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Verification under the terms of Article 35 of the Euratom Treaty

Technical Report

CROATIA
Zagreb

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

1-3 October 2019

Reference: HR 19-05

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35

OF THE EURATOM TREATY

FACILITIES	Routine and emergency radioactivity monitoring arrangements Monitoring of radioactivity in drinking water and foodstuffs
LOCATIONS	Zagreb, Croatia
DATES	1-3 October 2019
REFERENCE	HR 19-05
TEAM MEMBERS	Mr V. Tanner (team leader) Ms M. Mihaila
REPORT DATE	27 December 2019
SIGNATURES	

V. Tanner

M. Mihaila

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Annex 1 Verification programme

Abbreviations

CBRN	Chemical, Biological, Radiological, Nuclear
CEWS	Croatian Early Warning System
CPD	Civil Protection Directorate
EURDEP	EUropean Radiological Data Exchange Platform
GM	Geiger-Müller
HPGe	High-purity Germanium
IAEA	International Atomic Energy Agency
IMROH	Institute for Medical Research and Occupational Health
LIMS	Laboratory Information Management System
MoA	Ministry of Agriculture
MoH	Ministry of Health
SI	State Inspectorate -Sanitary inspection
MoI	Ministry of the Interior
RBI	Ruđer Bošković Institute

TECHNICAL REPORT

1 INTRODUCTION

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

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

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

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

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 Preamble

The Commission notified Croatia of its decision to conduct an Article 35 verification in a letter addressed to the Croatian Permanent Representation to the European Union. The Civil Protection Directorate (CPD) of the Ministry of the Interior (MoI) was designated to lead the preparations for the visit.

2.2 Documents

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

2.3 Programme of the visit

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

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

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

[3] Replies to the preliminary information questionnaire addressed to the national competent authority, received on 3 September 2019

The opening meeting included presentations on Croatian automatic radiation monitoring system and other environmental radioactivity monitoring arrangements. The verification team pointed to the quality and comprehensiveness of all the presentations and documentation.

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

MINISTRY OF THE INTERIOR – CIVIL PROTECTION DIRECTORATE (CPD)

Ms. Zdravka Tečić	Head of Radiological and Nuclear Safety Sector
Ms. Sanja Krča, dr.sc.	Head of Nuclear Safety Department
Ms. Sonja Šoštarić	Professional Associate, Unit for the Environment and Radioactive Waste
Ms. Stela Popović, dr. med.	Head of Department for Radiological and Nuclear Emergency

INSTITUTE FOR MEDICAL RESEARCH AND OCCUPATIONAL HEALTH – RADIATION PROTECTION UNIT (IMROH)

Mr. Branko Petrinec	Senior Research Associate
Mr. Tomislav Bituh	Research Associate
Mr. Zdenko Franić	Scientific Advisor

RUĐER BOŠKOVIĆ INSTITUTE (RBI)

Ms. Gorana Karanovic	Senior Associate
Ms. Ivana Coha	Senior Associate
Ms. Ivana Tucakovic	Research Associate
Mr. Željko Grahek	Senior Research Associate, Head of the Laboratory for Radioecology

MINISTRY OF AGRICULTURE (MoA)

Ms. Darija Vratarić

STATE INSPECTORATE - SANITARY INSPECTION (SI)

Ms. NadA Laktić

Ms. Kristina Vuljanić

Mr. Josip Piskać

MINISTRY OF HEALTH (MoH)

Mr. Mario Vukoja

3 LEGAL FRAMEWORK FOR RADIOACTIVITY MONITORING

3.1 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

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

- Act on Radiological and Nuclear Safety (OG 141/13, 39/15, 130/17 and 118/18)
- Ordinance on Environmental Monitoring of Radioactivity (OG 40/18)
- Act on the water for human consumption (OG 56/13, 64/15,104/17,115/18)
- Ordinance on the conformity parameters, analysis methods, monitoring and water safety plans for human consumption and manner of registry of legal entities operating public water supply (OG 125/17)

3.2 LEGISLATIVE ACTS REGULATING RADIOLOGICAL SURVEILLANCE OF FOOD

In Croatia, the following legal texts regulate the monitoring of radioactivity in food:

- Act on food (81/13; 14/14, 115/18)
- Act on the Import of Feed and Food from third countries (OG 39/13, 114/18)
- Law on the State Inspectorate (OG 115/18)

3.3 INTERNATIONAL LEGISLATION AND GUIDANCE DOCUMENTS

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

The Euratom and the European Union legislation

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

- Commission Regulation (EC) No 1609/2000 of 24 July 2000 establishing a list of products excluded from the application of Council Regulation (EEC) No 737/90 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Commission Regulation (EC) No 1635/2006 of 6 November 2006 laying down detailed rules for the application of Council Regulation (EEC) No 737/90 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Commission Implementing Regulation (EU) 2016/6 of 5 January 2016 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station and repealing Implementing Regulation (EU) No 322/2014
- Commission Recommendation 2000/473/Euratom of 8 June 2000 on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole
- Recommendation 2004/2/Euratom of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation
- Commission Recommendation 2003/274/Euratom of 14 April 2003 on the protection and information of the public with regard to exposure resulting from the continued radioactive caesium contamination of certain wild food products as a consequence of the accident at the Chernobyl nuclear power station

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

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

4 BODIES HAVING COMPETENCE IN RADIOACTIVITY MONITORING

4.1 Civil Protection Directorate of the Ministry of the Interior

The Civil Protection Directorate (CPD) of the Ministry of the Interior (MoI) is in charge of radiological surveillance in Croatia. The responsibilities of the CPD are defined in the Act on Radiological and Nuclear Safety (OG 141/13, 39/15, 130/17 and 118/18). The duties are distributed within units according to the Regulation on internal organization of the Ministry of the Interior (OG 24/19) and in the internal act.

Implementing measures for radiological and nuclear safety are pursued through regular activities of the following organisational units of the CPD:

- **Radiological and Nuclear Safety Sector** is responsible for approving activities with ionizing radiation sources; nuclear activities and activities of managing radioactive waste and disused sources. It issues permits for transportation and transit of ionizing radiation sources, conducts independent analyses of safety and issues decisions and approvals for location, design, construction, use and decommissioning of nuclear facilities. It takes part in the procedure for issuing location permits and building permits, and in the procedure for issuing operation permits for structures that accommodate ionizing radiation sources, or in which operations involving ionizing radiation sources are carried out. This sector is also competent for granting authorisation to professional technical services and nuclear safety experts; organising tests on the presence of the type and intensity of ionizing radiation in the environment, food, feed, medicaments and general use items under regular conditions, and in cases of suspected emergency. It also organises professional education on the implementation of radiological and nuclear safety measures.
- **Radiological and Nuclear Emergency Department** within the CPD provides expert assistance in the case of a radiological or nuclear incidents or accidents and takes part in organising the system of preparedness in the case of an emergency. It prepares and carries out necessary expert and technical activities of the preparedness program and activities in the case of an emergency, and drafts the Assessment of nuclear and radiological risk for the Republic of Croatia. In addition, it approves the preparedness and response plans for a radiological emergency and plans operations involving ionizing radiation sources and other tasks within its scope.
- **Radiological and Nuclear Safety Inspection** within the CPD is responsible for carrying out inspections and monitoring the implementation of provisions of the Act and provisions adopted on the basis thereof.

4.2 Ministry of Health and Ministry of Agriculture

Jurisdiction in the area of food safety is divided between the Ministry of Health and the Ministry of Agriculture, while the area of food safety for animals, animal health and welfare, and plant health and protection are under the jurisdiction of the Ministry of Agriculture.

Ministry of Health is responsible for legislation for drinking water consumption (Directive 2013/51/EURATOM).

State Inspectorate Border Sanitary Inspection supervises shipments in accordance with the Regulation (EU) 2016/6 on introduction of special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima Nuclear Power Plant, in accordance with the provisions of the Law on the Import of Feed and Food from third countries.

4.3 Rudjer Bošković Institute

The Laboratory for Radioecology of the Ruđer Bošković Institute (RBI) provides contributions to the knowledge and to the better understanding of biogeochemical behaviour of natural and artificial radionuclides in the environment. RBI is accredited according to ISO/IEC 17025. Its work is based on development and advancement of methods and procedures for alpha, beta and gamma radioactivity measurements. It carried out a survey of radionuclides in drinking water according to Drinking Water Directive 2013/51/EURATOM (E-DWD) to check the compliance with the parametric values.

The institute has no direct role in the routine environmental radioactivity monitoring in the Republic of Croatia, but it participates in monitoring of radioactivity in environment of the NPP Krško and in monitoring of radioactivity in the Danube river; in addition it maintains laboratory capabilities to carry out monitoring projects and mobile equipment for local monitoring in the event of an emergency. It participates also in the monitoring of liquid discharges from the Krško NPP to the Sava River flowing through Zagreb. It also operates an automatic continuous sampler of the river water for radioactivity analysis (one-month composite sample).

4.4 Institute for Medical Research and Occupational Health

The Radiation Protection Unit of the Institute for Medical Research and Occupational Health (IMROH) carries out research in the field of radiation protection and radiation science, which is facilitated via scientific research projects and professional activities on public health related issues. IMROH is in charge of implementing the off-line environmental radioactivity surveillance programme in Croatia; it also operates a mobile laboratory for monitoring in the event of an emergency. In addition, it carries out radioactivity analyses on commercial basis.

IMROH is accredited according to ISO/IEC 17025. Quality assurance is performed by the competent authority (Croatian Accreditation Agency) by verifying the methodology of evaluating the results of measurements and by verifying the availability of documentation on the basis of which the evaluation of measurement results is performed. Additionally, IMROH regularly participates in domestic and international interlaboratory comparisons and proficiency tests.

5 RADIOACTIVITY MONITORING IN CROATIA

5.1 AUTOMATIC DOSE RATE MONITORING NETWORK

5.1.1 General

The Ministry of Interior operates on-line national radioactivity monitoring (the Croatian Early Warning System CEWS) in Croatia. This monitoring system consists of 33 measuring stations (25 BITT technology devices and 8 ENVINET a.s. devices), and a central unit where the data are collected, analysed and stored.

The BITT and ENVINET stations are not identical, so technically there are two different networks providing data to the same central system. Each monitoring station continuously measures the ambient gamma dose rate. Radionuclide concentrations in the atmosphere and certain meteorological parameters are measured at two BITT stations. After each measuring cycle, data from measurement stations are fed back to the central units located at the MoI. If elevated radiation levels are detected, an alarm system is automatically triggered and the duty officer examines the measurement data. Results on the continuous monitoring are available on the web site https://gis.ericsson.hr/rns/. Within the central unit, a software application for remote management of the measuring stations as well as data analysis has been implemented.

All monitoring locations of the telemetric networks operated by MoI (33 gamma dose rate stations and two stations measuring aerosol particles and meteorological parameters) are shown in figure 1.

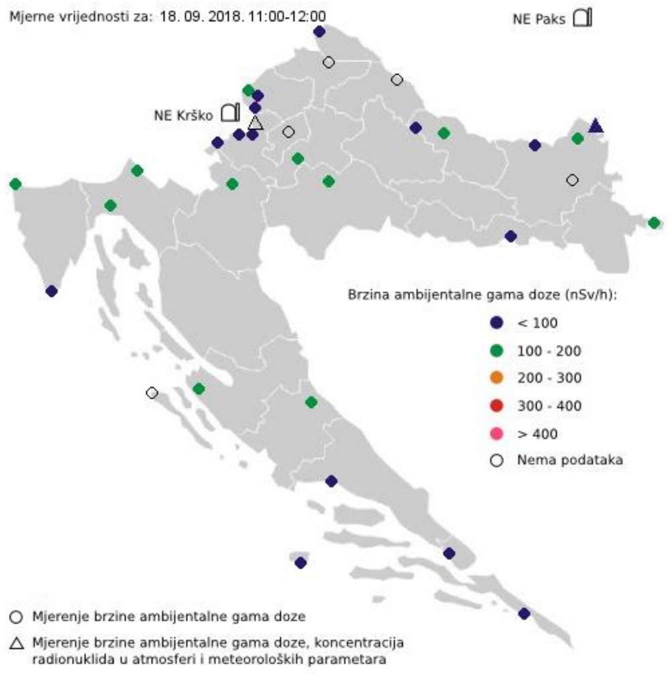

Figure 1. Locations of the stations of the Croatian Early Warning System (CEWS) (circles: gamma dose rate monitors; triangles: air radionuclide concentrations and dose rate monitors)

5.1.2 BITT station network

In the BITT station network there are five types of measuring stations, as described in table I.

Table I. Main characteristics of the BITT station types

Station Type	Description
A	***BITT RS04H/232***: γ dose rate, wide range, redundant communication
B	***BITT RS04L/232***: γ dose rate, reduced range, redundant communication
C	***BITT RS04L/232Solar***: γ dose rate, reduced range, single communication, autonomous
D	***BITT AMS02A with RS04H/232***: γ dose rate, wide range; air monitoring; meteorology; redundant communication
E	***BITT AMS02A with RS04L/232***: γ dose rate, reduced range; air monitoring; meteorology; redundant communication

Type A stations – *BITT RS04H/232*

Type A stations are used for measuring gamma dose rate. The BITT RS04H/232 station consists of a dose rate measuring probe (sensor), a data logger, a communications terminal, a DC-UPS system, a cabinet and all necessary cable interconnections.

The gamma dose rate sensor is physically separated from the data logger. Measuring range of the sensor is 10 nSv/h – 10 Sv/h. Data logger, communication terminal and the UPS system are located in a single wall mounted indoor cabinet. The cabinets are installed in existing buildings supplied with electric power and wired communication links. The gamma dose rate sensor is installed outdoors on a tripod. Sensor and the data logger are connected by an underground cable connection.

The stations support bidirectional communication with the central unit by using DSL as primary connection and GPRS as secondary (backup) connection. The secondary link is used if the communication cannot be established through the primary link. Switching between the communication links is done without human intervention. The communication terminal for the DSL connection (i.e. DSL modem/router) is located inside the measuring station cabinet. The communications terminal for the GPRS connection (i.e. GPRS modem/router with SIM cards) is an integral part of the measuring station.

The stations have lightning and power surge protection. Maintenance is carried out once a year.

Type B stations – *BITT RS04L/232*

For Type B stations, the required gamma sensor measuring range is reduced to 10 nSv/h – 15 mSv/h. All other characteristics are identical to the characteristics of Type A stations.

Type C stations – BITT RS04L/232 Solar

Type C stations are outdoor located autonomous stations, which are used for measuring gamma dose rate at locations where electric power and wired communication lines are not available. The station consists of gamma dose rate measuring sensor, data logger, communications terminal, solar panel with battery, cabinet and all necessary cable interconnections. Measuring range of the sensor is 10 nSv/h – 15 mSv/h.

Type D station – *BITT AMS02A* with *RS04H/232*

The Type D station is a station for measuring gamma dose rate, air radioactivity and meteorological parameters. It consists of a gamma dose rate sensor, meteorological sensors, an air measuring unit, data logger, communications terminal, outdoor container, UPS system and all necessary cable interconnections. Measuring range of the gamma dose rate sensor is 10 nSv/h – 10 Sv/h.

Air is pumped through the system at a flow rate of ca. 6 m^3/h. Aerosols are collected on glass fibre filters (60 mm diameter) and immediately analysed by alpha and beta spectrometry (PIPS detector with an area of 1700 mm^2) and by gamma measurement (2x2" NaI(Tl) detector). A subsequent special active carbon filter (60 mm diameter) allows analysis of elemental iodine with a 2x2" NaI(Tl) detector. The AMS-02 device contains racks with 400 aerosol filters and 100 iodine filters. Before each measurement, a series of energy calibrations is performed using ^{137}Cs in the filter geometry. The filters (including check filters for calibration) are moved within the device using a robotic manipulator system.

All the components except the sensors are located inside the container. The station supports bidirectional communication with the central unit by using DSL as the primary connection and GPRS as the secondary (backup) connection. The secondary link is used if communication cannot be established through the primary link. Switching between the communication links is done without human intervention.

The mast for the meteorological sensors and the gamma dose rate probe are mounted on top of the container. The station has lightning and power surge protection.

Type E station – *BITT AMS02A* with *RS04L/232*

For the Type E station the required gamma sensor measuring range is reduced to 10 nSv/h – 15 mSv/h. All other characteristics are identical to the characteristics of the Type D station.

All BITT devices are powered by a photovoltaic cell with the peak output of 240W. At night and in the time without sufficient solar output the devices are supplied by a back-up battery.

One of BITT stations is located at the premises of Ruđer Bošković Institute in Zagreb (Figure 2).

Figure 2. CEWS monitoring station (BITT) at the Ruđer Bošković Institute in Zagreb

5.1.3 ENVINET station network

Within the IPA 2011 project "*Upgrading of emergency preparedness system in the Republic of Croatia*" the existing BITT system was upgraded with eight gamma dose rate probes installed at the locations Velika Gorica, Sisak, Beli Manastir, Virovitica, Ploče and Knin. These monitoring stations were provided by ENVINET a.s. in the Czech Republic. Type of the stations is NuEM RAMS. This is an autonomous monitoring station for monitoring of radiation situation (input of spatial dose equivalent of environment). Radiometric station is designed for radiation monitoring networks in the specified territory and for including into networks of early detection. Measurements are done using two GM tubes (low and high dose rate). The system is powered by a solar system. Data transfer is performed through the GSM network; data are recorded by a web service running on the application server.

Figure 3. CEWS monitoring station (ENVINET) at Ploče

5.2 MONITORING OF RADIOACTIVITY IN THE ENVIRONMENT

5.2.1 Introduction

Besides the on-line environmental monitoring, off-line environmental monitoring is in place on the territory of Croatia. The main laboratory performing national environmental monitoring is the Radiation Protection Unit of the Institute for Medical Research and Occupational Health (IMROH) in Zagreb. The programme includes monitoring of radioactivity in air, water, soil, biota and food. In addition, there are equipment available for mobile monitoring in emergencies.

The following equipment is used by IMROH in the national environmental radioactivity programme:

Gamma spectrometry

IMROH has three HPGe gamma spectrometers with the following characteristics:

Resolution	below 1.5 keV at 40 keV or below 2.5 keV at 1.33 MeV
Relative efficiency (at 1.33 MeV ^{60}Co)	16% - 70% (depending on the detector)
Number of channels in spectrum	at least 4096
Energy interval (calibrated)	from 40 to 2000 keV
Calibration uncertainty	below 10% in the energy interval from 40 to 2000 keV

Samples are prepared and packed in different geometries: Marinelli beakers (1 L) or plastic containers (100 mL and 200 mL) depending on the matrix.

^{90}Sr analysis

IMROH has a low-level beta GM multi-counter system RISØ GM-25-5 (efficiency for ^{90}Sr on a filter paper on thallium disc ~50 %). The radiochemical separation procedure is described in detail in the U.S. Department of Energy document[4].

4 U.S. Department of Energy, Environmental Measurements Laboratory (EML) procedures manual. HASL 300 Series, 1957-1997

^{226}Ra analysis

IMROH has an alpha-spectrometer based on a Passivated Implanted Planar Silicon (PIPS) Detector (surface area 450 mm^2; resolution <20 keV for at 5.5 MeV ^{241}Am; 1024 channels; energy range 3 to 8 MeV). The radiochemical separation procedure (precipitation with $BaSO_4$) is described in detail in the U.S. Department of Health, Education and Welfare document[5].

5.2.2 External gamma dose and dose rate

IMROH uses thermo-luminescent dosimeters (TLD) for determination of ambient equivalent dose H*(10) for photons in the energy range between 30 keV and 3 MeV. TLDs are placed at different locations in Zagreb and periodically in other cities in Croatia (Figure 4). After the measurement, the TLDs are placed into a reader (Type: Panasonic UD-716), the raw data from the reader is analysed using an algorithm and the dose is calculated.

Active electronic dosimeters (AED) for measurement of dose rate are available (sensitivity: 10 nSv/h; energy range 30 keV to 4.4 MeV). In addition, there is a digital survey meter with the dose rate range from 0.1 µSv/h to 0.99 Sv/h in the energy range from 36 keV to 1,3 MeV.

Figure 4. TLD locations

5.2.3 Air

Aerosol contamination in the air is sampled using two high-volume air samplers (Fig. 6). At the IMROH premises in Zagreb air is pumped continuously through a cellulose filter (Petrianov FPP-15-1.5) using a high volume sampler (ASS-500; 1.5 m above the ground, 500 – 750 m^3/h) (Fig. 5).

5 U.S. Department of Health, Education and Welfare (USDHEW). Radio-assay procedures for environmental samples. Environmental health series radiological health. Public Health Service Publication No. 999-RH-27 (1967); 5.49–5.52

Figure 5. High-volume air sampler at IMROH in Zagreb

Collected samples are measured by gamma spectrometry; anthropogenic and natural radionuclides are determined.

Monthly, during 14 days, air is pumped through a charcoal filter for gamma spectrometric determination of iodine (^{131}I, ^{132}I, ^{133}I, ^{134}I, ^{135}I) using a medium volume sampling system. Total beta activity in air is measured daily by sampling on a filter paper by continuously pumping ~130 m^3/day (1 m above the ground).

The second location for sampling air is in Zadar. Air is sampled on filter paper by continuously pumping about 100 m^3/day (1 m above the ground). Samples are measured quarterly by gamma spectrometry (anthropogenic and natural radionuclides are determined). Total beta activity is measured daily from the same filter samples.

Figure 6. Air sampling locations (Zagreb and Zadar)

5.2.4 Dry/wet deposition

Liquid precipitation is collected continuously for one month at collector surface areas of 0.25 m^2, 0.5 m^2 and 1 m^2. The samples are analysed by gamma spectrometry (anthropogenic and natural radionuclides are determined) quarterly **(**Zagreb, Zadar, Osijek) and semi-annually (Bjelovar, Pula, Rijeka, Dubrovnik). Samples for determination of ^{90}Sr are collected monthly (Zagreb) and semi-annually (Osijek, Zadar) (Figure 7).

Dry deposition sample is collected on a Vaseline covered plate (0,0929 m^2; 1 m above the ground) at IMROH in Zagreb. These samples are collected continuously during three months and then measured by gamma spectrometry; anthropogenic and natural radionuclides are determined.

Figure 7. Deposition collection locations

5.2.5 Water

Surface water

Surface water samples are collected at the following locations:

- River water: Sava (two locations in Zagreb, Sisak, Županja), Drava (Varaždin, Osijek), Dunav (Batina, Vukovar), Neretva (Opuzen), Krka (Skradin)
- Lake water: (Plitvice lakes-Kozjak, Vransko lake)

All locations are shown in Figure 8. Samples are collected once or twice a year. They are analysed by gamma spectrometry (anthropogenic and natural radionuclides), beta counting (^{90}Sr) and alpha counting (^{226}Ra).

Figure 8. Surface water sampling locations

Ground water and drinking water

Ground and drinking water samples are collected at the following locations:

- Tap water: Zagreb, Rijeka, Pula, Međimurje, Zadar, Split, Dubrovnik, Osijek
- Cistern water: Bale, Marina, Pag, Doli

All locations are shown in Figure 9. Samples are collected once or twice a year (except Zagreb where 1 L/day is measured quarterly). They are analysed by gamma spectrometry (anthropogenic and natural radionuclides) and beta counting (^{90}Sr).

Figure 9. Ground water and drinking water sampling locations

In addition to monitoring of radionuclides in drinking water within the regular national monitoring, a three year study (starting in 2016) of radioactivity in drinking water in the water supply zones has been performed. This was initiated by the Ministry of Health and other national institutions taking part in drinking water control (i.e. Croatian waters, Croatian Institute for Public Health and scientific institutions) in order to confirm that the concentration activities of the radionuclides in the 60 water supply zones are in compliance with the parametric values stated in the Directive 2013/51/EURATOM, and to prove that extensive monitoring is not needed. The laboratory for radioecology of the Ruđer Bošković Institute measured the content of ^{3}H, ^{222}Rn and gross α and β in drinking water. The analyses were performed on the samples delivered to RBI by the national or regional Institutes for Public Health. Sampling was performed according to the instructions provided by the RBI. For the gross α and β, radon and tritium determinations adapted procedures described in ISO 10704:2015, IS0 13164-2:2013 and 9698:2010 were used. For the radon, tritium and gross α and β activity determination, Canberra HPGe gamma spectrometry system, TriCarb 3180 TR/SL liquid scintillation counter and Canberra i-Matic counter with PIPS detector were used respectively.

Seawater

Seawater samples are collected at Rovinj, Plomin, Rijeka, Kaštela, Split and Dubrovnik (Fig. 10). Samples are collected once or twice a year. They are analysed in IMROH by gamma spectroscopy (anthropogenic and natural radionuclides) and beta and alpha counting (^{90}Sr and ^{226}Ra).

Figure 10. Seawater sampling locations

5.2.6 Soil

Soil samples (uncultivated and cultivated soil) are collected at Zagreb, Osijek, Zadar, Gospić (Fig. 11). Samples are collected once a year in layers (0-5 cm; 5-10 cm; 10-15 cm) of uncultivated soil (0-20 cm). They are analysed by gamma spectrometry (anthropogenic and natural radionuclides) and beta counting (^{90}Sr).

__Figure 11. Soil sampling locations__

5.2.7 Terrestrial and aquatic biota and flora

Terrestrial and aquatic biota and flora are sampled at the following locations:

- Aquatic (marine) biota: Rovinj, Plomin, Rijeka, Kaštela, Split, Dubrovnik (see Figure 12).
- Terrestrial flora (mushrooms, berries, moss, Iceland moss): NW Croatia region (NWC), Slavonia, Costal region (CR), Istria, Lika

Samples are collected once or twice a year. They are analysed by gamma spectroscopy (anthropogenic and natural radionuclides are determined) and beta counting (^{90}Sr).

__Figure 12. Aquatic (marine) biota sampling locations__

5.3 MONITORING OF RADIOACTIVITY IN FOODSTUFFS AND FEEDING STUFF

5.3.1 Milk

Milk samples are collected at markets (Zagreb, Varaždin) and on farms (Osijek, Zadar) (Fig. 13). Samples are collected monthly (Zagreb, Osijek, Zadar) or during two months (Varaždin, Pušća). Seven litres of milk are evaporated under UV lamps, ashed at 450 °C (for gamma spectrometry) and at 650 °C (for determination of ^{90}Sr).

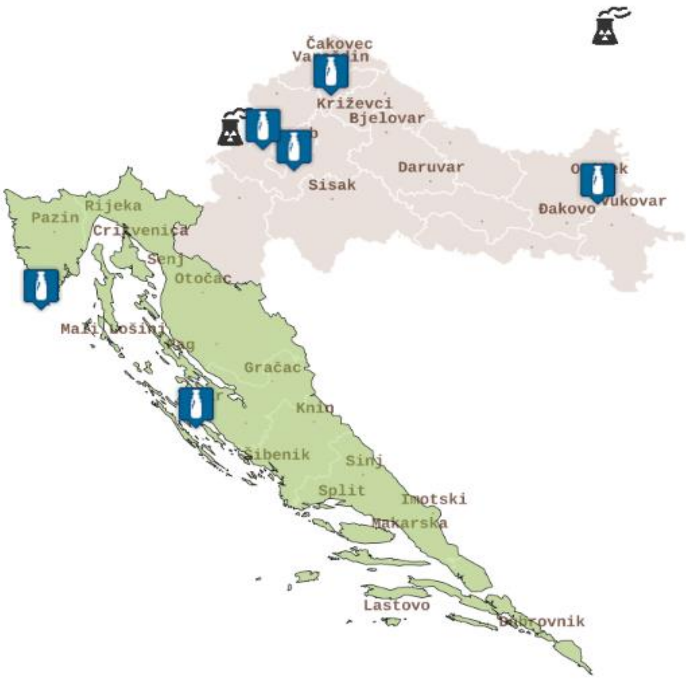

Figure 13. Milk sampling locations

5.3.2 Mixed diet

Mixed diet is sampled at five locations in Zagreb in kindergartens and student canteens. Samples are collected once a year. Samples are dried at 105 °C and ashed at 450 °C (for gamma spectrometry) and at 650 °C (for determination of ^{90}Sr).

5.3.3 Foodstuffs

Foodstuffs are sampled in three regions (Slavonia, NWC, Coastal region) in open markets. Foodstuffs collected are lettuce, beans, cabbage, potatoes, apples, eggs, chicken, beef, pork, lamb, fish, wheat and Swiss chard. Samples are collected twice a year (type of sample depends on the season). Samples are dried at 105 °C and ashed at 450 °C (for gamma spectrometry) and at 650 °C (for determination of ^{90}Sr).

5.3.4 Feeding stuffs

Feeding stuffs (grass, lucerne and silage) are collected in three regions (Slavonia, NWC, Coastal region) at farms and fields. Samples are collected twice a year. Samples are dried at 105 °C and ashed at 450 °C (for gamma spectrometry) and at 650 °C (for determination of ^{90}Sr).

5.4 EMERGENCY MONITORING

In addition to the automatic monitoring system, in Zagreb the following organisations have mobile radiation monitoring capabilities for radiological emergency situations:

- Civil protection service units are equipped with personnel dose meters and a limited number of dose rate monitors and contamination monitors.
- Ruđer Bošković Institute has hand-held monitoring equipment for local monitoring of dose rate and contamination, and capability to identify radionuclides.
- Institute for Medical Research and Occupational Health operates a mobile laboratory, which has capability to measure dose rate, alpha/beta contamination, environmental sample activity (HPGe gamma spectroscopy), air radioactivity, ground contamination and neutron radiation.

There is no airborne environmental radiation monitoring capability in Croatia. Radioactive iodine can be measured at the IMROH laboratory (medium-volume sampling system) and in the two small-volume automatic stations of the CEWS network (not located in Zagreb).

6 VERIFICATIONS

6.1 INTRODUCTION

Verification activities were carried out in accordance with the agreed programme. 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.

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

6.2 RUDJER BOŠKOVIĆ INSTITUTE

6.2.1 General

The verification team visited the Laboratory for Radioecology of the Ruđer Bošković Institute, Division for Marine and Environmental Research, situated at Bijenička road 54, 10000 Zagreb.

The Laboratory for radioecology has been accredited in 2008 by the Croatian Accreditation Agency for gamma-spectrometric, ^{89,90}Sr, ^{3}H, ^{55}Fe and gross alpha/beta measurements (HRN EN ISO/IEC 17025:2007). The laboratory participates regularly in international intercomparison exercises. Quality assurance and control procedures are implemented according to accreditation rules.

No remarks.

6.2.2 Laboratory for radioecology

Sample management of the laboratory is based on paper log books and Excel sheets on computer – there is no dedicated laboratory information management system (LIMS).

The laboratory has three fixed and two portable Canberra HPGe gamma spectroscopy systems. Depending on the sample mass and activity, the spectra are measured for 80 000 to 200 000 seconds. The measured spectra are analysed using Canberra Genie 2000 software. The detector systems are calibrated using mixed radionuclide standards supplied by Eckert & Ziegler Analytics Inc. The efficiency of the system is checked regularly during intercomparison exercises. Radionuclide activity calculations are carried out manually in Excel sheets. Efficiency is calculated in function of energy and geometry based on experimental data. Canberra LabSocs programme is available for efficiency calibrations. Detection limits of respective radionuclides are calculated for each measurement depending on measurement parameters. Calculated results lower than detection limits are reported as 'below detection limit' obtained in that measurement.

The laboratory quality management includes regular controls of HPGe-detector efficiency, resolution and energy calibration stability. The controls are carried out by comparing a measured value to pre-defined limit values – no long term trend is analysed.

The laboratory has one liquid scintillation counter (Tri-Carb 3180) for ^{3}H, ^{55}Fe and ^{89,90}Sr analysis. A second system is being acquired and will be delivered at the end of 2019.

The laboratory has also a proportional counter PIPS Canberra iMatic (alpha/beta counting) for the alpha/beta screening of drinking water samples.

There are adequate equipment and facilities for sample preparation (dryers, furnaces, evaporators, etc.) and sample storage after analysis (1-2 years). The laboratory has also a ^{3}H electrolytic enrichment system for water samples. Recorded and analysed spectra, as all other relevant data in electronic form are archived on the server of the laboratory.

Verification team recommends that the Ruđer Bošković Institute maintain long-term trend graphs of gamma spectroscopy system maintenance parameters (resolution and energy stability).

Verification team suggests that the Ruđer Bošković Institute considers implementation of a dedicated laboratory information management system (LIMS), in particular if the number of samples increases.

Verification team commends the meticulous approach to manual sample activity calculation demonstrated at the Ruđer Bošković Institute. However, if the number of samples increases a more automated procedure will be needed.

6.2.3 Mobile radiation monitoring equipment

RBI Laboratory for radioecology has a hand-held radiation monitoring equipment kit (Thermo Scientific FH40 lab-1) for monitoring personnel dose, ambient dose rate, gross alpha/beta and surface contamination at the RBI site and surroundings. These equipment are for local use; they are not part of the national emergency monitoring system.

No remarks.

6.2.4 On-site monitoring facilities

One of the stations of the automatic radiation monitoring network (CEWS) is located outside the RBI laboratory for radioecology (Fig. 2). This station is the only automatic radiation dose rate monitoring station in Zagreb.

The device of the C type is located on a small patch of grass between two small roads. Power is supplied by a solar panel and mains electricity. In the surrounding area there are a number of low buildings and semi mature trees though neither affect the probe, nor are they likely to have an adverse effect in the foreseeable future.

No remarks.

6.3 MINISTRY OF THE INTERIOR, CIVIL PROTECTION DIRECTORATE

6.3.1 Automatic dose rate monitoring network

The verification team visited the Civil Protection Directorate headquarters, situated at Nehajska 5 in Zagreb. The automatic dose rate monitoring network was presented to the team, including its public and restricted web interface. The data includes dose rate from all stations, and concentrations of Radon, ^{137}Cs and radioactive iodine from the two automatic air monitoring stations (Sveti Križ and Batina). Alarm messages are transmitted to the CPD duty officer for response within one hour.

At the time of the verification, data from the BITT automatic network was not transmitted to the data centre due to technical problems in the IT system (Alarm messages were received and the stations themselves were operational.)

The verification team recommends that the CPD proceed to make the data transmission from the BITT network stations operational as soon as possible.

6.3.2 First responders' monitoring equipment

The verification team visited the Civil Protection Directorate storage facility, where equipment for different types of civil protection operations are held. The radiation monitoring equipment available is the following:

- Dose rate monitors Mirion RDS-31 (14 units)
- Telescopic dose rate monitors Mirion RDS-31 (4 units)
- Alpha/beta monitors Berthold LB124 (10 units)
- Personal dosimeters Mirion RAD-60S (98 units)

The equipment is available for quick deployment to the civil protection services operating in a radiation environment, but there is no formalised plan on their distribution and use.

The verification team recommends that the Croatian authorities set up procedures for the equipment distribution, operation, data gathering and transmission of data to the central monitoring authority.

6.4 Institute for Medical Research and Occupational Health, Radiation protection unit

6.4.1 General

The verification team visited the Radiation protection unit of the Institute for Medical Research and Occupational Health, situated at Petrovaradinska 110 in Zagreb. The location is temporary – a new building for the laboratory is being constructed and it is expected to be available in 2022.

The unit carries out the regular environmental and food radioactivity monitoring programmes and maintains fixed and mobile radioactivity monitoring devices. In addition, it measures radioactivity in samples of imported food and different commercial samples. The regular monitoring programme is based on annual public procurement, which has created delays in the implementing and financing of the activities.

IMROH is accredited according to ISO/IEC 17025 for all the measurement methods used on performing radioactivity measurements. IMROH regularly participates in national and international (JRC-IRMM, IAEA) inter-laboratory comparisons and it is a member of the IAEA's ALMERA network.

Verification team suggests that the regular monitoring programme be based on two or three year contracts.

6.4.2 Radiation protection unit laboratory

The IMROH radiation protection unit laboratory consists of a sample preparation area, radiochemical laboratory area and counting rooms for alpha/beta counting and gamma spectroscopy. The rooms are temperature and humidity controlled, but small – the laboratory will have new facilities in 2022 when the new building is available.

Altogether there are 12 staff members assigned to laboratory tasks (3 for gamma spectroscopy, 2 for Radon monitoring, 4 for ^{226}Ra and ^{90}Sr monitoring and 3 technicians).

The laboratory staff take environmental samples according to the annual programme. The number of samples is small, so a simple paper log and Excel are used for sample management. Hand-written stickers are used to identify the samples - the laboratory has no dedicated sample management database (LIMS) or bar-coding system. The current system is time consuming and cumbersome, but sufficient as long as the number of samples remains low.

Sample preparation and storage equipment includes refrigerators, ovens and furnaces. In addition, there are evaporation equipment for water samples.

Laboratory counting equipment is the following:

- Alpha counter (Canberra Alpha Analyst, two chambers)
- Beta counter (Risø GM-25-5, 5 counting places)
- 3 Gamma spectroscopy systems (Ortec HPGe, one system not operational)

The laboratory quality management includes regular controls of HPGe-detector efficiency, resolution and energy calibration stability. The control is carried out by comparing a measured value to pre-defined limit values – no long-term trend is analysed.

Verification team recommends that the IMROH radiation protection unit laboratory maintain long-term trend graphs of gamma spectroscopy system maintenance parameters (resolution and energy stability).

Verification team suggests that the IMROH radiation protection unit laboratory considers implementation of a dedicated laboratory information management system (LIMS), in particular if the number of samples increases.

6.4.3 Mobile radiation monitoring equipment

IMROH Radiation protection unit operates a mobile laboratory van (Fig. 14), which is equipped with the following monitoring equipment:

- Portable gamma spectroscopy system (Ortec, electrically cooled) for in-situ measurements, calibrated for both environmental samples and ground contamination measurements
- ORTEC Detective-EX Portable Neutron and Gamma Nuclide Identifier with suitcase and cooling system
- Thermo Eberline FH 40G-L10 2x
- Thermo neutron probe ERM&P FHT 752 S
- Thermo alfa-beta-gamma probe for contamination FHZ 732
- Thermo gamma probe FHZ 612
- Thermo computer program and patch cable
- Thermo gamma probe FHZ 672 E-10
- Thermo telescopic probe
- Thermo FH40 LAB-0 sampling set and brass shield
- Canberra RADIAGEM
- Canberra alfa-beta probe
- Canberra alfa-beta-gamma probe
- Canberra scintillation gamma probe
- Canberra telescopic probe
- Radeco air pump with filters
- Canbera InSpector 1000 NaI/LaBr Spectrometer with neutron detection probe
- Berthold LB 124 scintillation detector of surface contamination
- Berthold UMo LB 123 neutron detector
- Mirion RDS-31 S/R Multi-purpose Survey Meter 3x
- Mirion GMP-12SD Gamma Probe for RDS-31 3x
- Devices for measuring meteorological parameters
- Canberra HPGe detector with collimators
- Tripod for in-situ gamma spectrometer
- Plastic containers for sampling sea water
- Personal protective equipment

The equipment of the mobile laboratory does not include a sampling system for radioactive iodine in air, i.e. there is no mobile iodine monitoring capability in Croatia.

Figure 14. IMROH mobile radioactivity monitoring laboratory

Altogether four IMROH scientific staff members have been trained to operate the mobile laboratory. They take part in emergency exercises on regular basis. The van has air conditioning and a 220V power supply for long-term independent operation.

The verification team was informed that currently the monitoring van is maintained and operated by IMROH based on an informal agreement; a new agreement on its use during a radiological emergency, in which obligations and responsibilities will be more clearly defined, is in preparation.

> *Verification team recommends that the IMROH acquire an additional mobile system for monitoring radioactive iodine in air in the event of an emergency.*
>
> *Verification team recommends that the operation of the mobile monitoring equipment in the event of an emergency is duly formalised and documented. The document should also contain procedures for staff training, exercises and stand-by arrangements.*

6.4.4 On-site monitoring facilities

Air sampling

The IMROH Radiation protection unit operates a high-volume air sampler for aerosol sampling (Fig. 5). Sample is collected by continuously pumping air through a cellulose filter (Petrianov FPP-15-1.5) using a high volume sampler (type ASS-500), mounted 1.5 m above ground. The airflow is about 500 - 750 m^3/h. The system is equipped with a flow counter and an infrared filter heating system. There is no procedure for calibration control of the flow counter. Filters are measured in the IMROH laboratory by gamma spectroscopy.

IMROH operates also two medium-volume air sampling systems, one for particulate sampling and one for iodine sampling (charcoal cartridge). The sampling arrangements are identical, consisting of a pump, a flow counter and a filter cartridge holder. The systems are old and not set up in a firm and fixed manner (Fig. 15 and 16). There is no electrical back up for the pumps. The flow meters have no regular calibration control.

Figure 15. IMROH medium-volume air sampling pumps

Figure 16. IMROH medium volume air sampling flow counters

Wet deposition sampling

Liquid precipitation samples are collected at a height of 1 m above ground using collectors with surface areas of 0.25 m^2 and 0.5 m^2 (Fig. 17). Samples are collected quarterly in Zagreb, Zadar and Osijek; semi-annually in Bjelovar, Pula, Rijeka and Dubrovnik. These samples are measured by gamma spectrometry. For the determination of ^{90}Sr samples are collected monthly in Zagreb and semi-annually in Osijek and Zadar.

Dry deposition sampling

A dry deposition sample is collected quarterly on a *Vaseline®* covered plate with a surface of 0.0929 m^2, mounted 1 m above ground (Fig. 18). These samples are measured by gamma spectrometry.

> *Verification team recommends renewal of the two medium-volume air sampling systems in the near future. Particular attention should be paid on the accuracy of the total flow measurement and electrical back up.*
>
> *Verification team suggests control of the high and medium volume air samplers' flow counter calibrations.*

Figure 17. IMROH wet deposition collectors

Figure 18. IMROH dry deposition collector

7 CONCLUSIONS

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

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

(1) Overall, the environmental radioactivity monitoring programmes in Zagreb comply with the requirements of Article 35 of the Euratom Treaty.

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

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

(4) A few recommendations and suggestions have been formulated. They concern in particular renewal of monitoring equipment, calibration control procedures and advance planning of emergency monitoring. Notwithstanding these recommendations, the verified parts of the monitoring system for environmental radioactivity in Zagreb are in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

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

(6) The Commission services kindly request the Croatian authorities to submit, before the end of 2021, a progress report on how the team's recommendations have been implemented and on any significant changes in the set-up of the monitoring systems. Based on this report the Commission will consider the need for a follow-up verification in Croatia.

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

ANNEX 1

VERIFICATION PROGRAMME

EURATOM ARTICLE 35 VERIFICATION IN CROATIA (ZAGREB)

1 – 3 October 2019

Tuesday 1 October

08.00 Rudjer Bošković Institute (RBI)
Laboratory for radioecology (LRE)
(Bijenička cesta 54, 10000 Zagreb)
- Environment monitoring laboratory
- On-site monitoring facilities

14:00 Opening meeting
Ministry of the Interior, Civil Protection Directorate
(Nehajska 5, 10000 Zagreb)
- European Commission Art. 35 verification programme introduction
- Discussion of recommendations given by the Commission in 2013
- Overview of environmental radioactivity monitoring arrangements in Croatia
- Overview of environmental radioactivity monitoring arrangements in Zagreb
- Verification planning

Wednesday 2 October

09.30 Institute for Medical Research and Occupational Health (IMROH)
Radiation Protection Unit
(Petrovaradinska 110, Zagreb)
- Environment monitoring laboratory
- Food monitoring laboratory
- On-site monitoring facilities
- Mobile monitoring facilities
- Air sampling
- Dry/wet deposition sampling
- Mobile monitoring systems

Thursday 3 October

09.30 Verification of other environment monitoring facilities in Zagreb
- Automatic dose rate monitoring network (CEWS) data centre
- Dose (TLD) and dose rate monitoring
- Public information arrangements

14:00 Verification of other emergency monitoring facilities in Zagreb
- Radiation measurement equipment of the first responders in the case of emergency

15:00 Closing meeting with the national competent authority
Ministry of the Interior, Civil Protection Directorate
(Nehajska 5, 10000 Zagreb)