 20 ml PE vial with 2 ml water of combustion : 12 ml Ultima Gold LLT cocktail;
- Measurement time: 500 min/ vial;
- H-3 window.

# The 7th OBT Intercomparison exercise

## 5. Registration of the participants and schedule:

- Registration deadline: 15th April 2024; **22 sub-samples** were distributed to the participating laboratories from 11 countries: Austria (1), Belgium (2), Canada (3), Croatia (1), France (4), Japan (5), Monaco (1), Republic of Korea (1), Romania (2), Slovenia (1) and United Kingdom (1).
- Sample dispatch: April 2024;
- Reporting results deadline: 15th of October 2024, using the reporting form in Excel format.

The 7th OBT inter-laboratory comparison exercise

A new intercomparison exercise will be organized on **dried fruit samples** (Grapes – *Vitis vinifera*). The samples will be sent to each laboratory which expresses its interest in checking its **Organically-Bound Tritium** (OBT) analytical skills.

The fruits were sampled, homogenized and dried by the organizer (**SNN-Cernavoda NPP, Environmental Control Laboratory**) before dispatching. Also, the samples were grinded by the organizer for ease of packaging and shipment. The quantity sent to each laboratory will be sufficient to prepare at least the **five replications** of the OBT analysis requested from each participant.

For this exercise the focus will stay on **OBT** without any discrimination between E-OBT and NE-OBT fractions. Therefore, there is no need to rinse the sample.

The samples will be sent by the organizer between **April – May 2024**.

The participant will have to give their results the latest on the **15th of October 2024**.

**IDENTIFICATION OF THE SAMPLE**

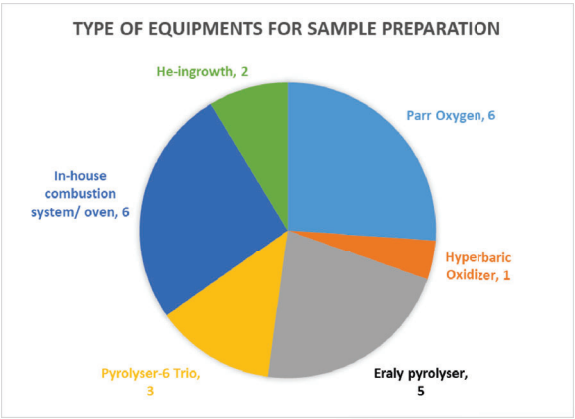
| | |
|---|---|
| Type | Dehydrated grapes – *Vitis vinifera* |
| Mass | 75 g |
| Reference date | 18th September 2023 |
| Sampling location | Cernavoda, Romania |
| Reporting OBT activity | **Bq/L** combustion water and **Bq/kg** dehydrated sample (*) |

(*) Except for the labs using the helium ingrowth method


# The 7th OBT Intercomparison exercise


## 6. Evaluation of the results:

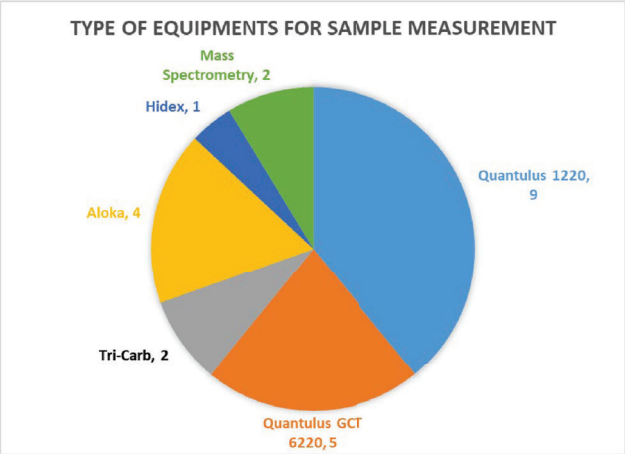
- Environmental Control Laboratory of the Cernavoda NPP prepared the evaluation of the results using **ISO 13528:2022** *"Statistical methods for use in proficiency testing by interlaboratory comparison"*, robust method, algorithm A.
- Results were reported for OBT_water of combustion [Bq/L] and for OBT_dehydrated sample [Bq/kg].
- Types of equipments for sample treatment:



# The 7th OBT Intercomparison exercise

## 6. Evaluation of the results (cont.):

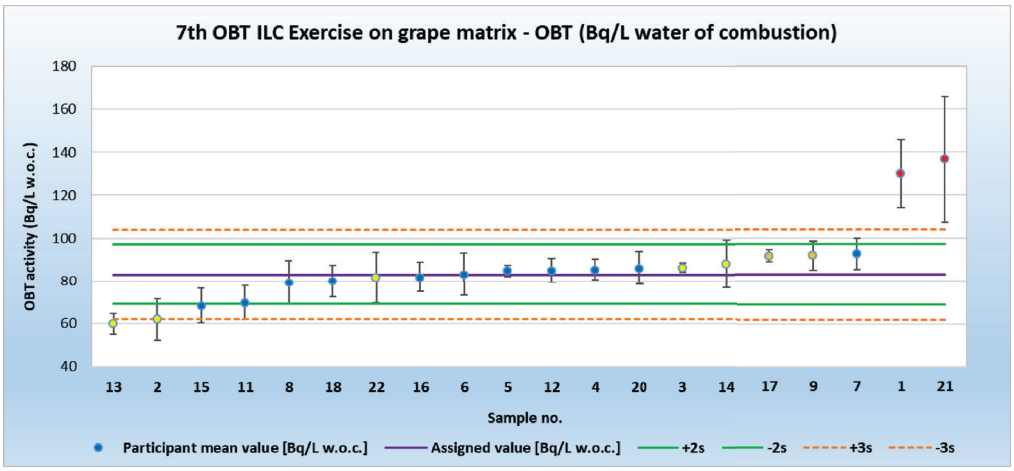
- Types of equipments for sample measurement:




# The 7th OBT Intercomparison exercise

## 6. Evaluation of the results (cont.):

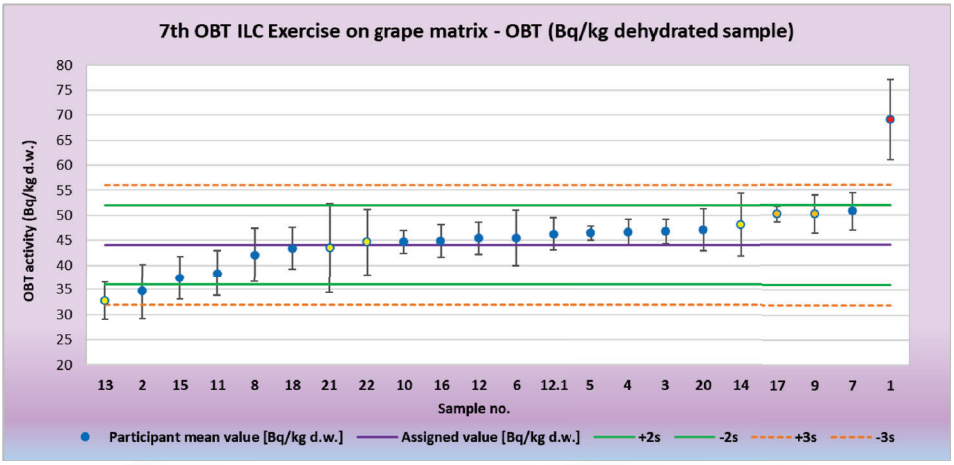
- Results of Sample#19 were not included in the evaluation due to its inconsistency with the other 21 labs.
- OBT activity range with all data: 59.7 Bq/L to 136.6 Bq/L w.o.c.;
- OBT activity range without outliers: **59.7 Bq/L to 92.6 Bq/L w.o.c**.



# The 7th OBT Intercomparison exercise

## 6. Evaluation of the results (cont.):

- OBT activity range with all data: 32.7 Bq/kg to 69.0 Bq/kg d.w.;
- OBT activity range without outliers: **32.7 Bq/kg to 50.8 Bq/kg d.w.**;
- Hydrogen % experimental values reported: 5.95% to 6.12 %;
- Hydrogen % provided in the reporting form: 6.09 ± 0.22 % (ICSI, Râmnicu Vâlcea, Romania).





# The 7th OBT Intercomparison exercise

## 6. Evaluation of the results (cont.):


- Assigned values – robust analysis (Algorithm A), ISO 13528:2022, Bq/L w.o.c., Bq/kg d.w.

| **Assigned value (Bq/L w.o.c.)** | | | |
|---|---|---|---|
| Approach | Bq/L | Standard deviation s(Xpt) or S* | Standard uncertainty u(Xpt) |
| Arithmetic mean (all data) | 86.8 | 20.8 | |
| Arithmetic mean (excluding outliers) | 82.1 | 8.5 | |
| Median | 83.8 | 9.8 | |
| **Robust analysis (Algorithm A)** | **83.0** | **7.0** | **2.5** |

| **Assigned value (Bq/kg d.w.)** | | | |
|---|---|---|---|
| Approach | Bq/kg | Standard deviation s(Xpt) or S* | Standard uncertainty u(Xpt) |
| Arithmetic mean (all data) | 45.4 | 7.3 | |
| Arithmetic mean (excluding outliers) | 44.2 | 5.0 | |
| Median | 45.4 | 4.3 | |
| **Robust analysis (Algorithm A)** | **44.0** | **4.0** | **1.4** |

# The 7th OBT Intercomparison exercise

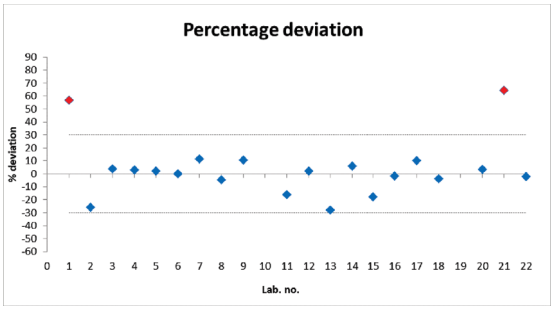
**6. Evaluation of the results** (cont.):

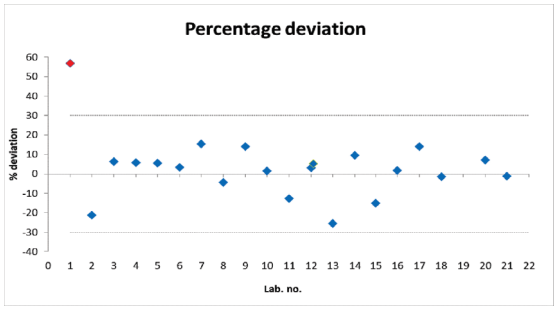
- Evaluation criteria:

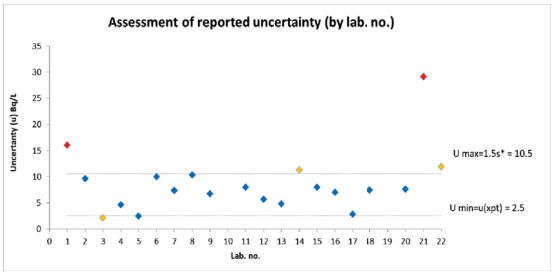
| Criteria | % Deviation | Z score | Zeta score | Uncertainty |
|---|---|---|---|---|
| Calculation | $D_i = \frac{(x_i - x_{ref.})}{x_{ref.}} \times 100$ | $z = \frac{(x_i - x_{ref.})}{s^*}$ | $\zeta_i = \frac{(x_i - x_{ref.})}{\sqrt{u^2(x_i) + u^2(x_{ref.})}}$ | $u_{min} = u(x_{ref})$<br>$u_{max} = 1.5s^*$ |
| Pass criteria | $(x_{ref.} + 3s^*) > D_i > (x_{ref.} - 3s^*)$ | $\lvert z\rvert \le 2$ - PASS<br>$2 < \lvert z\rvert \le 3$ - CHECK<br>$\lvert z\rvert > 3$ - FAIL | $\lvert\zeta\rvert \le 2$ - PASS<br>$2 < \lvert\zeta\rvert \le 3$ - CHECK<br>$\lvert\zeta\rvert > 3$ - FAIL | $u_{min} < u(x_i) < u_{max}$ |

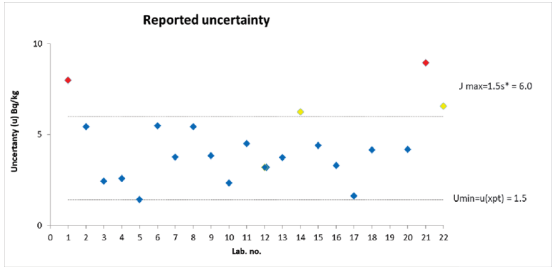
# The 7th OBT Intercomparison exercise

**6. Evaluation of the results** (cont.): Evaluation criteria: **% Deviation**; **Uncertainty**



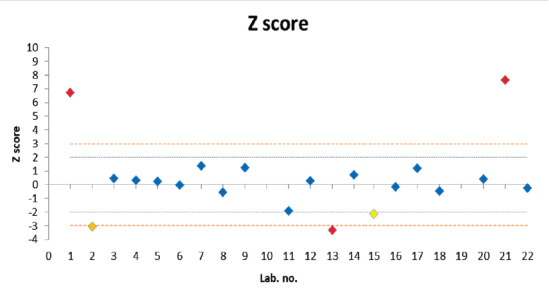



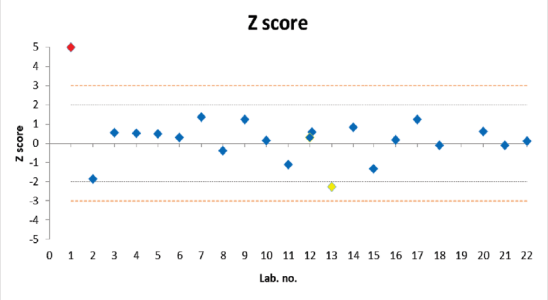

Results [Bq/L w.o.c.]

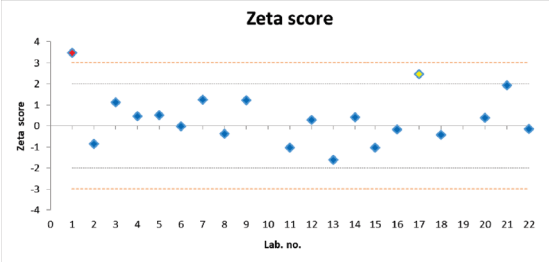
Results [Bq/kg d.w.]

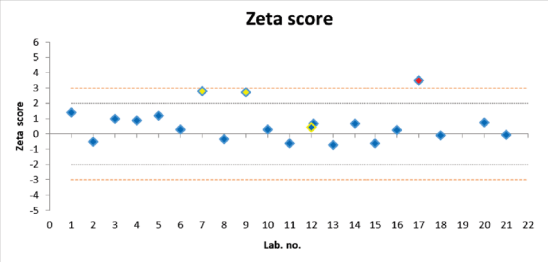
# The 7th OBT Intercomparison exercise

## 6. Evaluation of the results (cont.): Evaluation criteria: **Z score**; **Zeta score**




Results [Bq/L w.o.c.]

Results [Bq/kg d.w.]

## Published articles related to HTO and OBT (2023 – 2024) – by the Radioprotection Department of the Cernavodă NPP

Fusion Science and Technology

Taylor & Francis

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ufst20

Evaluation of Environmental Tritium Activity Levels and the Impact on the Public Health around the Cernavoda Nuclear Power Plant after 25 Years of Operation

Simona Zaharov, Alexandru E. Nedelcu & Liliana A. Samson

To cite this article: Simona Zaharov, Alexandru E. Nedelcu & Liliana A. Samson (2023): Evaluation of Environmental Tritium Activity Levels and the Impact on the Public Health around the Cernavoda Nuclear Power Plant after 25 Years of Operation, Fusion Science and Technology, DOI: 10.1080/15361055.2023.2214701

To link to this article: https://doi.org/10.1080/15361055.2023.2214701

Published online: 11 Jul 2023.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at https://www.tandfonline.com/action/journalInformation?journalCode=ufst20

Applied Radiation and Isotopes 210 (2024) 111336

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Interlaboratory comparison exercises for organically-bound tritium in the development of reference materials of environmental samples

Simona Zaharov, N. Baglan, A.E. Nedelcu, C. Varlam, I. Vagner

ARTICLE INFO

ABSTRACT

1. Introduction

https://doi.org/10.1016/j.apradiso.2024.111336

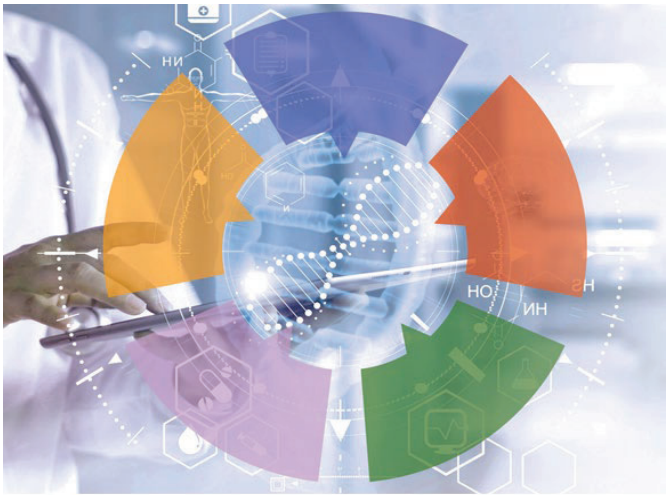
Received 5 September 2023; Received in revised form 20 March 2024; Accepted 30 April 2024

Available online 8 May 2024

0969-8043/© 2024 Elsevier Ltd. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

# Conclusions

- The results obtained during the **7th OBT ILC exercises** are encouraging as most of the participating labs didn't change the observed dispersion of the results for a similar activity level.
- The **Environmental Control Laboratory** is ***certified by CNCAN according to the ISO 17025 requirements***; it is permanently interested in the new developed radioanalytical techniques and is improving its methods according to the national requirements and the international standards in the nuclear field.
- **Nuclearelectrica – Cernavodă NPP** is interested to continue the participation to the next OBT Workshops and Inter-laboratory exercises with the following expected benefits:
  - ***to promote good analytical practice for tritium analysis;***
  - ***to reduce analytical uncertainties in OBT analysis;***
  - ***to provide data to a better OBT model validation and more accurate public dose estimates.***





SNNMISSION - We generate clean energy at standards of excellence| SNNVISION - We build a sustainable future for tomorrow's generation

# Acknowledgements


- All contributing Laboratories to the 7th OBT ILC exercise.
- My colleagues from the Environmental Control Laboratory for their work during the 7th OBT ILC exercise.
- National University of Science and Technology Politehnica and EURACHEM for organizing this workshop.


## Thank you!

Safety and Sustainability Professional Excellence Care for Employees Empathy and Responsibility Sustainable Development