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Verification under the terms of Article 35 of the Euratom Treaty

Technical Report

GREECE
Athens

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

11-13 December 2019

Reference: GR 19-04

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35

OF THE EURATOM TREATY

FACILITIES	Routine and emergency radioactivity monitoring arrangements Monitoring of radioactivity in drinking water and foodstuffs
LOCATIONS	Athens, Greece
DATES	11-13 December 2019
REFERENCE	GR 19-04
TEAM MEMBERS	Mr V. Tanner (team leader) Ms F. Tzika Mr M. Hübel (observer)
REPORT DATE	23 April 2020
SIGNATURES	

V. Tanner F. Tzika

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Abbreviations

ALMERA	Analytical Laboratories for the Measurement of Environmental Radioactivity
AUTH	Aristotle University of Thessaloniki
BfS	Bundesamt für Strahlenschutz, Germany
BIPM	Bureau International des Poids et Mesures
CBRN	Chemical, Biological, Radiological, Nuclear
DLI	Department of Licensing and Inspection
EEAE	Greek Atomic Energy Commission
ERL	Environmental Radioactivity Laboratory
ERMD	Environmental Radioactivity Monitoring Department of the EEAE
ESYD	Hellenic Accreditation Council
EURDEP	EUropean Radiological Data Exchange Platform
FWHM	Full Width at Half-Maximum
GSRT	General Secretariat of Research and Technology GSRT
GM	Geiger-Müller
HEU	High Enriched Uranium
HPGe	High-Purity Germanium
IAEA	International Atomic Energy Agency
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
INRaSTES	Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety
JRC	Joint Research Centre (EC)
LEU	Low Enriched Uranium
LIMS	Laboratory Information Management System
LSC	Liquid Scintillation Counting
MDA	Minimum Detectable Activity
NCSR	National Centre for Scientific Research, Greece
NIST	National Institute for Standards, Maryland, USA
NPL	National Physical Laboratory, UK
NTUA	National Technical University of Athens
PROCORAD	Association for the Promotion of Quality Controls in Radiotoxicological bioassay
PTB	Physikalisch-Technische Bundesanstalt, Germany
UOI	University Of Ioannina

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 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 Greece of its decision to conduct an Article 35 verification in a letter addressed to the Greece Permanent Representation to the European Union. The Greek Atomic Energy Commission (EEAE) was designated to lead 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 verification visit. The information provided was used as a source during drawing up the descriptive sections of the current report.

2.3 PROGRAMME OF THE VISIT

The Commission and the EEAE 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 Greek automatic radiation monitoring system and other environmental radioactivity monitoring arrangements. The verification team pointed to the quality and comprehensiveness of all the presentations and documentation.

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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 18 October 2019

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:

Representatives	**Institution/Laboratory**	**Function**
Dr. C. Housiadas Dr. C. Potiriadis Dr. K. Kehagia Dr. A. Maltezos Dr. K. Karfopoulos Mr. S. Kyriakopoulos	Greek Atomic Energy Commission (EEAE)	Chairman Nuclear physicist, Head of (ERMD) Radiochemist (ERMD) Nuclear physicist (ERMD) Mechanical engineer (ERMD) Electronics engineer, MSc (ERMD)
Dr. E. Carinou	Division of Licensing and Regulatory Inspections (EEAE)	Medical physicist, Deputy Director of the Division
Dr. A Boziari	Dosimetry and calibration department, Secondary standard calibration laboratory (EEAE)	Medical physicist, Head of laboratory
Ms. V. Tafili	International and Public Relations Office (EEAE)	Communication expert, Deputy Head of the Office
Dr. K. Eleftheriadis Dr. G. Kuburas	Environmental Radioactivity Laboratory (ERL), Institute of Nuclear & Radiological Sciences and Technology, Energy & Safety, NCSR, Demokritos	Director of Research Collaborating Researcher
Dr. N. Petropoulos Dr. D. Mitrakos Dr. P. Rouni Mr. I. Mitsios	Nuclear Engineering Department, National Technical University of Athens (NTUA)	Assistant Professor, Head of NED-NTUA Assistant Professor Lecturer Research assistant (PhD student)
Mr. G. N. Karamanlis	Athens Airport R.F.F.S	Fire Lieutenant Colonel
Mr. P. Nisianakis Dr. Gialleli Angelika-Ioanna	Analytika Ergastiria Athinon Athens Analysis Laboratories SA	Scientific Director of the chemical laboratory Chemist

3 LEGAL FRAMEWORK FOR RADIOACTIVITY MONITORING

3.1 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

In Greece, the following legal texts regulate the monitoring of radioactivity in the environment:

- Law 4310/2014 “Research, Technological Development and Innovation and other provisions”, Art. 43, par. 4.kh
- Presidential Decree 404/1993 “Organization of the Greek Atomic Energy Commission”, Art. 4, par. 3.c
- Presidential Decree 101/2018 “Adaptation of Greek legislation to Council Directive 2013/59/Euratom of December 5, 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom, (EE L13 / 17.1.2014) - Establishment of radiation protection regulations “, Art 72, 69.3.β, 97
- Joint Ministerial Decision Π/112/1057/2016/01.02.2016, “Establishment of requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, in compliance with the Council Directive 2013/51/Euratom of 22 October 2013”
- Decision 134069 Amendment of the Decision Π/112/1057/2016 (Β΄ 241) “Establishment of requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, in compliance with the Council Directive 2013/51/Euratom of 22 October 2013”

The list of legislative acts establishing the responsibilities of the various actors in this domain is the following:

- Joint Ministerial Decision D. Π/112/1057/2016/01.02.2016, “Establishment of requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption, in compliance with the Council Directive 2013/51/EURATOM of 22th of October 2013”
- Ministerial Decision No. 1299/2003, Approval of the General Plan for Civil Protection, under the Code Name Xenokratis, Government Gazette Folio No. 423/B/10.04.2003
- Presidential Decree No. 101/2018, Adaptation of the Greek legislation to Council Directive 2013/59/Euratom of December 5, 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, (EE L13/17.1.2014) - Establishment of radiation protection regulations, Government Gazette Folio No 194/A/20.11.2018

3.2 LEGISLATIVE ACTS REGULATING RADIOLOGICAL SURVEILLANCE OF FOOD

In Greece, the following legal text regulates the monitoring of radioactivity in food:

- 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

3.3 INTERNATIONAL LEGISLATION AND GUIDANCE DOCUMENTS

The list below includes the Euratom and the European Union legislation and the main international standards and guidance 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
- 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)

4 BODIES HAVING COMPETENCE IN RADIOACTIVITY MONITORING

4.1 GREEK ATOMIC ENERGY COMMISSION

The Greek Atomic Energy Commission (EEAE) is the national regulatory authority, supervised by the General Secretariat of Research and Technology (GSRT) under the Ministry Development and Investments. EEAE is competent for the control, regulation and supervision in the fields of nuclear energy, nuclear technology, radiological and nuclear safety and radiation protection.

The statutory responsibilities of the EEAE in the context of this report are:

- Protection of workers, the general public and the environment from the use of ionising (and non-ionising) radiation through implementation of:
  - Monitoring the environmental radioactivity by measuring air, water and soil samples;
  - Individual monitoring of exposed workers in Greece;
  - Recurrent inspection of installations using radioactive materials in the medical, industrial, research, and educational sectors;
  - Licensing of ionising radiation practices in the medical industrial, research, safety and educational sectors;
  - Issuing certificates of compliance from the radiation protection point of view for medical applications;
  - Licensing of import, export, transport, storage, use and disposal of fissile and non-fissile radioactive materials;
  - Licensing of the import and use of radiation producing equipment.
- Drafting and implementation, in compliance with EU Directives, of radiation protection regulations, including guidance documents.
- Education and training of workers on radiation protection issues.
- Implementation of emergency preparedness and response plans.

The Environmental Radioactivity Monitoring Department (ERMD) of the EEAE coordinates and implements the national Environmental Radioactivity Monitoring Programme (ERMP). It operates the Telemetric Radioactivity Monitoring Network (TRMN) and the Environmental Radioactivity Laboratory, where various measurements are performed.

According to the provisions of the current legislation with regard to monitoring the levels of radioactivity in drinking water, the EEAE:

- determines the program and frequency of sampling in cooperation with the Ministry of Health and issues the respective protocol;
- performs measurements of radioactivity in drinking water;
- approves other laboratories, accredited by a competent government agency, to perform measurements of radioactivity in drinking water;
- issues certificates of compliance with regard to radioactivity in water and informs the Ministry of Health;
- proposes to the Ministry of Health corrective and preventive measures to protect human health from radioactive substances;
- keeps the national database regarding radionuclide concentrations in drinking water;

- informs the Ministry of Health and the European Commission about the results of measurements in drinking water.

EEAE, in cooperation with General Secretariat of Civil Protection, draws up plans for responding to radiological or nuclear emergencies. At operational level, the role and responsibilities of EEAE, as well as, of all the other authorities, are defined within the "Xenokratis" General Plan for Civil Protection regarding radiological and nuclear emergencies. Also, the EEAE participates in the emergency response teams of the National Emergency Plan for Chemical, Biological, Radiological and Nuclear (CBRN) threats.

EEAE's equipment devoted to emergency planning includes a mobile laboratory, measurement and detection systems, protective equipment, specialized vehicle with the possibility of carrying and stabilizing shielded radioactive sources, and computer codes for modelling atmospheric dispersion and transport of radioactivity. Real-time environmental radioactivity monitoring data (telemetric network) are available through the EEAE website during emergencies. A link to EURDEP is also provided. Moreover, the EEAE participates in the early notification systems of the EU and the International Atomic Energy Agency (IAEA).

The EEAE laboratories participate in international and European laboratory networks and take part in inter-comparison exercises. The laboratories have been accredited by the Hellenic Accreditation Council (ESYD) according to ISO 17025. More specifically, EEAE in general implements an integrated management system. The integrated management system is certified since December 2013 in accordance with the requirements of ISO 9001:2015 standard and incorporates all functions and accreditations of EEAE. The list of EEAE accreditations/certifications includes:

- Accreditation according to ISO/IEC 17025 standard for:
    - non-ionizing radiation measurements,
    - individual monitoring by the use of whole body dosimeters and extremity dosimeters,
    - gamma spectrometry measurements,
    - radon measurements,
    - calibrations in radiotherapy, diagnostic radiology, radiation protection, individual monitoring.
- Accreditation as an "inspection body", type A, according to ISO/IEC 17020 standard by ESYD in order to perform inspections in radiation facilities and applications (radiology, nuclear medicine, radiotherapy, radiography and industry).
- Certification according to ISO 29990 standard, regarding the scope "Design, development and provision of non-formal education and training in radiation protection and nuclear safety".

In the framework of environmental radioactivity monitoring in normal and emergency situations, the EEAE is assisted by a network of cooperating laboratories from universities and research centres in Greece (Table I in section 6.4).

4.2 National Centre for Scientific Research

The National Centre for Scientific Research "Demokritos" (NCSR "D"), is a multidisciplinary research centre, that started its operation in 1959. The relevant institute in the framework of Article 35 verification is the Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety (INRaSTES) which comprises, amongst other laboratories, the Environmental Radioactivity Laboratory (ERL).

The ERL is entrusted with a small part of the national ERMP, namely measurements of air and food stuff. In the past the ERL also run the research reactor (GRR-1) site-related environmental radioactivity

monitoring programme. This is no longer the case as GRR-1 is in extended shutdown and all the used HEU and LEU fuel elements have been repatriated to United States since 2019. Currently ERL maintains 4 measurement stations for air filter collection described in detail below, which are measured by total α/β and γ- spectrometry. It also provides a service of measurement of Cs-137 in exported and imported foodstuffs according to legislation.

The Ministry of Health (MoH) is responsible for protecting and promoting the health of the population through the adoption and implementation of public health policies, ensuring the universal and equitable access to health services of the national health system, as well as supervising and regulating the private institutions that provide health services. It sets the technical framework for the control of atmospheric pollution, ionizing and non-ionizing radiation.

Among the MoH responsibilities is also the sanitary control of drinking water and waste water. The General Directorate of Public Health and Quality of Life of the MoH approves the drinking water radioactivity program developed in cooperation with the EEAE, and it is informed by the EEAE about the results of measurements in drinking water. It decides on possible corrective and preventive measures to protect human health from radioactive substances.

Moreover, the MoH is one the three ministries responsible for the approval of the national radon plan which addresses the long-term risks from radon exposures in dwellings, buildings with public access and workplaces for any source of radon ingress, whether from soil, building materials or water. Within this framework, the MoH in cooperation with EEAE sets an information program for the members of the public giving an emphasis in priority areas.

Finally, the MoH participates in the joint commission for the safe management of radioactive waste and spent fuel in line with the provisions of the 2011/70 Directive.

5 RADIOACTIVITY MONITORING IN GREECE

5.1 AUTOMATIC MONITORING OF AMBIENT RADIATION DOSE RATE

There is an automatic network for monitoring ambient gamma dose rate in Greece. The network is a sub-system of the telemetric environmental radioactivity monitoring network. The system consists of 24 dose rate monitoring stations throughout the country. The results are transferred to the central database. All monitoring stations operate continuously on 24/7 basis. Alarm is recorded when the gamma dose rate value in air exceeds pre-specified values.

The gamma dose rate probes are Reuter Stokes spherical high-pressure ionisation chambers using argon as counting gas. Each dose rate detector has a sensitivity of <10 nSv/h for a 10-minute measurement. The energy range is from 50 keV to 10 MeV; the measuring range is from 10E-08 to 0.1 Gy/h with an accuracy of ±5% for the range between 10E-08 to 0.01 Gy/h and ±7% above 0.01 Gy/h. The directional response stability is ±2% over an angle of 4π.

Each detector is coupled with a tipping bucket rain intensity gauge (model Young, Traverse City, MI, USA). The device is connected to the local data logger and modem, allowing the registration and on-line consultation of precipitation data. In addition, an anemometer and a wind direction indicator can be connected to the RSS-131 microprocessor via spare ports and thus be linked to the data recording and transmission system. The frame supporting the gamma probe is designed to allow quick mounting of a pole with these meteorological instruments, should conditions require.

All systems for monitoring ambient gamma dose rate have backup power supplies and are linked to a local RSS-131 microprocessor. This microprocessor is in turn linked with data loggers and a modem. The data loggers ensure both data storage capacity and the remote alarm, the latter function being controlled by pre-set alarm levels. The alarm levels can be remotely modified. The modem ensures communication with the EEAE headquarters, as well as interrogation capabilities from the headquarters control room.

All stations contain an electrical power box with UPS, GSM module, as well as a data transmission box. Communication has been upgraded to GPRS TCP/IP for reliability purposes. PSTN lines are used as an alternative communication path. Data received from the stations are stored at the telemetry server hosted at the EEAE premises. All measurement results of the telemetric system are available on-line[4]. The mean daily values are available at the EEAE website, as well as at the European Radiological Data Exchange Platform (EURDEP). Figure 1 shows the locations of the automatic monitoring stations.

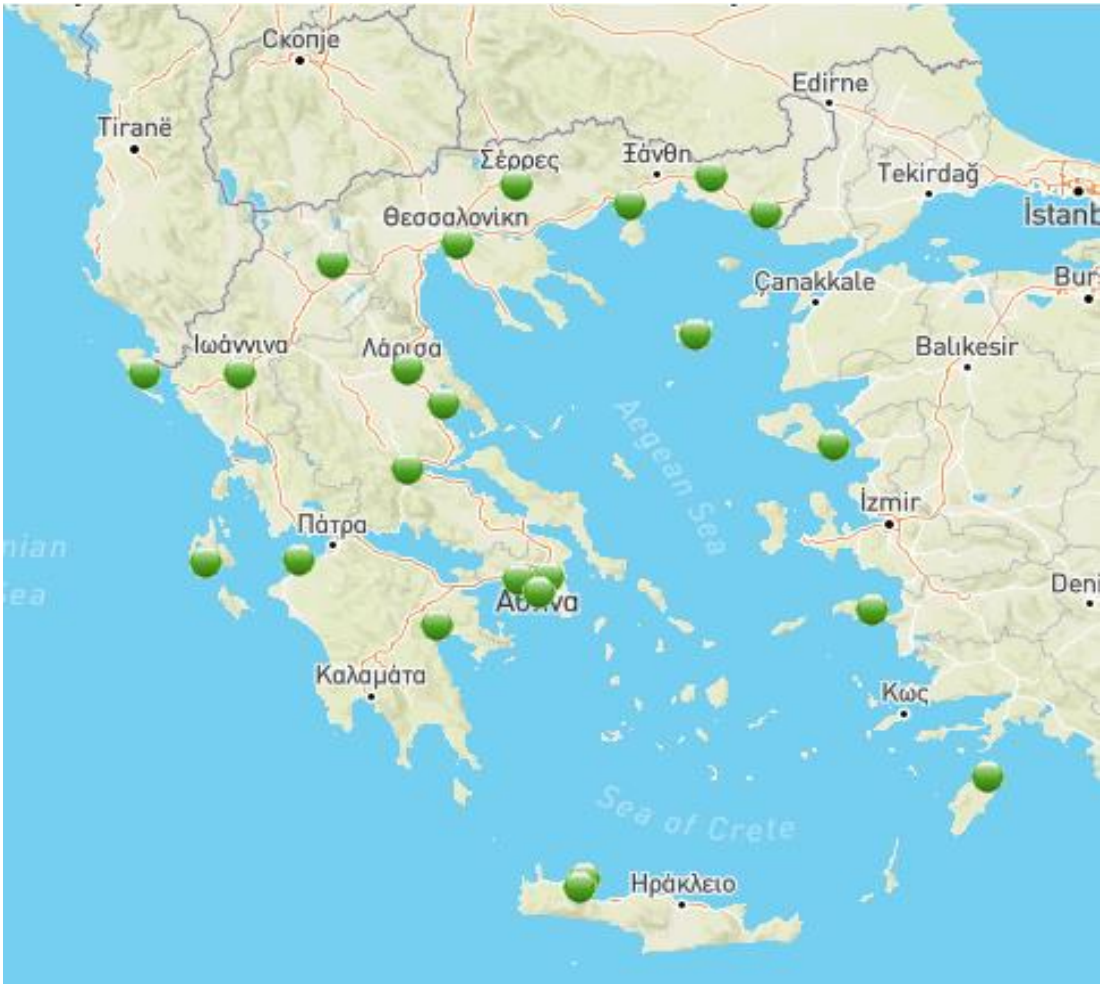

Figure 1. Automatic ambient gamma dose rate monitoring network

5.2 MONITORING OF RADIOACTIVITY IN AIR

Monitoring of radioactivity in air is carried out by filtering large volumes of air. Filters are then measured in a laboratory. There are three groups of air samplers in Greece:

- Automatic telemetric network of three Bitt stations for sampling particulate matter and iodine (low volume 6 m^3/h)
- ERMD-EEAE high volume station for sampling particulate matter and iodine
- Four ERL-Demokritos stations for sampling atmospheric particulate matter (two low volume and two high volume)

In the event of an emergency also the following equipment is available:

- NTUA high volume station for sampling particulate matter
- Department of Nuclear Physics (AUTH) high volume station for sampling particulate matter

[4] http://www.eeae.gr/en/environmental-radioactivity-levels

- Department of Electrical and Computer Engineering (AUTH) high volume station for sampling particulate matter
- Nuclear Physics Department (UOI) low-volume station for sampling particulate matter

Typical assessed nuclides are Cs-137, Cs-134, I-131, Pb-210, Am-241, Be-7, Pb-214, Bi-214, Co-60 and K-40.

Location of the samplers are presented in Figure 2. Although there is limited capability to monitor radioactivity in dry or wet atmospheric deposition in Greece (measurements performed by Nuclear Engineering Department -NTUA) these measurements are not performed in a routine basis. Collection of atmospheric deposition samples at the ERL was discontinued in 2015 due to lack of resources.

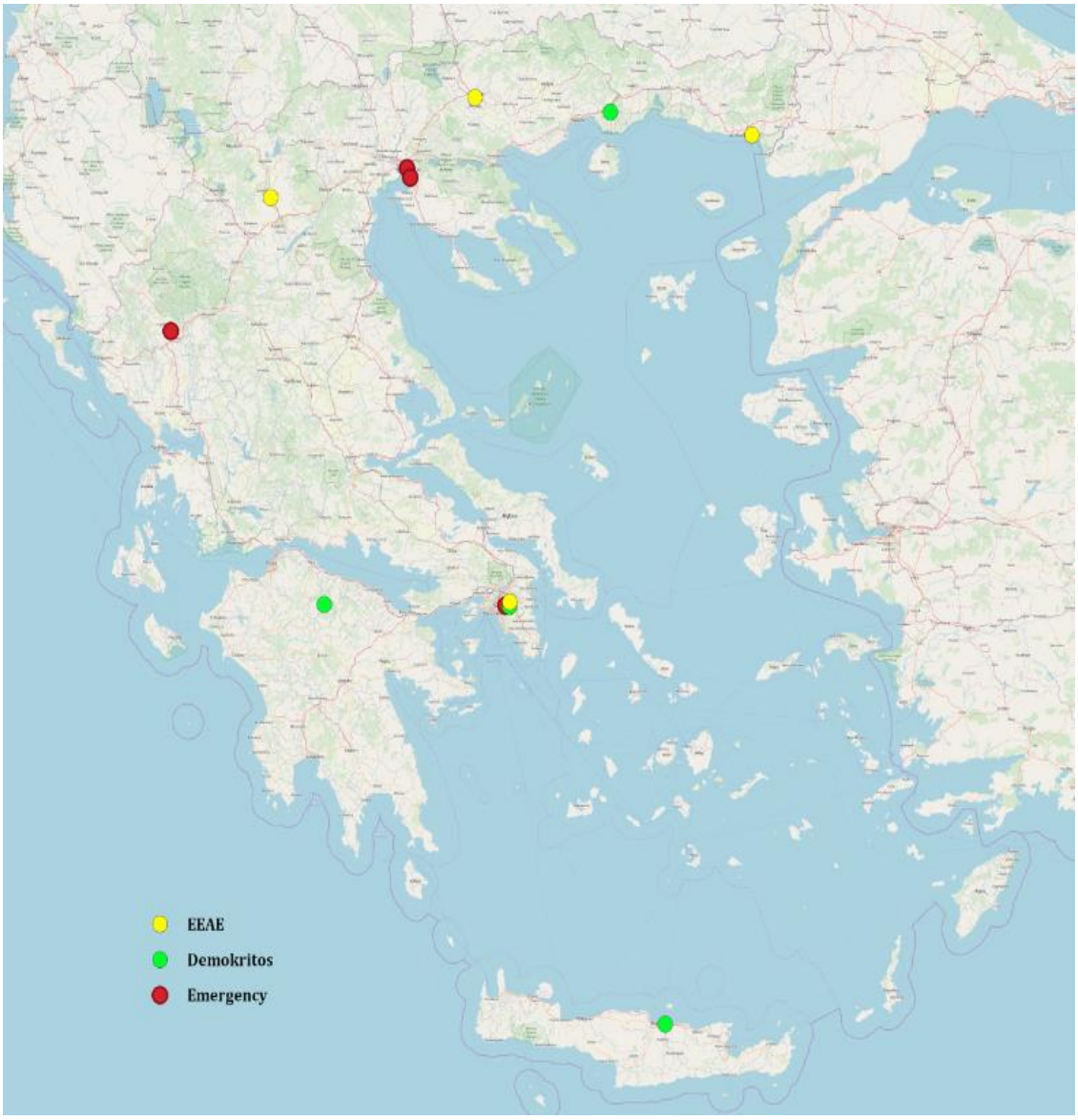

Figure 2. Air sampler locations

Telemetric Bitt automatic network

The telemetric network for atmospheric aerosol measurements consists of three monitoring stations located in northern Greece (Alexandroupolis, Serres and Ptolemaida). These stations perform measurements of natural and artificial alpha and beta radiation, as well as gamma spectrometry to detect artificial isotopes e.g. Cs-137 and I-131. The measurements are integrated every 30 minutes and recorded in a database at the central station of the network.

Each air monitoring station of the Bitt network consists of a container with a Bitt technology AMS-02 device (NaI(Tl) version), a Bitt technology RS03/X ambient gamma dose rate probe (proportional counter mounted on the roof of the container) and a 5 m meteorological mast with several meteorological probes (temperature at two heights, wind velocity and direction, precipitation volume and precipitation rate). Greece does not operate AMS-02 versions with high resolution gamma spectrometry using HPGe detectors.

Air is pumped through the system at a flow rate of ca. 6 m^3/h. Aerosols are collected on glass fibre filters (60 mm diameter) and immediately analysed by alpha and beta spectrometry (PIPS detector with an area of 1700 mm^2, resolution of ~55 keV for α and ~30 keV for β particles), and by gamma measurement (2x2" NaI(Tl) detector with a resolution of 8.5% for the 661 keV Cs-137 peak). A subsequent active carbon filter (60 mm diameter) allows analysis of gaseous iodine with a 2x2" NaI(Tl) detector. In case of elevated results organic iodine is measured in a temperature-controlled bypass system using a NaI(Tl) detector and activated carbon in a Marinelli geometry. The AMS-02 device contains racks with 400 aerosol filters and 100 iodine filters. Before each measurement series, energy calibration is performed using Cs-137 in filter geometry. The filters (including check filters for calibration) are moved within the device using a robotic manipulator system.

The container housing the device has air conditioning but no intruder alarm (all stations are located in fenced areas). A UPS keeps power for 15 minutes with the pump shut off; after that a controlled shutdown of the device is performed within a few minutes.

Maintenance of the device is performed by the EEAE (including remotely managed tasks with support from the producer, which has online access to the devices by using a Virtual Private Network – VPN). A database keeps track of the 'history' of used filters. It is routinely refreshed, which allows re-use of filters if they are not contaminated. EEAE can remotely restart the whole device via GSM.

Bitt technology SCADA (Supervisory Control and Data Acquisition) software is used for data management and presentation at the EEAE. Data transmission to EURDEP is in progress.

ERMD-EEAE high volume air sampling station

EEAE has at its headquarters a medium-volume air sampling station. The station has two filters in array one of glass fibre filter for particulate matter and one for active carbon filter for radioactive iodine. Air filters are changed approximately every 10 days (2-3 filters per month).

ERL Demokritos network

The ERL network consists of low-volume air samplers for total alpha/beta analysis. There are stations in Chrysoupoli, Kavala (Macedonia) and Herakleion (Crete). Filters are changed weekly.

In addition there is a high-volume sampler at the Demokritos Global Atmosphere Watch (GAW) station in Ag. Paraskevi, Attiki (filters are changed weekly) and a high-volume sampler at the Demokritos GAW station in Helmos Mountain 2314 m a.s.l (filters are automatically changed nominally every 48 hours). Analysis is carried out using gamma spectroscopy on a fraction of the collected filters from these two sites.

5.3 MONITORING OF RADIOACTIVITY IN WATER

5.3.1 Surface waters

ERMD-EEAE receives 3 litre samples of surface water every 2 years collected according to the sampling instructions agreed within the Memorandum of Collaboration with the Ministry of Environment and Energy, Special Secretariat for Water. The samples are analysed for Cs-137, alpha/beta emitters and Sr-90. Figure 3 shows the sampling locations.

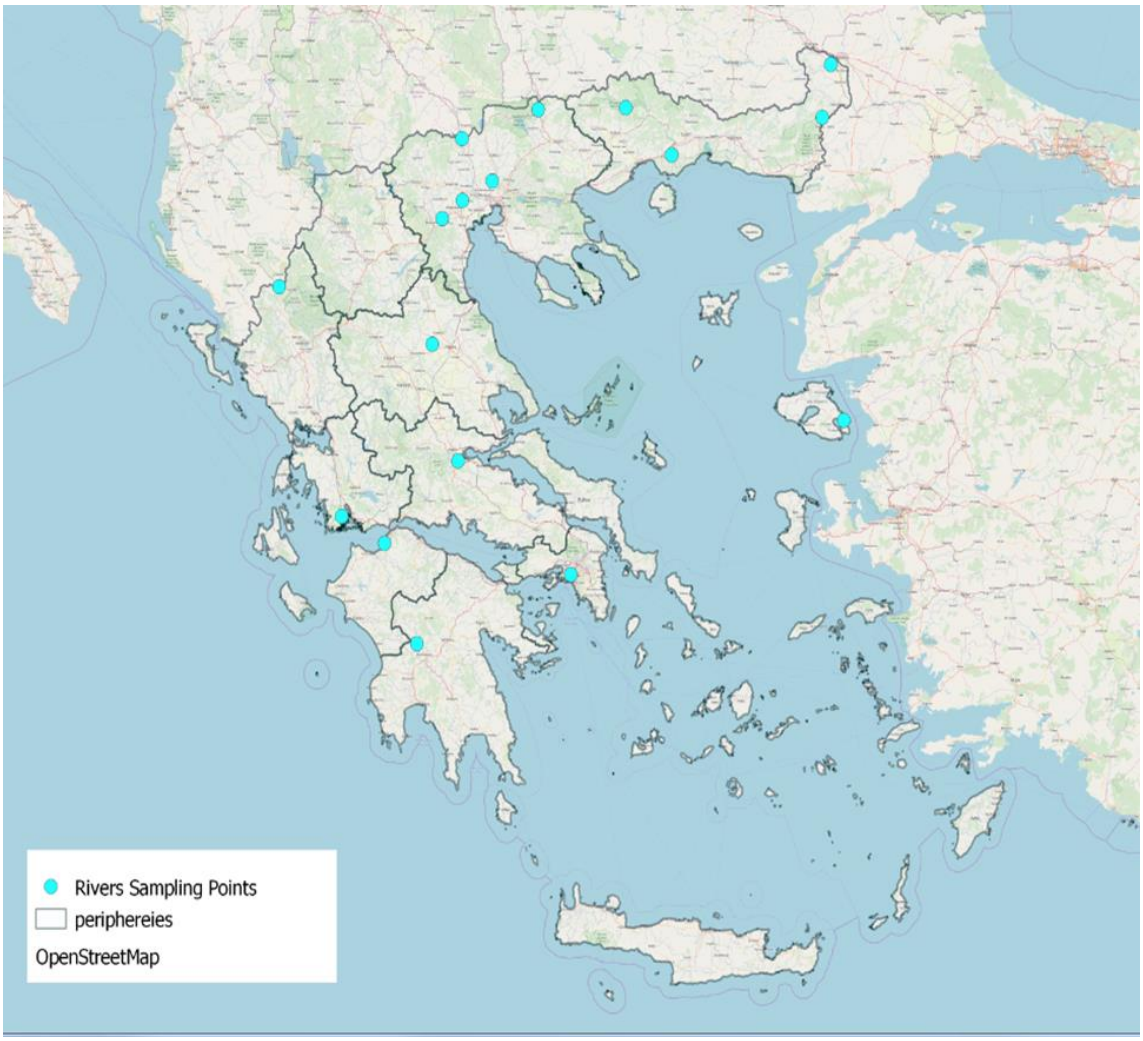

Figure 3. Surface water sampling locations

5.3.2 Ground water and drinking water

Sampling of ground water and drinking water is performed by the municipalities, by a representative of the regional public health department or by the two collaborating laboratories. Figure 4 summarizes, up to now, the sampling locations.

The three litre samples are acidified before shipping. Total alpha/beta activity and uranium isotopes (U-238 and U-234) are determined for the calculation of the Indicative dose. If the gross alpha or beta activity exceeds the screening levels 0.1 Bq/L and 1.0 Bq/L respectively, and the uranium activity concentrations exceeds 20% of the corresponding derived value, additional radionuclide activities are measured (Ra-226, Ra-228, Pb-210, Po-210).

In order to issue the certificate of compliance with regard to radioactivity in water, the EEAE asks for the submission of application for each water sample, including full details of the applicant (name, address, contact, VAT number etc.), as well as the results of the total measurements of alpha/beta radiation and uranium isotopes (U-238, U-234) by an approved laboratory. Currently, the approved laboratory in the Athens area to perform measurements of radioactivity in drinking water is the private laboratory Analytika Ergastiria Athinon.

The EEAE conducts also periodic random checks of tritium. Based on representative measurements of tritium in drinking water performed by EEAE in various parts of the country, and given the absence of anthropogenic tritium sources in Greece, systematic analyses of tritium are not required for a period of two years starting from the date of the relevant Board decision (October 2018).

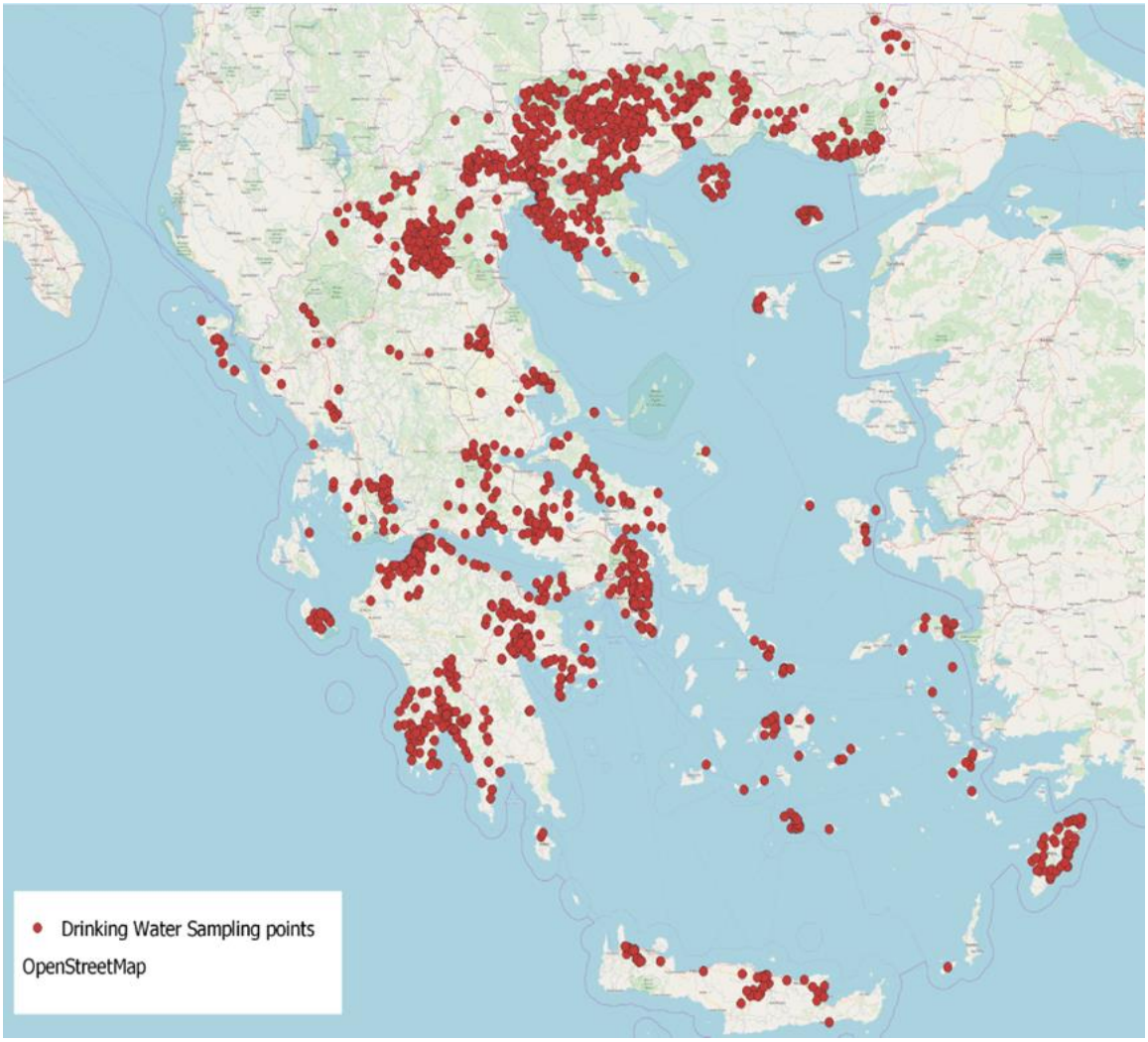

Figure 4. Drinking water sampling locations

5.4 MONITORING OF RADIOACTIVITY IN SOIL AND SEDIMENTS

Soil and sediment radioactivity measurements, apart from the ERMD have also been performed by the collaborating laboratories mainly in the framework of several research projects, but not as a regular part of the national monitoring programme. Natural isotope distribution maps are available[5].

There is no routine monitoring of terrestrial or aquatic biota and flora in Greece; this type of monitoring is carried out only in emergency situations.

5.5 MONITORING OF RADIOACTIVITY IN FOODSTUFFS AND FEEDING STUFF

5.5.1 Milk

The national monitoring programme includes sampling of milk from markets in the Athens area twice a year systematically, and in arbitrary dates in between. Samples are analysed for Cs-137, Cs-134 and I-131.

[5] http://nuclear.ntua.gr/arcas/research/maps.en.html

5.5.2 Mixed diet

The initial table on which the average consumption statistics for all types of food were made has been provided by the Hellenic Statistical Authority. The calculations were carried out based on the average monthly consumption quantities of Greek households in 2013[6].

The broader category of vegetables is subdivided into sub-categories from a 2012 study[7]. The sub - division of fresh vegetable quantities into subcategories, in the absence of any recent data, was based on data from a 2002 study which was about the average vegetable consumption in men and women.

Meat category is subdivided into meat subgroups based on meat production and consumption data from a 2006 study[8].

Cheese consumption category was sub - divided into some types of cheese such as white and yellow cheese. Statistics on the fruit consumed was carried out on the weekly consumption per household by 2004 and, although not representative, is indicative of fruit consumption in Greece today.

Food consumption estimation is based on a 2005 study[9] on adult, male and female food consumption in Greece. The same study also provided fats consumption rates, which are in Greece almost entirely 100% vegetable (olive oil and other vegetable oils).

All the above include rice, bread and bakery items, pasta, beef, pork meat, sheep and goat meat, poultry, other meats, fish, eggs, yoghurt, yellow cheese, white cheese, processed cheeses, bulk cheese, lemon tree, tangerines, oranges, bananas, apples, pears, peaches, grapes, watermelons, melons, nuts, legumes, potatoes, leafy vegetables, fruity vegetables, rooted vegetables, cabbages, onions, garlic, processed vegetables, tomato paste, seed oils, butter, margarine, olive oil, sugar, honey and jams.

5.5.3 Foodstuffs

The national monitoring programme includes sampling of various foodstuffs: milk, oil, fish feed, farine lacte, seed oil, jam, cheese, tobacco, peanuts, fish, olives, olive oil, roe, anchovy marinated, marinated sardine, anchovy frozen, sardine frozen, octopus frozen, frozen squid, chopped tomatoes in tomato juice, cheese manuri, feta cheese, sheep and goat milk, mixed cheese sample, sea bass, dried mushrooms, cow cheese, goat milk, sativa milling rice, sheep bones, sheep flesh, sheep flesh, mutton flesh, feta cheese. Sampling is done arbitrarily each year. Samples are analysed for Cs-137, Cs-134, I-131 and K-40.

5.5.4 Feeding stuffs

Fish feed, poultry feed are sampled arbitrarily within the year. Samples are analysed for Cs-137 and Cs-134.

5.6 EMERGENCY MONITORING

5.6.1 EEAE mobile monitoring laboratory

The EEAE (ERMD) has a mobile laboratory which is intended for emergency response situations. The mobile station is equipped with standard radiation monitoring and source localisation equipment (large plastic scintillator) as well as personal protective equipment and decontamination material.

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6 Hellenic Statistical Authority, Piraeus, 12.9.2014, Family Budgets Survey 2013

7 Vasileiou et al. Characteristic Elements of "Mediterranean Diet": The Consumption of Vegetables and Legumes in Greece (1950-2005), Journal of Management and Sustainability Vol. 2, No. 1; March 2012

8 N. Diamantidis, H. Metaxopoulos, G. Goulas "The production of quality meat in Greece. Present and future". Animal production. Agriculture - Livestock 10, 2006

9 A. Naska et. al. Dietary habits in Greece: The European Prospective Investigation into Cancer and nutrition (the EPIC project), Archives of Hellenic Medicine 2005, 22(3):259–269)

The mobile monitoring laboratory is equipped with a high volume pump for air filter sample collecting and there is a shielding installation in it where an in situ HPGe detector could be equipped. Thus, both in situ and in vitro measurements could be performed.

The mobile laboratory is equipped with a diesel generator but could be also supplied by the public network, offering adequate power autonomy.

5.6.2 Fire brigade's CBRN vehicles

Some of the fire brigades in Greece have a vehicle, which is intended for CBRN emergency response situations. The vehicle is equipped with standard radiation monitoring and personal protective equipment, as well as decontamination material and systems.

Altogether there are four such vehicles in Greece. One of these vehicles is placed at the Athens airport. According to the existing procedure and following to localisation of the radiological material and securing the area, the fire brigade may, in case of event at the airport, be supported by the airport custom officers team who have available also radionuclide identification capabilities. For all events in Athens the fire brigade will notify the EEAE, who will send a response team of specially trained staff for situation assessment, source recovery and management.

5.7 INFORMATION TO THE GENERAL PUBLIC

The EEAE has the institutional obligation[10] to provide information to the public and the State authorities. The tools the EEAE uses for this purpose are its website, the social media and the traditional channels (annual reports, leaflets, newsletters and events). The following information, relevant to the environmental radioactivity monitoring, is available at the EEAE website:

- Telemetric environmental radioactivity monitoring network: the average daily values
- Monitoring of drinking water: information about the legislation, the laboratories conducting analysis etc.
- Euratom Article 35 verification reports
- Emergency events: public information announcements and emphasis on lessons learned from events
- Findings of radiation detection systems installed in customs & steel industries (scrap metals)

A 'Dark site' is being developed for activation only in emergencies that require intense and long-term communication.

[10] Law 4310/2014 assigns to the EEAE the competence "*to provide sufficient information to the general public and workers regarding its areas of responsibility, keeping the principle of transparency and taking into account any best international practices…*".

6 LABORATORIES

6.1 GREEK ATOMIC ENERGY COMMISSION

The Environmental Radioactivity Monitoring Department of the EEAE[11] carries out laboratory analysis of soil, water (surface, drinking, underground), air (particulate matter and iodine), foodstuffs, feeding stuff, milk, mixed diet, thermal spring waters, indoor radon and NORM samples. The laboratory in terms of measurements management operates according to the implemented management system accredited according to ISO 17025 while in terms of internal organisation operates according to the implemented integrated management system in accordance with the requirements of ISO 9001:2015 and the internationally established requirements governing regulatory authorities and radiation facilities (IAEA Safety Standards, Leadership and Management for Safety, GSR Part 2).

The laboratory infrastructure comprises the following equipment:

- Gamma-spectroscopic systems: 2 HPGe (Canberra, p-type 70% & BEGe 50% low energy), calibrated with a multi-nuclide certified source (PerkinElmer); analysis are performed with Canberra Genie software.
- Alpha-spectroscopic system (Canberra): 24 chambers, 24 pips detectors, active area 600 mm^2, energy calibration with Pu-239/Am-241/Cm-244 source; for the analysis and storage of the spectra the AAnalyst and the Genie software are used. The tracers used for the analysis are U-232, Th-229 (for Th-isotopes & Ra-226), Pu-242, Am-243 and Po-209.
- Proportional counter (Tennelec): low background gas flow counter for gross α/β measurements
- In situ γ-spectroscopy: 2 portable HPGe systems (Canberra, 20% & 35% low energy)
- Mobile laboratory: HPGe 30%, proportional counter, etc.
- Track-etch detectors, electrets, active system for Radon measurements (alpha-guard)
- Radiochemistry laboratory equipment
- Liquid scintillation counter (Wallac Quantulus): gross α/β, Sr-90, H-3, C-14, Ra-228 and Pb-210
- Whole body counter (Canberra)
- Thyroid uptake monitor

According to the laboratory management system the measurement results are stored electronically. Detection limits are calculated according to ISO 11929:2010. Drinking water activity results are reported to the Ministry of Health.

The laboratory regularly participates in international intercomparison exercises (JRC, ALMERA, BfS, PROCORAD, IARMA, NPL).

6.2 ATHENS ANALYSIS LABORATORIES S.A

The Athens Analysis Laboratories S.A.[12] is a private laboratory, which carries out determination of uranium (U-234, U-238) activity and gross alpha/beta activity in drinking waters.

The samples received in the laboratory are assigned a unique 8-digit code and characterized as water for radioactivity analysis. The laboratory possesses one Liquid Scintillation Analyser (Quantulus GCT 6220-Low Activity Analyser provided by Perkin Elmer). The weekly calibration is done using an SNC (Self normalization and calibration) automated procedure with C-14 and tritium standards. Standards of U-236 and Sr-90 are used for calibration and optimum PSA value generation. The calculations for gross alpha/beta measurements and radon are done using an in-house made spreadsheet, whereas for tritium the result is automatically extracted to a spreadsheet by the software. No specific maintenance procedure is needed.

[11] P.O. Box 60092, 153 10 | Agia Paraskevi, Athens, Greece

[12] El. Venizelou Avenue 127 and Alikarnasou 31, 14231 Nea Ionia, Athens, Greece

The laboratory has one ICP-MS **(**iCAP Qc) with an ESI 4Q autosampler by Thermo Scientific. The measurements of the uranium isotopes are performed according to ISO 17294-2:2016[13]. First the sample is measured with external calibration with an internal standard (standard solutions 0.1, 1, 5, 20 µg/l) to provide U-238 concentration and then without internal standard to evaluate isotopic ratios (U-234, U-236). The calculation of the results is done using an in-house made spreadsheet.

Each daily assay is saved in a folder named with the date and archived by month and by the year for every category of measurement (gross alpha/beta, tritium, radon, uranium). If a result is below the detection limit, the value given is characterised as "not detected". The detection limits are the following:

- Gross alpha/beta activity 0.04 Bq/L / 0.4 Bq/L
- Uranium (U-234, U-238) 20 mBq/L

The results are registered to the Lablink Laboratory Information System after calculations performed by using the software of the equipment.

The measurement results of gross alpha/beta and uranium isotopes are sent to the EEAE so that a certificate of compliance with regard to radioactivity can be issued. After analysis the initial sample is stored at room temperature for up to 4 weeks.

The laboratory is accredited by the Hellenic Accreditation System (ESYD) for the analysis of water for human consumption, surface water and groundwater for tritium, gross alpha/beta, uranium and radon activity (certificate No.102-4). It participates in national and international inter-comparison proficiency tests.

6.3 Environmental Radioactivity Laboratory, Institute of Nuclear & Radiological Science & Technology, Energy & Safety

The Environmental Radioactivity Laboratory of the Institute of Nuclear & Radiological Science & Technology, Energy & Safety (National Centre for Scientific Research "Demokritos")[14] carries out measurements of foodstuff, feedstuff, building materials, air filters, seawater, thermal spring waters, and other various environmental samples.

Samples are delivered to the assigned laboratory's front desk along with associated sampling information. An internal protocol system is used for the registration of the samples. A dedicated form with the description of the samples is filled in. The form is duplicated every time the sample has to be moved to either the preparation room or the counting room.

The methodologies used to prepare samples before measurement are those specified by the IAEA Technical Report Series No 295[15]. Natural and anthropogenic radionuclides are assessed depending on the analytical method and material.

High purity germanium detectors (2), portable NaI(Tl) scintillators (2), alpha/beta pancake probes (3) and a gas proportional counter(1) are available. Calibration is done by means of multi gamma sources (in the same geometry as the sample containers), reference materials, and in-situ prepared isotope sources of known activities. Calculation of results is done on spreadsheets and by hand.

Records are held both in written and electronic form. The forms are archived in-house. Results are reported to the relevant Ministries and to the regulatory body (EEAE). Samples are stored in special

[13] Water quality – Application of inductively coupled plasma mass spectrometry (ICP-MS) – Part 2: Determination of 62 elements including uranium isotopes

[14] Patr. Gregoriou E & 27 Neapoleos St., GR-15341, Agia Paraskevi, Greece

[15] Measurement of Radionuclides in Food and the Environment, International Atomic Energy Agency, Vienna, 1989 and TRS 118, "Reference Methods for Marine Radioactivity Studies", International Atomic Energy Agency, Vienna, 1970

rooms and/or fridges for the required period. Results below detection limits are reported as being below the calculated MDA value.

The laboratory takes part each year at the ALMERA network proficiency tests.

6.4 OTHER ANALYTICAL LABORATORIES

In addition to the main laboratories described above, there are several other analytical laboratories involved in monitoring of radioactivity in Greece. Most of these laboratories are assigned to measure radioactivity only during an emergency situation. Table I below lists these laboratories.

Table I. Laboratories involved in radiological surveillance

Institution/Laboratory	City	Measurements provided to the EEAE
Nuclear Engineering Department, National Technical University of Athens (NTUA)	15780 Zografou, Athens	Gamma emitters (in emergency situations)
Department of Electrical and Computer Engineering Aristotle University of Thessaloniki (AUTH)	54124 Thessaloniki	Radon in waters, Gamma emitters (in emergency situations)
Department of Nuclear Physics, Aristotle University of Thessaloniki (AUTH)	54124 Thessaloniki	Gamma emitters (in emergency situations)
Nuclear Physics Department, University of Ioannina (UOI)	45110 Ioannina	Gamma emitters (in emergency situations)
Laboratory of Medical Physics, University of Ioannina (UOI)	45110 Ioannina	Gamma emitters (in emergency situations)
Hellenic Centre for Marine Research	19013 Anavyssos, Attiki	Gamma emitters in sea water (in emergency situations)
Department of Mineral Resources Engineering, Technical University of Crete	73100 Chania, Crete	Gamma emitters (in emergency situations)
Nuclear Technology Laboratory, Dept of electrical & Computer engineering, University of Thrace	67100 Xanthi	Gamma emitters (in emergency situations)
Agrolab RDS (private laboratory approved by EEAE)	57022 Sindos, Thessaloniki	Total alpha/beta & uranium isotopes in drinking water
Analytika Ergastiria Athinon (private laboratory approved by EEAE)	14231 Nea Ionia, Athens	Total alpha/beta & uranium isotopes in drinking water

7 VERIFICATIONS

7.1 INTRODUCTION

Verification activities were carried out in accordance with the agreed programme. This chapter summarises the verifications carried out by the verification team. The team has assessed the monitoring arrangements based on their own expertise and comparison with similar arrangements in other Member States.

The outcome of the verification is expressed as follows:

- A '*Recommendation*' is made when there is a clear need for improvement in implementing Article 35. These are included in the main conclusions of the verification. The Commission requests a report on the implementation of the recommendations – lacking implementation of a recommendation can lead to a reverification.
- A '*Suggestion*' is made when the verification team identifies an action, which would further improve the quality of the monitoring.

In addition, the team may '*commend*' particularly good arrangements, which could serve as a best practice indicator for the other EU Member States.

7.2 EEAE ENVIRONMENTAL RADIOACTIVITY MONITORING DEPARTMENT

7.2.1 General

The verification team visited the ERMD in order to discuss the department's activities in the area of the verification visit.

The eleven (11) member staff of the Department is composed of 3.5 specific scientists (PhD, permanent personnel -one is currently working part time), 3 laboratory scientific staff (2 PhDs, 1 MSc), 1 electronic engineer, 2 electrical engineers, 1 secretary.

The verification team noted the lack of space in the ERMD laboratories. As much as well organised the equipment, facilities and archives maybe be currently, the lack of space may present a challenge, e.g. in an emergency case when potentially contaminated samples have to be managed.

> *The verification team suggests that the ERMD prepares a dedicated sample management plan for emergency situations.*

7.2.2 Automatic dose rate monitoring

The verification team visited one of the 24 automatic stations of the Telemetric Radioactivity Monitoring Network located at Hellinicon at the premises of the National Meteorology Service (see Figure 5). The installation of the system dates back to 2000. The system was upgraded following to the 2012 Article 35 verification mission in terms of software, maintenance diagnostics unit and data communication (ADSL lines). The expected lifetime of the dose rate probe is 30 years.

The station consists of a dose rate detector, temperature sensor and a rain intensity monitor. It is well located in a fenced and guarded meteorological instrument garden. Power back-up battery is available (24 hours). The EEAE staff informed the verification team that the automatic dose rate monitoring detectors are rather old and that they are looking into the different technical options for upgrading the dose rate probes.

Figure 5. Ambient dose rate monitoring station at Hellinikon, Athens (part of the Telemetric Radioactivity Monitoring Network)

The team observed that based on the real-time display of the monitoring systems status the rain detector at Larissa was not operating. The team was informed that the geometry of the existing rain gauge is such that microparticles stack in the bottom, which blocks the 1 mm water hole. Such a problem happens often, depending on the collector placement. This is a generic problem for all rain gauges throughout the country. The ERMD staff informed the team that they are considering to replace the rain gauges by a different type.

The staff allocated to the management and maintenance of the telemetric network consists of 0.5 senior scientist (PhD), and 1 electronics engineer. The verification team noted that the allocated staff may not be sufficient to address the challenges of both management and maintenance of the telemetric system.

> *The verification team suggests allocation of more staff to the monitoring network management and maintenance.*
>
> *The verification team suggests starting the long-term planning for the modernisation of the automatic monitoring system.*

7.2.3 Aerosol monitoring network

The verification team witnessed a demonstration of the display of the status of the telemetric aerosol monitoring network. Aerosol monitor network includes three stations in Ptolemais, Serres and Alexandroupolis.

The verification team noted that currently the aerosol monitoring data from the automatic air sampling stations are not introduced in EURPED due to lack of resources.

> *The verification team recommends that the EEAE takes forward the plan for introducing the aerosol monitoring data into EURDEP.*

7.2.4 Air sampling station

The verification team visited the medium volume (nominal air flow rate 50 m^3/h) air sampling station (F&J special products) at the EEAE premises (see Figure 6). Typically the sample is collected for 7-10 days; shorter collection interval is used during an emergency situation. The sampler is installed on the roof of the EEAE secondary calibration laboratory and therefore conditions of restricted access apply. With the installed system sampling of gaseous iodine is also performed. There is an identical device in Thessaloniki, additionally this capability is available at the National Technical University of Athens and at the EEAE mobile monitoring vehicle. However, it should be noted that during the Fukushima accident, ERMD was the only lab which reported gaseous iodine concentrations in the ambient air in Greece.

The air sampler performs auto correction of the flow rate for calculation of the sampled air volume. The EEAE has a new flow rate meter to be used for the calibration of the air flow rate meters of the sampling stations.

The verification team suggests acquisition of a high-volume air sampler with a possibility to sample gaseous iodine.

The verification team suggests that a regular calibration of the air flow rate meter is performed.

The verification team commends the availability of flow meter calibration equipment at the EEAE.

Figure 6. Medium volume air sampling station at EEAE premises at Aghia Paraskevi, Attiki

7.2.5 Telemetric radioactivity monitoring network data centre

The verification team visited the telemetric radioactivity monitoring network (TRMN) data centre. The centre consists of a computer unit used to display results and manage the telemetric system, as well as of two local servers. Data from the telemetric monitoring network (24 dose rate and 3 aerosol monitoring sub-systems) are automatically collected in a database. Data are transferred to the storage server once per day. The collected data include measurements as well as meteorological data. The servers are connected to a UPS while alternative power supply capability also exists.

No remarks.

7.2.6 Radio-analytical laboratory

The verification team visited the EEAE radio-analytical laboratory, where analytical measurements of environmental samples are performed. The laboratory is staffed by six (6) persons; during the verification there were no open posts.

The laboratory has a sample preparation room for gamma spectrometry and a radiochemical preparation laboratory, which are well equipped with adequate equipment and facilities (grinding and homogenising equipment, dryers, furnaces, evaporators, etc.) to treat the samples related to analyses from the environmental radioactivity monitoring programme.

Sample registration is performed on a paper file and an Excel-sheet; a dedicated LIMS system is not available. The number of samples measured in the laboratory per week is about 10 by alpha-spectrometry, 10-20 by LSC and 7 by gamma-ray spectrometry. Capacity exists also for measurement of soil samples (about 100 such measurements have been performed in the frame of a research project). Air filters (active carbon and glass fibre) are measured by gamma spectrometry for 1 day (in the case of emergency 6 h). The mixed diet samples (homogenised sample volume 260 ml) are measured by gamma spectrometry using efficiency calibrations performed with reference sources of suitable densities.

Water samples undergo evaporation (by rotary evaporator), precipitation and electrodeposition in the radiochemical laboratory (Figure 7). Samples are measured for total alpha/beta radioactivity and U activity.

Measured samples are stored for 4 years (filters) or 2 months (others), after which they are disposed unless they exceed the exemption limits, in which case they are sent back to the owner (if other than EEAE).

The laboratory is accredited according to ISO 17025 for gamma spectrometry, alpha spectrometry and passive radon measurements. It regularly participates in intercomparison exercises on gamma and alpha spectrometry organised by the WHO (World Health Organization), ALMERA, IAEA, BfS, NPL, EU and PROCORAD.

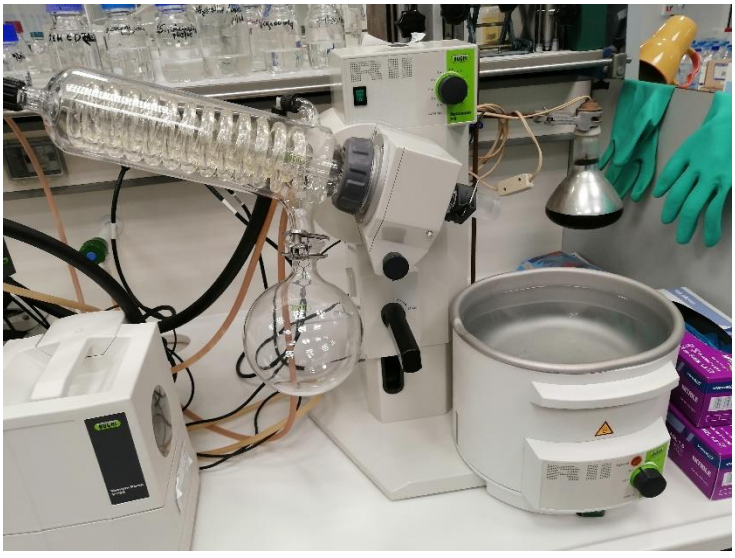

Figure 7. The rotary evaporator at the radiochemical laboratory of ERMD

Gamma spectrometry

Two HPGe high resolution gamma spectrometry systems with digital electronics (Figure 8) are available in the laboratory. The purchase of a third HPGe detector is planned. The detector efficiencies are calibrated regularly using multi-nuclide gamma sources of certified activities. In addition, energy and efficiency calibrations as well as resolution (FWHM) are monitored before each measurement, and at

least once per week using standard point sources (Am-241, Cs-137 and Co-60). Certified sources are available in point and typical sample geometries (air filter, Marinelli and active carbon filter). Calibration volume sources are available in typical matrix densities (0.5, 1.0, 1.3 g/cm^3 etc.). For other sample geometries and densities efficiency corrections from the reference source to the sample are calculated using the Monte Carlo computational method. Background spectra of 2-3 days counting time are acquired once per month.

True coincidence summing corrections are calculated using tested software on occasional basis, in particular for inter-laboratory comparisons.

The staff responsible for the gamma spectrometry consists of one laboratory responsible and two scientists.

Figure 8. HPGe detectors at the ERMD laboratory.

Alpha spectrometry and alpha-beta counting

A 24 channel alpha spectrometry system (Canberra Alpha Analyst) and a total alpha/beta counter (Tennelec Series 5) are available (Figures 9 and 10). The energy and efficiency calibration for the AAnalyst is performed by a Pu-239/Am-241/Cm-244 standard source (Ziegler-Eckert). The measurement time for samples with low activity is normally 5 days. The staff responsible for the alpha spectrometry consists of one laboratory responsible and an assistant scientist. The alpha/beta counter Tennelec is used only for the measurement of air filters and smear tests.

Figure 9. Alpha spectrometer and an electrodeposited sample at the ERMD

Figure 10. The total alpha/beta counter at the ERMD

Radon measurements

The EEAE Radon Laboratory is the only accredited radon laboratory in Greece. It is responsible for the maintenance and coordination of the national radon data base. It performs measurements of indoor radon concentrations in dwellings and workplaces.

Dwellings are measured with passive detectors, electret and CR39 detectors. The measurements are free of charge in the frame of the National Radon Action Plan; all measurements are entered to the data base for the completion of the national radon map and characterization of the priority areas. Apart from this service the laboratory performs surveys where and when needed.

For the measurements at workplaces, besides passive, active detectors are also used. The active detectors that the laboratory has are an alpha guard detector and a couple of Corentium detectors by Airthings. In the frame of the National Action Plan there are three categories of workplaces where radon measurements are mandatory: NORM industries, public buildings with high occupancy as well as schools and workplaces in priority areas.

The laboratory measures radon in water samples. The measurement is performed with the AlphaGuard aqua kit extension. The laboratory also owns the bottle extensions of electret system for measuring water samples. The equipment are shown in Figure 11. In addition, the laboratory performs measurements of soil with the RM2 Radon detector from Radon v.o.s.

The number of radon measurements is about 500 per year. In the current staff allocation one member of EMRD staff is responsible for the radon laboratory.

Figure 11. The AlphaGuard radon monitor and electret reader at the ERMD.

Liquid scintillation counting

The liquid scintillation counter (Quantulus, Figure 12) is used for measurements of H-3, C-14, Sr-90, Ra-228, Pb-210, alpha/beta activity and Rn. The efficiency is determined by the use of liquid standards, purchased from NIST. For alpha/beta calibration Am-241 and Cl-36 sources are used. The measurement time of the samples varies between 300-600 min. The staff responsible for the LSC consists of one laboratory responsible and an assistant scientist. Liquid scintillation counting in not among the accredited methods of the laboratory. Quality assurance is based on participation in the above mentioned international inter-laboratory comparison exercises.

If the number of incoming samples increases, the verification team suggests that the EEAE laboratory proceeds to acquire a dedicated laboratory information management system (LIMS).

The verification team suggests acquisition of additional radon monitoring systems to provide back-up for the current equipment.

Figure 12. Liquid Scintillation Counter (Wallac Quantulus) at the ERMD

7.3 EEAE MOBILE MONITORING SYSTEMS

The verification team visited the EEAE mobile monitoring laboratory vehicle (Figure 13). The vehicle has an independent power supply for long-term autonomous operation. The radiation monitoring equipment available for the mobile laboratory are stored in an environmentally protected storage container next to the parking place of the mobile laboratory (Figure 14). The vehicle may be equipped in approximately 10 minutes with radiation pagers, dose rate monitors (Ionization Chambers, plastic scintillators and NaI telescopic probe), contamination monitors, radionuclide identifiers (exploraniums, identifinders), large (5 L) mountable plastic scintillator (with dose rate mapping capability), and personal protective equipment. A portable air sampler and two in-situ high resolution HPGe gamma-ray spectrometers (one electrically cooled and one cooled by liquid nitrogen), as well as a mobile lead shielding (for the HPGe in-situ spectrometer) and lead shield container for source recovery are also available at the ERMD.

The HPGe spectrometers are stored in warm status, which means that in the case of an emergency the staff would need at least two hours to cool them down to the operating temperature.

The portable air sampler is stored in the ERMD area (underground floor) and would require two staff members to transport it to the vehicle in case of emergency event.

The ERMD plans to acquire also back-pack type equipment for carrying out environmental radiation surveillance on foot.

Two scientists and two drivers are trained for emergency response using the mobile laboratory. The EEAE has also a pool of trained first responders (5 persons trained as leaders, 7 as members of the responding team). First responders are supported by a supporting team staying at the EEAE headquarters during the response (this team consists of 10 persons of different specialities).

No remarks.

Figure 13. EEAE mobile monitoring laboratory

Figure 14. EEAE mobile monitoring equipment (NaI telescopic probe, dose rate & contamination monitors, neutron survey monitor, portable air sampler)

7.4 EEAE Ionizing Radiation Calibration Laboratory

The EEAE Ionizing Radiation Calibration Laboratory is a secondary standard calibration laboratory, which has developed and maintains the national standards of Gy, Sv, Cb/kg for gamma, X-ray and beta radiation in the country. Since 2003 it is assigned by the Hellenic Institute of Metrology (EIM) as the designated laboratory for gamma, X-ray ionizing radiation metrology applications. The calibrations are performed in terms of Air Kerma, Absorbed Dose, Personal Dose Equivalent at depths of 10 and 0.07 mm (Hp(10) and Hp(0,07)), Ambient Dose Equivalent at depth of 10 mm, H*(10), and exposure in the fields of radiotherapy, diagnostic radiology and mammography, as well as in radiation protection and individual monitoring.

The verification team visited the Ionizing Radiation Calibration Laboratory, as among others it is responsible for the calibration of the survey meters and other radiation protection equipment (incl. electronic personal dosimeters) of the fire brigades, as well as the radionuclide identifiers of the Greek customs. The laboratory is certified according to ISO 17025 by the Hellenic Accreditation System. The measured dosimetric quantities are traceable to BIPM or PTB. The calibration frequency of the above mentioned equipment is every two years. The service is offered for free by the EEAE to the fire brigades and the customs according to the existing co-operation arrangement.

No remarks.

7.5 EEAE PUBLIC INFORMATION ARRANGEMENTS

During the verification mission the EEAE communication officer presented to the verification team the activities regarding provision of public information and the channels of communication focusing on three case studies of past real emergencies: the Fukushima Daiichi NPP accident (2011), the Ru-106 case (2017), and the detection of increased levels of uranium in drinking water (Greece 2019).

The available on-line data to the public include the data from the telemetric monitoring network (dose rate and airborne radioactivity in green/yellow 40 nSv/h/red 300 nSv/h colour code), as well as the radon concentration maps (with colour code and actual radon concentrations)[16]. The website does not include instant dose rate values, which are sent to EURDEP, but the 24h mean values. The alarm levels are different at each station, due to different natural background. When these levels are exceeded the colour of the station is changed on the website.

The future plans in the public communication field include the implementation of public information actions such as the launch of mobile apps and pilot information campaigns in schools. The EEAE is also developing a dark site to be activated in the case of radiological emergency, with the aim to host also the measurements of the telemetric network.

The International and Public Relations Office communication office of the EEAE has one communication officer and half assistant.

The verification team observed the following good practices:

- English translation of the key information on the EEAE website;
- Participation in research projects with a focus on communication and stakeholder involvement in emergency preparedness and response for radiological events.

The verification team noted that the staff responsible to respond to the need for information and enquiries from the public may need support in a real emergency situation.

No remarks.

7.6 INSTITUTE OF NUCLEAR TECHNOLOGY AND RADIATION PROTECTION

7.6.1 General

The verification team visited the Environmental Radioactivity Laboratory (ERL) and their on-site air sampling station. The laboratory analyses samples of foodstuff, feedstuff, building materials, air filters, seawater, thermal spring waters, and various other environmental matrixes. Additionally it carries out radioactivity measurements on commercial import/export materials, mainly foodstuffs.

7.6.2 Environmental Radioactivity Laboratory

Environment and food samples are usually collected by the laboratory staff. Samples are registered under a unique sample name. The registration information includes the necessary data (sample type, sampling period, date and time of sample arrival, sampling location, sample volume/mass etc.). Where necessary, the sample is directed to the sample preparation unit and treated physically and/or chemically. The parameters and measurement results are added to the sample analysis sheet. There is no dedicated laboratory information management system in the laboratory - calculations are made using MS Excel spreadsheets, where all the sample data are recorded. These files are used for electronic storage of the results, in parallel to the physical (paper) storage.

The results of the routine environmental radioactivity control measurements are reported to the EEAE. Samples are stored in special rooms and/or fridges for the required period.

[16] http://eeae.gr/en/environmental-radioactivity-levels

The radio-analytical equipment of the ERL consist of four Canberra high resolution HPGe gamma spectrometers (two operational) and a Tennelec total alpha/beta counter (old, but in good working order, Figure 15). The total alpha/beta counter has automatic sample changing capability. The verification team was informed that it is very difficult to obtain spare parts for this system. Of the two operating HPGe spectrometry systems one employs digital and the other analogue electronics. Two other HPGe systems are out of order.

Efficiency calibrations for the HPGe detectors are performed using certified multi-nuclide gamma ray sources of disk and Marinelli type geometries. There is no regular efficiency calibration control programme. For samples, which differ from these geometries/densities, the EFFTAN code is used to calculate energy specific efficiency transfer correction factors. Control measurements are performed regularly for energy and resolution of the systems, but these are not documented nor stored. The counting room background is measured once per month.

The laboratory has no quality accreditation, but it aims at having the total alpha/beta and gamma spectroscopy measurements accredited in the future. The EEAE has issued a certificate for the ERL as one of the collaborating laboratories. In addition, the laboratory takes part each year at the ALMERA proficiency tests organised by the IAEA.

The staff of the Environmental Radioactivity Laboratory consists of two permanent researchers, one research engineer, as well as three post-doc researchers, one part-time collaborating researcher and three PhD Fellows under contracts. The radio-analytical measurements (100-150 samples annually) are performed by the part-time staff member and one post-doc researcher.

In the case of emergency, the laboratory collaborates with the EEAE in the implementation of environmental monitoring according to the National Emergency Plan.

The laboratory facility has sufficient working space, but there are a lot of old equipment left from past operations still stored in the analytical rooms.

The verification team recommends establishing trend control sheets for regular follow-up of HPGe detector stability (energy, efficiency and resolution).

If the number of incoming samples increases, the verification team suggests that the ERL laboratory proceeds to acquire a dedicated laboratory information management system (LIMS).

The verification team suggests renewal of the total alpha/beta counter in the near future.

The verification team suggests removal of old, non-functional equipment from the laboratory rooms.

Figure 15. ERL laboratory counting equipment (HPGe gamma spectroscopy and total alpha/beta)

7.6.3 Air monitoring station Demokritos

The ERL air monitoring network consists of four air sampling stations 1) in Chysoupoli, Kavala (Macedonia), 2) Heraklion airport, (Crete), 3) Helmos Mountain (high Altitude station, Kalavryta, (Peloponnese) and 4) the Demokritos Agia Paraskevi site. The verification team visited the station at Aghia Paraskevi-Attiki, which is located at the Demokritos site. The station has two air samplers of max. air flow rates 300 and 2 m^3/h. The high volume air sampler has automatic regulation of the flow rate. The sampler is under the accreditation system of the laboratory, which requires <5% variation of the air flow rate. The air flow rate meter is calibrated regularly. The sampling time is about 1 week. The ERL staff operates the station. Under routine conditions, the air samples are measured for gross beta activity, while a fixed group of specific radionuclides (Be-7, Cs-137, Th-228, K-40) is examined and quantified by means of high-resolution gamma spectrometry. In the case of emergency, the determination of specific radionuclides will be performed by means of high-resolution gamma spectrometry. There is no sampling for gaseous iodine monitoring at this station.

In the past the laboratory performed also radioactive atmospheric deposition sampling, but lack of resources led to termination of this activity. There is no sampling of this type being performed in Greece.

No remarks.

7.7 Athens Analysis Laboratories S.A

The verification team visited the water laboratory of the Athens Analysis Laboratories S.A. This private laboratory carries out analysis of some 40 000 water samples each year, including about 1000 samples for radioactivity analysis.

Drinking water samples originate from a ground water source, a surface water purification facility or from a sea water desalination plant (Greek islands). The samples (1 L each) are collected by the customers of the company (typically municipal water production facilities). Registration and management of samples is done using a dedicated Laboratory Information Management System (LIMS).

The laboratory is well equipped with adequate equipment and facilities for measurement of uranium (U-234, U-238) activity and total alpha/beta activity in drinking water, among other chemical measurements the company offers. Tritium analysis is possible too, but the number of tritium samples is very low. The radio-analytical capability includes a well-equipped radiochemical laboratory, a Liquid Scintillation Counter (Quantulus GCT 6220) for the gross alpha/beta measurements in drinking waters and an ICP-MS (Thermo Scientific iCAP Q) for the determination of the uranium isotopes U-238 & U-234.

The whole process from water sample preparation to results reporting lasts about one week. In the case of instrument (LSC or ICP-MS) failure their maintenance contract foresees sending technical assistance within 24-28 hours.

Calibrations are performed using standard solutions once per month (in the case of ICP-MS an internal standard is added during the U isotopes measurement). Control charts for gross alpha/beta measurements are maintained based on monthly measurements of a standard water sample.

Calculation of activity results is performed using in-house Excel spreadsheets. Activity results of gross alpha/beta and uranium isotopes are recorded in a database. In addition, the results are sent to the EEAE in order to issue the relevant certificates of compliance. Once the certificate is issued the company sends the certificate and the measurement results to the customer. The samples are stored for 1 month after measurement and then disposed.

The laboratory is accredited according to ISO 17025 for both techniques (gross alpha/beta activity and U-234/U-238). The accreditation body includes an auditor from the ERMD EEAE.

The number of trained staff allocated to radio-analytical measurements is two for the LSC and three for the ICP-MS.

The verification team noted that the laboratory facility lacks suitable working space - the company is in the process of moving to new premises during year 2020. The impact of the removal operation on the continuity of their services provision is estimated as low on the basis of their planning to complete the whole operation within one weekend.

No remarks.

7.8 NTUA Nuclear Engineering Department

The verification team visited the laboratories of the Nuclear Engineering Department of the National Technical University of Athens (NED-NTUA), including the gamma spectrometry laboratory and the on-site monitoring facilities. The institute maintains facilities for monitoring of radioactivity in air, soil and atmospheric depositions (wet and dry) based on an informal agreement with the EEAE. Results are communicated to the EEAE on a regular basis. For emergency situations, the NTUA has a -formal role to carry out monitoring according to the national emergency plan.

The monitoring equipment consists an on-line NaI radioactivity monitor (window adjusted to Cs-137 gamma ray energy as a main fission product) (Figure 16), a fixed medium volume air sampler (Figure 17) and five portable medium-volume air samplers (Staplex TFIA-2) (Figure 18).

The NaI radioactivity monitor measures the radioactivity in air averaged every hour at a window including the 662 keV (Cs-137) peak. The system serves as an early warning system. The system is rather old and maintenance is difficult due to the shortage of nuclear electronics (NIM modules) such as analogue spectrum stabilizers etc. An upgrade using modern electronics is only a matter of resources.

The air sampler (DH-50810E by F&J) has a nominal flow rate of 60 m^3/h. Also this system is rather old (more than 20 years in operation). An air filter sample is collected once a month for 7-10 days. An adaptor allows the installation of an active carbon filter. However, there is no stock of such filters due to lack of resources in combination with the short validity time of such filters. The air flow rate has not been calibrated. The system and filter types are the same with the air sampler at the EEAE. Since the EEAE maintains a stock of active carbon filters they could be made available to the NED-NTUA in the event of an emergency. In addition, the EEAE could make available a flow rate meter for the calibration of the sampler flow rate. Figure 19 shows the folding process of the filter before placing on the gamma spectrometer (Figure 20).

The gamma spectrometry laboratory is equipped with five germanium detectors: one Low Energy Germanium Detector (LEGe), two High Purity Germanium Detectors (HPGe), one Extended Range Germanium Detector (XtRa), equipped with a Compton Suppression System, and one in-situ portable Broad Energy Germanium Detector (BEGe). A number of reference sources and solutions (different geometries) are available for quality control and calibration purposes. The efficiency calibration for the specific sample geometries, including efficiency corrections for true coincidence summing effects and self-absorption, is also performed using a validated Monte Carlo method (Penelope MC code). The laboratory is a member of the International Committee on radionuclide Metrology (ICRM) and participates in Intercomparison Exercises organised by ALMERA, EC JRC, NPL and EEAE on a regular basis – at least once a year, as well as in Intercomparison Exercises organized within ICRM-GSWG (ICRM Gamma Spectroscopy Working Group). Accreditation of gamma ray spectrometry laboratory according to ISO 17025 is pending.

In an emergency situation the laboratory would be able to provide air sampling results within hours. The estimated soil monitoring capability is of the order of 20-40 samples per day for Cs-137 - depending on the activity levels and required accuracy – using high resolution gamma-ray spectrometry. The laboratory can also perform wet and dry deposition sampling. In such case a pre-concentration

procedure is applied before sample measurement. It can also carry out in-situ gamma ray spectrometry.

The laboratory building is spacious and well suited for the purpose. The laboratory is power self-sufficient, which in an emergency situation may prove essential.

The verification team was demonstrated also the additional capacities of the NED-NTUA, in particular α-spectroscopy, liquid scintillation counting (TriCarb 2910 TR, new HIDEX Liquid Scintillation Counter pending method development/validation), kinetic phosphorescence analysis (fast determination of uranium in liquid samples – the unit was for the moment not operational with laser unit replacement pending), radon measurements and calibration of radon measuring instruments (active and passive).

The verification team suggests regular control of the air sampler flow measurement calibration.

The verification team suggests renewal of the outdoor monitoring equipment at the laboratory roof in the near future.

Figure 16. NTUA early warning on-line system for Cs-137 radioactivity in air

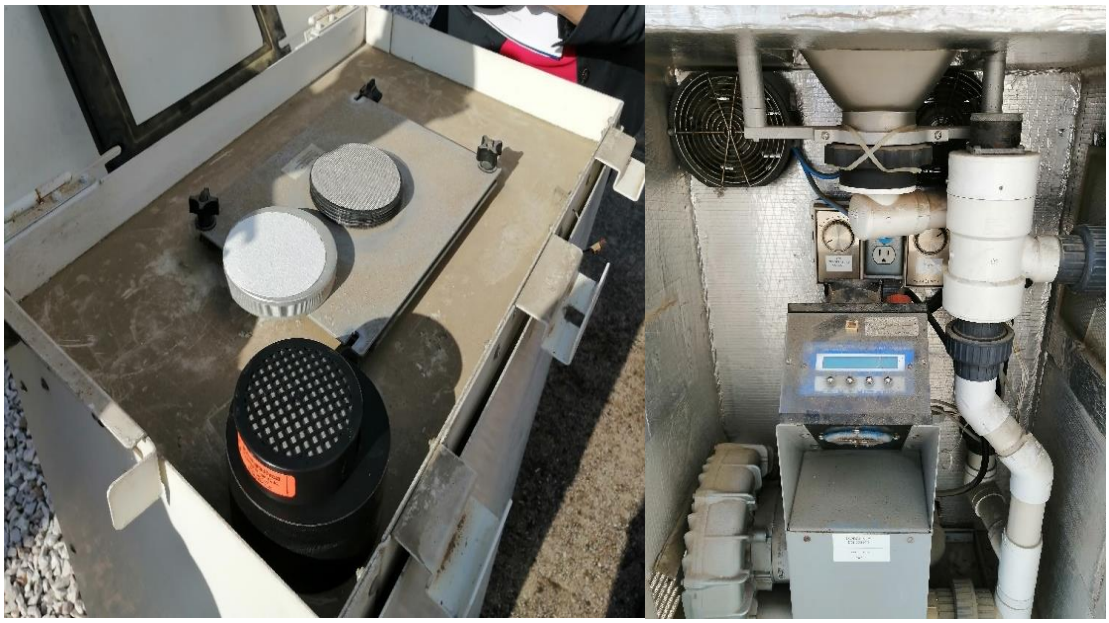

Figure 17. NTUA high volume air sampler and optional iodine cartridge

Figure 18. NTUA portable air sampler

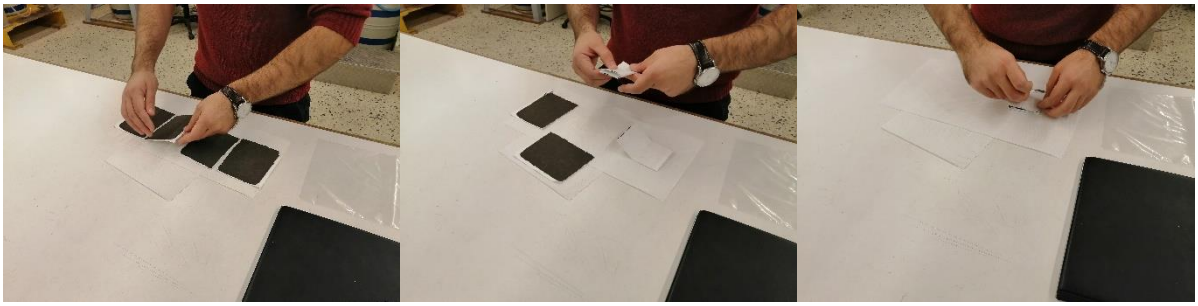

Figure 19. The air sample filter (8"x10" glass fibre) is folded to geometry of 5.08×6.35×0.9 cm^3 in preparation for measurement by gamma ray spectrometry.

Figure 20. Gamma ray spectrometry equipment at the NTUA

7.9 FIRE BRIGADES' RADIATION MONITORING EQUIPMENT

The verification team visited the Athens airport fire brigade's CBRN vehicle (Figure 21). The vehicle is equipped with radiation monitors, including telescopic dose rate and contamination probes, personal protective equipment and decontamination material/systems. The fire brigade has also available radiation pagers and may request additional support from the custom officers, who can provide their portable radionuclide identifiers.

The fire brigade staff receive regular training on using the CBRN vehicle and the radiation protection equipment and participate in specially designed exercises.

The verification team noted the direct communication line and good collaborating relationship between the fire brigade and the EEAE staff (good practice).

No remarks.

Figure 21. Athens airport fire brigade's CBRN container

8 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 environmental radioactivity monitoring programmes in Athens comply 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 Athens 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 Athens are adequate. The Commission ascertained that these facilities are continuously available.

(4) A few recommendations and suggestions have been formulated. They concern in particular renewal of monitoring equipment, calibration control procedures and laboratory management systems. Notwithstanding these remarks, the verified parts of the monitoring system for environmental radioactivity in Athens 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 Greece competent authority through the Greece Permanent Representative to the European Union.

(6) The Commission services kindly request the Greece authorities to submit, before the end of 2021, 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 Greece.

(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

EURATOM ARTICLE 35 VERIFICATION GREECE (ATHENS)

11 – 13 December 2019

DRAFT PROGRAMME

Wednesday 11 December

09:30 Opening meeting
(Greek Atomic Energy Commission EEAE, Agia Paraskevi)

- European Commission Art. 35 verification programme introduction
- Radioactivity monitoring program in Greece
  - Overview of environmental radioactivity monitoring arrangements in Greece
  - Overview of environmental radioactivity monitoring arrangements in Athens
- Discussion of recommendations given by the Commission in 2005 and 2012
- Verification planning

13:30 EEAE Environmental Radioactivity Monitoring Department (ERMD)
(Greek Atomic Energy Commission EEAE, Agia Paraskevi)

- Laboratory facilities
- On-site monitoring facilities
- Food monitoring
- Drinking water monitoring

16.00 Automatic dose rate monitoring network (TRMN) data centre
(Greek Atomic Energy Commission EEAE, Agia Paraskevi)

- Monitoring of radiation dose rate

Thursday 12 December

09.30 Institute of Nuclear Technology and Radiation Protection
(Patr. Gregoriou E & 27 Neapoleos St., Agia Paraskevi)

- Environmental Radioactivity Laboratory (ERL)
- Food monitoring
- On-site monitoring facilities

14:00 Athens Analysis Laboratories S.A
(El. Venizelou Avenue 127 and Alikarnasou 31, Nea Ionia)

- Laboratory facilities for drinking water monitoring

Friday 13 December

09.30 Dose and dose rate monitoring (Hellinikon – near the old airport from Athens)

11.30 Nuclear Engineering Department, National Technical University of Athens (NTUA) *(15780 Zografou, Athens)*

- Laboratory facilities for monitoring in emergency situations

14:45 Verification of other environment monitoring facilities in Athens

- Dose and dose rate monitoring (Campus EEAE-Demokritos)
- Mobile monitoring systems (Campus EEAE-Demokritos)
- Mobile air samplers (Campus EEAE-Demokritos)
- Fire brigades' radiation measurement equipment (EEAE)
- Public information arrangements

16:00 Closing meeting with the national competent authority