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

HUNGARY
Paks Nuclear Power Plant

Discharge and environmental radioactivity monitoring
National environmental radioactivity monitoring network in the vicinity

2 - 5 April 2019

Reference: HU 19-02

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35

OF THE EURATOM TREATY

FACILITIES	- Facilities for monitoring discharges of gaseous and liquid radioactive effluents into the environment at the Paks nuclear power plant - Facilities for monitoring environmental radioactivity in the vicinity of the Paks nuclear power plant - Associated analytical laboratories
LOCATIONS	Paks, Tolna, Pécs, Budapest
DATES	2 – 5 April 2019
REFERENCE	HU 19-02
TEAM MEMBERS	Mr Alan Ryan, DG ENER (team leader) Mr Simon Murphy, DG ENER Mr Agris Ozols, DG ENER Mr Raf Van Ammel, DG JRC
REPORT DATE	4 May 2020
SIGNATURES	

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Appendix 1	Verification programme

Abbreviations

BCGO DEPNC	Baranya County Government Office, Department of Environmental Protection and Nature Conservation
BCGO DPH	Baranya County Government Office, Department of Public Health
BCGO DPH LS	Baranya County Government Office, Department of Public Health, Laboratory Section
NFCSO	National Food Chain Safety Office
NFCSO FCSLD	National Food Chain Safety Office, Food Chain Safety Laboratory Directorate
NFCSO RRL	National Food Chain Safety Office, Food Chain Safety Laboratory Directorate's Radiological Reference Laboratory
FCSC RFL	Food Chain Safety Centrum Non-profit Ltd, Regional Food Chain Laboratory
HAEA	Hungarian Atomic Energy Authority
ISFS	Interim Spent Fuel Store at Paks under PURAM
HAS CER	Hungarian Academy of Sciences, Central Energy Research Institute
NDGDM	National Directorate General for Disaster Management
NDGDM NEIAC	National Directorate General for Disaster Management, Nuclear Emergency Information and Analysis Centre
NERMS	National Environmental Radiation Monitoring System
NERMS RISC	National Environmental Radiation Monitoring System, Radiation Information Service Centre
NNERS	National Nuclear Emergency Response System
NPHC	National Public Health Centre
NPHC DRR	National Public Health Centre, Directorate for Radiobiology and Radiohygiene
NREWMS	National Radiation Early Warning, Monitoring and Surveillance System
Paks NPP	Paks Nuclear Power Plant
PERMS	Paks NPP Plant Environmental Radiation Monitoring System
PURAM	Public Limited Company for Radioactive Waste Management
RAMDAN	Radiological Monitoring and Data Acquisition Network (of Public Health Sector)
TCGO DPH	Tolna County Government Office, Department of Public Health
TCGO DPH RL	Tolna County Government Office, Department of Public Health, Radiochemical Laboratory
RNG	Radioactive Noble Gases
RAI	Radioactive Iodine
RAE-β	Radioactive Emitters of Beta particles

1 INTRODUCTION

Article 35 of the Euratom Treaty requires that each Member State shall establish the facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with the basic safety standards [(1)]. Article 35 also gives the European Commission (EC) the right of access to such facilities in order that it may verify their operation and efficiency. The radiation protection and nuclear safety unit (ENER D.3) of the EC's Directorate-General for Energy (DG ENER) is responsible for undertaking these verifications. Directorate-General Joint Research Centre provides technical support during the verification visits and the preparation of the reports.

The main purpose of verifications performed under Article 35 of the EURATOM Treaty is to provide an independent assessment of the adequacy of monitoring facilities for:

- Liquid and airborne discharges of radioactivity into the environment by a site (and control thereof).
- 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] was published in the EU Official Journal on 4 July 2006 describing practical arrangements for the conduct of Article 35 verification visits in Member States.

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 PREAMBLE

The EC's decision to conduct an Article 35 verification was notified to Hungary by a letter addressed to the Hungarian Permanent Representation to the European Union. The Hungarian Government subsequently designated the Hungarian Atomic Energy Authority (HAEA) to lead the preparations for this visit.

2.2 DOCUMENTS

In order to facilitate the work of the verification team, the national authorities supplied a package of information in advance. Additional documentation was provided during and after the visit. Appendix 1 to this report lists all documentation received. The information thus provided has been extensively used for drawing up the descriptive sections of the report.

2.3 PROGRAMME OF THE VISIT

The EC and the HAEA discussed and agreed upon a programme of verification activities, with due respect to the Commission Communication of 4 July 2006 setting out practical arrangements for the conduct of Article 35 verification visits.

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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 of 17.1.2014, p. 1)

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, p. 2–5)

During the opening meeting, held at the Paks NPP, presentations were given on the following topics:

- The scope and planning of ET Article 35 verification (Mr. Alan Ryan);
- National environmental radioactivity monitoring network in Hungary (Mr. Árpád Vincze);
- The structure of the food chain control authority in Hungary (Mr. Ferenc Deák);
- The Radiological Monitoring and Data Acquisition Network, RAMDAN (Mr. Nándor Fülöp);
- Paks NPP: overview of the present status (Mr. Tibor Bujtas);
- Baranya County Government Office Laboratory Department (Mr. Zsolt Ulrich);
- Radiohygiene Laboratory of Department of Public Health of Tolna County Government Office (Ms. Irén Kerekes);
- Gamma dose rate measurement with TLDs around Paks NPP (Mr. Zsolt Homoki).

Subsequently, presentations were given by the following entities during the course of the verification visit:

- Radioanalytical monitoring program of National Food Chain Safety Office (NFCSO, Mr. Attila Nagy)

The verification team notes the quality and comprehensiveness of all presentations and documentation.

The verifications were carried out in accordance with the programme in Appendix 2.

The following representatives of the national authorities and other parties involved took part in the verification:

Table I. Representatives taking part in the verification

Name	Title/function	Organization
Ms Eszter Szilágyi	Lieutenant Colonel, Deputy head of Department	National Directorate General for Disaster Management, Nuclear Emergency Information and Analysis Centre
Mr Nándor Fülöp	Head of Information Centre of RAMDAN	National Public Health Centre, Department of Radiobiology and Radiohygiene, Division of Ionising Radiation Protection (Ministry of Human Capacities)
Ms Tünde Ádámné Sió	Head of Reference Laboratory	Food Chain Safety Laboratory Directorate of National Food Chain Safety Office
Mr Nagy Attila, PhD	Director	Food Chain Safety Laboratory Directorate of National Food Chain Safety Office
Ms Enikő Lókiné Nagy	Head of Department	Laboratory Section of the Department of Public Health of the Baranya County Government Office
Mr Zsolt Ulrich	Senior Laboratory Fellow	Laboratory Section of the Department of Public Health of the Baranya County Government Office.
Mr Tibor Bujtás, PhD	Head of Radiation and Environmental Protection Department	Magyar Villamos Muvek Zrt (MVM) Paks NPP Ltd.
Mr László Daróczi	Work Manager Environmental Protection Section	MVM Paks NPP Ltd.
Mr Árpád Vincze	Department Head	HAEA, Radiation Source Oversight Department
Mr Sándor Kapitány, PhD	Team Leader	HAEA, Radiation Source Oversight Department
Mr Muck Péter	Environmental Manager	Department of Environmental Protection and Nature Conservation of Pécs District Office of the Baranya County Government Office
Ms Németh Lídia, PhD	Head of the Department of Public Health	Department of Public Health of Tolna County Government Office
Ms Kerekes Irén	Senior Laboratory Fellow	Radiohygiene Laboratory, Department of Public Health of Tolna County Government Office

3 LEGAL FRAMEWORK FOR ENVIRONMENTAL RADIOACTIVITY MONITORING

3.1 GENERAL PROVISION - ACT ON ATOMIC ENERGY NO. CXIV (1996)

Nuclear legislation in Hungary is based on the Act on Atomic Energy (Act CXVI, 1996) that came into force on 1 June 1997. The Act on Atomic Energy (hereafter, the Act) establishes the basis for the development of a legislative and regulatory system for the safe application of nuclear energy. The Act specifies that the tasks of control and surveillance of the safe application of nuclear energy are the responsibility of the Government.

The Act stipulates that atomic energy shall only be used in ways identified by (derived) legal instruments (governmental and ministerial decrees) and shall be subject to regular supervision by designated competent authorities. The Act is available on the HAEA website (www.haea.gov.hu) for downloading.

The Act defines the main responsibilities of the following organisations:

- The Hungarian Atomic Energy Authority (HAEA) is the Atomic energy oversight organisation. It is the national radiation protection authority and the national nuclear safety authority. It is responsible for granting the licenses for all facilities that may have any radiological effect on the environment. Additionally, HAEA is responsible for carrying out the central collecting, processing, recording and evaluation of data related to the national radiation situation (including the data of the various Hungarian environmental monitoring programmes);
- The Ministry of Human Capacities ensures the availability of data coming from the public health monitoring system for the centralised national environmental monitoring system;
- The Ministry of Agriculture as responsible for environment and water protection is responsible for defining the maximum quantity of radioactive materials that may be released to the atmosphere and to water bodies (*i.e*. discharge limits). The Ministry is also responsible for the determination of radioactivity in soil, flora, fauna and products of both vegetable and animal origin.

Other bodies and organisations also participate in radiological protection *e.g*.

- The Ministry of the Interior particularly with respect to matters of early warning and emergency preparedness in case of radiological incidents,
- The Ministry for National Development
- The Ministry of Defence.

The Act covers a range of domains including environmental radioactivity and radioactive discharge monitoring.

3.2 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

3.2.1 Decree 15/2001 (VI.6) KöM

The decree on 'discharges of airborne and liquid radioactivity and their monitoring when using atomic energy' requires the regional environmental inspectorates (Department of Environmental Protection and Nature Conservation of District Offices of the County Government Offices) to establish environmental monitoring programmes for facilities (nuclear power reactor, research reactor, training reactors, uranium mine, radioactive waste depository, A-level isotope laboratories, interim spent-fuel storage) and other areas.

Nuclide-specific measuring methods must be applied to determine activity concentration in environmental samples. Gross-beta measurement results may only be used for monitoring trends. Detection limits shall be calculated according to international and national standards. Only accredited laboratories can carry out the monitoring for regulatory purposes.

This decree is also relevant for discharge monitoring of Paks NPP. See chapter 3.4.1 for details.

3.2.2 Decree 8/2002 (III.12) EüM

The decree 'on the operation and structure of the radiological monitoring and data acquisition network of the health sector' describes the legal background and principles of operation of Hungarian radiation monitoring network (ERMAH – Hungarian acronym; RAMDAN – English acronym). The sampling/monitoring programme focuses on air, surface waters, soil, drinking water, essential human food chain components and the most representative foodstuffs (originating either from domestic production or from imports) consumed by the population in significant amounts. Main analytical procedures are gross beta counting and gamma ray spectrometry.

3.2.3 Decree 201/2001 (X.25)

The decree 'on the quality requirements of drinking water and monitoring process' describes the requirements for the monitoring of radioactivity in drinking water by gross alpha and beta measurements. In the case of exceeding the authorised limits, specific analysis, for natural and artificial radionuclides, are carried out. The decree also contains guidance for the calculation of indicative radiation dose.

3.2.4 Decree 489/2015 (XII.30)

The decree 'on monitoring radiation conditions relevant for public exposure of natural and artificial origin and on the scope of quantities obligatory to be measured' describes the legal background and principles of operation of the National Environmental Radiation Monitoring System (NERMS). It defines the structure of the monitoring systems and networks as well as the monitoring and reporting requirements. The decree also stipulates the radiation monitoring of the human food chain. The national environmental monitoring shall be organised by a steering committee represented by members of all ministries and/or organisations involved and shall be chaired by the HAEA. The decree requires the HAEA to operate the NERMS Radiological Information Service Centre for data collection and evaluation of the system.

This decree also requires the evaluation of the environmental effects around special installations (nuclear power plants, training and research reactors, nuclear waste management facilities, *etc*.). The authorities shall draw up specific regional monitoring arrangements.

3.2.5 Decree 385/2016 (XII.2)

The decree on defining the public health care tasks of the Capital Government Office and County Government Offices as well as territorial offices, and designating the state health care administration organisation' described the radiation hygiene laboratory duties of the Government Offices.

3.2.6 Decree 167/2010 (V.11)

The structure and tasks of the National Nuclear Emergency Response System are outlined in the Govt. Decree 167/2010 (V.11.) Korm. on the national nuclear emergency response system. It lists the organizations involved in the Nuclear Emergency Response System, and their key roles in the different operational modes. The decree outlines the minimum content of National Nuclear Emergency Plan. The decree also stipulates the basic operational aspects of the National Radiation Monitoring and Warning System.

3.2.7 Decree 487/2015 (XII.30)

This decree 'on the protection against ionizing radiation and the corresponding licensing, reporting (notification) and inspection system' introduces basic standards of radiation protection. The decree provides compliance with the 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.

This decree is also relevant for discharge monitoring of Paks NPP, see chapter 3.4.4 for details.

3.3 Legislative acts regulating the radiological surveillance of foodstuffs

3.3.1 Act XLVI (2 July 2008)

This Act 'on Food-chain and Its Official Control' assigns the Ministry of Agriculture the responsibility for controlling the whole food chain.

3.3.2 Decree 22/2012 (II.29)

According to this decree 'on National Food-chain Safety Office', in compliance with EU Directive 882/2004/EC, Article 12, any kind of analysis regarding foodstuffs shall be carried out by dedicated, accredited laboratories.

3.3.3 Decree 8/2002 (III.12) EüM

The decree 'on the operation and structure of the radiological monitoring and data acquisition network of the health sector' establishes a network and a programme for regular radiological monitoring of environmental components (air, plants, foodstuffs of plant and animal origin, surface and drinking water, *etc*.) coming directly or potentially in contact with the human body. It ensures compliance with both Article 35 of EURATOM Treaty and Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption.

3.3.4 Decree 201/2001 (X.25.)

This decree 'on the requirements and monitoring of the drinking water quality' sets up requirements for the monitoring of drinking water and defines parametric values for radioactive substances in accordance with the 2013/51/EURATOM directive.

3.4 Legislative acts regulating discharge monitoring

3.4.1 Decree 15/2001 (VI.6) KöM

The decree 'on discharges of airborne and liquid radioactivity and their monitoring when using atomic energy' specifies that the user of atomic energy (*i.e*. Paks NPP) shall derive its annual limits of radioactive effluent discharge and prepare the regulation for discharge monitoring. The annual limits and the discharge monitoring regulation shall be licensed.

3.4.2 Decree 118/2011 (VII.11)

The decree 'on the nuclear safety requirements of nuclear facilities and on related regulatory activities' imposes that the operator of nuclear installations shall design and operate a discharge monitoring system.

3.4.3 Decree 155/2014 (VI.30)

The decree 'on the safety requirements for facilities ensuring interim storage or final disposal of radioactive wastes and the corresponding authority activities' prescribes that the operator of radioactive waste disposal facility shall design and operate a discharge monitoring system.

3.4.4 Decree 487/2015 (XII.30)

This decree 'on the protection against ionizing radiation and the corresponding licensing, reporting (notification) and inspection system' stipulates that any user of atomic energy other than nuclear installations or radioactive waste disposal facilities shall design and operate a discharge monitoring system.

3.4.5 Decree 112/2011 (VII.4)

This decree 'on the scope of authority of the Hungarian Atomic Energy Authority in relation to European Union obligations and international obligations in connection with atomic energy, on the designation of co-authorities contributing to the regulatory proceeding of the Hungarian Atomic Energy Authority, and the scientific council assisting the work of the Hungarian Atomic Energy

Authority' sets the basic tasks of HAEA in relation to European Union obligations, international obligations and international cooperation activity in connection with atomic energy. Additionally it determines those general rules on regulatory oversight which are not specified in thematic decrees on application of atomic energy, such as rules for penalty, licensing activity on transport of radioactive materials, certification of radioactive sources, accountancy protocol for and licensing for nuclear materials, operation of Scientific Council, etc.

3.5 GUIDANCE AND INTERNATIONAL REFERENCES

The Hungarian authorities based the national regulatory framework on the following documents:

- Commission Recommendation 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, 2000/473/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;
- IAEA TRS 295: Measurement of radionuclides in food and the environment: A guidebook;
- IAEA TECDOC 1092: Generic Procedures for Monitoring in a Nuclear or Radiological Emergency;
- IAEA Safety Series 19 (Pub1103): Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment;
- IAEA Safety Guide (Pub1216) RS-G-1.8: Environmental and source monitoring for purposes of radiation protection;
- IAEA TRS 472: Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments;
- IAEA TECDOC 1616: Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments;
- ICRP-SG5: Analysis of the Criteria Used by the International Commission on Radiological Protection to Justify the Setting of Numerical Protection Level Values;
- ICRP 103: The 2007 Recommendations of the International Commission on Radiological Protection;
- EURACHEM Guide: Quantifying Uncertainty in Analytical Measurement, 3rd Edition (2012)
- EURACHEM Guide (2007): Use of uncertainty information in compliance assessment;
- IAEA TECDOC 1401: Quantifying uncertainty in nuclear analytical measurements;
- ISO 11929 standards, versions 2000 or 2010 (as implemented in concerned organizations);
- IAEA AQ/48 (2017): Determination and Interpretation of Characteristic Limits for Radioactivity Measurements.

4 MONITORING PROGRAMMES AND RESPONSIBLE ORGANISATIONS

4.1 INTRODUCTION

According to the Act on Atomic Energy No. CXIV (1996), the government, the nuclear energy supervision body and several ministries have competence in the field of radiation protection. In general, the Hungarian Atomic Energy Authority is responsible for the occupational radiation safety and radiation protection of the public. Additionally, the sectoral bodies are responsible for the sector specific radiation safety. The minister responsible for health is responsible for patients' safety. The minister for environmental protection is responsible for the discharge monitoring. The minister for food chain safety is responsible for over foodstuff monitoring, *etc*.

4.2 ENVIRONMENTAL RADIOACTIVITY MONITORING

Monitoring of the radioactivity in the environment (air, soil, plants, surface and underground water) is carried out by several organisations according to their specific responsibilities. This is due to the subordination of specific responsibilities to different ministries as specified in Act on Atomic Energy No. CXIV (1996). In order to the coordinate the environmental radioactivity monitoring, Hungary operates the National Environmental Radiation Monitoring System (NERMS), which consists of all environmental monitoring organisations.

4.2.1 National Environmental Radiation Monitoring System

The NERMS Steering Committee chaired by the Hungarian Atomic Energy Authority (HAEA) governs the activities of NERMS. The NERMS Steering Committee requires the radiation monitoring networks belonging to the NERMS members to perform the annual environmental sampling and measuring programme. . The NERMS Information Centre collects and processes the measurement data from the individual monitoring networks, and prepares annual reports based upon these data.

Organisations such as research institutions, universities and the Hungarian Meteorological Service (OMSZ) also provide data on environmental radiation monitoring to the NERMS.

4.2.2 Baranya County Government Office

As an environmental protection authority, the Baranya County Government Office exercises the national competence and performs environmental radiation monitoring. Its tasks and responsibilities relevant for radiation monitoring are described in the Decree No. 15/2001 (VI.6) KöM on the control of airborne and liquid radioactive discharges, issued by the minister responsible for environmental protection. The Decree No. 71/2015 (III.30) on the designation of bodies responsible for environmental and nature protection regulates official and administrative tasks.

The Department of Environmental Protection and Nature Conservation of the Pécs District Office of the Baranya County Government Office, is the national competent inspectorate to verify the fulfilment of requirements related to release limits and other environmental radiological requirements contained in regulations applicable to nuclear facilities (such as Paks NPP) and radioactive waste disposal sites. It also acts as a territorial competent inspectorate for conventional environmental protection issues.

The Department of Public Health of the Baranya County Government Office operates the Laboratory Section where the Environmental Measurement Centre has the national level authority to measure the radioactivity in the environmental samples.

The Baranya County Government Office falls organisationally under the Prime Minister's Office, whilst technical direction comes from the Ministry of Agriculture.

4.2.3 Radiological Monitoring and Data Acquisition Network

As a public health authority, the Radiological Monitoring and Data Acquisition Network (RAMDAN) performs the radiological monitoring activities of the health sector. RAMDAN has several regional laboratories and one central laboratory. Key elements of the monitoring program are specified in the Decree No. 8/2002 (III.12) EüM on the structure and operation of radiological monitoring and data acquisition network of the public health sector, issued by the minister of health.

The regional laboratories are incorporated into the regional competent departments for public health of the County Government Offices. One laboratory typically serves 3-4 counties.

The central laboratory is the Department of Radiobiology and Radiohygiene of the National Public Health Centre. It has the capability to carry out specific measurement programs both at the national level and for nuclear facilities such as Paks NPP.

The organisational leader of the National Public Health Centre is the Ministry of Human Capacities.

4.2.4 **National Food Chain Safety Office**

As part of the food chain safety system, the National Food Chain Safety Office, as the back office of the Ministry of Agriculture, has the authority to coordinate the monitoring of foodstuffs and environmental samples related to agriculture and forestry.

The responsibility of the National Food Chain Safety Office covers the whole food chain, including radiological surveillance of food and feed and issues connected to agricultural safety.

The Food Chain Safety Laboratory Directorate of the National Food Chain Safety Office operates one accredited Radioanalytical Reference Laboratory with two sites (Szombathely and Szekszard). They perform radioanalytical measurements at regional and national level on samples of food and feed related to agriculture and forestry. More detail can be found in please see chapter 6.9.3.

The Departments of Food Chain, Plant and Soil Protection are part of the County Government Offices. The Regional Food Chain Laboratories of Food Chain Safety Centre Non-profit Ltd. created by National Food Chain Safety Office perform the actual radioanalytical measurements of raw and processed food and feed at regional level.

On request of the public health, the Radiological Monitoring and Data Acquisition Network (see chapter 4.2.3 above) also analyses foodstuffs.

4.2.5 **Hungarian Atomic Energy Authority**

The nuclear energy supervision body – the Hungarian Atomic Energy Authority – grants the licenses for applications of ionising radiation. For the nuclear facilities and radioactive waste disposal sites, the licensing documentation includes the environmental monitoring programmes. The requirements depend on the type of facility and their lifecycle.

The Hungarian Atomic Energy Authority evaluates the monitoring programme during the licensing process.

Whenever an alarm in an environmental monitoring system is triggered, the Hungarian Atomic Energy Authority leads the corresponding investigation.

4.2.6 **Local monitoring**

The operators of nuclear facilities and radioactive waste disposal sites run their own environmental radiation monitoring programme according to the facility design plans (approved by the Hungarian Atomic Energy Authority) and the corporate regulation (implementing code) (approved by the Department of Environmental Protection and Nature Conservation of Pécs District Office of the Baranya County Government Office).

4.3 List of laboratories

- Laboratory Section of the Department of Public Health of the Baranya County Government Office (Pécs): National level authority to measure the radioactivity of the environmental samples.
- Laboratories of Radiological Monitoring and Data Acquisition Network for the public health sector.

Table II. Laboratories involved in RAMDAN

Name of the operating institution	Address	Territories of competence (counties)
Central Laboratory: Department of Radiobiology and Radiohygiene of the National Public Health Centre	1221 Budapest, Anna u. 5.	methodological guidance
Public Health Department of the Budapest Capital Government Office	1138 Budapest, Váci út 174.	Budapest (BUD), Pest county
Public Health Department of the Borsod-Abaúj-Zemplén County Government Office	3530 Miskolc, Meggyesalja u. 12.	Borsod-Abaúj-Zemplén, Heves, Nógrád
Public Health Department of the Csongrád County Government Office	6726 Szeged, Derkovits fasor 7-11.	Csongrád, Békés, Bács-Kiskun
Public Health Department of the Hajdú-Bihar County Government Office	4028 Debrecen, Rózsahegy u. 4.	Hajdú-Bihar, Szabolcs-Szatmár-Bereg, Jász-Nagykun-Szolnok
Public Health Department of the Győr-Moson-Sopron County Government Office	9024 Győr, Jósika u. 16.	Győr-Moson-Sopron, Vas, Zala
Public Health Department of the Tolna County Government Office	7100 Szekszárd, dr. Szentgáli Gy. u. 2.	Tolna, Baranya, Fejér, Somogy
Public Health Department of the Veszprém County Government Office	8200 Veszprém, József A. u.36.	Veszprém, Fejér, Komárom-Esztergom

- Laboratories of the National Food Chain Safety Office

Name of the operating institution	Address	Territories of competence (counties)
Food Chain Safety Laboratory Directorate of National Food Chain Safety Office: Radioanalytical Reference Laboratory at Budapest	1182 Budapest, Fogoly u. 13-15.	BUD
Food Chain Safety Laboratory Directorate of National Food Chain Safety Office: Radioanalytical Reference Laboratory at Szekszárd	7100 Szekszárd, Tormay B. u. 18.	TOL

Name of the operating institution	Address	Territories of competence (counties)
Food Chain Safety Laboratory Directorate of National Food Chain Safety Office: Radioanalytical Reference Laboratory at Szombathely	9700 Szombathely, Zanati út 3.	VAS
Food Chain Safety Centrum Nonprofit Ltd.: Regional Food-chain Laboratory at Kecskemét	6001 Kecskemét, Halasi út 34.	BAC
Food Chain Safety Centrum Nonprofit Ltd.: Regional Food-chain Laboratory at Miskolc	3501 Miskolc, Stadion u. 39/a	BOR
Food Chain Safety Centrum Nonprofit Ltd.: Regional Food-chain Laboratory at Debrecen*	4030 Debrecen, Diószegi út 30.	HAJ
Food Chain Safety Centrum Nonprofit Ltd.: Regional Food-chain Laboratory at Kaposvár	7400 Kaposvár, Cseri major	SOM
Food Chain Safety Centrum Nonprofit Ltd.: Regional Food-chain Laboratory at Veszprém*	8200 Veszprém, Mártírok útja 11/A	VES

* Laboratory closed in January 2019.

- Laboratory of Hungarian Academy of Sciences Centre for Energy Research
- Laboratory of the Paks Nuclear Power Plant

5 PAKS NPP SITE AND ITS RADIOLOGICAL SURVEILLANCE PROGRAMME

5.1 SITE DESCRIPTION

Paks Nuclear Power Plant is situated in Tolna county, 118 km south of Budapest, 5 km south of the centre of the Paks city, 1 km west of the river Danube and 1,5 km east of the main road No 6. The southern state border is 63-75 km from the site, 94 km downstream from the plant along the river Danube.

The Paks NPP operates four type VVER-440/213 reactors, brought into operation between 1982-1987. The reactors are located in twin unit buildings. Each of the reactor units had an electric output capacity of 440 MWe by design. The combined electric power of the power plant was therefore 1760 MWe. The output value was first increased to 470 MWe thanks to modernisation efforts. A second upgrade (see Table 4), approved by the Hungarian Atomic Energy Authority, increased the power to 500 MWe (473 MWe net).

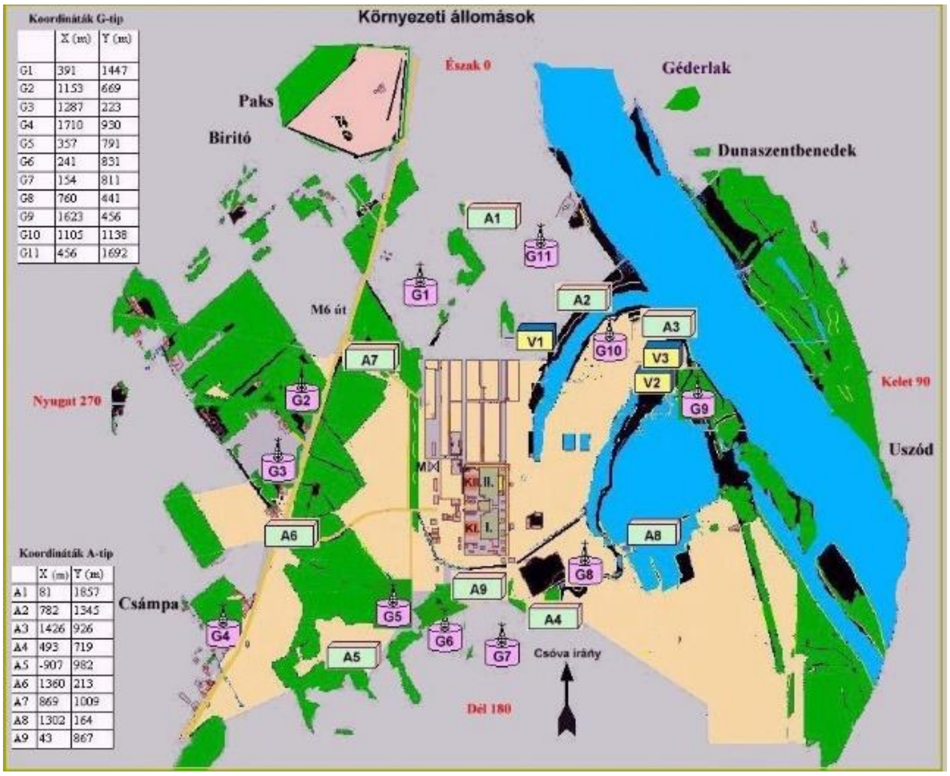

Figure 1. Geographical location of the NPP and surrounding environmental monitoring stations

The site map in Figure 1 shows the radiation monitoring stations located around the NPP. The stations A1 to A9 are environmental remote monitoring and sampling stations ("A" type). The stations G1 to G11 are environmental remote monitoring stations ("G" type). The "A" type and "G" type monitoring stations are part of the dose rate telemetric monitoring network (see chapters 5.4 and 6.2).

The stations V1, V2 and V3 are water sampling and measuring stations (*cf*. chapters 5.3.2 and 5.5.4).

Table III. Dates of start-up and subsequent upgrades of the reactor units

Unit	Year of start up	Year of power upgrade
Unit 1	1982	2008
Unit 2	1984	2009
Unit 3	1986	2010
Unit 4	1987	2007

During preparations for the extension of service life (long-term operation), the Paks NPP developed and submitted to the HAEA the programme that encompassed the production of the operability preconditions of Paks NPP units 1-4 for the 20 years lifetime extension. The HAEA approved the programme. Based on the execution and the results of the programme, the Paks NPP elaborated the documentation for the approval of the lifetime extensions for each unit. The HAEA approved the extensions. The table 5 shows the lifetime extension dates in relation to the original start-up dates.

Table IV. Start and end dates of operation of the reactor units

Unit	Start up date	Start of extension date	End of extension date
Unit 1	14/12/1982	01/01/2013	31/12/2032
Unit 2	26/08/1984.	01701/2015	31/12/2034
Unit 3	15/09/1986	01/01/2017	31/12/2036
Unit 4	09/08/1987	01/01/2018	31/12/2037

The power units are power plant systems with pressurised water reactors, light water is used as moderator. They are operated with thermal reactors and producing saturated steam. The power units are designed with two closed water loops; therefore, they contain a radioactive primary circuit and a non-radioactive secondary circuit. The nuclear power plant operates as a baseline power plant with relatively steady load. The produced electricity is supplied to the national electricity grid at 400 kV and 120 kV.

Table V. Main technical characteristics of units in the Paks NPP

Reactor type	Pressurised water, water-cooled, water moderated energy reactor, type number: V-213
Thermal power of reactors	1485 MW
Number of primary circuits for each reactor	6
Total volume of primary circuits	237 m^3
Pressure in primary circuit	123 bar
Number of turbines per reactor	2

Reactor type	Pressurised water, water-cooled, water moderated energy reactor, type number: V-213
Nominal pressure of secondary circuit main steam	43,15 bar
Average temperature of heat transfer	284 ± 2 °C

5.2 DISCHARGE LIMITS

The decree 16/2000 (VI.8) EüM (Ministry of Health) (superseded by decree 487/2015 (XII.30). in 2016) set a 1 mSv/year dose limit to the public. According to the decree, the authority might set the dose constraint to the public. The competent healthcare authority set a reduced dose constraint of 90 μSv/year for the Paks NPP. In accordance with the decree 15/2001 (VI.6) KöM (Ministry of Environment Protection), the Paks NPP (as nuclear power user) shall request to approve its annual discharge limits based on the 90 μSv/year dose limitation. The Environment Protection Authority approves the discharge limits based on an application containing all data required to verify the calculations. During normal operations of the nuclear power plant, the reference group dose due to internal and external exposure cannot exceed the dose constraint of 90 μSv/year. This includes the dose form of discharge of airborne and liquid radioactive materials from the Paks NPP.

The gas and liquid radioactive discharge limitations by radionuclide were determined, taking the dose constraint into account. In case of combined discharge of different radionuclides by different pathways or methods, the discharge limit criterion is calculated by using the formula:

$$\sum_{ij} \frac{R_{ij}}{El_{ij}} \leq 1$$

where El_{ij}: the emission limit of radionuclide **i** emitted by emission pathway **j** (Bq/year), and

R_{ij}: the annual emission of radionuclide **i** emitted by emission pathway **j** (Bq/year).

The discharges are calculated for every radionuclide and every discharge pathway or method. The following condition, as described in the above formula, has to be met annually: in case of more than one radionuclide discharge and/or in case of more than one discharge pathway the aggregate discharge shall be is lower than or equal to unity. This aggregated ratio of the annual emissions to the emission limits was 0.0032 for the Paks NPP in 2018.

The decree 16/2000 (VI.8) EüM was replaced with decree 487/2015 (XII.30). Under the new decree the dose limit of 1 mSv/year residential dose limit and the 90 μSv/year dose limitation remain.

5.3 DISCHARGES, MEASUREMENTS AND MONITORING

The decree 15/2001 (VI.6) KöM (Ministry of Environment Protection)[3] determines that the discharges are measured and defined based on the Discharge Monitoring Regulation (KiESZ). This regulation specifies the rules, methods and equipment of discharge monitoring, including the characteristics of performance and effectiveness of the equipment. The discharges regulation for the PAKS NPP has to be approved by the competent environment protection authority the Baranya County Government Office.

For every discharge, either airborne or liquid, remote monitoring systems monitor the discharges in addition to the sampling procedures of the NPP. The airborne discharges are released via the dual

[3] Decree's §6, 2nd indention's point b)

discharges stacks of each of the twin-reactor blocks. In each of the discharge stacks, identical remote monitoring and sampling systems are operating continuously. Liquid discharges are sampled from liquid storage tanks for inspection, depending on the required measurements. Automatic samplers and remote monitoring systems also monitor the liquid discharges.

The KiESZ defines warning and alert levels assigned to each remote monitoring system, and the factory inspection levels for liquid discharges. The limits for liquid and airborne discharges for the nuclear power plant are defined in the environment protection permit of the service life extension of Paks NPP. The Pécs District Office of Baranya County Government Office issued the permit number 391-18/2017.

5.3.1 **Airborne discharges**

The following monitoring systems of airborne discharges are in operation:

- The Isokinetic Sampling System (KS-411-M) is a high volumetric flowrate sampling system capable of representative, isokinetic continuous sampling of the aerosols, iodine, inert gases, steam, *etc*. from the main airflow (*i.e*. air exiting the operational premises through air ventilation duct H1). The sampler is constructed in compliance with the recommendations of DIN 25423-1 and ANSI/HPS N13.1-1999. They are made to ensure that the sampling losses such as diffusional, gravitational and impaction loss are low. The equipment is manufactured by KÁLMÁN SYSTEM Kft.;
- The Air Speed/Volumetric flowrate System (KS-411-S) is a wind velocity/volumetric flowrate measuring system for continuous long-term monitoring of the velocity and flowrate of the main airflow. It provides data for the main data acquisition and display system (SCADA) every minute. The system is manufactured by KÁLMÁN SYSTEM Kft. and is equipped with type LN 450 GS-S – EGE airflow detector probe. Their accuracy is assessed every 12 months;
- The PING – airborne discharge monitoring system with volumetric flowrate for sampling 26-30 litre/minute, consisting of two ABPM 201-L radioactive aerosol measuring stations and two IM 201-L radioactive iodine measuring stations, both measuring in range from 1 Bq/m^3 to 1 MBq/m^3, and two NGM 204-L radioactive inert gas measuring stations measuring in range from 100 Bq/m^3 to 1 GBq/m^3 (Kr-85). The PING system provides data to SCADA every 10 minutes. The units are tested and calibrated with a solid radiation source every year.;
- A BITT probe is placed in the ventilation bridge (measuring dose rates in the range from 10 nSv/h to 10 Sv/h). This probe provides data for the SCADA every minute. It is calibrated annually;
- The isotope-selective inert gas measuring system NEKISE consisting of two ORTEC-manufactured, He cooled HPGe detectors, one for each of the twin-reactor blocks. This system monitors Ar-41, Kr-87, Kr-88, Xe-133, and Xe-135. The detection limits are in the range from 25 to 500 Bq/m^3, the volumetric flow rate used for sampling is 4 – 6 m^3/h. The system provides data for the SCADA every 10 minutes, derived from 60 minutes of aggregated spectrum.

The alert levels set on airborne discharge remote monitoring systems are given in the table below:

Table VI. Alert levels set on airborne discharge remote monitoring systems

Type	Warning [Bq/10 min]	Alert [Bq/10 min]	Warning [Bq/h]	Alert [Bq/h]
RNG	$1{,}6 \times 10^{12}$	$1{,}0 \times 10^{14}$	$5{,}2 \times 10^{12}$	$3{,}8 \times 10^{13}$
RAI	$2{,}7 \times 10^{7}$	$1{,}0 \times 10^{10}$	$8{,}9 \times 10^{7}$	$6{,}4 \times 10^{8}$
RAE-β	$7{,}9 \times 10^{6}$	$2{,}6 \times 10^{7}$	$2{,}6 \times 10^{7}$	$1{,}9 \times 10^{8}$

For noble gases, the alert levels in the monitoring system for airborne discharge are set as follows:

Table VII. Alert levels set on airborne discharge system for noble gases

Level [Bq/h]	^{41}**Ar**	^{85m}**Kr**	^{87}**Kr**	^{88}**Kr**	^{133}**Xe**	^{135}**Xe**
Warning	$1{,}6 \times 10^{12}$	$1{,}4 \times 10^{13}$	$2{,}5 \times 10^{12}$	$9{,}9 \times 10^{11}$	$6{,}8 \times 10^{13}$	$8{,}2 \times 10^{12}$
Alert	$5{,}3 \times 10^{12}$	$4{,}7 \times 10^{13}$	$8{,}3 \times 10^{12}$	$3{,}3 \times 10^{12}$	$2{,}3 \times 10^{14}$	$2{,}7 \times 10^{13}$

5.3.2 Liquid discharges

Concerning liquid discharges, a number of sampling and measurements sampling of the liquid storage tanks or systems take place before any discharge of wastewater. These include total-beta, total-alpha activity concentration and pH measurements. The method of discharge is defined based on the results of the control measurements.

Water discharge rules for the radioactive contaminated wastewaters of the Paks NPP are:

Table VIII. Discharge rules for the radioactive wastewaters

Tank or origin (Alphanumeric code)	**Activity [Bq/dm^3]**	**pH**	**Possible discharge methods**
TM50B001-B004	$A_\beta \le 100$ (ÜM) $100 < A_\beta \le 1000$ (ÜM+SV) In case of 01TM50B001-4: $A_\alpha \le 0.5$ (ÜM) $0.5 < A_\alpha \le 5$ (ÜM+SV)	6 - 10	Clean faecal channel Hot water channel Faecal channel
	$A_\beta \le 1000$	< 6, or$10 <$	TM04B001-B003
	$1000 < A_\beta$	any	TM04B001-B003
01XZ01B001(B002) 01XZ12B001(B002) 01XZ23B001	$A_\beta \le 500$ (ÜM) $500 < A_\beta \le 1000$ (ÜM+SV)	$6 <$	Faecal channel
RJ20B001	$A_\beta \le 3$ (ÜM)	any	Sludge basin
	$3 < A_\beta \le 1000$	6 - 10	TM50B004
	$3 < A_\beta$	< 6, or$10 <$	TM04B001-B003
	$1000 < A_\beta$	any	TM04B001-B003
RZ18B001 and Steam Generator (during outage or maintenance)	$A_\beta \le 3$ (ÜM)	< 6, or$10 <$	RZ18B001→RV21B001→ Sludge basin
			RP99→RP02→ Sludge basin *
	$A_\beta \le 30$ (ÜM)	6 - 10	RZ18B001→RV21B001→ hot water channel
			RP99→RP02→hot water channel (*)
	$3 < A_\beta$	< 6, or$10 <$	RZ18B001→ TM04B001-B003

Tank or origin (Alphanumeric code)	Activity [Bq/dm^3]	pH	Possible discharge methods
	$A_\beta \leq 1000$	6 – 10	RJ20B001 → TM50B004→ as per TM50B001-B004 (*)
Main steam collector, feed water conduit (during outage or maintenance)	$A_\beta \leq 3$ (ÜM)	< 6, or10 <	RV19B001→RV21B001→ Sludge basin
	$A_\beta \leq 10$ (ÜM)	6 - 10	RV19B001→RV21B001→ Hot water channel
	$3 < A_\beta$	any	RV21B001→RP99→ In accordance with RJ20B001

Here, (ÜM) denotes a permit from a duty engineer, and (SV) denotes a permit from a strategic level manager on radiation protection. A star (*) means that the method is applicable only for discharges of steam generator.

The following remote monitoring systems of liquid discharges are in operation, using SAS203 (NaI) detectors. Warning and alert levels are set:

Table IX. Warning and alert levels for liquid discharges

Station/shaft	Alphanumeric code of discharge method	Warning level [kBq/m^3]	Alert level [kBq/m^3]
Hot water channel hollow section	10/30VE50R198ZP19 20/40VE50R199ZP19	40	85
Safety cooling water	10/20/30/40VX51R601ZP19 10/20/30/40VY51R601ZP19 10/20/30/40VW51R601ZP19	40	85
V1	00XS11R901YJ08	10	20
V2	00XS22R901YJ08	10	20
V2–V1*	00XS09R604KZP99	5*	10*
F1	01NG00R187	500	1000
Sewage pre-breather pool	00NG02R601ZP19 00NG01R601ZP19	250	500
V3	00XS23R901YJ08	250	1000

* The difference between V2 and V1 stations

The site map in chapter 5.1 shows also the location of type “V” monitoring stations.

The remote monitoring systems provide data for the main data acquisition and display system (SCADA) every 10 minutes. Testing and calibration of the measuring probes takes place every year.

5.3.3 **Discharge sampling**

The laboratory sampling system in operation at the Paks NPP is capable of continuously sampling aerosols and inert gases, radioactive iodine in different chemical forms, tritium and radiocarbon.

The laboratory sampling system consists of:

- A combined sampling unit (01/02XS41, 01/02XS42 and 01/02XS43, see Figure 2). The two main parts of the device are a filter holding unit and the associated pump unit. The filters are placed in FD02 capsules in this order: on top is the aerosol filter, below the elemental iodine filter, and on the bottom is the filter with charcoal for filtering organic iodine. The volumetric flowrate of continuous sampling is between 1.5 and 1.8 m^3/hour, the aerosol[4] and iodine[5] filters are replaced daily for 01/02XS43 and weekly for 01/02XS41 01/02XS42. The iodine cartridges[6] are replaced every week.
- The tritium Samplers (01XS41A901/902 and 02XS41A901/902, see Figure 2). An absorption pillar with 2 pieces of custom developed molecular sieve (type 4 A, weight 400 g). After filtering out the aerosols, one path is for bound tritium, the other is for bound tritiated water after the catalytic oxidation of the hydrogen gas at 450 °C. The sampling volumetric flowrate is 15 dm^3/h. The maximum exposition time is 336 hours.
- The radiocarbon samplers (01XS41A903/904 and 02XS41A903/904, see Figure 2). This is a custom developed sampling device made of two 500 cm^3 NaOH bubblers containing 3 M NaOH solution. After filtering out aerosols, one is for bound of carbon dioxide (CO_2), the other is for bound carbon dioxide and hydrocarbons ($C_nH_m + CO_2$) post catalytic oxidation at 450 °C. The sampling volumetric flowrate is 10 dm^3/h. The maximum exposition time is 336 hours.
- Inert gas samplers (01/02XS44A905 and 01/02XS44A906). There are two continuous samplers are in operation. The first is used for determining the isotopic composition of noble gases in the air by the laboratory, and replaced every working day. The second is for determining Kr-85 in air by the laboratory on monthly basis, thus replaced monthly. The sampler for defining isotopic composition is a custom- made sampler with a programmable exposition time in the range between 1 and 7 days. The volumetric flowrate of the sampling is between 5 and 10 dm^3 per set time period. The Kr-85 sampler is a programmable device custom-made by MTA ATOMKI. The exposition time is programmable between 14 and 31 days. The volumetric flowrate of the sampling is variable between 15 and 27 dm^3 per set time period.

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[4] Russian made aerosol filter type: AFA-RMP-20, 70 mm diameter

[5] Filter developed by BME (Budapest Technical University) for binding iodine vapour (70 mm diameter, type: BME PACI)

[6] Cartridge for binding organic iodine compounds, type: KC-9

Figure 2. Left side: large and small volume air samplers inside a combined sampling unit. Right side: carbon (above) and tritium (below) samplers

The air inlet of the combined sampling unit is shown in below.

Figure 3. Air inlet the combined sampling unit

The sampling and measurement programme of discharge monitoring is summarised in the table 10.

Table X. Radiation protection evaluation of liquid and airborne radioactive discharges based on sampling and evaluations performed in laboratory

Evaluation target	Measuring frequency	Samples/ year	Sample preparing methods	Sample volume, geometry	Measuring methods	Measuring time [s]	Detection limits
Liquid discharges							**[Bq/dm^3]**
Total-beta, tank	Daily	1200	Evaporation	∅50 mm bowl	total-beta counting	3 000	3.0
Isotopic composition, tank	Weekly	208	none	1 dm^3 Marinelli	γ-ray spectrometry	50 000	0.5
^3H, only for tanks: 01/02TM, XZ, RJ, RZ	Weekly	256	Distillation	20 cm^3 cuvette	Liquid scintillation counting	3 x 60 3 x 600	200 9
Radiostrontium, tank	Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation counting	36 000	0.03
^{14}C, tank	Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation counting	12 000	0.1
Alpha-emitters, tank	Quarterly	16	Electrochemical separation	∅50 mm bowl	Alpha-particle spectrometry	500 000	0.0001
Total-alpha, tank	Daily	300	Evaporation	∅50 mm bowl	total-alpha counting	3 600	0.25
Gamma-ray-emitters, tank	Quarterly	16	Chemical preparation	∅50 mm bowl	Gamma-ray spectrometry	50 000	0.4
Channel waters * (V1, V2 and V3)	Daily	1100 36 12 36 12 12	Evaporation (300 cm^3) Monthly average calculation (15 dm^3) Chemical separation (^{90}Sr) Distillation (^3H) Evaporation (150 cm^3) Chemical separation (^{14}C)	∅60 mm bowl 35x35x5 mm ∅50 mm bowl 20 cm^3 cuvette ∅50 mm bowl 20 cm^3 cuvette	total-beta measure gamma-ray spectrometry beta-count Liquid scintillation count total-alpha count Liquid scintillation count	10 000 50 000 50 000 18 000 60 000 25 000	0.05 0.001 0.001 2.0 0.01 0.1

Evaluation target	Measuring frequency	Annual # of samples	Sample preparing methods	Volume of a sample	Measuring methods	Measuring time [s]	Detection limits
Airborne discharges							**[Bq/m^3]**
Aerosol, radioiodine	Daily Weekly	1460 416	none	∅50 mm bowl	γ-ray spectroscopy	5 000 50 000	0.01 0.0004
Radiostrontium	Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation counting	36 000	1 x 10^{-5}
Noble gases	Daily	522	none	7,32 litres bottle	γ-ray spectrometry	5 000	5 x 10^3
^3H (^3H_2TO/^3HT)	Every 2 weeks	212	Desorption	20 cm^3 cuvette	Liquid scintillation counting	3 x 600	0.05
^{14}C ($^{14}CO_2$/$^{14}C_nH_m$)	Every 2 weeks	212	Chemical separation	20 cm^3 cuvette	Liquid scintillation counting	1200 3600	0.4 0.25

* The evaluation of channel waters - except for total-alpha and radiocarbon measurements - are performed by the environmental monitoring laboratory.

5.4 SITE-RELATED MONITORING

In Chapter 6, 2nd indent point f of the decree 15/2001 (VI.6) KöM (Environment Protection Ministry) determines that in conjunction with the use of nuclear energy the operator shall:

1) monitor any radioactive exposure in its air and water environment;

2) develop an Environment Monitoring Regulation (KöESZ).

According to appendix 5 of the decree, the Environment Monitoring Regulation has to specify the monitoring, methods and equipment, including the performance and effectiveness of the devices used to perform the monitoring.

The remote monitoring system of the Paks NPP environmental monitoring is made up of type A, B, G and V remote environmental monitoring stations. The site map in chapter 5.1 shows the locations of type A, G and V stations.

The groundwater monitoring wells monitor the radionuclides in groundwater flowing beneath the operational area. In conjunction with the „preventive monitoring”. Monthly or quarterly sampling of the 54 wells is performed.

Other environmental samples such as surface water, sludge, fish, and milk are also examined as part of the monitoring programme.

Table XI. Tests performed in the Paks NPP operational sampling programme for radiation protection monitoring of its environment

Sample type	Sampling	Samples/year	Processing		Measuring		Detection limit
	Location (replacement) frequency		Method	Sample volume, geometry	Method	Time [s]	
Aerosol (remote iodine monitoring)	10 (A1 - A9, B24) weekly	–[a]	—	∅ 25 mm	γ-ray spectrometry	20 000	5 mBq/m^3
Elemental iodine (remote iodine monitoring)	10 (A1 - A9, B24) weekly	–[a]	—	∅ 25 mm	γ-ray spectrometry	20 000	5 mBq/m^3
Organic iodine (remote iodine monitoring, charcoal)	10 (A1 - A9, B24) monthly	–[a]	—	∅ 60*50 mm	γ-ray spectrometry	20 000	5 mBq/m^3
Aerosol (large volume)	10 (A1 - A9, B24) weekly (B24) monthly	520 12	radiochemical (^{90}Sr)	40*40*10 mm	γ-ray spectrometry, gross beta counting	50 000 3 000	5 $\mu Bq/m^3$ 1 $\mu Bq/m^3$
Elemental iodine (large volume)	10 (A1 - A9, B24) monthly	30 - 120[a]	—	40*40*10 mm	γ-ray spectrometry	50 000	5 $\mu Bq/m^3$
Organic iodine (charcoal) (large volume)	10 (A1 - A9, B24) monthly	120[a]	—	Marinelli	γ-ray spectrometry	50 000	20 $\mu Bq/m^3$
Air HT, HTO	10 (A1 - A9, B24) monthly	240	desorption	20 cm^3 cuvette	liquid scintillation counting	18 000	1 mBq/m^3
Air CO_2, C_nH_m	10 (A1 - A9, B24) monthly	240	chemical separation	Proportional counter tube	gross beta counting	50 000	0.1 mBq/m^3
Atmospheric fallout	10 (A1 - A9, B24) monthly	120	evaporation to dryness	35*35*5 mm	γ-ray spectrometry	50 000	0.2 Bq/m^2

Sample type	Sampling	Samples/year	Processing		Measuring		Detection limit
	Location (replacement) frequency		**Method**	**Sample volume, geometry**	**Method**	**Time [s]**	
Soil	10 (A1 - A9, B24) every half a year 14 – 10 (operational area) - yearly	20 14 10	drying, pulverisation, homogenisation, (^{90}Sr) microwave acid digestion	Marinelli (1 – 2 kg) ∅ 50 mm bowl	γ-ray spectrometry, gross beta counting alpha-particle spectrometry	20 000 10 000	0.5 Bq/kg 0.5 Bq/kg 0.01 Bq/kg
Grass	10 (A1 - A9, B24) II, IV quarters	20 20	drying, pulverisation, homogenisation radiochemical (^{90}Sr)	Marinelli (*circa* 0.4 kg) ∅ 50 mm bowl	γ-ray spectrometry, gross beta counting	80 000 10 000	0.5 Bq/kg 0.5 Bq/kg
Dose by TLD	26 (A, B, C, L, OMSZ) monthly	312	—	Al_2O_3 capsule	TL evaluation	300	5 µSv/month (5 nGy/h)
Local measurement	10 (A1 - A9, B24) yearly	10 10	—	*in situ* (ground level), at 1 m height from ground	γ-ray spectrometry, dose rate	5 000 60	30 Bq/m^2 5 nGy/h
Local measurement	8 (operational area) yearly 26 (operational area) every half a year	8 52	—	in situ (ground level), pathway monitoring	γ-ray spectrometry, dose rate	5 000 5 000	30 Bq/m^2 50 nGy/h
Groundwater	52 wells monthly T58, V205 quarterly	624 120 120 *ad hoc*	distillation (^{3}H) ion exchange separation (for ^{14}C or ^{90}Sr)	20 cm^3 cuvette ∅60 x 30 mm prop. Counter ∅ 50 mm bowl	Liquid scintillation counting, γ-ray spectrometry, beta counting (for ^{14}C or ^{90}Sr)	18 000 50 000 50 000 50 000	2 Bq/dm^3 5 mBq/dm^3 1 mBq/dm^3 1 mBq/dm^3

Sample type	Sampling	Samples/year	Processing		Measuring		Detection limit
	Location (replacement) frequency		Method	Sample volume, geometry	Method	Time [s]	
Fishing lakes (water)	4 (4 designated lakes) quarterly	16 16 4	evaporation (300 cm^3) distillation (^3H) annual average count (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	Gross beta measurement, Liquid scintillation counting, γ-ray spectrometry	10 000 18 000 50 000	0.05 Bq/dm^3 2.0 Bq/dm^3 0.01 Bq/dm^3
Intercepting ditch (water)	4 (designated locations) quarterly Faddi ditch – monthly	16 16 12 5	evaporation (300 cm^3) distillation (^3H) annual average count (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	Gross beta measurement, Liquid scintillation counting, γ-ray spectrometry	10 000 18 000 50 000	0.05 Bq/dm^3 2.0 Bq/dm^3 0.01 Bq/dm^3
Lime/chemical pools (water)	quarterly	8 8 2	evaporation (300 cm^3) distillation (^3H) annual average count (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	Gross beta counting, Liquid scintillation counting, γ-ray spectrometry	10 000 18 000 50 000	0.05 Bq/dm^3 2.0 Bq/dm^3 0.01 Bq/dm^3
Danube (water)	2 (2 designated locations), yearly	2 2 2	evaporation (20 dm^3) distillation (^3H) ion exchange separation (^{90}Sr)	35 x 35 x 5 mm 20 cm^3 cuvette ∅ 50 mm bowl	γ-ray spectrometry, Liquid scintillation counting, gross beta counting	50 000 18 000 50 000	5 mBq/dm^3 2.0 Bq/dm^3 1 mBq/dm^3
Danube sludge	3 (3 designated locations) every half a year	6 6	drying, pulverisation, homogenisation, radiochemical (^{90}Sr)	Marinelli (*circa* 2 kg) ∅ 50 mm bowl	γ-ray spectrometry, gross beta counting	20 000 10 000	0.5 Bq/kg 0.5 Bq/kg
Fishing lakes (sludge)	4 (4 designated lakes) yearly	4	wet homogenisation	Marinelli (*circa* 2 kg)	γ-ray spectrometry	20 000	0.5 Bq/kg

Sample type	Sampling	Samples/year	Processing		Measuring		Detection limit
	Location (replacement) frequency		Method	Sample volume, geometry	Method	Time [s]	
Intercepting ditch, Fadd ditch (sludge)	4 (4 designated locations) every half a year	8	wet homogenisation,	Marinelli (*circa* 2 kg)	γ-ray spectrometry	20 000	0.5 Bq/kg
Lime	2 (2 pools) every half a year	4	wet homogenisation	Marinelli (*circa* 2 kg)	γ-ray spectrometry	20 000	0.5 Bq/kg
Faecal sludge	10 (dehydrators)	ad hoc	boxing	Marinelli (*circa* 2 kg)	γ-ray spectrometry	5 000	2.0 Bq/kg
Milk	1 (designated farm) monthly	12	boxing	Marinelli (1.5 dm^3)	γ-ray spectrometry	50 000	0.5 Bq/dm^3
Fish	2 (4 designated lakes) one every quarter	4 4	prepared raw meat innards	Marinelli (*circa* 1 kg) 65 x 30 mm	γ-ray spectrometry	50 000 50 000	0.5 Bq/kg 10 Bq/kg

a: Sample replacement is regular, measuring is only performed in extraordinary situations - for example in case of accident

5.4.1 **Stations of type A and B**

The Paks NPP conducts the following measurements using the type A and B stations:

- measurement of elemental iodine activity in aerosol by total beta counting. The measuring range is $6 \times 10^2 – 5 \times 10^7$ Bq/m^3. The warning level is set at 1 kBq/m^3, the alert level at 10 kBq/m^3;
- measurement of activity of four iodine isotopes (I-131, I-132, I-133, I-135) in their organic and elemental forms by temperature stabilised NaI(TI) scintillation detector. The measuring range is $6 \times 10^3 – 5 \times 10^7$ Bq/m^3. The warning level is set at 8 kBq/m^3, the alert level at 10 kBq/m^3;
- environmental gamma dose rate measurements by BITT (Bitt Technology, RS03) probes in the measuring range of 10 nSv/h – 10 Sv/h. The warning level is set at 250 nSv/h, the alert level at 500 nSv/h.

In addition, the type A and B stations are used for measurements after sampling, such as:

- environmental gamma radiation dose by thermo-luminescent dosimeters (TLD);
- aerosol and iodine sampling;
- air sampling for tritium and radiocarbon measurements;
- activity deposition by atmospheric fall-out (rain collection);
- activity deposition on soil and grass.

Below the dry and wet deposition (fallout) sampling devices are shown (Figure 4 and Figure 5).

Figure 4. Automated dry deposition sampler (top view on the right)

Figure 5. Automated wet deposition sampler

5.4.2 Stations of type G

Type G stations perform the remote measurement of environmental gamma dose rate by BITT (Bitt Technology, RS03) probe in the measuring range of 10 nSv/h – 10 Sv/h. The warning level is set at 250 nSv/h, the alert level at 500 nSv/h.

The type „G” stations are used for performing measurements after sampling, such as:

- environmental gamma radiation dose by thermo-luminescent dosimeters (TLD);
- activity deposition by atmospheric fall-out (rain collection);
- activity deposition on soil and grass.

Figure 6 shows an ambient dose rate probe together with the TLD in its sleeve. The white hanging tube holds a capsule (see Figure 7) used for monthly ambient radiation background dose monitoring.

Figure 6. BITT probe and the TLD (black sleeve attached to the holder)

Figure 7. Al_2O_3 containing capsule for monthly background dose integration

5.4.3 Meteorological monitoring

The meteorological monitoring system continuously provides metrological data required for atmospheric propagation calculations during normal operation and in case of accident. The meteorological monitoring system consists of the follow stations/data sources:

- **primary** data source: SODAR (**SO**nic **D**etection **A**nd **R**anging) wind profile measuring station mounted on a 10 m tall tower. It measures wind direction, wind velocity, radiation background and precipitation. The system is enclosed in an earthquake resistant housing with the data collection unit installed nearby;
- **secondary** data source: The 120 m tall (steel construction) meteorological measuring tower. Next to it the ground level station housing additional the measuring devices of and the data collection unit. At the height of 120 m, one measures temperature, wind velocity, gusts of wind, wind direction, and fluctuations of the wind direction. At the height of 50 m, one measures wind velocity, gusts of wind, wind direction, and fluctuations of the wind direction. At the height of 20 m, one measures temperature and its gradient, wind velocity, gusts of wind, wind direction, and fluctuations of the wind direction. At the height of 2 m, temperature, radiation background and precipitation are measured; (Figure 8.)
- **tertiary** data source: National Meteorology Service (*Országos Meteorológiai Szolgálat* (OMSZ) provides these data to the NPP).

Figure 8. The meteorological tower at the Paks NPP

5.5 PARTICIPATING LABORATORIES

5.5.1 Laboratory of the Paks NPP for discharge samples

The National Accreditation Authority (accreditation No NAH-1-1195/2015) accredited the Discharge Monitoring Laboratory according to the standard MSZ EN ISO/IEC 17025:2005.

Discharge samples are stored in the laboratory. The samples to demonstrate compliance with the legal discharge limits are kept until cross-comparisons with the environment protection authority are finished.

The Paks NPP laboratory archives measurement results both on paper and digitally. The custom developed SQL digital database is located on the main server of the NPP and accessed via its management software. For the radionuclides monitored as required by the environmental protection authority, laboratory records the results of the discharge monitoring together, and if necessary records its respective limits of detection.

Table XII. Devices used for measurement of the samples in the laboratory

Name	Manufacturer	Lab ID	In operation since	Accuracy testing	
				method	frequency
Gamma-ray spectrometry measurements					
HPGe based measurement system	Canberra	KIL 17	2014	RHA*	quarterly
HPGe based measurement system	Canberra	KIL 18	2007	RHA*	quarterly
HPGe based measurement system	Canberra	KIL 19	2003	RHA*	quarterly
HPGe based measurement system	Oxford-Tennelec	KIL 20	1997	RHA*	quarterly
HPGe based measurement system	Canberra	KIL 26	2004	RHA*	quarterly
Devices used for measuring low energy beta emitting radionuclides					
liquid scintillation counter	Perkin-Elmer	KIL 21	2016	RHA*	half - yearly
liquid scintillation counter	Perkin-Elmer	KIL 31	2010	RHA*	half - yearly
Devices used for Beta-particle-counting					
Plastic scintillation nuclear spectrometer	Gubo Bt., Gamma	KIL 23	1996	RHA*	monthly
LB4200 alpha and beta counter device with 8 measurement chambers	Canberra	KIL 24	2017	RHA*	weekly
Alpha-particle spectrometric measurements					
Alpha spectrometer with PIPS detector	Canberra	KIL 28	2008	RHA*	quarterly
Alpha spectrometer with PIPS detector	Canberra	KIL 29	2012	RHA*	quarterly
Alpha spectrometer with PIPS detector	Canberra	KIL 30	2008	RHA*	quarterly

*RHA: Authentic Radioactive Reference Material (*Radioaktív Hiteles Anyagminta*)

As legally required (decree 15/2001 (VI.6) KöM, 4th appendix, KiESZ), the laboratory reports the analytical results monthly, quarterly and yearly to the environmental protection authority. These results are also sent to the nuclear authority.

The Paks NPP Discharge Monitoring Laboratory participates in Inter-laboratory Comparison Proficiency tests organised by the IAEA. No measurements are outsourced.

5.5.2 Paks NPP environmental laboratory

The National Accreditation Authority has accredited the Environment Monitoring Laboratory according to the MSZ EN ISO/IEC 17025:2005 standard (accreditation No is NAH-1-1680/2015). The laboratory participates in Inter-laboratory Comparisons Proficiency tests organised by the IAEA.

Samples are stored in the laboratory. The samples to demonstrate compliance with discharge limits are kept until the cross-comparisons with the environment protection authority are finished.

The Paks NPP environmental laboratory archives measurement results on paper and digitally. The custom developed SQL digital database is located on the main server of the NPP and accessed via its management software. No measurements are outsourced.

Table XIII. Devices used for the measuring of samples

Name	Manufacturer	Lab ID	In operation since	Accuracy testing method / frequency
Gamma-ray spectrometry measurements				
HPGe based measurement system	Canberra-Packard	KEL DET1	2006	authentic reference material / yearly
HPGe based measurement system	Canberra-Packard	KEL DET2	2005	authentic reference material / yearly
HPGe based measurement system	Canberra-Packard	KEL DET3	1987	
HPGe based measurement system	Canberra-Packard	KEL DET4	1997	authentic reference material / yearly
HPGe based measurement system	Canberra-Packard	KEL DET5	2008	authentic reference material / yearly
HPGe based measurement system (portable)	Canberra-Packard	KEL 16	2006	authentic reference material / yearly
Devices used for measuring low energy beta emitting radionuclides				
liquid scintillation spectrometer	Canberra-Packard	KEL 17	1994	authentic reference material / every half a year
liquid scintillation spectrometer	Perkin-Elmer	KEL 18	2006	authentic reference material / every half a year
Devices used for Beta-particle-counting				
FHT 770 T alpha and beta counter device with 6 measurement locations	FAG	KEL 19	1994	authentic reference material / after every gas replacement

LB4110 low backgrounds gross beta counter	Canberra	KEL 21	2013	authentic reference material / after every gas replacement
Device used for environmental dose rate measurements				
PorTL device	KFKI-AEKI	KEL 20	2008	authentication / yearly

As legally required (decree 15/2001 (VI.6) KöM, appendix 5, KöESZ), the laboratory reports the analytical results monthly and yearly reporting to the environmental protection authority. These results are sent to the nuclear authority as well.

Figure 9 shows several HPGe detectors located in this laboratory.

Figure 9. Detectors in the environmental laboratory of Paks NPP

5.5.3 Regulator's laboratory for discharge samples

The regulator's laboratory - Laboratory Section of the Department of Public Health of the Baranya County Government Office – is located on Szabadság Street 7, in Pécs, H-7623. The laboratory reports to BCGO DEPNC and NERMS RISC. This laboratory is accredited according to the ISO/IEC 17025 standard.

Measurements of airborne release samples are conducted as follows:

- samples are registered electronically and on paper;
- separate sampling channels are used for taking weekly regulatory discharge aerosol and elemental iodine filter samples from each reactor unit;
- weekly samples are measured by gamma spectroscopy using HPGe detectors, using standardised procedures. Evaluation of the spectra is done automatically by a specific software;

- samples are collected and stored for 3 months and used for Sr-90 analysis;
- preparation of the collected samples for Sr-90 measurements is carried out in accordance with an a standardised procedure, as are the measurements.

Measurements of liquid discharge samples are conducted as follows:

- samples are registered electronically and on paper;
- weekly samples are measured by gamma spectroscopy using HPGe detectors;
- tritium measurements are carried out by liquid scintillation counting;
- weekly samples are collected and stored for 3 months and used for Sr-90 analysis;
- preparation of the collected samples for Sr-90 measurements is carried out in accordance with an standardised procedure, as are the measurements.

The laboratory is equipped with three p-type semiconductor detectors (HPGe, CANBERRA, relative efficiency 30-35%) and two n-type semiconductor detectors (HPGe, ORTEC, relative efficiency 30%). Those detectors are used for gamma-ray spectroscopic analyses.

For beta-particle counting, the laboratory is using a Thermo fisher ESM FHT 770-T and a CANBERRA LB4200 type alpha and beta counting device.

For analysis of tritium, the laboratory uses a Canberra-Packard TRI-CARB 2250CA and a Quantulus GCT 6220.

5.5.4 **Regulator's laboratory for site-related environmental samples**

The regulator's laboratory - Laboratory Section of the Department of Public Health of the Baranya County Government Office – is located on Szabadság Street 7, in Pécs, H-7623. The laboratory is operated by Baranya County Government Office and reports to BCGO DEPNC and NERMS RISC.

The National Accreditation Council has accredited this laboratory according to ISO/IEC 17025:2005 standard (accreditation No NAH-1-1315/2015). The laboratory regularly participates in inter-comparison exercises organised by the IAEA.

Measurements of airborne samples (particles from discharges) are conducted as follows:

- samples are collected at the environmental stations installed within the 30 km radius of the NPP;
- samples are registered electronically and on paper;
- samples are measured by gamma-ray spectroscopy using HPGe detectors, using standardised procedures. Evaluation of the spectra is done automatically by a specific software;
- measurement results are recorded on paper, entered into a local database and sent to the NERMS RISC database.

Measurements of channel water samples are conducted as follows:

- samples are collected at the environmental stations V1, V2, and V3;
- samples are registered electronically and on paper;
- weekly samples are aggregated into one monthly sample for measurement;
- gross beta counting is performed on all samples;
- samples are measured by gamma-ray spectroscopy using HPGe detectors, using standardised procedures;
- tritium measurements are carried out by liquid scintillation counting;
- weekly samples from V3 station are collected and stored for 3 months and used for Sr-90 analysis;
- sample preparation and measurements of Sr-90 are carried out in accordance with standardised procedures,

- measurement results are recorded on paper, entered into a local database and sent to the NERMS RISC database.

Measurements of underground water samples are conducted as follows:

- samples are registered electronically and on paper
- tritium measurements are carried out by liquid scintillation counting;
- measurement results are recorded on paper, entered into a local database and sent to the NERMS RISC database.

Measurements of surface water, sediment, vegetation and fish sampled from the Danube river are conducted as follows:

- sample are collected upstream and downstream from the Paks NPP, on the section of the river between Dunafoldvar and the state border;
- samples are registered electronically and on paper;
- samples are prepared for measurements in accordance with standardised procedures;
- tritium measurements are carried out by liquid scintillation counting;
- measurement results are recorded on paper, entered into a local database and sent to the NERMS RISC database.

6 SITE-SPECIFIC REGULATORY MONITORING

6.1 INTRODUCTION

The table below illustrates the type and number of regulatory measurements in 2017.

Table XIV. The distribution of the number of different type of regulatory measurements in 2017

Type of measurement	No of measurements	%
Gross beta counting	938	14.2
Determination of I-131	97	1.5
Gamma-ray spectroscopy by HPGe	4347	65.9
Tritium	420	6.4
Sr-89+Sr-90 (*)	397	6.0
Other measurements	400	6.1
Total:	6599	100

(*) with a preceding chemical separation step

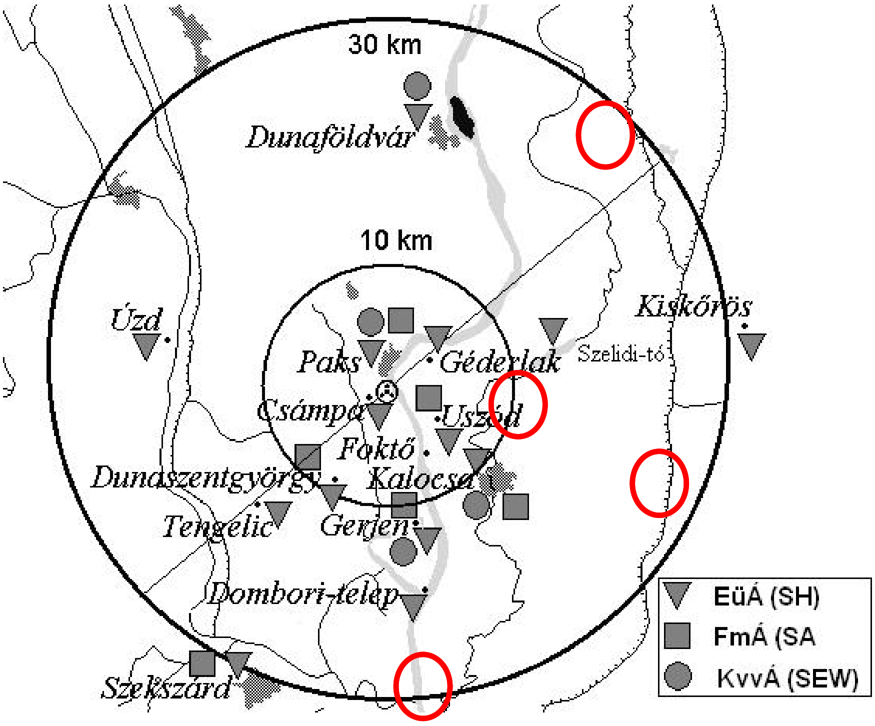


Figure 10. Placement of the regulatory environmental monitoring (measurement and sampling) locations in respect to the Paks NPP (in centre)

Decipher of EüÁ (SH), FmÁ (SA), and KvvÁ (SEW): EüÁ = RAMDAN, FmÁ = NFCSO, KvvÁ = BCGO DPH.

The red circles on this plan indicate locations of aerosol sampling stations discussed in chapter 6.3.

6.2 EXTERNAL GAMMA DOSE RATE

The telemetric monitoring stations G1 - G11 and A1 - A9 (see Figure 1) are operated by the NPP. These stations are described in detail in chapters 5.4.1 (“A” type) and 5.4.2 (“G” type). The stations provide data to the National Radiation Early Warning, Monitoring and Surveillance System in close to real time.

A network of dose measurement points with TLD’s in the 30 km radius of the Paks NPP complements the telemetric monitoring stations. The NPHC DRR (RAMDAN central laboratory) is maintaining the passive environmental dosimetry system since 1980. Panasonic environmental TLDs are placed at *circa* one metre above the ground at 39 locations as indicated on Figure 11. The detectors are exchanged quarterly, and NPHC DRR performs their reading and dose evaluation. The TLD reader and calibration equipment (Panasonic system) is the same used by the National Personal Dosimetry Service. The average quarterly gamma dose rates are subsequently calculated based on the total collected gamma dose and the exposure time. The results are published in the NERMS’s annual report.

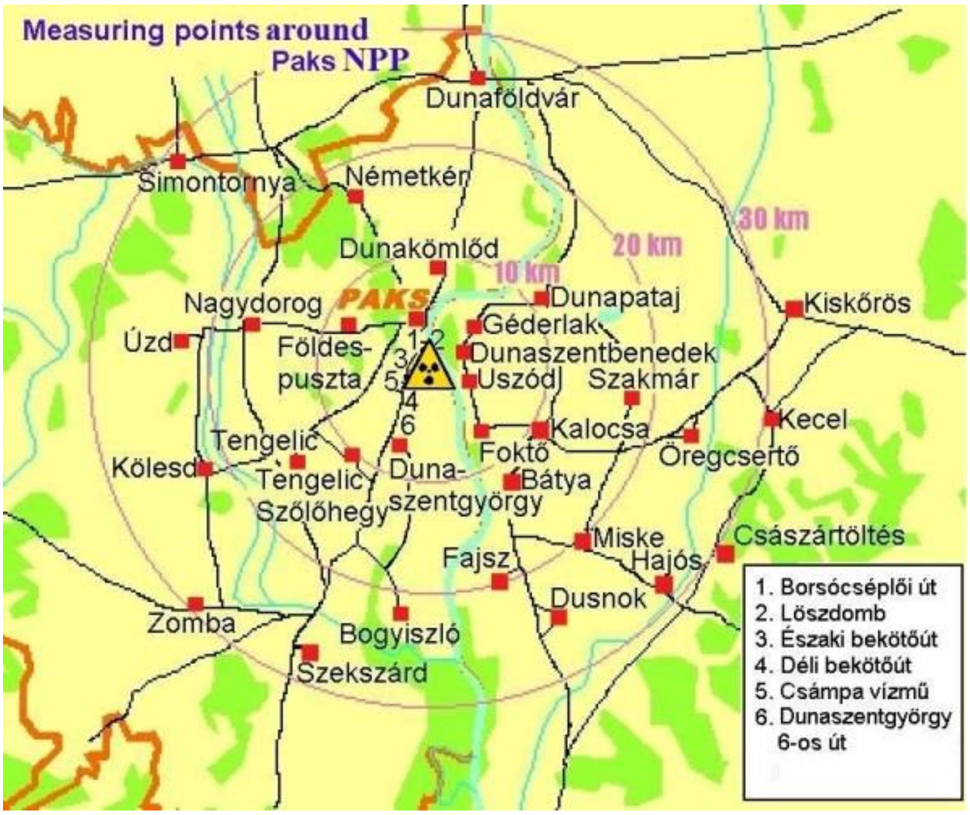


Figure 11. Placement of the TLD measurement locations in respect to the Paks NPP (in centre)

6.3 AIR

The TCGO DPH RL (Tolna County Government Office, Department of Public Health, Radiohygiene Laboratory) maintains four low-volume (air flow is less than 5 m^3/h)aerosol sampling stations at Kalocsa, Csámpa, Szekszárd and Dunaföldvár. . The locations of these sampling stations are indicated by red circles on Figure 10. Two stations (in Csámpa and Dunaföldvár) are located in the Northwest semicircle, and two stations (in Kalocsa and Szekszárd) are located in the Southeast semicircle. These stations use nitrocellulose membrane filters. The filters are exchanged on workdays at the station located in Szekszárd. At the other three stations the filters are exchanged weekly. The sampled air volume is measured by gas flow meters. The filters are analysed in the laboratory of TCG DPH RL. The total beta activity is determined by a scintillation counting. The monitoring station in Szekszárd operates also a Hunter medium-volume air sampler (airflow is *circa* 150 m^3/h) produced by Senya Oy Finland. This sampler utilises a glass fibre filter that is exchanged weekly. The filter is analysed by gamma-ray spectrometry. A technical problem with this medium-volume air sampler resulted in no data for the year 2017.

Activities of the Laboratory Section of the Department of Public Health of the Baranya County in this domain Government Office are described in chapter 5.5.4.

The medium-volume air sampling station in Szekszárd is shown below.

Figure 12. The medium-volume air sampling station operating in Szekszárd

6.4 ATMOSPHERIC FALLOUT

The same four stations collect fallout samples monthly. After sample preparation by evaporation and ashing, the total beta activity is measured by scintillation counting. The samples are analysed by gamma-ray spectrometry as well.

More fallout samples are collected by the NPP in monitoring stations A1 and A5 monthly. The laboratory of NPHC DRR determines tritium in these samples after electrolytic enrichment process.

The Radioanalytical Reference Laboratory of Food Chain Safety Laboratory of National Food Chain Safety Office operates an additional fallout sampler located in Szekszárd. Since the food chain laboratory at Szekszárd is closed recently, measurements of these fallout samples are carried out by the food chain laboratory located at Kecskemét.

6.5 SURFACE WATER

The BCGO DPH Laboratory Section and TCGO DPH Radiological laboratory perform regular sampling and measurements on the river at locations near Dunaföldvár, Paks, Gerjen, Kalocsa, Baja and Mohács.

The TCGO DPH Radiological laboratory and BCGO DPH Laboratory Section at Szelidi-lake perform also monitoring of surface water at the Szelidi-lake, the Kondor-lake and the dead leg of the Danube at Dombori.

The monitoring comprises determination of activity in water, algae and fish samples in addition to weekly and monthly gross beta measurements.

The laboratory of NPHC DRR takes monthly samples from the river Danube above the Paks NNP and at Mohács. It receives samples taken by the NNP from the warm channel V2 station. After sample preparation, the NPHC DRR laboratory determines gross beta activity, K-40 and H-3 in these samples. The Sr-90 activity is measured in the 3-monthly aggregate samples after chemical preparation. They samples are also analysed by gamma-ray spectrometry. As the volume of these aggregate samples is 45 litres, it is decreased to 150 ml by evaporation. Before the total beta counting, the samples are evaporated and ashed at 380℃. Before the tritium measurement, the samples are concentrated electrolytically and then analysed by liquid scintillation counting. The K-40 is measured by atomic absorption spectrometry.

Figure 13 shows he channel next to the V2 station. The equipment used for continuous monitoring and sample taking is shown in Figure 14.

Figure 13. The warm channel and sampling tubes (grey leading to V2 monitoring station)

Figure 14. Left: continuous monitoring of the water flowing to Danube River; right - sampling in action

The staffs of the National Food Chain Safety Office take monthly water samples from the Danube river at Uszód, Gerjen, and Baja. The food chain laboratory located at Kecskemét carries out the tritium measurements in these samples in co-operation with the Radioanalytical Reference Laboratory.

6.6 GROUND WATER AND DRINKING WATER

TCGO DPH Radiological laboratory monitors the drinking water at five locations. The sampling points cover public wells, tap water in public buildings, and on site of the NPP. Samples are analysed for gross alpha and gross beta activity, H-3 and Sr-90 content, and gamma emitters by gamma spectroscopy.

The laboratory of NPHC DRR also gets samples from the ground water monitoring wells M5 and T24 taken by the NPP on monthly basis. The H-3 concentration is determined in these samples without electrolytic enrichment process.

6.7 SOIL AND SEDIMENTS

The TCGO DPH RL measures the gross beta activity, gamma emitters and Sr-90 in soil monthly sampled at Kalocsa, Dunaföldvár, Paks, and Fadd-Dombori.

The staff of National Food Chain Safety Office takes samples mainly from area south of the NPP. The measurement of the samples is carried out by the food chain laboratory located at Kecskemét.

The BCGO DPH Laboratory Section and TCGO DPH Radiological laboratory measure the activity in sediment samples collected from upstream and downstream of the NPP monthly and quarterly.

6.8 Food and feed

6.8.1 Animal feed

The FCSC RFL takes animal feed samples monthly at Foktő, Paks and Dunszentgyörgy, with analysis for gross beta activity, gamma emitters, and Sr-90.

6.8.2 Vegetation

Wild and cultivated plants are collected within a 30 km radius of the NPP in Uszód, Foktő, Gerjen, Kalocsa and Dunaszentbenedek. The TCGO DPH RL and FCSO perform analysis to determine gross beta activity, gamma emitters and Sr-90.

6.8.3 Foodstuffs

The TCGO DPH RL and FCSO take milk samples simultaneously with animal feed samples. Samples are taken at farms located at Dunszentgyörgy, Foktő, Fajsz, Paks, and Tolnatej PLC diarycompany. Analysis is performed to determine gross beta activity, gamma emitters and Sr-90 content.

The NFCSO analyses meat samples by gamma-ray spectroscopy.

The BCGO DPH LS performs sampling and analysis of fish taken downstream the Danube 13 times a year. Gross beta activity, gamma emitters and Sr-90 content is determined.

6.9 Overview of monitoring arrangements

This chapter summarises the currently implemented environmental monitoring arrangements for the surroundings of the Paks NPP. No measurements related to the monitoring are outsourced.

6.9.1 Tolna County Government Office

Department of Public Health, Radiochemical Laboratory monitoring programme for monitoring the vicinity of the NPP

Table XV. Sampling frequency and measurements for environmental monitoring

Sample	Sampling location	Sampling frequency	Annual No of samples	Type of measurements	Annual No of measurements
Aerosol (low V sampler)	Szekszárd	daily	Working days	gross β	150
Aerosol (low V sampler)	Csámpa	weekly	52	gross β	52
Aerosol (low V sampler)	Dunaföldvár	weekly	52	gross β	52
Aerosol (low V sampler)	Kalocsa	weekly	52	gross β	52
Aerosol (medium V sampler)	Szekszárd	weekly	52	GSP	52
Fall-out	Szekszárd	monthly	12	gross β, GSP[7]	12 / 12
Fall-out	Csámpa	monthly	12	gross β, GSP	12 / 12
Fall-out	Dunaföldvár	monthly	12	gross β, GSP	12 / 12
Fall-out	Kalocsa	monthly	12	gross β, GSP	12 / 12

[7] GSP – **G**amma ray **SP**ectrometry

Sample	Sampling location	Sampling frequency	Annual No of samples	Type of measurements	Annual No of measurements
Drinking water	Szekszárd	monthly	12	gross β, H-3	12 / 12
Drinking water	NPP Paks	monthly	12	gross β, H-3	12 / 12
Drinking water	Paks Kápolna út	monthly	12	gross β	12
Drinking water	Dunaföldvár	monthly	12	gross β	12
Drinking water	Kalocsa	monthly	12	gross β	12
Drinking water	Szekszárd	quarterly	4	Sr-90, GSP[8]	4 / 4
Drinking water	NPP Paks	quarterly	4	Sr-90, GSP	4 / 4
Drinking water	Paks Kápolna út	quarterly	4	Sr-90, GSP	4 / 4
Drinking water	Dunaföldvár	quarterly	4	Sr-90, GSP	4 / 4
Drinking water	Kalocsa	quarterly	4	Sr-90, GSP	4 / 4
Surface water (river Danube)	Gerjen	monthly	12	gross β, H-3	12 / 12
Surface water (river Danube)	Paks	monthly	12	gross β	12 / 12
Surface water (river Danube)	Dunaföldvár	monthly	12	gross β, H-3	12 / 12
Surface water (river Danube)	Kalocsa	monthly	12	gross β	12
Surface water (lake)	Lake Paks-Kondor	monthly	12	gross β	12
Surface water (lake)	Dombori	monthly	12	gross β	12
Surface water (lake)	Lake Szelidi	monthly	12	gross β	12
Surface water (river Danube)	Gerjen	quarterly	4	Sr-90, GSP	4 / 4
Surface water (river Danube)	Paks	quarterly	4	Sr-90, GSP	4 / 4
Surface water (river Danube)	Dunaföldvár	quarterly	4	Sr-90, GSP	4 / 4
Surface water (river Danube)	Kalocsa	quarterly	4	Sr-90, GSP	4 / 4
Surface water (lake)	Lake Paks-Kondor	quarterly	4	Sr-90, GSP	4 / 4
Surface water (lake)	Dombori	quarterly	4	Sr-90, GSP	4 / 4
Surface water (lake)	Lake Szelidi	quarterly	4	Sr-90, GSP	4 / 4
Soil	Csámpa	monthly	12	GSP	12
Soil	Paks	monthly	12	GSP	12
Soil	Dunaföldvár	monthly	12	GSP	12

[8] GSP – **G**amma ray **SP**ectrometry

Sample	Sampling location	Sampling frequency	Annual No of samples	Type of measurements	Annual No of measurements
Soil	Dombori	monthly	12	GSP	12
Soil	Kalocsa	monthly	12	GSP	12
Sediment	Gerjen-Duna	monthly	12	GSP	12
Sediment	Paks-Duna	monthly	12	GSP	12
Sediment	Dunaföldvár-Duna	monthly	12	GSP	12
Sediment	Kalocsa-Duna	monthly	12	GSP	12
Sediment	Dombori	monthly	12	GSP[9]	12
Sediment	Lake Szelidi	monthly	12	GSP	12
Cow milk (raw)	Szekszárd	monthly	12	gross β, GSP	12 / 12
Cow milk (raw)	Dunszentgyörgy	monthly	12	gross β, GSP	12 / 12
Cow milk (raw)	Fajsz	monthly	12	gross β, GSP	12 / 12
Cow milk (raw)	Szekszárd	quarterly	4	Sr-90, GSP	4 / 4
Cow milk (raw)	Dunszentgyörgy	quarterly	4	Sr-90, GSP	4 / 4
Cow milk (raw)	Fajsz	quarterly	4	Sr-90, GSP	4 / 4

6.9.2 Baranya County Government Office

Department of Public Health Laboratory Section monitoring programme for monitoring the vicinity of the NPP

Table XVI. Sampling frequency and measurements for environmental monitoring

Sample type	Location	Frequency	Sample/ year	Measurement	Measurements / year
Surface water	Dunaföldvár, Duna 1560.6 fkm	monthly	12	gross β / H-3 / GSP	12 / 12 / 4
Surface water	Gerjen, Duna 1516.6 fkm	monthly	12	gross β / H-3 / Sr-90 / GSP	12 / 12 / 2 / 4
Surface water	Hercegszántó, Duna 1433.0 fkm	quarterly *	4	gross β / H-3	4 / 4
Surface water	Duna, at border (Mohács)	13 / year	39	gross β / H-3 / Sr-90 / GSP	39 / 13 / 13 / 26
Surface water	Duna- valley canal 14.0 cskm	yearly	1	gross β / GSP	1 / 1
Surface water	Szelidi-tó	yearly	1	gross β / GSP	1 / 1
Surface water	inland seweer (5 db)	yearly	5	gross β / GSP	5 / 5

[9] GSP – **G**amma ray **SP**ectrometry

Sample type	Location	Frequency	Sample/ year	Measurement	Measurements / year
surface water	Paks, fishpond	Half a year	2	H-3 / GSP	2 / 2
Mud	Duna 1560.6 fkm	Quarterly	4	gross β / GSP	4 / 4
Mud	Duna 1526,0 fkm	Quarterly	8	gross β / GSP	8 / 8
Mud	Duna 1516.0 fkm	Quarterly	8	gross β / Sr-90 / GSP	8 / 4 / 8
Mud	Duna, at border (Mohács)	13 / year	52	gross β / Sr-90 / GSP	52 / 52 / 52
hydrophyte	Duna 1560.6 fkm	occasionally	1	gross β / GSP	1 / 1
hydrophyte	Duna, at border (Mohács)	occasionally	2	gross β / GSP	2 / 2
fish	Duna, at border (Mohács	13 / year	26	gross β / Sr-90 / GSP	26 / 26 / 26
fine dust		weekly	52	GSP	52
settling dust		monthly	24	GSP	24

* if there is no international sampling

6.9.3 Radioanalytical Monitoring Network under the responsibility of the Ministry of Agriculture

The tasks of and laboratories involved in this monitoring network are described in chapter 4.2.4. All laboratories are accredited according to the MSZ EN ISO/IEC 17025:2005.

Since 2007, the Food chain Laboratories of the network of Agricultural Offices operates a general data-management system. This laboratory data management system is a countrywide uniform information network for handling the sample data from registration until reporting of results. This allows direct sample registration to veterinary officers responsible for food and feed sampling.

Table 18 lists the environmental samples collected at Paks NPP area for gamma-ray spectrometry measurement in the laboratories of RMN of MA, the result of sample preparation and acquisition time of the gamma spectrum.

Table XVII1. Sample preparation and measurement in RMN of MA laboratories

Sample	Sample amount, kg or L	Final state of the sample	Acquisition time, s
Soil	1 – 2	air dried	80 000
Pasture	2 – 3	ash	80 000
Lucerne	2 – 3	ash	80 000
Fodder	2 – 3	ash	80 000
Sorrel, spinach	3	ash	80 000
Milk	5	ash	80 000
Milk products	1	ash	80 000
Meat	2	ash	80 000
Mushroom	2 – 3	dry, ash	80 000
Potato	2 - 3	ash	80 000

Sample	Sample amount, kg or L	Final state of the sample	Acquisition time, s
Vegetable	3 - 4	ash	80 000
Fruit	3 – 4	ash	80 000
Cereals	2 – 3	ash	80 000
Fall-out	m^2/month	evaporation residue	80 000

No measurements are outsourced.

The laboratories typically use:

- gross alpha counting
- gross beta counting,
- gamma-ray spectrometry with either HPGe or scintillation detectors (using InterWinner or Genie 2000 analytical software),
- liquid scintillation counting for the determination of H-3 and/or C-14,
- low background alpha and beta counters for determination of Sr-90 ($SrSO_4$ measurement)
- alpha spectrometry for determining isotopes of U and Pu as well as Po-210.

Alpha and beta counters and gamma spectrometers with HPGe and with scintillation detectors are available in the Budapest (BUD) and Bacs County (BAC) laboratories. The BUD laboratories also operates an alpha spectrometer and a liquid scintillation counter. The following table lists the types and producers of the above-mentioned equipment.

Table XVIII. The measurement equipment in RMN of MA laboratories

Gamma-ray spectrometers			
Lab code	**Detector type**	**Manufacturer**	**Relative Efficiency [%]**
BUD	p-type	Canberra	30
BUD	n-type	Canberra	30
BUD	n-type	Canberra	30
BUD	n-type	Canberra	30
BUD	n-type	EURISYS	30
BUD	n-type	Canberra	45
BAC	n-type	Canberra	40
BAC	p-type	Canberra	25
BAC	p-type	Canberra	30
BUD	LABR3 (LaBr)	Canberra	N/A
BAC	ND-134 (NaI(Tl))	GAMMA	N/A
Low background alpha and beta counters			
BUD	LB-5	Oxford	
BAC	PEGASE	Eurisys Mesures	
BUD	4 chambers	Ortec	

Gamma-ray spectrometers			
Lab code	**Detector type**	**Manufacturer**	**Relative Efficiency [%]**
Liquid Scintillation Counter			
BUD	Quantulus 1220 (*)	Perkin-Elmer	
Other equipment			
BUD	AUTOMESS 6150AD+6150AD-b dose rate meter	Automation und Messtechnik	
BUD	AlphaGuard Radon monitor	Genitron Instruments	
BAC	AUTOMESS 6150AD+6150AD-b dose rate meter	Automation und Messtechnik	

(*) Unique equipment - in case of any problem with it, there is no replacement possibility within the laboratory network.

The equipment is calibrated as follows:

- gamma spectrometry using volumetric calibration sources in different geometries and densities prepared from certified reference solution;
- calibration source for Sr-90 measurement is made from a reference source received from national metrological institute;
- tracer technique (isotope dilution) is applied for the calibration of alpha spectrometers;
- Liquid Scintillation Counter is calibrated using a certified reference solution.

Measurement results are calculated by the analytic software of the respective instruments. It produces relevant reports. These are complemented by a spreadsheet for alpha and beta counting, alpha-particle spectrometry and liquid scintillation counting.

The following archiving procedures are applied:

- samples in the form of ash are stored for 5 years in the laboratory;
- measurement results are introduced into the laboratory data management system; the same data archiving procedure is in force for the whole system (outside the responsibility of each radioanalytical laboratory);
- the laboratories keep a local archive of the results in paper form;
- on a yearly basis, obtained spectra are also archived on a server (in addition to the temporary storing of the data on the local network server which is also archived).

The handling of data and reporting is performed by the Central laboratory data management system. This system allows preparing the individual sample reports and execution of queries. For yearly reports, however MS Excel spreadsheets and charts are used. Transmission of individual reporting data to National Environmental Radioactivity Monitoring System (NERMS) occur once a year.

The RMN of MA laboratories participate in both national and international proficiency tests, and inter-laboratory comparison exercises, such as:

- Euratom Art 35 inter-comparisons organised by JRC-Geel;
- IAEA: ALMERA and other available proficiency tests at least yearly;
- Inter-comparisons organised for the internal network at regular intervals.

Since 2005, the Radioanalytical Reference Laboratory acts as an IAEA Collaborating Centre for the production and characterisation of matrix reference materials of terrestrial origin. In this field, the primary objective is the production and characterisation of reference materials for the organisation of inter-laboratory comparison and proficiency test exercises, and the development and validation of radioanalytical procedures. These activities are closely linked with the IAEA sub-programmes to enhance the reliability and comparability of measurement results obtained by nuclear and nuclear-related analytical techniques in Member State laboratories through the provision of reference materials, organisation of proficiency tests and inter-comparison exercises, and training. The Radioanalytical Reference Laboratory is an active member of the IAEA Advisory Group for the production and characterisation of reference materials.

6.9.4 Laboratories of the Radiological Monitoring and Data Acquisition Network

The names and addresses of the RAMDAN laboratories are listed in chapter 0. They operate within the structure of regional Government Offices but under the coordination of National Public Health Centre, Department of Radiobiology and Radiohygiene. The laboratories send the measurement results to the RAMDAN Information Centre, maintained by the NPHC DRR. They are responsible to perform the main monitoring programme of RAMDAN. RAMDAN laboratories are participating in the IAEA-organised international proficiency tests and inter-comparison measurements since 2011.

Table XIX. List of proficiency tests and inter-laboratory comparison exercises to which RAMDAN have participated

Year	Organising institution	Samples	Measurements
2011	IAEA-TEL-2011-03	soil, water	gross β, ^{3}H, GSP[10], ASP[11], ^{40}K
2011	ISIGAMMA 2011 - Swiss Federal Nuclear Safety Inspectorate	soil (ambient)	in-situ GSP
2011	NFCSO RRL	not specified	^{90}Sr, ^{3}H
2011	NFCSO RRL	building material	GSP
2011	NFCSO RRL	environment, soil (ambient)	in-situ GSP
2011	NRIRR	soil (ambient), aerosols, fallout	gamma dose rate, gross β
2012	NFCSO RRL (RRL-2012-23 and -24)	water, nettles, soil	gross α and β, ^{90}Sr
2012	EC JRC ILC Water (A-B-C) 2012	drinking water	gross α and β
2012	IAEA-TEL-2012-03, and -04	water, grass, soil	GSP, ASP, ^{90}Sr
2013	DD-KTVF	water	^{3}H
2014	IAEA-TEL-2014-03	non-identified	GSP, ^{90}Sr
2014	EC JRC	air filter	GSP
2015	NFCSO RRL	moss	gross α and β, GSP
2015	HAEA	water	^{3}H
2015	IAEA-TEL-2015-03	water, rice, soil	GSP, ASP, ^{90}Sr
2016 2014	EC JRC MetroERM / ENV57IAEA-TEL-2014-04 ALMERA	air filters, sediment, water	GSP

[10] GSP – **G**amma ray **SP**ectrometry

[11] ASP – **A**lpha **SP**ectrometry

Year	Organising institution	Samples	Measurements
2016.02.	MRI ILC-Raw Milk-2016	raw milk	GSP, ^{90}Sr
2016	IAEA-TEL-2016TEL2016-03	water, clover, pine-wood leaf	gross α and β, ^{90}Sr, GSP
2017	MRI ILC-Raw Milk 2017	raw milk	GSP, ^{90}Sr
2017.03.	IAEA-TEL-2017-03	water, milk powder, $CaCO_3$, water	GSP, ^{90}Sr, ^{3}H
2017.06.	ConVex-3	drinking water, soil, water	GSP
2017.07.	PAA	drinking water	^{3}H
2018.06.	IAEA-TEL-2018-03	drinking water, soil, water	GSP

6.9.5 Mobile monitoring systems

There are a number of organisations performing monitoring activities in the vicinity of NPP using mobile systems described below. The mobile laboratories of the Ministry of Defence (Hungarian Army) and Hungarian Academy of Sciences are not included in the list below.

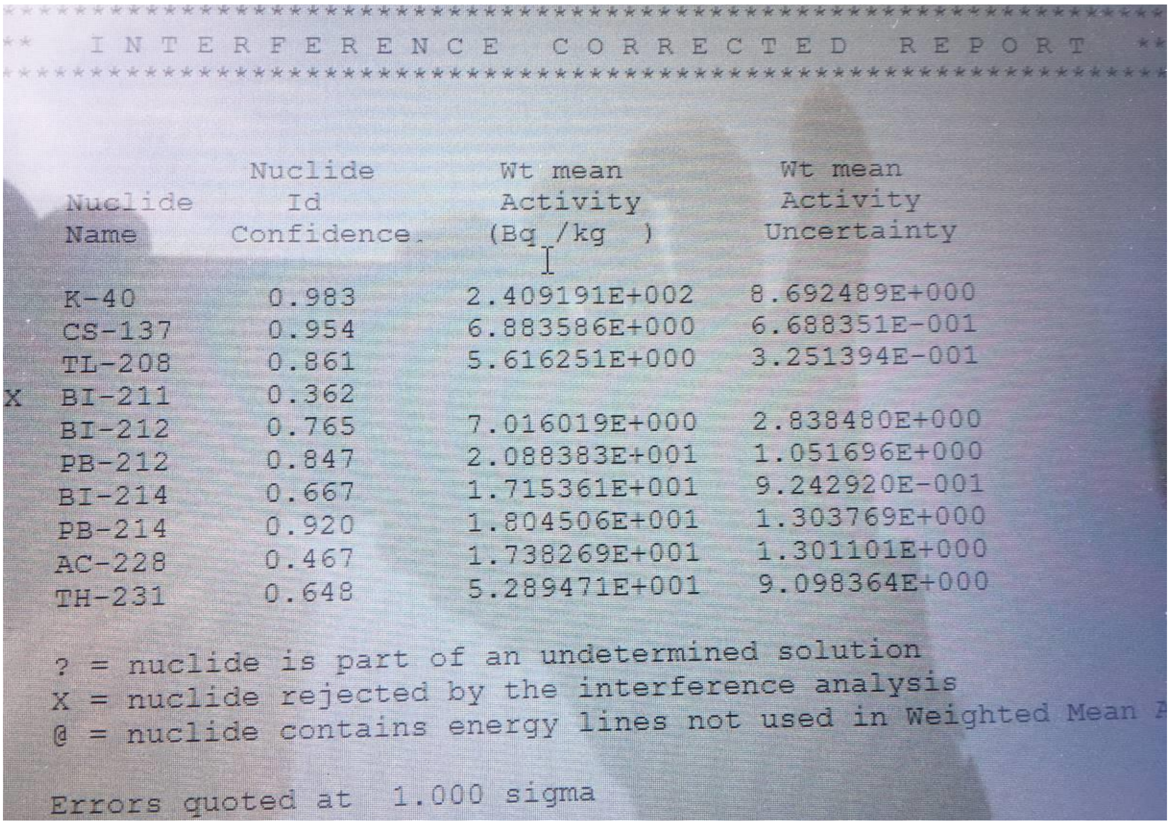
Table XX. List of mobile monitoring systems operating in the area of Paks NPP

	Ministry of Agriculture	Ministry of Human Capacities	Paks NPP	Disaster Management Branch Offices
Response time [h] Wh / NWh[12]	0 / 6	1 / 6	1 / 1	0 / 2
Vehicle type	Land Rover Defender	Ford Transit	Renault Traffic 4x4	Land Rover
Power supply	one 600 W inverter: 75 Ah, one 300 W inverter: 18 Ah	one 300 W inverter, one aggregator	two aggregators: 900 W and 1600 W, one 100 Ah accumulator	Honda EM30 3000 W, Generator
Number of personnel	2	2 + driver	3	3
In-situ gamma spec instruments	Canberra HPGe, Inspector	Canberra HPGe, Inspector	Canberra HPGe, Inspector	-
Dose rate meters	Automess 6150 AD-b	Automess AD 6/H with scintillation detector	Automess, FH 40 F1, FHZ 621 G	BNS-98, BNS-94FM, IH-95
GPS	Garmin III	GARMIN GPS map 176C	Evermore	Navi Soft

12 Working hours / Non-working hours

	Ministry of Agriculture	**Ministry of Human Capacities**	**Paks NPP**	**Disaster Management Branch Offices**
Sampling	soil, food, feed, plants	-	soil, air, water, sediment	soil, air
Analysis software	Genie 2000	Genie2000, Excel	Genie 2000 v 3.0	AmarMet
Surface contamination measurements	Automess 6150 AD-k	Contamat FHT 111M	LB 122	IH-95, IH-295 Beta-Gamma

An example of radionuclide identification performed after *in situ* gamma-ray spectrometry few hundred metres from the site boundary is given in the picture taken from the screen of the mobile equipment run by the Paks NPP (see Figure 15).



** I N T E R F E R E N C E   C O R R E C T E D   R E P O R T **

	Nuclide Name	Nuclide Id Confidence.	Wt mean Activity (Bq /kg)	Wt mean Activity Uncertainty
	K-40	0.983	2.409191E+002	8.692489E+000
	CS-137	0.954	6.883586E+000	6.688351E-001
	TL-208	0.861	5.616251E+000	3.251394E-001
X	BI-211	0.362		
	BI-212	0.765	7.016019E+000	2.838480E+000
	PB-212	0.847	2.088383E+001	1.051696E+000
	BI-214	0.667	1.715361E+001	9.242920E-001
	PB-214	0.920	1.804506E+001	1.303769E+000
	AC-228	0.467	1.738269E+001	1.301101E+000
	TH-231	0.648	5.289471E+001	9.098364E+000

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean A

Errors quoted at 1.000 sigma

Figure 15. Radionuclide identification screen on mobile gamma spectrometer

7 VERIFICATIONS

7.1 INTRODUCTION

Verification activities were carried out in accordance with the agreed programme (Appendix 2). This chapter summarises the verifications carried out the 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 Art. 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. Implementation of suggestions is not controlled after the verification.

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 MONITORING OF RADIOACTIVE DISCHARGES AT THE PAKS NPP

7.2.1 Gaseous discharges

The verification team visited the common sampling point for the two stacks of Units 3 & 4. Airflow is measured via the average result from a 3 x 3 array of isokinetic sampling probes. Measures are in place to discount the result from one probe in case of malfunction.

Two separate systems sample the air; the first for laboratory analysis (aerosols and noble gases) and the second for continuous monitoring (aerosols, noble gases, total beta and gamma).

System for laboratory analysis

Three identical parallel lines, of which one takes daily samples and two take weekly samples. One of the weekly samples is submitted to the regulator. The system can sample iodine in different chemical forms using various filters (aerosol, paper and active carbon). The flow is controlled to about 40 m^3/day.

System for continuous monitoring

A paper roll with silicon (pips) detectors for aerosol monitoring is installed. There is also an active carbon filter with a window for I-131 detection with a NaI detector. A noble gases gross beta counter in located in a shielded chamber (silicon detector).

The systems operate in parallel. They are used to give an indication of discharges *i.e*. operational and not suited for quantitative / regulatory reporting.

No remarks.

7.2.2 Liquid discharges

The verification team visited the condensate tanks (4 x 70 m^3) in Block 1 (Units 1 & 2). The tanks collect the steam condensate. When one tank is full, the next tank is connected and filled. Depending on operational conditions, the time to fill one tank varies from around eight hours to two weeks. The full tanks are homogenised prior to sampling (5 litre sample) from the bottom of the tank. Sampling containers are pre-labelled in the laboratory and the date / time are noted at the time of sampling. After analysis, the Chief Engineer can take the decision to discharge the tank. The Head of

Environmental Protection is consulted when the results of the total beta activity > 100 Bq/l. The upper limit for discharge is 1000 Bq/l. If necessary liquids can be sent for treatment. A weekly combined representative sample is analysed by gamma spectrometry and tritium.

An operator from the dosimetry service breaks the seal on the discharge valve and records the discharged volume and duration of the discharge. The operator also notes the placing and breaking of the seals.

Water from the sumps also goes to the condensate tanks along with liquid generated during boric acid adjustments. In addition, during an outage water from the steam generators also follows the same route.

Wash waters *e.g*. from showers and the laundry are collected in a dedicated tank. They are subject to the same sampling and analysis as the condensate tanks, though the seal numbers are not recorded. During normal operation little or no activity is detected. Activity is usually detected during outages. The contents of the wash water tanks can be sent for treatment if required, however such an instance has not yet been recorded.

Site drainage (rain, snow) and cooling waters are discharged directly to the channel leading to the River Danube. There is a sampling point prior to discharge.

The team visited the sampling station on the discharge channel prior to final discharge to the Danube. There are two sampling points:

- V2 – the "clean / warm waters" including the cooling waters and the site drains. There is continuous sampling (every 30 s) with 5 samples per week sent for analysis. There is a daily gross beta analysis and a monthly measurement of gamma and tritium.
- V3 – waste waters from the NPP auxiliary buildings (condensate *etc*.). Sampling and analysis is the same as V2, but only take place during discharges from the auxiliary buildings.

The temperature of the discharges in the channel is also measured as there is a discharge limit of 30 °C for discharges to the Danube.

No remarks.

7.3 OPERATOR'S LABORATORY FOR DISCHARGE SAMPLES

The laboratory is accredited under ISO/IEC 17025:2005. There is a chemical preparation room, used for storage of samples and evaporation of samples analysed by alpha spectrometry. In the sample preparation room samples are prepared by distillation (Sr-90 sample preparation). Liquid scintillation counting samples are prepared for tritium and radiocarbon analysis.

The analysis room contains a liquid scintillation counter, 5 liquid nitrogen cooled gamma-ray spectrometers, 5 alpha-particle spectrometers and a gross beta counter with 8 measurement chambers.

All samples are uniquely identified at the sampling point and assigned a running number in the laboratory. Whilst the person preparing the samples registers them, their name is not recorded.

All personnel are trained to perform all the analyses, following established procedures. There is no recording of the performance of the personnel.

For gamma spectrometry, weekly background checks are performed and a check source measured every 3 months. (*i.e*. very long interval) Criteria to accept the results of the check source measurement are a FWHM < 3 keV, energy offset < 1.5 keV, activity is < 10 % deviation from the certified value. Recalibration is only done if deemed necessary. Results of proficiency test are good, but the laboratory tends to underestimate their reported uncertainties.

Aerosol samples are registered and measured immediately for gamma and total beta activity. The same applies for the I-131 in the filters. During shut down As-76 is sometimes encountered in these filters.

For tritium samples are heated to 450 °C and condensed in a liquid nitrogen bath.

Liquid and airborne Sr-90 is sampled and measured on a quarterly basis. The filters are heated and the Sr-90 is collected on ion exchange resins which are analysed by liquid scintillation counting.

Verification team suggests increasing the frequency of performance checks of the equipment and introducing a graphical trend follow-up of equipment performance with clear set criteria.

7.4 ON-SITE ENVIRONMENTAL MONITORING

The verification team visited a limited number of representative equipment forming part of the operator's on-site monitoring programme.

Of primary importance, especially in the event of an emergency is access to reliable meteorological data. Winds are generally from N/NW and are measured with a SODAR wind profiler since 2013. Every 2 seconds, the SODAR wind profiler emits a sound pulse and detects its echo. The maximum vertical range of detection is 500 m; divided in 5 m steps. The SODAR wind profiler operates in parallel with the nearby meteorological tower that supplies data on temperature, rainfall, radiance, *etc*. Both the tower and the SODAR are located on seismic resistant bases in the vicinity of the cooling water intake.

The verification team visited also the T70 piezometer for ground water sampling located nearby.

A number of gamma dose rate stations (BITT probes) were visited inside the plant perimeter. There is a short term plan to upgrade the UPS power supply providing 72 h-back-up power. Following the need to incorporate lessons learnt during post-Fukushima stress tests, a number of these stations might be relocated to reduce their seismic threat.

Every 6 months, the operator's emergency vehicle (Ford Transit 4x4) is driven on a pre-defined route inside the perimeter fence to take measurements as part of an exercise. The vehicle is fully equipped to measure surface contamination. Personnel is trained to undertake sample of soil, air and water for subsequent laboratory analysis. The use of the Falcon 5000 (Canberra) in-situ gamma-ray spectrometer was demonstrated.

No remarks.

7.5 OPERATOR'S LABORATORY FOR ENVIRONMENTAL SAMPLES

Laboratory operations commenced in 1981, prior to the plant start-up in 1982. Staff consists of a laboratory responsible and an assistant, 3 laboratory operators and 2 sampling technicians. In the laboratory, a separate area is designated for the reception of potentially higher activity samples, typically from V3 (technological water) stations.

Accreditation according to ISO/IEC 17025:2005 is valid until September 2019 and covers all activities of the laboratory operations, measurements, sampling, and analysis. Only the hand held devices are not covered by the accreditation. Future accreditation will be under the 2017 version of the standard.

All aspects of laboratory operation, from sample reception, recording, preparation, analysis and recording of results were expansively discussed. Calibration of the gross beta measuring instrument is carried out at each gas replacement. The five HPGe detectors are calibrated annually using certified sources, or more regularly if anomalies are observed. In addition, both energy and efficiency are monitored. All instruments had logbooks for all calibrations. At the time of the visit, the FHT 770T gross beta measuring instrument was not operational, though provision had been made in the 2019 budget for its replacement.

No remarks.

7.6 OFF-SITE ENVIRONMENTAL MONITORING (OPERATOR AND REGULATORY AUTHORITY)

One of the 9 “A” type stations was visited. It contains a thermo-luminescent dosimeter (TLD), an aerosol and iodine sampling facility, an air sampling facility for tritium (H-3) and radiocarbon (C-14) measurements. The air sampler uses a gas meter for flow rate measurement; its filter is exchanged weekly. At the same location, a fallout sampler was located (see Figure 4). Soil sampling by the regulatory authority was demonstrated (grass removed and sample taken at a depth of 5-10 cm). Additionally a gamma dose rate probe and TLD were seen. Several “G” type stations were build up in 2004; these were not visited. Similarly the “C” type stations situated in the 30 km boundary from the plant were not visited.

One large volume air sampler was opened during the verification to demonstrate its filters. These are shown in the Figure 16 and Figure 17 below.

Figure 16. The large volume air sampler (left – assembled, right – taken apart)

Figure 17. The large volume air sampler disassembled. On the left – filter at the bottom of the sampler, mesh in the middle, on the right – fine filters situated on the top part.

Gamma dose rate probes rely on cables for power and communication but can function on battery power if located near an "A" type station. In the future, their autonomy will be extended to 72 h. Operational arrangements prevent two adjacent probes being unavailable simultaneously.

V1 (incoming), V2 (outgoing) and V3 (technological) water sampling stations were also visited (described in chapter 7.2.2).

No remarks.

7.7 TOLNA COUNTY PUBLIC HEALTH LABORATORY

This laboratory analyses food and environmental samples taken in the vicinity of the Paks NPP and in the surrounding area. It is not formally accredited; nevertheless, applies methods accredited elsewhere. Current staff comprises three persons, down from five in the past. In the event of an emergency two people will be on duty. Over 2000 analyses are performed annually, with about 900 directly related to the NPP. Separate areas are dedicated to food and environmental samples.

Currently only one gamma detector is available, though a second detector is due to be delivered soon. As a result, measurement times have been reduced to maintain the same throughput of samples. A UPS provides backup power in the event of a mains power failure.

All equipment (balances, ovens, analytical, *etc*.) was clearly identified. Registration and identification of samples was fit for purpose, though the laboratory is not equipped with a laboratory information management system.

Outside of the laboratory, the station equipped with both low and high (Hunter) volume air samplers was visited. Both had problems in 2017; operation was resumed in 2018. Fallout is also collected here.

No remarks.

7.8 BARANYA COUNTY GOVERNMENT OFFICE

The Dept. of Public Health, Radiochemical Laboratory has ISO/IEC 17025 accreditation for over 20 years for all analytical techniques utilised. Its national competence in the field of radiological environmental monitoring derives from Decree 71/2015. The samples analysed at the laboratory include the aerial and liquid discharges from the Paks NPP; environmental monitoring including surface and groundwater; samples from the Danube (sediment, plants, and fish) and aerial monitoring such as gamma dose rates, radioactivity in air concentration and deposition of radionuclides.

The laboratory also takes part in international cooperation, mainly with Serbia and Croatia. It participates in both national and international proficiency test, most recently for IAEA in October 2018. The laboratory is run by three analysists, a QA manager and a section head.

The team visited all areas of the laboratory relevant for the environmental monitoring. Sample preparation takes place in the chemical and physical preparation rooms. In the chemical preparation room samples are split and liquid samples evaporated for Sr-90 analysis. In the physical preparation room a range of techniques are available, such as distillation, digestion, crushing and grinding.

All samples have a unique ID; some have a second ID if results are reported to another body.

The liquid scintillation counter room has two counters. The background is measured prior to each measurement but it is not clear what the acceptance criteria are and how the results are used to correct the sample measurements. No standards are measured with the samples. A standard quench series is run once per month.

The gamma laboratory monitors site discharges and reports to both the operator and regulator. The weekly water samples are measure for gamma and tritium content. Sr-90 is measured on a quarterly basis. The backgrounds and standards do not appear to be measured systematically and again acceptance / rejection criteria are unclear. However the results from participations in proficiency tests appear to be acceptable.

Finally, results seem to be entered manually in databases. , which will leave open the possibility of transcription errors

> *The verification team suggest a more systematic approach to follow-up the performance of analytical equipment and personnel. The use of control charts can help in this aspect.*

> *The verification team suggests a more automated system of sample following and reporting to reduce the risk of transcription errors.*

7.9 NATIONAL FOOD CHAIN SAFETY OFFICE

Most sampling related to the NPP programme is carried out by staff from the Szekszard laboratory and analysis is performed at the Kecskemét laboratories. Nevertheless, it was decided to visit the radioanalytical reference laboratory in Budapest. This serves as the national reference laboratory and since 2005, as an IAEA collaborating centre. All laboratories subordinated to the national food chain safety office have ISO/IEC 17025 accreditation and employ identical accredited methods.

The visited laboratories were comprehensively equipped and well staffed. All equipment was labelled and calibrations were in date.

Currently, all measurement protocols are printed and checked by three people before manual input to the central computer. This, along with sampling, has been identified as a risk factor according to the ISO/IEC 17025:2017 standard. Work has already begun to address these issues with a view to adhering to the new standard and ensuring that ISO/IEC 17025 accreditation can continue in the future.

In addition to routine analysis, the reference laboratory is fully equipped to prepare reference materials, notably for inter-laboratory comparison exercises.

> *No remarks.*

8 CONCLUSIONS

All verification activities that had been planned were completed successfully. In this regard, the information supplied in advance of the visit, as well as the additional documentation received during and after the verification activities, was useful.

The information provided and the verification findings lead to the following observations:

(1) The verification activities that were performed demonstrated that the facilities necessary to carry out monitoring of levels of radioactivity in air, water and soil at the Paks nuclear power plant and in its vicinity are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.

(2) The verification activities that were performed demonstrated that the facilities necessary to carry out monitoring of levels of radioactivity in air, water and soil at the Paks nuclear power plant in the event of a radiological emergency are adequate. The Commission could verify the availability of a representative part of these facilities.

(3) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the gaseous and liquid discharges at the Paks nuclear power plant are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.

(4) The verification summary is presented in the 'Main Conclusions' document that is addressed to the Hungarian competent authority through the Permanent Representative of Hungary to the European Union.

(5) The Commission services ask the Hungarian competent authority to inform them of any major changes in the monitoring systems with regard to the situation at the time of the verification.

(6) The verification team acknowledges the excellent co-operation it received from all persons involved in the activities it performed.

APPENDIX 1

THE VERIFICATION PROGRAMME

Art. 35 Euratom verification in Hungary

Paks NPP
Discharge and environmental radioactivity monitoring
National environmental radioactivity monitoring network in the vicinity
1 – 5 April 2019

	Team 1	**Team 2**
2 April 2019	9.00 Opening meeting and access formalities	
	13.30 – 17.00 Liquid discharge monitoring	13.30 – 17.00 On-site environmental monitoring
3 April 2019	9.00 – 12.30 Gaseous discharge monitoring	9.00 – 12.30 Off site environmental monitoring
	13.30 – 17.00 Operator's laboratories for discharge monitoring	13.30 – 17.00 Operator's laboratories for environmental monitoring
4 April 2019	9.00 – 11.30 Regional laboratories for discharge monitoring	9.00 – 11.30 Regional laboratories for environmental monitoring
	13.30 – 16.00 Closing meeting	
	16.00 - 18.00 EC teams travel to Budapest	
5 April 2019		9.00 – 13.00 NRIRR laboratories Budapest