EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY

DIRECTORATE D – Nuclear energy, safety and ITER
D.3 – Radiation protection and nuclear safety

Verification under the terms of Article 35 of the Euratom Treaty

Technical Report

PORTUGAL
Lisbon

Routine and emergency radioactivity monitoring arrangements
Monitoring of radioactivity in drinking water and foodstuffs

3-5 December 2018

Reference: PT 18-05

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35

OF THE EURATOM TREATY

FACILITIES	Routine and emergency radioactivity monitoring arrangements in Lisbon Monitoring of radioactivity in drinking water and foodstuffs in Lisbon
LOCATIONS	Lisbon, Portugal
DATES	3-5 December 2018
REFERENCE	PT 18-05
TEAM MEMBERS	Mr V. Tanner (team leader) Ms M. Mihaila
REPORT DATE	28 May 2019
SIGNATURES	

V. Tanner	M. Mihaila

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TECHNICAL REPORT

1 INTRODUCTION

Under Article 35 of the Euratom Treaty, all Member States must establish the facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with basic safety standards[1]. Article 35 also gives the European Commission the right of access to such facilities to verify their operation and efficiency. The radiation protection and nuclear safety unit of the European Commission's Directorate-General for Energy is responsible for undertaking these verifications. The Joint Research Centre Directorate-General provides technical support during the verification visits and in drawing up the reports.

The main purpose of the verifications under Article 35 of the Euratom Treaty is to provide an independent assessment of the efficiency and adequacy of monitoring facilities for

- liquid and airborne discharges of radioactivity from a site into the environment;
- levels of environmental radioactivity at the site perimeter and in the marine, terrestrial and aquatic environment around the site, for all relevant pathways;
- levels of environmental radioactivity on the territory of the Member State.

Taking into account previous bilateral protocols, a Commission Communication[2] describing practical arrangements for Article 35 verification visits in Member States was published in the *Official Journal of the European Union* on 4 July 2006.

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 PREAMBLE

The Commission notified Portugal of its decision to conduct Article 35 verification in a letter addressed to the Portuguese Permanent Representation to the European Union. The Portuguese Ministry of Foreign Affairs (MFA), through the Directorate General for European Affairs, was subsequently designated as the contact point and coordinator for the preparations for the visit.

2.2 DOCUMENTS

To assist the verification team in its work, the national authorities supplied an information package in advance[3]. Additional documentation was provided during and after the visit. The information thus provided was used extensively in drawing up the descriptive sections of the report.

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[1] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom (OJ L 13, 17.1.2014)

[2] Commission Communication *Verification of environmental radioactivity monitoring facilities under the terms of Article 35 of the Euratom Treaty — Practical arrangements for the conduct of verification visits in Member States* (OJ C 155, 4.7.2006)

[3] Replies to the preliminary information questionnaire addressed to the national competent authority, received on 16 November 2018

2.3 PROGRAMME OF THE VISIT

The Commission and the MFA discussed and agreed on a programme of verification activities in line with the Commission Communication of 4 July 2006.

The opening meeting included presentations on Portugal's early warning network RADNET and other environmental radioactivity monitoring arrangements. The verification team pointed to the quality and comprehensiveness of all the presentations and documentation.

The team carried out the verifications in accordance with the programme in Annex 1. It met the following representatives of the national authorities and other parties involved:

Ministry of Foreign Affairs

Directorate General for European Affairs

- Ms. Lénia Real, Deputy Director General for European Affairs
- Ms. Cristina Falcão de Campos, Head of the Sectoral Policies Department
- Mr. Pedro Forbes Lemos, Policy Officer, Sectoral Policies Department

Ministry of Home Affairs

International Relations Department

- Mr. Mauro Martins, Senior Officer

Portuguese National Authority for Civil Protection (ANPC)

- Ms. Patrícia Gaspar, 2nd National Operational Commander
- Ms. Patrícia Pires, Head of the Hazards and Land Use Planning Unit
- Ms. Ana Freitas, Head of the International Relations Unit

Ministry of Science, Technology and Higher Education

Instituto Superior Técnico (IST), the School of Engineering and Architecture of the University of Lisbon

- Mr. José Marques, Vice-President of IST for the *Campus Tecnológico e Nuclear*
- Mr. João Garcia Alves, Deputy Director of the Radiation Protection and Safety Laboratory
- Ms. Maria José Madruga, Contact Person for article 35 of the EURATOM Treaty, Radiation Protection and Safety Laboratory
- Mr. Mário Reis, Head of the Environmental Radioactivity Nucleus, Radiation Protection and Safety Laboratory
- Ms. Maria Manuel Meruje, Legal Advisor

Ministry of the Environment and the Energy Transition

Portuguese Environment Agency (APA)

- Ms. Ana Teresa Perez, Member of the Executive Board
- Mr. João Oliveira Martins, Head of the Emergency Preparedness and Response Unit
- Mr. Francisco Cardoso, Senior Officer, Emergency Preparedness and Response Unit
- Mr. Luis Portugal, Senior Officer, Emergency Preparedness and Response Unit
- Ms. Márcia Farto, Junior Officer, Emergency Preparedness and Response Unit

3 LEGAL FRAMEWORK FOR RADIOACTIVITY MONITORING

3.1 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL AND FOOD RADIOACTIVITY MONITORING

The following legal acts regulated environmental and food radioactivity monitoring in Portugal at the date of the verification[4]:

- Decree-Law 165/2002 of July 17th establishes the general principles of protection, as well as the competences and attributions of the institutions related to radiological protection for peaceful uses of nuclear energy.

  (https://data.dre.pt/eli/dec-lei/165/2002/07/17/p/dre/pt/html)

- Decree Law 174/2002 of July 25th regulates the procedures to be adopted in case of a radiological emergency.

  (http://dre.pt/pdf1sdip/2002/07/170A00/54735479.pdf)

- Decree-Law 138/2005 of August 17th establishes a national environmental monitoring system to measure the level of radioactivity in air, water and soil, in compliance with the monitoring and reporting requirements (under Articles 35 and 36 of the Euratom Treaty, and in accordance with the Recommendation of the European Commission, of 8 June 2000 (COM/473/EURATOM)). The monitoring system is managed by IST, which succeeded the former Technological and Nuclear Institute (*Instituto Tecnológico e Nuclear, I.P.*) and must also prepare an annual report (*Relatório de Vigilância Radiológica a Nível Nacional*).

  (https://data.dre.pt/eli/dec-lei/138/2005/08/17/p/dre/pt/html)

- Decree-Law 29/2012 of February 9th extinguishes the Technological and Nuclear Institute (*Instituto Tecnológico e Nuclear*, I.P.), attributing all its competences to IST and regulating the transfer of assets and attributions from the former to the latter.

  (https://data.dre.pt/eli/dec-lei/29/2012/02/09/p/dre/pt/html)

- Law 84/2017 of August 18th increases the planning obligations and the programming of intervention measures in situations of radiological emergency or nuclear accidents, amending the Decree-Law n. 36/95, of February 14th, and the Decree-Law n. 174/2002, of July 25th.

  (https://dre.pt/pesquisa/-/search/108021179/details/maximized)

Additionally, a bilateral cooperation protocol between Portugal and Spain for the management of early warning radiological monitoring networks is in place since 1995. This protocol foresees the deployment of a Spanish monitoring station in Portugal and of a Portuguese monitoring station in Spain, and the exchange of information between both networks.

[4] The Decree-Law 108/2018 of December 3rd transposes Council Directive 2013/59/EURATOM of 5 December 2013 into Portuguese Law and modifies the previous regulatory framework concerning the activities described in this report as of April 2nd 2019. The new legislation has thus no impact on the verification.

3.2 INTERNATIONAL LEGISLATION AND GUIDANCE DOCUMENTS

The list below includes the Euratom and the European Union legislation and the main international legislation and guidance documents that form the basis for environmental radioactivity monitoring and the radiological surveillance of foodstuffs and feeding stuffs.

The Euratom and the European Union legislation

- The Euratom Treaty
- Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom
- Council Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption
- Council Decision 87/600/Euratom of 14 December 1987 on Community arrangements for the early exchange of information in the event of a radiological emergency
- Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety
- Council Regulation (Euratom) 2016/52 of 15 January 2016 laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency, and repealing Regulation (Euratom) No 3954/87 and Commission Regulations (Euratom) No 944/89 and (Euratom) No 770/90
- Council Regulation (EEC) No 2219/89 of 18 July 1989 on the special conditions for exporting foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency
- Council Regulation (EC) No 733/2008 of 15 July 2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Council Regulation (EC) No 1048/2009 of 23 October 2009 amending Regulation (EC) No 733/2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Commission Regulation (EC) No 1609/2000 of 24 July 2000 establishing a list of products excluded from the application of Council Regulation (EEC) No 737/90 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Commission Regulation (EC) No 1635/2006 of 6 November 2006 laying down detailed rules for the application of Council Regulation (EEC) No 737/90 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power-station
- Commission Implementing Regulation (EU) 2016/6 of 5 January 2016 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station and repealing Implementing Regulation (EU) No 322/2014

- Commission Recommendation 2000/473/Euratom of 8 June 2000 on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole
- Commission Recommendation 2004/2/Euratom of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation
- Commission Recommendation 2003/274/Euratom of 14 April 2003 on the protection and information of the public with regard to exposure resulting from the continued radioactive caesium contamination of certain wild food products as a consequence of the accident at the Chernobyl nuclear power station

International legislation and guidance documents, issued mainly by the International Atomic Energy Agency (IAEA)

- *Radiation Protection and Safety of radiation Sources: International Basic Safety Standards*, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna, 2014
- *Clearance of materials resulting from the use of radionuclides in medicine, industry and research*, IAEA-TECDOC-1000, IAEA, Vienna, 1998
- *Generic models for use in assessing the impact of discharges of radioactive substances to the environment*, Safety Reports Series No 19, IAEA, Vienna, 2001
- *Handbook of parameter values for the prediction of radionuclide transfer in temperate environments*, Technical Reports Series No 364, IAEA, Vienna, 1994
- *Management of radioactive waste from the use of radionuclides in medicine*, IAEA-TECDOC-1183, IAEA, Vienna, 2000
- *Regulatory control of radioactive discharges to the environment: Safety Guide*, Safety Standards Series No. WS-G-2.3, IAEA, Vienna, 2000
- *Sources and effects of* ionizing *radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report to the General Assembly, Vol. I, United Nations, New York, 2000
- World Health Organisation (WHO), *Guidelines on the quality of drinking water (Guidelines for drinking-water quality*, 4th ed. 2011)

International Conventions

- Convention on Nuclear Safety
- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

4 BODIES HAVING COMPETENCE IN RADIOACTIVITY MONITORING

4.1 INTRODUCTION

At the date of the verification, the authorities with responsibilities in radiological protection, radioactive waste management, spent fuel, nuclear safety, transport of radioactive materials and radiological emergency preparedness and response in Portugal are the following:

- School of Engineering and Architecture of the University of Lisbon (Instituto Superior Técnico – IST)
- Portuguese Environment Agency (Agência Portuguesa do Ambiente – APA)

- Directorate-General of Health (Direção-Geral da Saúde – DGS)
- Directorate-General of Foodstuffs and Veterinary (Direção-Geral de Alimentação e Veterinária – DGAV)[5]
- Regional Health Authorities (Autoridades Regionais de Saúde – ARS)
- Regulatory Commission for the Safety of Nuclear Installations (Comissão Reguladora para a Segurança das Instalações Nucleares – COMRSIN)
- National Civil Protection Authority (Autoridade Nacional de Proteção Civil – ANPC)

The Decree-Law 174/2002 of July 25th states that whenever a radiological emergency occurs in Portugal, the holder of an installation where the accident took place should notify the National Authority for Civil Protection (ANPC) and the relevant Technical Intervention Authority (TIA). According to the above-mentioned Decree-Law, and depending on the circumstances, a TIA may be called on to intervene. The functions of this authority may be performed by:

- The Directorate-General of Health in radiological emergencies within installations, except those concerning mining activities and other installations in the nuclear fuel cycle;
- The Portuguese Environment Agency in radiological emergencies from which a risk to the general public or to the environment may arise (i.e. emergencies with potential or actual effects external to the installation), including risks deriving from the past mining activities concerning radioactive materials;
- The School of Engineering and Architecture of the University of Lisbon (IST) in radiological emergencies taking place during the transport of radioactive materials or caused by the loss of sealed radioactive sources.

In all other cases, the TIA will be appointed by the Ministry of the Interior.

4.2 National Authority for Civil Protection

The National Authority for Civil Protection (ANPC) presides over the National Operational Coordination Centre, promotes, supports and ensures the functioning of the National Commission for Civil Protection, presides over the National Commission for Radiological Emergencies and coordinates the entities responding to an emergency at national and district level and commands the emergencies if considered necessary. It promotes risk and vulnerability assessment, planning and preparedness activities at the national level and ensures the coordination of public and private entities participating in planning and preparedness. The ANPC also promotes and verifies the adequacy and prepares the approval process of nuclear and radiological external emergency plans.

The ANPC is the national competent authority and contact point for the international notification of emergencies affecting Portugal and for the offer and request of international assistance. In case of a nuclear or radiological emergency, it activates Initial Assessment Teams, which perform monitoring of environmental radioactivity for decision support.

[5] According to article 6(b) of the Decree 282/2012 and the EU Regulation 2016/6, imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station

4.3 PORTUGUESE ENVIRONMENT AGENCY

The Portuguese Environment Agency (APA) is the competent authority[6] for the management of the Portuguese Radiological Early Warning Network. This network is called RADNET and was established under the framework of Council Decision 87/600 Euratom and not within the scope of article 35 of the Euratom Treaty. RADNET was designed and is operated as an early warning network for nuclear emergencies; it is not part of the national environment monitoring network, as defined by the Decree-Law 138/2005 of August 17th.

APA is the National Warning Point and the contact point for the reception of notifications of emergencies occurring abroad in the framework of the Early Notification Convention of the IAEA, the National Officer for the International Nuclear and Radiological Event Scale (INES), and the national contact point for the reception of notifications from EC ECURIE. It analyses and advises on internal emergency plans whenever the practice poses a risk of offsite consequences and acts as a National Contact Point for emergencies occurring abroad.

APA follows up on the nuclear safety aspects related to the risk of accidents in facilities where fissile or fertile materials are used or produced and proposes corrective actions to protect the environment and population in case of a radiological emergency or prolonged exposure to environmental contamination.

4.4 INSTITUTO SUPERIOR TÉCNICO

According to Article 12 of the Decree-Law 138/2005, the competent authority for the environmental radioactivity monitoring and for the surveillance of foodstuffs in Portugal is the Instituto Superior Técnico (IST), the School of Engineering and Architecture of the University of Lisbon, which succeeds the former Technological and Nuclear Institute (Instituto Tecnológico e Nuclear).

The IST has three technological development laboratories, i.e. the Nuclear Energy Laboratory (LEN), the Accelerators and Radiation Technology Laboratory (LATR) and the Radiation Protection and Safety Laboratory (LPSR), with the following nuclear and radiological facilities and activities:

- At LEN, 1 MW pool type research reactor (since September 2017 in permanent shutdown and in transition to decommissioning)
- At LATR, the Radiosterilization Unit
- At LPSR:
  - Laboratory for Metrology of Ionizing Radiation
  - Individual and environmental radiation dose monitoring laboratory
  - Radiobiology laboratory
  - National dose register
  - Radioanalytical techniques for measurement of natural and artificial radionuclides in environmental samples, foodstuff, feedstuff, construction materials, water for human consumption, indoor Radon, etc.
  - Safety assessment of radiological facilities, equipment and environment
  - Transport of radioactive material
  - Control of sealed radioactive sources and orphan sources
  - Radioactive waste management facility (low and intermediate activity waste)

[6] Under article 18 (b) of the Decree-Law n. 165/2002 of July 17th and article 8(1) of the Decree Law 174/2002 of July 25th

The Radiation Protection and Safety Laboratory (LPSR) is organized into three sections, i.e. Metrology and Dosimetry, Environmental Radioactivity and Operational Radiation Protection. The LPSR laboratories are located at the IST campus at Bobadela (close to Lisbon); they are the only radiological laboratories in Portugal.

Annex 4 presents the IST matrices and accredited analytical methods, Annex 5 the recent intercomparison exercises in which the IST participated, and Annex 6 the measurement devices available in the IST laboratories

5 RADIOACTIVITY MONITORING IN PORTUGAL

5.1 General

There are no active nuclear facilities in Lisbon or in its vicinity. The research reactor at the IST site has been closed, but there is still used nuclear fuel in the facility. Occasionally nuclear powered vessels (military aircraft carriers and submarines) visit the Lisbon harbour.

APA operates an advanced automatic dose rate monitoring system, which covers the whole country. Radioactivity in air is monitored by using a high volume aerosol sampling station located at the IST. Atmospheric deposition radioactivity is assessed through rainwater collectors at the IST. In addition, the routine radiation monitoring surveillance includes laboratory analysis of several environmental samples and food. Table I below summarises the different sample types. Figures 1-3 below show the main monitoring locations in the Lisbon area and at the IST site. The IST website[7] contains reports on the monitoring results.

Both APA and IST maintain capability to carry out mobile radiation monitoring in the event of a radiological accident or other situation requiring additional monitoring.

Table I. Summary of samples and radionuclides assessed in the main monitoring locations in the Lisbon area and at the IST site

Type of Samples	Radionuclides, Parameters assessed	Measurement methods
Rain water	^{7}Be, ^{137}Cs, ^{3}H, Gross alpha/beta, ^{90}Sr	HPGe detectors Liquid scintillation counter Gas flow proportional counter
Aerosols	^{7}Be, ^{137}Cs, ^{210}Pb, ^{131}I	HPGe detectors
Surface water	^{137}Cs, ^{3}H, Gross alpha/beta, ^{90}Sr	HPGe detectors Liquid scintillation counter Gas flow proportional counter
Sediments	Natural and anthropogenic radionuclides	HPGe detectors
Aquatic plants	Natural and anthropogenic radionuclides	HPGe detectors
Drinking water	Gross alpha/beta, ^{3}H, ^{222}Rn, ^{137}Cs, ^{90}Sr	Liquid scintillation counter HPGe detectors Gas flow proportional counter

[7] http://www.IST.tecnico.ulisboa.pt/docum/pt_bib_reltec.htm

Milk	^{137}Cs, ^{131}I, ^{40}K, ^{90}Sr	HPGe detectors Liquid scintillation counter
Mixed diet	^{137}Cs, ^{40}K, ^{90}Sr	HPGe detectors Liquid scintillation counter
Foodstuffs	^{137}Cs, ^{131}I, ^{40}K, ^{90}Sr	HPGe detectors Liquid scintillation counter
Soils	Natural and anthropogenic radionuclides	HPGe detectors

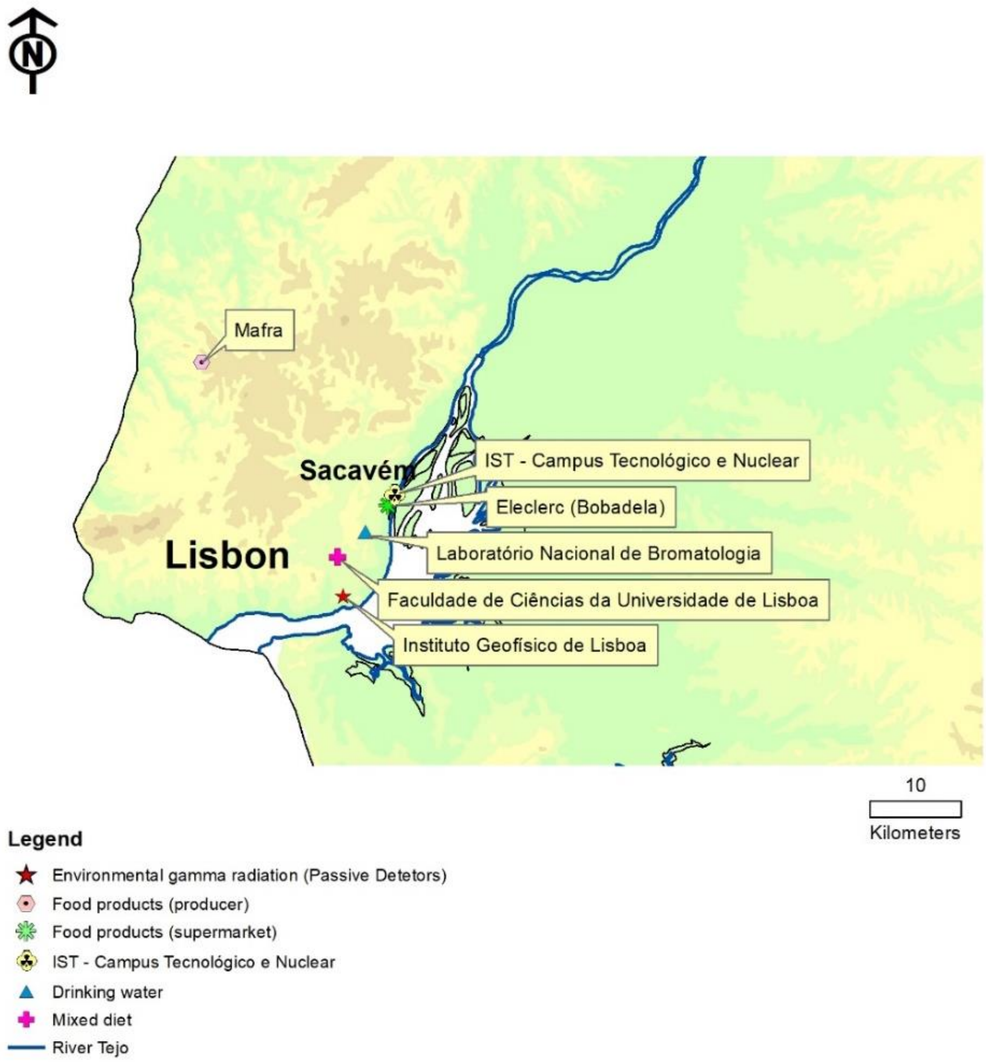

Figure 1. Map of the Lisbon area with the identification of the sampling locations and the Campus Tecnológico e Nuclear of Instituto Superior Técnico in the northern part of the city

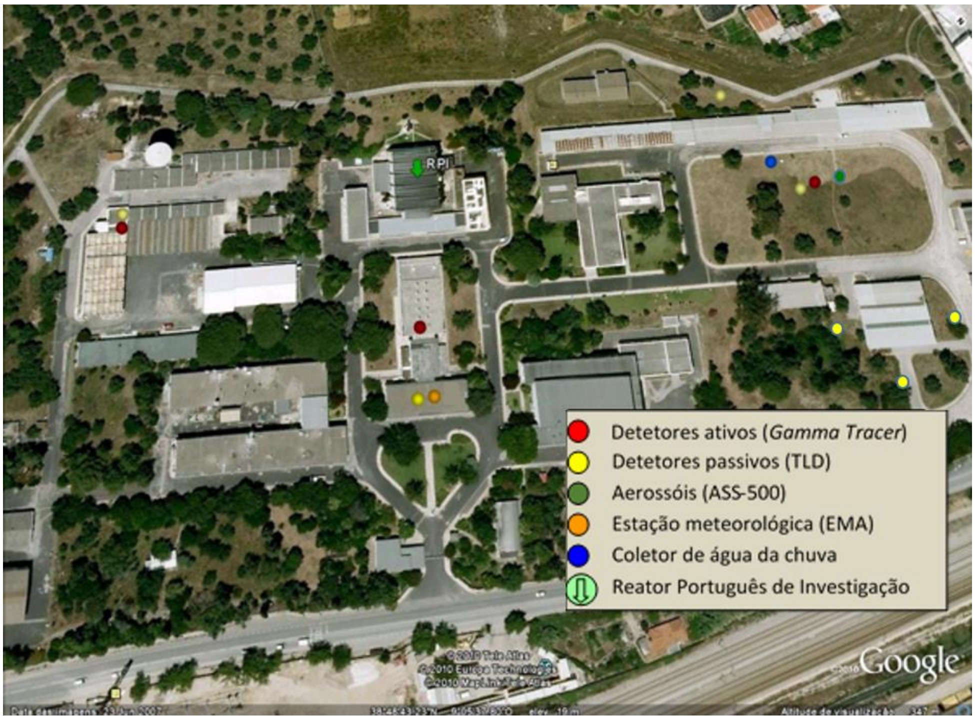

Figure 2. Map of IST campus with the identification of the monitored sites: active detectors (red circles), TLD (yellow circles), high volume aerosol collector (green circle), meteorological station (orange circle), rain water collector (blue circle) and the Portuguese Research Reactor (green arrow)

Figure 3. Aerial view of the IST and surrounding area showing the location of the soil sampling sites (pink circles) within and outside the IST

5.2 MONITORING OF EXTERNAL GAMMA DOSE AND DOSE RATE

5.2.1 RADNET monitoring network

RADNET is a sparsely distributed network located in the Portuguese mainland (16 stations for measurement in air and 2 in water) and the autonomous regions (one station in Funchal, Madeira, and one in Ponta Delgada, the Azores – see Figure 4). In Talavera la Real, Spain, one station is deployed in the framework of the bilateral cooperation protocol between Portugal and Spain for the management of early warning radiological monitoring networks. In the Lisbon area, RADNET has currently two stations near the Lisbon airport, a DLM1450 station and a new SARA station. In 2019, the DLM1450 station will be decommissioned and fully replaced by the SARA station. Besides these stations, the ones nearest to Lisbon are located in Abrantes (SARA station) and Sines (DLM1450 station).

The network is operated by APA. Management of the network is performed via the central unit located at the premises of APA in Lisbon, with the Envinet GmbH NMC software (version 2.9.0 Germanium).

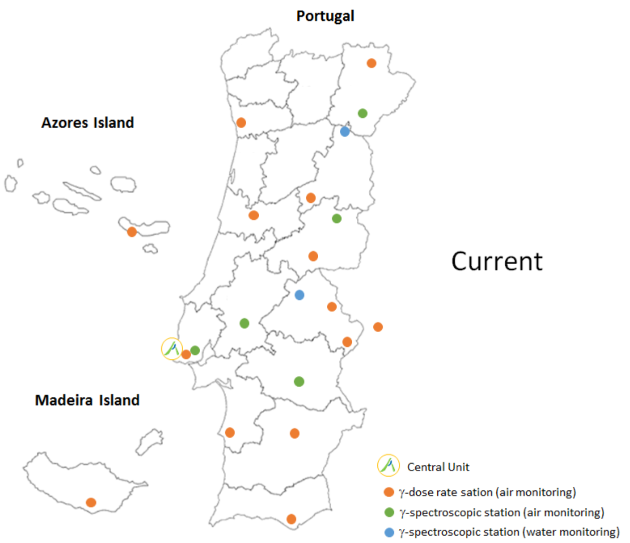

Figure 4. RADNET stations

Currently RADNET includes 14 Envinet DLM1450 stations, which measure gamma dose rates (H*(10)) only, and 5 Envinet Sara Stations, which measure gamma dose rates (H*(10)) and have spectrometric capabilities and increased sensitivity. Additionally, one Envinet DLM1450 station is installed in a vehicle and two Envinet Mira Stations can be deployed anywhere. RADNET also includes two continuous water monitoring stations deployed in the Tagus and Douro international rivers. These stations are also from the manufacturer Envinet, model Sara Water, measuring the gamma dose rate (H*(10)) and having also spectrometric capabilities.

Sampling is performed at intervals of one minute. The local microprocessor calculates averages for intervals of 10 minutes, which in turn will provide the basis for calculating the average values at intervals of 2 hours. The measured data are transmitted hourly to the central unit in routine operation via a switched telephone network or GPRS (for the new SARA and MIRA stations). The microprocessor in the remote station has a memory capacity to store data collected and a battery that guarantees operation in case of a power failure from the outside network. The software performs data processing of local self-diagnosis on the operating conditions of each station.

In the event of occurrence of abnormal situations, the remote station takes the initiative to send messages to the central unit informing about the corresponding status. An alarm is triggered when the measured radiation levels are above a threshold pre-set from the central station, which currently is set at about three times the average value measured in normal circumstances. In this case, the alarm received at the central unit activates an automatic audible and visual warning, installed in the APA facilities. A warning is also sent to the duty officer. The central unit, in addition to being able to access the values measured continuously from any remote station, can program and process the data, as well as monitor, test and program the system without the need for local intervention except for reconfiguration of the probes' parameters.

The annual Quality Assurance Program (QAP) includes a maintenance program for all the stations all year around, with a response time of 24 to 48 hours after the identification of the failure. The QAP also includes a yearly inspection to the stations, semi-annual reports on the conditions of the network and a yearly report with the evaluation of availability of the data.

Before the end of 2019 RADNET will be expanded with one Envinet SARA station to measure the external gamma dose rate in the air, one Envinet Sara Water station to be deployed in the Guadiana river (also an international river) and three aerosol and ^{131}I monitoring stations, increasing and diversifying the coverage of national territory (see Figure 5). Additionally, all the older DLM1450 stations will be substituted by Envinet Sara stations.

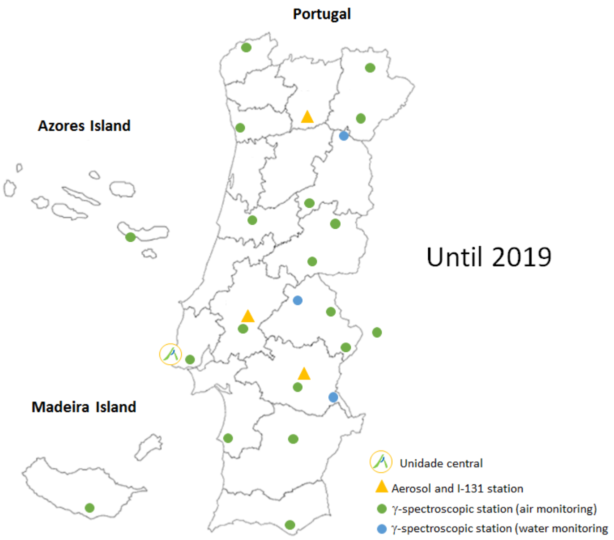

Figure 5. RADNET stations deployment by the end of 2019

5.2.2 IST monitoring network in Lisbon

At the IST in Lisbon, monitoring of external gamma radiation with active devices is performed with a shortlink system composed of three GammaTracer-XL probes and a monitoring station from the Saphymo GmbH. The probes are equipped with a radio communication system (433.5 MHz) that sends data to the monitoring station at predefined time intervals. The Shortlink system is based on the unidirectional radio principle: the probe sends information for the control station without receiving any type of confirmation. Communication with the probes is established through a sender with an infrared port and a portable computer. The maximum distance for the transmission of data is 5 km through radio and 10 m through infrared. For the programming and maintenance checks of the probes, a portable server with an infrared gate is used.

Each probe is composed of two Geiger-Müller radiation counters, one sensitive to low dose rates and the other to high dose rates. For intermediate dose rates both operate simultaneously. The probes operate in the 45 to 2000 keV energy range and in the 10 nSv/h to 10 Sv/h gamma dose rate ranges. Gamma dose rate is measured by each probe every minute, stored and communicated to the monitoring computer at 60-minute intervals. At present, the first trigger level is set at 300 nSv/h and if reached, the data communication interval is shortened to 10 minutes. The second trigger level is set at 1 μSv/h, when the data communication interval will be one minute. In routine conditions, annual charts are produced based on the monthly averages measured by each probe.

5.2.3 TLD monitoring network

The thermoluminescence dosimeters (TLD) used for environmental monitoring of external gamma radiation dose consist of Harshaw TLD-100 two-element cards inserted in a Harshaw 8855 holder. The dosimeters are calibrated in terms of the environmental dose equivalent (H*(10)) and evaluated on a quarterly basis. Currently the programme includes 7 monitoring locations at the IST campus in Lisbon and 8 locations in other parts of the country (Fig. 6).

Figure 6. TLD monitoring locations

5.3 MONITORING OF RADIOACTIVITY IN AIR

5.3.1 Air samplers

Radioactivity in air is monitored by collecting aerosol particles using an aerosol sampling station type ASS-500 (Physik Technic Innovation), located at the IST campus in Lisbon. The sampling station is equipped with a high volume suction pump (around 800 m^3/h), a continuous flow meter and an air volume accumulator. Air is filtered through a 44 X 44 cm filter (Petrianov type FPP-15-1.5). Filters are changed on a weekly basis. All gamma emitters on the range from 46 to 2000 keV are assessed.

5.3.2 Atmospheric deposition collectors

Atmospheric deposition is sampled in two locations (IST in Lisbon and Castelo Branco). The sample collection device consists of a total atmospheric deposition collector, in a quadrangular pyramid trunk, with a 1 m^2 collection area. At the beginning of each month, the collector is washed with water and a 50 L plastic container is placed underneath, and removed at the end of the month. When the precipitation exceeds the capacity of the container, it is replaced by one or more containers in order to collect the whole sample corresponding to the monthly precipitation. If more than one container is used, aliquots of each container are withdrawn in order to obtain a representative sample.

From the precipitation sample collected, 1 litre is used for determination of gross beta activity in suspended matter (particulate phase, $\varnothing$> 0.45 μm), and 1 litre for ^{3}H analysis. From the remaining sample, after filtration, 3 to 5 litres are used for determination of gross alpha/beta activity in soluble phase ($\varnothing$< 0.45 μm) and a maximum of 30 litres concentrated to 1 litre (by slow evaporation on an electric plate) for the determination of gamma-emitting radionuclides (^{7}Be, ^{137}Cs) and ^{90}Sr activity concentration (beta measurement), in the soluble phase.

5.4 MONITORING OF RADIOACTIVITY IN WATER

Monitoring of radioactivity in water is carried out by collecting samples for radiological analysis in the laboratory. There are no on-line water monitoring devices in Lisbon, but the RADNET system includes two water monitoring stations (rivers Tagus and Douro). The sampling is based on the following standards:

- International Standard ISO 5667-5:1991. Water quality, Sampling Part 5: Guidance on sampling of drinking water and water used for food and beverage processing
- Norma Portuguesa NP EN25667-1, 1997. Qualidade da água. Amostragem. Parte 1: Guia geral para o Planeamento de programas de Amostragem (ISSO 5667-1:1980)
- Norma Portuguesa NP EN25667-2, 1996. Qualidade da água. Amostragem. Parte 2: Guia Geral das técnicas de amostragem
- International Standard ISO 5667-3:2003. Water quality, Sampling Part 3: Guidance on the Preservation and Handling of Water Samples

5.4.1 Surface waters

On national level, monitoring is carried out at rivers Tagus, Zêzere, Guadiana, Mondego and Douro. The results are published in the annual reports of Environmental Radioactivity Monitoring Programmes[8].

Water samples for the gross alpha/beta, tritium (^{3}H), strontium (^{90}Sr) and caesium (^{137}Cs) determinations are collected separately in identified plastic containers. Surface water samples are collected at running water locations, away from river banks and about 30 cm from the surface. When the river conditions do not allow this sampling procedure, the samples are taken at the river bank, at the same locations. A bucket is used to collect the water sample, which is transferred to the respective plastic container by passing it through a funnel with a calibrated net of 64 μm to retain the suspended matter from the sample. If the sample presents a large amount of suspended matter, an auxiliary mesh filter (200 μm) can be used, which is placed above and in series with that of the 64 μm filter.

From the water sample collected, one litre is used for determination of gross beta activity in suspended matter (particulate phase, ∅> 0.45 μm) and 1 litre for ^{3}H analysis. From the remaining sample, after filtration, 1 to 3 litres are used for determination of gross alpha/beta activity in soluble phase (∅< 0.45 μm) and a maximum of 30 litres concentrated at 1 litre (by slow evaporation on an electric plate) for the determination of ^{137}Cs (gamma spectrometry) and ^{90}Sr (beta measurement) activity concentrations in the soluble phase.

5.4.2 Drinking water

In the Lisbon region drinking water samples are collected at the Bromatology Laboratory (Laboratório de Bromatologia - see Figure 1). On national level, samples are collected at the Zêzere River and other randomly chosen locations in the mainland Portugal.

Drinking water samples are collected directly from the tap. The tap is opened and the water allowed to flow slowly for approximately 30 seconds before sampling. The specific sampling methods are the following:

[8] http://www.IST.tecnico.ulisboa.pt/docum/pt_bib_reltec.htm

Gross Alpha/beta activities

One litre of tap water is collected in a plastic container (cleaned and rinsed with the same water before sampling). The sample is maintained refrigerated from collection to laboratory delivery, which should not exceed 2 days. If this interval is exceeded, the sample is acidified with 0.2 mL of concentrated nitric acid (65% w/w HNO_3) per liter of sample.

Tritium (^3H)

One litre of tap water is collected in a plastic container (properly cleaned and rinsed with the same water before sampling). The container is completely filled until overflow and well capped to avoid air bubbles. The sample is maintained refrigerated, at low temperature, from the collection to the laboratory delivery, which should not exceed 2 days.

^{137}Cs and ^{90}Sr

Thirty litres of tap water are collected in a plastic container (properly cleaned and rinsed with the same water before sampling). When delivered to the laboratory, the samples are be acidified with 0.2 mL of concentrated nitric acid (65% w/w HNO_3) per litre of sample.

Radon (^{222}Rn)

The tap water is collected in a borosilicate amber flask of 250 mL capacity, properly cleaned. Before sampling, the water should flow at high pressure to remove air and water contained in the piping and tap. The faucet is kept open for about 5 minutes and, shortly before the sampling collection, the flow should be reduced, allowing the water to run at low pressure (on the wire). Finally, the flask is placed under the tap and the sample is collected slowly to avoid the formation of air bubbles inside. Alternatively, when there are no faucets at the place of collection, the water is collected into a vessel. The vessel is slowly filled and the flask submerged in order to prevent the formation of air bubbles inside it, which can be verified after flask inversion. If there are air bubbles, an empty bottle is used and the procedure repeated. After collection, the flask is tightly sealed and identified. The date and time of collection is noted. The sample should be maintained refrigerated and delivered to the laboratory as soon as possible. The time between the collection and the beginning of the analysis should not exceed 4 days.

5.5 MONITORING OF RADIOACTIVITY IN SOIL AND SEDIMENTS

5.5.1 Soil

Soil is sampled at the IST campus and at one location in the surroundings of the IST (See Figure 3). On national level sampling is done in randomly chosen locations. These locations should be flat open areas with little or no vegetation, constituted mainly by undisturbed soils. A sampling area of approximately 1 m^2 is selected. In the selected area five samples are collected, one in each vertex and one in the center of the square, about 10 cm deep. The collection is carried out with a metal shovel and the composite sample, resulting from the 5 samples, is placed in a plastic bag or box. The sample quantity is around 1.5 kg.

5.5.2 Sediments

Sediment is sampled in rivers Tagus, Zêzere, Guadiana, Mondego and Douro. The samples are collected in the riverbed with a sediment collector (Berthois cone) in a river area with running water which is always flooded and about one meter from the bank. The collector is thrown as many times as necessary to fill a plastic box (≈5 kg). The water in excess is drained from the sediment.

5.5.3 Terrestrial biota and flora

Terrestrial biota and flora are not considered in the monitoring programme, only soil and foodstuff.

5.5.4 Aquatic biota and flora

Freshwater plants are collected at the Tagus River. The aquatic plants are collected by hand, with a rake, near the shore to the maximum depth of the operator (1.5 m depth). The plants submerged and fixed to the sediment with rhizomes or roots (Potamogeton pectinatus) are extracted by dragging the bottom with the rake. The emergent plants (Cyperus eragrostis) are plucked by the roots and the sediment in which they are inserted are disaggregated with a rake, to facilitate manual extraction. All the collected plants are washed in river water to remove aggregate sediments to the roots and rhizomes and impurities aggregated to the leaf parts. The samples (2-3 kg) are transported to the laboratory in identified plastic bags.

5.6 MONITORING OF RADIOACTIVITY IN FOOD

5.6.1 Milk

Milk is sampled at Vila do Conde, Tocha, Portalegre, Águas de Moura, Madeira and the Azores Islands. In mainland Portugal, milk sampling is performed by Autoridade de Segurança Alimentar e Económica (ASAE) (Portuguese Food Safety and Economic Authority), within a Memorandum of Understanding with the IST. In Azores and Madeira Islands milk sampling is carried out by the Inspeção Regional das Atividades Económicas dos Açores (Azores Regional Inspection of Economic Activities) and the Secretaria Regional do Ambiente e Recursos Naturais da Madeira (Madeira Regional Secretariat for the Environment and Natural Resources) respectively.

The sampling plan for the following year is sent by the IST to the ASAE and to the Azores and Madeira responsible entities in the end of the year. Samples (2 litres without any treatment) are collected (identified plastic or glass containers) in tanks at the entrance of dairy processing and distribution factories. The milk samples come directly from the producer through dairy cooperatives to the factory. The samples are delivered refrigerated at the laboratory together with the filled sampling forms.

5.6.2 Mixed diet

Mixed diet is sampled at the canteen of the University of Lisbon. The meal samples (lunch and dinner), consisting of soup, main course, bread, desserts (fruit or sweet) are sampled in identified plastic boxes on a monthly basis. The quantity sampled is around 1-1.2 kg.

5.6.3 Foodstuffs

Foodstuff samples are purchased by the IST at a local supermarket. Samples consist of meat (turkey), fish (sardines), mussels, fruit (melon), tomato and flour. On national level, samples are randomly collected directly from the producers in Portugal and in the Azores and Madeira Islands and consist of leaf vegetables (cabbage/lettuce), tuber (potatoes/onions/carrots), meat (pork/veal) and fruit (orange/apple/banana). Foodstuff sampling is performed by the same entities as described for milk. The samples, around 2 kg of each product, are collected and conditioned in identified plastic bags. The samples are delivered refrigerated at the laboratory.

5.7 ANALYTICAL METHODS

5.7.1 Aerosol particles

Measurement of gamma emitters in aerosol filters by high-resolution gamma spectrometry

After collection using a high volume sampler, the filters are pressed using an hydraulic press to fit a cylindrical geometry (5 cm diameter and 1 cm thickness) and measured by high resolution gamma spectrometry on HPGe detectors. The detectors are placed in a lead shield with copper and tin lining to reduce the natural background radioactivity level. Efficiency calibration of the detectors is performed by using NIST-traceable multi-gamma radioactive standards (POLATOM) with energies ranging from 46.5 to 1836 keV, and customized in a Petrianov filter to exactly reproduce the geometry of the samples. Genie 2000 software is used for data acquisition and analysis. GESPECOR software is used to correct for matrix (self-attenuation) and coincidence summing effects. External QC is assured through participation in intercomparison exercises organized by international organizations. This technique is accredited according to the ISO/IEC 17025 standard.

5.7.2 Surface water, drinking water, rainwater

Measurement of gross alpha/beta activity concentration in non-saline water using a proportional counter

The method is based on the ISO standards 9696:2017 and 9697:2015 for gross alpha and gross beta activities respectively. The water sample is acidified (for preservation) with 0.2 mL of concentrated nitric acid (65% w/w HNO_3) per liter of sample. Sample volume (250 mL to 5 L) is measured and transferred to a beaker in order to obtain a mass density after the calcination step of 1 to 10 mg/cm. This volume depends of the water dissolved salt concentration and is calculated before evaporating to dryness, 20 mL of the water sample. The value of the transferred volume is recorded. The water sample is slowly evaporated almost to dryness, converted to the sulphate form and then ignited at 350ºC. The dry residue is weighted and disposed homogeneously (uniform thickness) in a steel planchet. Samples are measured using a Tennelec (Canberra) XLB-S5 Proportional Counter (counting time of 240 min). Background measurements are performed with empty planchets. Calibration of the detector is performed using ^{241}Am (Eckert & Ziegler Analytics) and $^{90}Sr/^{90}Y$ (Amersham) standards in a $CaSO_4$ matrix.

Measurement of gross alpha/beta activity concentration in non-saline water using a liquid scintillation counter

This method is based on the ISO standard 11704:2010. The sample is acidified (for preservation) with 0.2 mL of concentrated nitric acid (65% w/w HNO_3) per litre of sample. A water aliquot of 20 mL is used for the determination of the dry residue concentration. If the mass of the residue is ≤ 0.5 g a thermal pre-concentration is applied until a concentration factor (f_c) of ≈ 15. If the mass of the residue is > 0.5 g a thermal pre-concentration until a lower concentration factor (f_c) or no pre-concentration is applied. The mass corresponding to the initial volume is defined as a function of the f_c by ensuring that the mass corresponding to the volume after concentration is not less than 8 g. In any case, the pH should be adjusted with nitric acid concentrate, so that the pH value of the concentrated sample should not be lower than 1.5±0.5 and no precipitation should be observed. The sample amount (8 g) is mixed with 12g of cocktail (Ultima Gold LLT, Perkin Elmer) into the scintillation glass vial. Background samples are prepared in the same way as the routine samples using a nitric acid solution (0.03 mol/L). The measurements are performed using a liquid scintillation spectrometer (Tri-Carb 3170 TR/ SL, Perkin Elmer) equipped with pulse decay analysis (PDA) option. The counter is previously optimized and calibrated using a set of ^{241}Am and $^{90}Sr/\ ^{90}Y$ standards prepared with the same activity (≈ 10 Bq) from certified standard solutions (^{241}Am from Eckert & Ziegler Analytics and $^{90}Sr/\ ^{90}Y$ from Amersham) with different volumes of CCl_4 (0-50 µl) and consequently with different quenching levels. The quenching effect is quantified by the tSIE parameter (Transformed Spectral Index of the External standard). The measurements are performed in normal counting mode, in the channel region 76-215 keV for gross alpha and 26-905 keV for gross beta, using an optimum pulse decay discriminator (PDD) setting at 123.

***Determination of tritium activity concentration using isotopic enrichment*[9]**

This method is based on the ISO standard 9698:2010 with isotopic enrichment. The water samples are purified by distillation, followed by isotopic enrichment procedure using electrolysis through direct current. The samples (8 mL of water mixed with 12 mL of Ultima Gold LLT™ scintillation cocktail in borosilicate glass vials) are measured in a Tri-Carb 3170 TR/SL (PerkinElmer) liquid scintillation counter in low-level mode. Before counting, the samples are stabilized in the dark to avoid light interference.

Determination of radon (^{222}Rn) activity concentration using two-phase liquid scintillation counting method

This method is based on the ISO standard 13164-4:2015. A liquid scintillation vial, with 10 mL of the specific scintillation cocktail immiscible with water (Opti-Fluor O) is weighed. With the aid of a syringe, 10 mL of water is withdrawn from the water container. The needle of the syringe is inserted into the scintillation vial and the sample slowly injected below the cocktail surface without causing turbulence, in order to minimize any loss of radon. After transferring the sample, the scintillation vial is immediately closed (the cap was tightly closed) and weighed to determine the mass of the sample (the date and time of preparation are recorded). Then, the vial is shaken for a few seconds vigorously and cleaned with ethanol, in order to remove any electrostatic charge.

Before measurement, the sample is stored in the dark for 3 hours until equilibrium is reached between ^{222}Rn and its short-lived progeny. The ^{222}Rn activity is measured in a liquid scintillation counter (Tri-Carb 3170 TR/SL). For the detection system calibration, 10 standards of ^{226}Ra are prepared from a ^{226}Ra certified standard solution. The standards are allowed to attain equilibrium between ^{226}Ra and ^{222}Rn for 30 days and are measured after that period for 5 cycles each along with 10 blank samples. A pulse decay discriminator (PDD) is selected in order to optimize alpha/beta separations. Blank samples are prepared in a similar way as the samples, by adding 10 mL of distilled water to 10 mL of the organic scintillation cocktail. The detection limit obtained in this method is typically 0.50 Bq/L for 2 hours counting time.

Determination of ^{137}Cs and ^{90}Sr activity concentration by beta measurements

From 30 liters of water, filtered by 0.45 µm membranes, strontium (Sr^{2+}) is isolated from cesium (Cs^{+}), after concentration of the sample (adding concentrated HNO_3 and H_2O_2 to digest the organic matter) by evaporation to dryness. The dry residue is dissolved and the carriers Sr^{2+} and Cs^{+} are added to the solution. After purification of the solution, sodium carbonate is added to the solution and a precipitate is generated. Sr^{2+} is retained in this precipitate and Cs^{+} remains in solution.

Strontium is separated from the carbonate precipitate using a specific resin (100-150 µm Sr-C50-A from EICHROM) and stored until the radioactive balance between ^{90}Sr and the ^{90}Y (20 days). The ^{90}Y is measured in the low background, beta proportional counter, (Tennelec/Canberra XLB-S5).

Cesium is separated from the solution being fixed to ammonium phosphomolybdate and then precipitated as cesium chloroplatinate. The ^{137}Cs is measured in the low background, beta proportional counter (Tennelec/Canberra XLB-S5).

9 The methodology is described in the paper "A.R.Gomes et al (2017). Determination of tritium in water using electrolytic enrichment: methodology improvements. J. Radioanal. Nucl. Chem., 314: 669-674."

Determination of ^{137}Cs activity concentration by gamma spectrometry

Since 2015, ^{137}Cs determinations have been carried out by gamma spectrometry. 30 liters of water after filtration (0.45 µm membranes) are concentrated to 1 liter by evaporation (adding concentrated HNO_3 and H_2O_2 to digest the organic matter) and measured directly by gamma spectrometry in a Marinelli container. Other gamma emitters, such as ^{7}Be in rainwater, are also measured. After that, the sample is evaporated to dryness, strontium (Sr^{2+}) is isolated from cesium (Cs^{+}) and determined by beta measurements, as described above.

Determination of gross beta activity in solid phase by beta measurements in surface waters and rainwaters

One liter (or more depending of the suspended matter content) of water is filtered and the beta activity, using the beta proportional counter (Tennelec/Canberra XLB-S5a), measured in the filter after drying.

5.7.3 Soil

Determination of natural and artificial radionuclides activity concentrations by gamma spectrometry

Soil samples are homogenized, dried at 40ºC, crushed, sieved and the fraction <1000 µm used for analysis. Representative aliquots of the samples are transferred to 160 cm^3 plastic containers. The containers are closed, sealed and left aside for about one month to ensure secular equilibrium between radium isotopes and its short-lived progenies in uranium and thorium radionuclide series. The samples are counted for 15 h and analyzed for ^{235}U, ^{228}Ra (determined through ^{228}Ac), ^{226}Ra (determined through ^{214}Pb and ^{214}Bi daughters), ^{210}Pb, ^{137}Cs, ^{40}K and ^{7}Be by gamma spectrometry using HPGe detectors.

5.7.4 Sediments

Determination of natural and artificial radionuclides activity concentrations by gamma spectrometry

Sediment samples are homogenized, dried at 110ºC, crushed, sieved and fractions less than 63 µm (silt/clay) and between 250 µm and 63 µm (sand) used for analysis. Representative aliquots of each sieved sample are transferred to 10 cm^3 plastic containers (Petri dishes). The containers are closed, sealed and left aside for about one month to ensure secular equilibrium between radium isotopes and its short lived progenies in uranium and thorium radionuclide series. The samples are counted for 15 h and analyzed for ^{235}U, ^{228}Ra (determined through ^{228}Ac), ^{226}Ra (determined through ^{214}Pb and ^{214}Bi daughters), ^{137}Cs and ^{40}K by gamma spectrometry using HPGe detectors.

5.7.5 Terrestrial and aquatic biota and flora

Determination of natural and artificial radionuclides activity concentrations by gamma spectrometry

Freshwater plants are washed abundantly under a flow of tap water, for definitive removal of sediments and other materials considered as impurities. When applicable, roots and aerial parts are separated for separate analyses. A final wash is performed by plunging the plants into distilled water. The vegetable material is cut and distributed in batches for weighing, mass being recorded before and after drying (72 h) in an oven at 50 ºC. The dried material is homogenized and packed in sealed plastic vials for a further (about 30 days, the time required for the restoration of the secular equilibrium among all descendants of the natural radioactive families) determination of the activity concentration of the radionuclides by gamma spectrometry using HPGe detectors.

5.7.6 Milk

Determination of natural and artificial radionuclides activity concentrations by gamma spectrometry

Milk samples (1 Liter) are put in Marinelli holders and measured for ^{131}I, ^{137}Cs and ^{40}K by gamma spectrometry using HPGe detectors.

Determination of ^{90}Sr activity concentration by liquid scintillation counting[10]

The milk sample (1 L) is evaporated, dried and burned gradually until 600 ºC in a muffle furnace. ^{90}Sr is separated from the other interfering elements using a strontium-specific resin (Eichrom) after the incineration and dilution in acidic medium. Beta measurement in the solution is performed by liquid scintillation using a Packard Tri-Carb 3170 TR/SL counter. The concentration of ^{90}Sr activity is determined after the radioactive balance between ^{90}Sr and ^{90}Y.

5.7.7 Mixed diet and foodstuffs

Determination of natural and artificial radionuclides activity concentrations by gamma spectrometry

Mixed diet samples are prepared in the usual household manner, ground, homogenized and placed in a 1-liter Marinelli holder. ^{137}Cs and ^{40}K are determined by gamma spectrometry using HPGe detectors.

Determination of ^{90}Sr activity concentration by liquid scintillation counting

The analytical procedure is similar to the one applied for milk samples.

5.8 MANAGEMENT OF SAMPLES AND RESULTS

Measurement results are recorded in a SIAC 2000 database. Backups are regularly made to the main server. Results below the detection limits are reported as "<dl value".

Data handling and reporting are managed through the SIAC 2000 database and specific spreadsheets on the computers dedicated to the different radioanalytical techniques.

For gross alpha/beta analysis in water, samples are stored acidified (pH ≈ 2) in the sample storage room for up to 1 month. For the tritium analysis, the remaining sample is stored in a smaller volume bottle in order to maintain the collection conditions (vial fully filled, no air bubbles). If necessary, the analysis could be repeated up to 2 months after collection. The sample is stored in the refrigerator during this time.

After measurement, the samples are stored or discarded. Samples of fresh milk and foodstuffs are either discarded after analysis (if not required for another type of analysis) or incinerated and stored for determination of other radionuclides. The other samples (e.g., soils, sediments, ashes, filters, etc.) are stored until the publication of the results. At the end of the storage period, samples are disposed of in the sewage (liquid samples) or in the household waste (solid samples).

The IST laboratory is accredited in compliance with EN ISO/IEC 17025:2005 (Accreditation certificate L0620) by the Portuguese Accreditation Institute (IPAC). The accredited methods are listed in Annex

[10] The methodology is fully described in the paper "I. Lopes, M.J. Madruga. Application of Liquid Scintillation Counting Technique to the Determination of ^{90}Sr in Milk Samples"; Advances in Liquid Scintillation Spectrometry, J. Eikenberg, M. Jaggi, H Beer, H Baehrle (Ed) 331-337 (2009) Radiocarbon, The University of Arizona, USA.

4. Annexes 5 presents the list of the international intercomparison exercises and proficiency tests, in which the LPSR participated in 2012-2018.

5.9 MOBILE MEASUREMENT SYSTEMS

The IST can perform targeted environmental radioactivity monitoring on special situations, for example during visits of foreign nuclear vessels to the Lisbon harbour. The equipment used consists of a portable gamma spectrometry system, aerosol sampler, a portable meteorological station and an external gamma dose rate meter.

The APA has a mobile spectroscopic detection and survey system MONA for use in land vehicles, aircrafts or watercrafts, from the manufacturer Envinet Ltd. This system has two 1L NaI detectors working in a master-slave mode with wireless transmission of data to a laptop with special software. Its purpose is the detection and localization of radiation sources or contamination in the environment. The system acquires the gamma spectrum, identifies the isotopes, and calculates the total gamma dose rate as well as the dose rate for each identified nuclide. It uses GPS data to assign the actual monitoring location to the related data records and spectra. Until now, the system has only been used in land vehicles. Its base station is in the APA premises but it is available for use anywhere in Portugal.

5.10 INFORMATION FOR THE GENERAL PUBLIC

Under Article 9 of the Decree-Law 138/2005, the IST prepares and publishes the annual report of the Portuguese Environmental Radioactivity Monitoring Programme. The report is sent to the relevant authorities and to the European Commission. The reports are available to the public at the IST website[11].

The data from RADNET (gamma dose rates) is available online to the public at the APA website[12]. The data is updated every two hours. Simultaneously, the same data is published with the same frequency at the EC EURDEP system (EUropean Radiological Data Exchange Platform). Some of the new stations are still in a test phase and for that reason their values are not yet available to the public and to the EURDEP.

6 VERIFICATIONS

6.1 AGÊNCIA PORTUGUESA DO AMBIENTE

6.1.1 Early warning radiological monitoring network

The Portuguese Environment Agency (APA) maintains the automatic radiation monitoring network RADNET. The network monitors radiation in air (16 fixed and 2 mobile stations) and water (2 stations). Data from the network is provided to EURDEP (5h delay on the public website) and IRMIS[13]. The verification team visited the APA headquarters and the monitoring sites close to the Lisbon airport.

The monitoring site Lisbon 101 is located at an old meteorological monitoring area, which will be closed in 2019. The radiation monitoring equipment (Technidata) consist of a dose rate probe (IGS

11 http://www.IST.tecnico.ulisboa.pt/docum/pt_bib_reltec.htm

12 https://sniamb.apambiente.pt/content/rede-de-alerta-de-radioactividade-no-ambiente

13 International Radiation Monitoring Information System (IAEA)

421B-H outdoors), measurement electronics and a local dose rate display inside the building. A battery is available for 65h operation without electrical power.

The Lisbon 101 site will be formally relocated to the fenced meteorological instrument garden of IPMA close to the airport, where the equipment is already in operation. The monitoring equipment is an Envinet SARA station (dose rate and radiation energy spectrum for nuclide identification) equipped with a solar panel and a precipitation sensor (Figure 7). There is no local display. This station will be connected to RADNET in 2019.

Figure 7. Envinet SARA dose rate monitoring station with a solar panel

The RADNET central servers (2) are located at the emergency room at the APA headquarters[14]. The room is equipped with UPS systems and a diesel generator for electrical back up. The verification team was informed that APA plans to install a back-up server in a secondary location in the future. The system polls data from the monitoring stations on 1-hour intervals. Dose rate data is made available and stored, but not processed otherwise. Alarm limit is three times background. Alarms are transmitted to the duty personnel via automatic telephone call and an SMS message.

[14] Rua da Murgueira 9/9A – Zambujal, 2610-124 Amadora, Portugal

The verification team was informed, that APA plans to connect three automatic aerosol radioactivity monitoring stations to the RADNET in 2020. These stations will have also activated charcoal cartridges for monitoring gaseous radioactive iodine. Currently the RADNET network does have the capability for iodine monitoring.

Figure 8. Envinet MIRA mobile radiation dose rate monitor

Radiation dose rate data is available on-line at the APA website. The site displays both current and historical data. Verification team noted that the website provides dose rate data using unit mSv/h also for the submerged water monitoring stations, which can be misleading.

> *Verification team suggests that the APA clarifies the radiation dose rate unit, which is used for the detectors under water in order to avoid misleading information on the public website.*
>
> *Verification team supports the APA plans to install automatic detection capability for gaseous radioactive iodine in Portugal.*
>
> *Verification team commends the availability of the APA radiation website also in English.*

6.1.2 Mobile radiation monitoring capabilities

APA has the following mobile radiation monitoring equipment for use in the event an emergency:

- One mobile Envinet SARA station, which can be located in the emergency area and connected to RADNET (dose rate and NaI gamma spectrum)
- Two Envinet MIRA stations, which can be located in the emergency area and connected to RADNET (dose rate and precipitation) (Fig. 8)
- One Envinet MONA station for locating radioactive sources (large NaI detector, which can be installed on a car or helicopter)
- Thermo Scientific INTERCEPTOR NaI monitor for nuclide identification
- Ortec RADEagle portable NaI monitor
- Portable radiation dose rate meters, neutron detectors and surface contamination monitors
- Environmental sampling tools

Altogether five staff members have been trained to use the mobile equipment.

No remarks.

6.2 INSTITUTO SUPERIOR TÉCNICO

The radiological laboratories[15] of the Instituto Superior Técnico (IST) are the only radiological laboratories in Portugal. They carry out practically all the radio-analytical work included in the radiological monitoring programmes in Portugal, including personnel radiation dosimetry and special surveillance tasks (visits of nuclear powered vessels etc.). The verification team visited the IST laboratories in Lisbon.

6.2.1 Environmental radioactivity laboratory

The laboratory is accredited to carry out Radon, ^{3}H, gross alpha/beta and ^{137}Cs determinations. The facility is equipped with a UPS and a diesel generator for electrical back-up power.

Sample receipt and preparation

The laboratory is well equipped to store and prepare both environmental and food samples for analysis; several rooms of the laboratory building are reserved for sample storage and preparation. Samples are mostly taken by the laboratory staff. After the analysis, the samples are kept until the end of the reporting period, typically at least one year.

The laboratory has an old database for recording samples and their measurement results, but no modern Laboratory Information Management System (LIMS).

Tritium analysis

In order to measure ^{3}H in water, the laboratory is equipped with evaporation facilities and a ^{3}H-enrichment system, which produces a concentrated sample for measurement in a liquid scintillation counter. The enrichment is done with electrolysis. It is a slow process (one week), but indeed significantly reduces the ^{3}H detection limit in water samples when compared to direct measurement of the evaporated sample.

[15] Laboratório de Proteção e Segurança Radiológica (Radiation Protection and Safety Laboratory – LPSR), Estrada Nacional 10 (km 139.7), 2695-066 Bobadela LRS

Gamma spectroscopy

The gamma spectroscopy room is equipped with two HPGe detectors (Canberra) and one HPGeLi low-energy detector (Canberra). The systems are calibrated for the measurement geometries (Marinelli, soil sample, air filter, etc.) using commercial calibration standards. If needed, a mathematical sample density correction is applied to experimental calibration curves. Weekly system controls (energy, efficiency, resolution) are carried out to ensure system stability using a ^{152}Eu standard.

Figure 9. IST laboratory gamma spectroscopy systems

Gross alpha/beta counting

The laboratory is equipped with a liquid scintillation counter (Hewlett Packard Tri-Carb 3170 TR/SL) and a gas proportional counter Tennelec XLB-S5 for gross alpha/beta counting (radon and ^{3}H screening in water). The equipment are old, but functional. The verification team noted that the laboratory counting room is used also for storing old equipment, which are not used any more.

Monitoring equipment

The IST Environmental laboratory carries out environmental sampling near the laboratory building. The sampling equipment includes the following:

- High-volume air sampler ASS-500 (Fig. 10). The device uses a 44×40 cm Petranoff filter. Airflow (1164 m^3/h during the verification, but variable due to filter clogging) is measured with a calibrated flow counter. The filter is changed and analysed weekly.
- Three ambient gamma dose rate monitors (GammaTracer), which are part of the IST campus radiation surveillance system. The devices have high and low dose rate GM-tubes and radio communications for transmitting the dose rate once every hour. The alarm limit is 300 nSv/h.
- Precipitation collector (1×1 m)

The verification team recommends that the IST radiological laboratories be equipped with a modern Laboratory Information Management System (LIMS).

The verification team recommends modernisation of the gross alpha/beta counting equipment.

The verification team suggests removal of old equipment from the laboratory rooms.

The verification team commends the sophisticated enrichment method for improving the detection limit in Tritium in water analysis.

Figure 10. IST laboratory high-volume air sampler

6.2.2 Operational radiation protection laboratory

The IST Operational radiation protection laboratory carries out specific radiation monitoring tasks, for example, identification of orphan radioactive sources and radiation surveillance during visits of nuclear powered vessels in Portugal. It has the following equipment:

- Spectroscopy systems: four NaI (3x3''), one HPGe (3x3'')
- Mobile equipment:
    - Portable gamma spectrometers: Canberra InSpector 1000 with probes IPRON-3 (NaI de 3x3'') and Scionix Holland IPRON-5 (NaI de 5x5''), RIIIDEye X-GN with neutron probe, three NanoSPEC, Target Systemelectronic GmbH (NaI de 3x3''), Exploranium GR-130
    - Gamma dose rate monitors: Victoreen 450P-DE-SI, Victoreen 190N-SI, two Mini-Instruments SmartION 2120S, two Canberra Eurisys Radiagem 3 with probe TELE SHDE, Graetz X5 DE with probe Telescope Probe DE, Radiagem 2000, Atomtex AT1123, THERMO FH 40G-L, Canberra Colibri TTC/GPS
    - Neutron dose rate monitor: Victoreen RP-N
    - Contamination monitors: Radiagem 2000 with Canberra probes SG-1R, SABG-15 and SAB-100, THERMO FH 40G-L with probe FHZ 732, Nardeux MIP 10 probes Eurisys Mesures SBG
    - Portable air sampler: Two STAPLEX Type TF1A-2

No remarks.

6.2.3 Radiation metrology laboratory

The IST Radiation metrology laboratory maintains national radiation standards. It has an impressive collection of equipment for radiation metrology, in particular for medical uses of radiation (X-ray and teletherapy systems calibration).

No remarks.

6.2.4 Individual monitoring laboratory

The IST Individual monitoring laboratory provides services for monitoring radiation dose with TLD dosimeters. The laboratory has a staff of three. The dosimeters are used for both personnel and environment ambient background dose monitoring. The personnel monitoring programme covers about 3200 persons in Portugal.

The laboratory uses Harshaw 8814 holders for personnel monitoring and Harshaw 8855 holders for environmental monitoring. The same TLD card is used for both personnel and environment monitoring. In the environment monitoring six TLDs are used together (2 pre-irradiated, 2 post-irradiated and 2 unirradiated) (Fig. 11). This sophisticated configuration allows for determination of the site-specific fading factor, improving the monitoring accuracy compared to usual single TLD monitoring. Seven environmental TLDs are placed on the IST campus in Lisbon and eight in other locations in Portugal. The TLDs are exposed for three months and then analysed in the laboratory TLD readers (two identical Harshaw readers). This programme is the only passive environmental radiation dose monitoring in Portugal.

The verification team commends the IST's sophisticated environmental TLD programme.

Figure 11. TLD dosimeters of the IST environmental radiation surveillance programme

6.3 NATIONAL AUTHORITY FOR CIVIL PROTECTION

The verification team visited the National Operational Coordination Centre of the National Authority for Civil Protection (ANPC) in Carnaxide. The 24h centre coordinates nationwide civil protection operations, including possible situations involving radioactive material or radiation exposure. The Portuguese civil protection system includes civil protection agent institutions such as the armed forces, police and both professional and volunteer fire brigades.

The team was informed that in Portugal some of the local fire brigades have equipment for detecting elevated levels of radiation, but there are still some local civil protection services without basic radiation monitoring capability. The ANPC Rapid Assessment Teams are equipped and trained to respond to radiation incidents and they have equipment for radiation dose rate and contamination monitoring. Radiation events are always considered national events, so coordination happens via the national centre and the teams can be deployed anywhere in Portugal.

> *The verification team suggests that the ANPC reviews the feasibility of making basic radiation dose rate monitoring equipment available in each local fire brigade.*

7 CONCLUSIONS

All planned verification activities were completed successfully. The information supplied in advance of the visit, as well as the additional documentation received during and after the verification activities, proved very useful.

The information provided and the verification findings gave rise to the following observations:

(1) Overall, the national environmental radioactivity monitoring programme in Portugal complies with the requirements of Article 35 of the Euratom Treaty.

(2) The verification activities found that the facilities needed to carry out continuous monitoring of levels of radioactivity in air, water and soil in Lisbon are adequate. The Commission ascertained that these facilities are in operation and running efficiently.

(3) The verification activities found that the facilities needed to carry out monitoring of levels of radioactivity in the air, water and soil in the event of a radiological emergency in Lisbon are adequate. The Commission ascertained that these facilities are continuously available.

(4) A few recommendations and suggestions have been formulated. They concern in particular laboratory data management, renewal of laboratory equipment and availability of radiation monitoring equipment at the local fire brigades. Notwithstanding these remarks the verified parts of the national monitoring system for environmental radioactivity in Lisbon are in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

(5) The team's recommendations are set out in the 'Main Conclusions' document addressed to the Portuguese competent authority through the Portugal Permanent Representative to the European Union.

(6) The Commission services kindly request the Portuguese authorities to submit, before the end of 2020, a progress report on how the team's recommendations have been implemented and on any significant changes in the set-up of the monitoring systems. Based on this report the Commission will consider the need for a follow-up verification in Portugal.

(7) The verification team acknowledges the excellent cooperation it received from all people involved in the activities it undertook during its visit.

ANNEX 1 – Verification programme

Monday 3 December

10h00 Opening meeting – MFA Directorate-General of European Affairs (DGEA)
(Rua da Cova da Moura, 1, 1350-115, Lisbon)

- Welcome – *Directorate-General of European Affairs*
- European Commission Art. 35 verification programme introduction – *EC Verification team*
- Overview of environmental radioactivity monitoring arrangements in Portugal/Lisbon – *presentations by APA, IST and ANPC*
- Verification planning – *EC Verification team and PT team*

13h30 Agência Portuguesa do Ambiente (APA)
Rua da Murgueira 9/9A – Zambujal, 2610-124 Amadora
Instituto Português do Mar e da Atmosfera –IPMA, Rua C do Aeroporto, 1749-077 Lisboa

- RADNET automatic dose rate monitor in Lisbon
- Early warning radiological monitoring network – RADNET
- Other radiation monitoring capabilities at APA

Tuesday 4 December

09h00 Instituto Superior Técnico (IST), Laboratório de Proteção e Segurança Radiológica (LPSR)
(*Estrada Nacional 10 (km 139.7) 2695-066 Bobadela LRS)*

- Monitoring of radioactivity in air, water and soil
- Monitoring of radioactivity in food and drinking water
- Radiation dose monitoring (TLD)
- Laboratory facilities
- Automatic radiation dose rate monitoring
- Mobile monitoring systems
- Other radiation monitoring capabilities at the IST

Wednesday 5 December

10h00 National Authority for Civil Protection (ANPC)
(Avenida do Forte, 2794-112 Carnaxide)

- National Operational Coordination Centre
- Initial Assessment Teams

15h00 Closing meeting - MFA Directorate-General of European Affairs
(Rua da Cova da Moura, 1, 1350-115, Lisbon)

Annex 2 – National radiological surveillance - Sparse network

Type of samples	Sampling locations	Sampling frequency	Type of analysis
Aerosols	- Sacavém (IST *campus*)	Weekly	^{7}Be, ^{137}Cs, ^{210}Pb, ^{131}I
Air	- Sacavém (IST *campus*)	Continuous	Ambient dose equivalent rate (active detectors)
Surface water	- Tejo River (V. Velha Ródão)	Monthly	Gross alpha/beta, residual beta*, ^{3}H, ^{90}Sr, ^{137}Cs; gross beta in particulate phase
Drinking water	- Zêzere River (Castelo de Bode dam)	Monthly	Gross alpha/beta, residual beta*, ^{3}H, ^{90}Sr, ^{137}Cs; gross beta in particulate phase
Drinking water	- Lisboa	Monthly	Gross alpha/beta, ^{3}H, ^{222}Rn, ^{137}Cs, ^{90}Sr (European Directive 2013/51 EURATOM; Decree-Law 152/2017[16])
Milk	- Vila do Conde (Portugal north) - Portalegre (Portugal east)	Monthly	^{137}Cs, ^{131}I, ^{90}Sr, ^{40}K
Mixed diet (complete meals)	- Lisboa	Monthly	^{137}Cs, ^{90}Sr, ^{40}K

*until 2017.

[16] The EU Council Directive 2013/51/Euratom was first transposed into national law by Decree Law 23/2016. A new Decree Law 152/2017 was published the following year taking into account all parameters for the water for human consumption.

Annex 3 - National radiological surveillance - Dense network

Type of samples	**Sampling locations**	**Sampling frequency**	**Type of analysis**
Rain water (dry/wet deposition)	- Sacavém (IST *campus*) - Castelo Branco	Monthly	Gross alpha/beta, ^{3}H, ^{7}Be, ^{90}Sr, ^{137}Cs; gross beta in particulate phase
Air	- Lisboa - Bragança - V. Nova de Gaia - Penhas Douradas - Castelo Branco - Faro - Funchal (Madeira Island) - Ponta Delgada (Azores Island)	Quarterly	Ambient dose equivalent rate (passive detectors-TLD)
Surface water	- Tejo River (V. Velha Ródão, Valada) - Tejo River (Fratel dam, Belver dam) - Zêzere River (Castelo de Bode dam) - Guadiana River (Alqueva dam) - Mondego River (Aguieira dam) - Douro River (Pocinho dam)	Monthly Quarterly Monthly Yearly Yearly Yearly	Gross alpha/beta, residual beta*, ^{3}H, ^{90}Sr, ^{137}Cs; gross beta in particulate phase
Sediments	- Tejo River (V. Velha Ródão, Valada) - Tejo River (Belver dam) - Guadiana River (Alqueva dam) - Mondego River (Aguieira dam) - Douro River (Pocinho dam)	Monthly Quarterly Yearly Yearly Yearly	Gamma spectrometry (natural and anthropogenic radionuclides)
Fish (fresh water)**	- Tejo River (V. Velha Ródão)	Monthly (when available)	Gamma spectrometry (natural and anthropogenic radionuclides)

*until 2017; ** until 2012.

Annex 3 - National radiological surveillance – Dense network (Cont.)

Type of samples	Sampling locations	Sampling frequency	Type of analysis
Aquatic plants (fresh water)	- Tejo River (V. Velha Ródão)	Monthly (when available)	Gamma spectrometry (natural and anthropogenic radionuclides)
Drinking water	- Randomly chosen covering the Portuguese national territory	Yearly	Gross alpha/beta, ^{3}H, ^{222}Rn (European Directive 2013/51 EURATOM; Decree-Law 152/2017)
Mussels (marine samples)	- Matosinhos - Figueira da Foz - Rio Tejo (estuary) - Rio Sado (estuary) - Cabo de S. Vicente - Quarteira	Yearly	Gamma and alpha spectrometry (natural and anthropogenic radionuclides)
Milk	- Tocha (Portugal center) - Águas de Moura (Portugal south) - Madeira island - Azores island	Quarterly Quarterly Twice a year Twice a year	^{137}Cs, ^{131}I, ^{90}Sr, ^{40}K
Mixed diet (individual components)	- Randomly chosen covering the Portuguese national territory - Madeira Island - Azores Island - Lisbon (supermarket)	Two or three times a year Twice a year Twice a year Yearly	^{137}Cs, ^{131}I, ^{90}Sr, ^{40}K
Soils	- Sacavém *campus* and surrounding area (2 locations) - Randomly chosen covering the Portuguese national territory	Monthly Yearly	Gamma spectrometry (natural and anthropogenic radionuclides)

Annex 4 - IST matrices and accredited methods

Matrices	Methods
Drinking waters, spring waters, natural minerals waters and freshwaters (except bathing)	Measurement of gross alpha/beta activity concentration in non-saline water. Thick source method (NRA_PT_01)
Drinking waters, spring waters, natural minerals waters and freshwaters (except bathing)	Measurement of gross alpha/beta activity concentration in non-saline water. Liquid scintillation counting method (NRA_PT_02)
Drinking waters, spring waters, natural minerals waters and freshwaters (except bathing)	Determination of tritium activity concentration. Liquid scintillation counting method (NRA_PT_03)
Drinking waters, spring waters, natural minerals waters and freshwaters (except bathing)	Determination of radon (^{222}Rn) activity concentration using two-phase liquid scintillation counting method (NRA_PT_09)
Solids and liquids	Determination of activity concentration by high-resolution gamma-ray spectrometry. Radionuclides in the energy range of 46.5 to 1836 keV (NRA_PT_11)

Annex 5 - IST list of intercomparison exercises and proficiency tests 2012-2018

Year	Organizing entity	Intercomparison exercises and proficiency tests
2018	IAEA-TEL, Austria	IAEA-TEL-2018-03 - World-wide proficiency test on determination of anthropogenic and natural radionuclides in water, soil sample and surface contamination measurement
	IARMA, England	IARMA Environmental Radioactivity Proficiency Test on the Determination of Gross Alpha/Beta in Water, EGROSS-PT-2018
	IARMA, England	IARMA Environmental Radioactivity Proficiency Test on the Determination of Tritium in Water, ETRIT-PT-2018
	European Commission (EC), Belgium	EC-JRC-REM 2018- proficiency test on ^{222}Rn mass activity measurements in water
	IAEA-RML, Austria	Proficiency Test for Tritium, cobalt, strontium and cesium isotopes in seawater 2018 (IAEA-RML-2018-1)
2017	EMPIR, EURAMET	Intercomparison for passive $H^*(10)$ area photon dosimeters
	IAEA-RML, Austria	Proficiency Test (IAEA-RML-2017-1)-Tritium, strontium and cesium isotopes in seawater
	IAEA-TEL, Austria	ALMERA Proficiency Test (IAEA-TEL-2017-03) - World-wide proficiency test on determination of anthropogenic and natural radionuclides in water, milk powder, Ca-carbonate
	European Commission (EC), Belgium	Proficiency testing on ^{131}I, ^{134}Cs, and ^{137}Cs activity measurements in maize powder
	SYKE, Finland	Proftest SYKE RAD 05/2017- Radon in ground water
	IAEA (ConvEx-3), Austria	Gamma-ray emitter’s radionuclides in spiked water
2016	European Commission (EC), Belgium	MetroERM/ENV57 Interlaboratory comparison on the measurement of ^{137}Cs, ^{134}Cs and ^{131}I in air filters
	IAEA-TEL, Austria	IAEA-TEL-2016-03 worldwide open proficiency test on determination of anthropogenic and natural radionuclides in water and biota
	Consejo de Seguridad Nuclear (CSN), Spain	Ejercicio interlaboratorio CSN-CIEMAT (2016)- Solo
	IAEA-RML, Austria	Proficiency Test (IAEA-RML-2016-01) -Tritium, Strontium and Cesium isotopes in Seawater
2015	European Commission (EC), Belgium	EC-JRC/IRMM Interlaboratory comparison on ^{137}Cs measurement in air filters
	Consejo de Seguridad Nuclear (CSN), Spain	Ejercicio interlaboratorio CSN-CIEMAT (2015)- Agua de consumo y marina
	IAEA-RML, Austria	Proficiency Test (IAEA_RML_2015-01)-Tritium, Strontium and Cesium isotopes in Seawater
	IARMA, England	IARMA- Environmental Radioactivity Proficiency Test on the Determination of Gross Alpha and Beta in Water, EGROSS_PT_2015
	SYKE, Finland	SYKE Prof test RAD 05/2015- Radon in ground water
	NORM4BUILDING (COST Action)	1st Intercomparison exercise on determination of natural radioactivity in ceramics

2014	IARMA, England	Proficiency Test on the Determination of Tritium in Waters in Environmental Levels
	IAEA-TEL, Austria	IAEA-TEL-2014-03 world-wide proficiency test on determination of anthropogenic and natural radionuclides in water, seaweed and sediment samples
	IAEA/OSPAR, Austria	Proficiency Test- Determination of Tritium, Strontium and Cesium isotopes in Seawater
	Consejo de Seguridad Nuclear (CSN), Spain	Ejercicio interlaboratorio CSN-CIEMAT (2014)- Cenizas Vegetales
2013	Consejo de Seguridad Nuclear (CSN), Spain	Intercomparación de dosímetros ambientales CSN, *H**(10)
	IAEA-TEL, Austria	IAEA-TEL-2013-04, proficiency test on determination of anthropogenic radionuclides in water, and flour samples
	Consejo de Seguridad Nuclear (CSN), Spain	Ejercicio interlaboratorio CSN-CIEMAT (2013)- Aire
	IAEA/OSPAR, Austria	Proficiency Test RCA RAS/7/021 Cesium and Strontium determination in Mediterranean sea water
2012	Unidad de Defensa Nuclear de Área NBQ y Materiales, Instituto Tecnológico La Marañosa (ITM), Spain	Ejercicio de Intercomparación de Dosimetría Ambiental Interlaboratorios (CIEMAT, IST-ITN, ENUSA, ITM), *H**(10)
	Consejo de Seguridad Nuclear (CSN), Spain	Ejercicio interlaboratorio CSN-CIEMAT (2012)- Solo
	NPL, England	Proficiency test – water sample (gamma Low)
	IAEA-TEL, Austria	Proficiency Test IAEA-TEL-2012-03, proficiency test on determination of radionuclides in soil, hay and water samples
	European Commision (EC), Belgium	EC interlaboratory comparison on gross alpha/beta activity in drinking waters

Annex 6 – Measurement devices available in the IST laboratory

Type of device	Manufacturer	Calibration	Standards
HPGe detectors (High resolution gamma-ray spectrometry)	Canberra and Ortec	Experimental calibration by using a multi-gamma radioactive standard with an energy range from 46.5 keV to 1836 keV, customized in a water-equivalent epoxy resin matrix to exactly reproduce the samples geometries	Multi-gamma radioactive customized source (POLATOM)
Tri-Carb 3170 TR/SL (Liquid scintillation counting)	Perkin Elmer	- Calibration using ^{241}Am and ^{90}Sr/^{90}Y with different volumes of CCl_4 for gross alpha/beta measurements - Calibration using ^{226}Ra for radon in water measurements - Calibration using ^{3}H for tritium measurements	^{241}Am (Eckert & Ziegler Analytics ^{90}Sr/^{90}Y (Amersham) ^{226}Ra (CMI – Czech Metrology Institute) ^{3}H (Analytics)
Tennelec XLB-S5 (Gas flow proportional counter)	Canberra	Calibration using ^{241}Am and ^{90}Sr/^{90}Y in a $CaSO_4$ matrix	^{241}Am (Eckert & Ziegler Analytics ^{90}Sr/^{90}Y (Amersham)
Harshaw 6600 reader, TLD Harshaw 8855 cards and holders	Thermo Scientific	The calibration of environmental dosimeters is performed in terms of *H**(10) at the Laboratory of Metrology of Ionizing Radiation of LPSR, on a quarterly basis.	IST-LPSR-LMRI is primary laboratory for the measurement of *H**(10).
GammaTracer XL probes	Saphymo GmbH	The probes are periodically sent to Saphymo for verification and calibration in terms of *H**(10). Last verification in April 2018.	Saphymo GmbH Frankfurt, Germany, traceable to PTB (Germany) and PHE (United Kingdom).

Annex 7 – Sample measurements of the IST monitoring programme

Type of samples	Radionuclides assessed	Measurement devices	Counting times
Rain water	^{7}Be, ^{137}Cs ^{3}H Gross alpha/beta, ^{90}Sr	HPGe detectors Liquid scintillation counter Gas flow proportional counter	15-24 hours 5 hours 4 hours for gross α/β; 3 hours for 90Sr
Aerosols	^{7}Be, ^{137}Cs, ^{210}Pb, ^{131}I	HPGe detectors	15 hours
Surface water	^{137}Cs ^{3}H Gross alpha/beta, ^{90}Sr	HPGe detectors Liquid scintillation counter Gas flow proportional counter	15-24 hours 5 hours 4 hours for gross α/β; 3 hours for 90Sr
Sediments	Natural and anthropogenic radionuclides	HPGe detectors	15-24 hours
Aquatic plants	Natural and anthropogenic radionuclides	HPGe detectors	15-24 hours
Drinking water	Gross alpha/beta, ^{3}H, ^{222}Rn	Liquid scintillation counter	4 hours for gross α/β; 5 hours for 3H; 2 hours for Rn-222
Milk	^{137}Cs, ^{131}I, ^{40}K ^{90}Sr	HPGe detectors Liquid scintillation counter	15 hours 4 hours
Mixed diet	^{137}Cs, ^{131}I, ^{40}K ^{90}Sr	HPGe detectors Liquid scintillation counter	48 hours 4 hours
Soils	Natural and anthropogenic radionuclides	HPGe detectors	15 hours