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DIRECTORATE-GENERAL FOR ENERGY

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D.3 – Radiation protection and nuclear safety

Verification under the terms of Article 35 of the Euratom Treaty

Technical Report

SWEDEN
Stockholm

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

4-6 December 2019

Reference: SE 19-03

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	Stockholm, Sweden
DATES	4-6 December 2019
REFERENCE	SE 19-03
TEAM MEMBERS	Mr V. Tanner (team leader) Ms K. Peedo Ms E. Diaconu (trainee)
REPORT DATE	25 May 2020
SIGNATURES	

V. Tanner K. Peedo

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Abbreviations

CBRN	Chemical, Biological, Radiological, Nuclear
EC	European Commission
EURDEP	EUropean Radiological Data Exchange Platform
FOI	Swedish Defence Research Agency
GM	Geiger-Müller
HPGe	High-purity Germanium
IAEA	International Atomic Energy Agency
EIONET	The European Environment Information and Observation Network
LIMS	Laboratory Information Management System
RADD	EC Radioactive Discharge Database
REM	EC Radioactivity Environment Monitoring database
SGU	Swedish Geological Survey
SLV	Swedish Food Agency
SMHI	Swedish Meteorological and Hydrological Institute
SSM	Swedish Radiation Safety Authority
TLD	Thermoluminescent dosimeter

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 Sweden of its decision to conduct an Article 35 verification in a letter addressed to the Sweden Permanent Representation to the European Union. The Swedish Radiation Safety Authority (SSM) 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 SSM 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 20 November 2019

The opening meeting included presentations on the Swedish 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:

Swedish Radiation Safety Authority (SSM)

- Hélène Asp, head of section, environmental assessment
- Sofia Eriksson, head of section radiation measurements
- Pål Andersson, analyst at the unit for environmental assessment
    - National environmental radioactivity monitoring, reporting according to Euratom Art. 35/36, contact person for Euratom Art. 35/36
- Simon Karlsson, analyst at the unit for emergency preparedness and response
    - Field radiation monitoring strategies for emergency preparedness, coordination of laboratories within the National Expert Response organisation
- Mikael Westin, analyst at the unit for emergency preparedness and response
    - Gamma monitoring networks, field radiation measurements
- Mats Eriksson, senior specialist, unit for radiation measurements
    - Responsible for the analytical laboratory

Swedish Defence Research Agency (FOI)

Department for Nuclear Weapons-Related Issues, Division for CBRN Defence and Security

- Johan Kastlander, Senior Scientist
    - Project manager for environmental radioactivity monitoring
- Martin Goliath, Senior Scientist,
    - Co-worker within the environmental radioactivity monitoring project

Swedish Geological Survey (SGU)

- Henrik Johansson, Geophysicist and team leader of the airborne geophysics group
    - Senior survey operator and data processor
- Cecilia Jelinek, Geophysicist
    - Survey operator and data processor

Swedish Food Agency

- Barbro Kollander, Senior Chemist
    - Project leader for the radiation group
- Christer Johansson, inspector
    - Inspector, Drinking water
- Agneta Tollin
    - Inspector, Drinking water
- Heidi Pekar, Senior Chemist
    - Member of the radiation group

Swedish civil contingencies agency

- Pelle Postgård, Senior Expert
    - RN Emergency management
- Thomas Degeryd, Advisor
    - Reinforcement resources

Civil protection in Stockholm

- Stefan Gustavsson, CBRN Coordinator

3 LEGAL FRAMEWORK FOR RADIOACTIVITY MONITORING IN SWEDEN

3.1 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

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

- Swedish radiation protection ordinance (2018:506) - The chapter 4, §5 of the ordinance assigns SSM the task of running a national environmental radioactivity monitoring program.
- Swedish radiation protection act (2018:396) - The chapter 5, §1 of the act states that any operator of a practice that may lead to releases of radionuclides or other exposure of humans or the environment to ionizing radiation shall measure, or in other ways monitor the releases and exposures.
- Regulation SSMFS 2008:23 - The Swedish Radiation Safety Authority's Regulations on Protection of Human Health and the Environment in connection with Discharges of Radioactive Substances from certain Nuclear Facilities[4]. The regulation further specifies the requirements of the Swedish radiation protection act (2018:396).

3.2 LEGISLATIVE ACTS REGULATING RADIOLOGICAL SURVEILLANCE OF FOOD AND DRINKING WATER

In Sweden, the following legal texts regulate the monitoring of radioactivity in food and drinking water:

- *Livsmedelsförordningen* 2006:813 (the food ordinance). The ordinance assigns responsibility and mandate regarding food quality to the Swedish food agency and other competent authorities in the food control chain.
- Regulation SLVFS 2001:30 *Livsmedelsverkets föreskrifter om dricksvatten* (the Swedish food agency's regulation on drinking water). Surveillance of radioactive nuclides in drinking water is regulated in SLVFS 2001:30 and transposed from the EU Directive 2013/51/Euratom. The Swedish Food Agency is the legislative authority. The surveillance of drinking water is the responsibility of the producers and the local health/environmental authority is responsible for the official control.
- Regulation LIVSFS 2005:21 L*ivsmedelsverkets föreskrifter om offentlig kontroll av livsmedel* (the Swedish food agency's regulation on public control of food). The regulation states that measurements of Cs-137 in reindeer should be made in accordance with the programs decided by the National food agency and which are revised yearly.
- Regulation LIVSFS 2012:3 *Livsmedelsverkets föreskrifter om främmande ämnen i livsmedel (the Swedish Food Agency's regulation on contaminants in food)*. The regulation states national maximum limits for certain contaminants, including Cs-137.

3.3 LEGISLATIVE ACTS REGULATING RADIOACTIVITY MONITORING FOR EMERGENCY PREPAREDNESS

In Sweden, the following legal texts regulate the monitoring for emergency preparedness:

- Civil Protection Act (2003:778)
- Civil Protection Ordinance (2003:789) regarding protection against accidents with serious potential consequences for human health and the environment.

These two acts lay down the responsibilities for municipalities and governmental authorities in radiation monitoring, i.e.:

[4] Unofficial English translation is available at: https://www.stralsakerhetsmyndigheten.se/contentassets/cf38f102a3c8428799a0593c748078af/ssmfs-200823-the-swedish-radiation-safety-authoritys-regulations-on-protection-of-human-health-and-the-environment-in-connection-with-discharges-of-radioactive-substances-from-certain-nuclear-facilities

- Municipalities shall have a rescue service programme for accidents in certain facilities with activities using ionizing radiation (Civil Protection Ordinance, chapter 3, §6).
- Municipalities are responsible for radiation monitoring and decontamination activities for protection against the effects of nuclear weapons at heightened alert/war (Civil Protection Act, chapter 8, §2).
- The County Administrative Boards in Sweden shall maintain a programme for rescue service and decontamination in case of accidents in nuclear facilities followed by significant releases of radioactive material. The programme shall include radiation monitoring (Civil Protection Ordinance, chapter 4, §21).
- Municipalities, especially those located within 50 km from the Swedish nuclear power plants, shall assist the County Administrative Board with radiation monitoring (Civil Protection Ordinance, chapter 4, §28).
- For rescue services in accordance with Chapter 4, Section 6 of the Civil Protection Act, SSM shall advise on radiation measurements and coordinate and assist with radiation protection assessments (Civil Protection Ordinance, chapter 4, §30).

The Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452) (off-site emergency preparedness and response) (§15) states that:

- SSM shall coordinate those measures required to prevent, identify and detect nuclear or radiological events that may result in damage to human health or to the environment.
- SSM shall maintain and lead a National Expert Response Organization for nuclear and radiological emergencies.
- SSM shall maintain the ability to carry out measurements, sampling and analysis in the field.

3.4 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 SWEDISH RADIATION SAFETY AUTHORITY

The Swedish Radiation Safety Authority (SSM) is a managing authority under the Ministry of the Environment since 1 July 2008, with national collective responsibility within the areas of radiation protection and nuclear safety. It has mandates from the Swedish Government within the areas of nuclear safety, radiation protection and nuclear non-proliferation. It can issue regulations in the field of radiation protection, including environmental monitoring and discharge control. The authority works proactively and preventively in order to protect people and the environment from the undesirable effects of radiation.

The SSM runs the national environmental monitoring program, which includes sampling points in Stockholm. Sampling is mainly performed by the organisations directly involved with the handling of the sampled media, i.e. dairies for milk, water plants for drinking water and so on. The samples are sent to the SSM laboratory for analysis.

The SSM also has resources in Stockholm for emergency preparedness. These include systems for mobile measurements, in-situ measurements, sampling of various media, analytical laboratory and a crisis centre.

4.2 SWEDISH GEOLOGICAL SURVEY

The Geological Survey of Sweden (SGU) is the expert agency for issues relating to bedrock, soil and groundwater in Sweden. Its main task is to meet society's need for geological information. The SGU is also responsible for the Good-Quality Groundwater objective, which also involves reducing the use of natural gravel. The SGU tasks are:

- Supporting the development of the mining, rock and mineral industry
- Promoting the use of geological information in societal planning
- Uniting and strengthening geological research in Sweden
- Bringing geology and geological knowledge to the fore in social debate and in schools

The SGU currently has some 250 employees, most of whom work at its headquarters in Uppsala. Others are stationed at the regional offices in Gothenburg, Lund, Stockholm, Malå, and also Luleå (Mining Inspectorate).

The Swedish geological survey operates systems for airborne radiation measurements, which can be used anywhere in Sweden, and internationally when needed. These systems are used for routine radiological mapping of the Swedish territory; in addition, they can provide valuable information in the event of a radiological fallout affecting Sweden.

4.3 SWEDISH DEFENCE RESEARCH AGENCY

The Swedish Defence Research Agency (FOI) is a civilian authority under the Swedish government and reports to the Ministry of Defence. Its main task is to provide cutting-edge research and expertise in defence and security. FOI headquarters are located in Kista, Stockholm; it also has research facilities in Grindsjön, Linköping and Umeå. Altogether, FOI has some 900 employees.

FOI runs, by appointment from the SSM, the systems for sampling and measurement of radionuclides in air and atmospheric deposition. One sampling station and the analytical laboratory are situated in Kista, Stockholm.

4.4 SWEDISH FOOD AGENCY

The Swedish Food Agency (SLV) is the central supervisory authority for matters relating to food. It has the task of protecting the interests of the consumer by working for safe food of good quality, fair practices in the food trade, and healthy eating habits. It issues regulations regarding food safety,

including maximum permitted levels of radionuclides in food and drinking water, which concern all producers in Sweden. Furthermore, it issues national monitoring programmes if needed, such as control of reindeer meat after the Chernobyl accident.

The responsibility of the SLV includes also radioactive contamination of food. Food control at the local level is the responsibility of the relevant local food control authority, usually the Environmental and Health Protection Authority. County administrations are responsible for support to and control of the municipal authorities' food control. SLV headquarters are in Uppsala. Altogether, it has 330 employees, some of them involved in radioactivity matters.

4.5 SWEDISH CIVIL CONTINGENCIES AGENCY

The Swedish Civil Contingencies Agency (MSB) is responsible for issues concerning civil protection, public safety, emergency management and civil defence as long as no other authority has responsibility. Responsibility refers to measures taken before, during and after an emergency or crisis.

The MSB has a rescue service ability to measure radiation using radiation measurement equipment. It handles national resources for measurement and remediation in the context of CBRN civil protection. Some of these resources are based in Stockholm.

5 RADIOACTIVITY MONITORING IN SWEDEN

5.1 INTRODUCTION

Measurements of environmental radioactivity in Sweden can be divided between those made during normal conditions, i.e. radiological monitoring of the environment both nationally and around facilities, as well as control of food that is put on the market, and those made in an emergency situation, i.e. characterising dose rates and ground deposition at and around the sites where accidents or other events leading to suspected releases of radionuclides have taken place. There are several actors involved in these measurements.

The national monitoring, which is generating all Swedish data currently reported to the REM database according to Euratom Treaty articles 35 and 36, is assigned to SSM. SSM appoints other organisations for parts of the sampling and measurements, for example the Swedish Defence Research Agency (FOI) performs the monitoring of radioactivity in air, and the Swedish Geological Survey (SGU) performs aerial surveys of ground gamma radiation (of which the analysis and reporting of Cs-137 is appointed by SSM). Most other laboratory analyses within the national monitoring program are done at the SSM laboratory. The majority of the results of this national monitoring is reported to the REM database.

Local monitoring of environment and discharges around the Swedish nuclear facilities are managed by the facilities according to programs defined or approved by the SSM. Sampling is done by independent organisations, for example the Swedish University of Agricultural Sciences, whereas sample measurements are done in the facilities' own laboratories. For control, a part of the samples is also measured at the SSM. The results from this local monitoring are not reported trough the REM database. Radioactive discharges from nuclear facilities are reported through the RADD database.

Control of radioactivity in food products and drinking water is the responsibility of the producers. For drinking water, the local environmental or health authorities in the municipalities check that the drinking water producer performs the mandatory surveys. This is checked through the official control of the local control authority in accordance with SLVFS 2001:30. Maximum levels of radionuclides, as well as other requirements within this control, are issued by the Swedish Food Agency and transposed from the directive 2013/51/Euratom into SLVFS 2001:30. The results of the controls performed by the producers are not reported through the REM database platform. For drinking water, a system for collecting the data has been implemented.

In an emergency situation there are a number of resources from different actors available. In addition to the national gamma dose rate monitoring stations and the air filter measurements, there are additional gamma stations run by the SSM near the three nuclear power plants. SSM also has equipment for mobile measurements, in-situ measurements, field sampling and laboratory analyses. SSM has also contracted and partly equipped other organisations (FOI, SGU, universities) to achieve similar capabilities, including airborne measurements (SGU).

Other national resources include a mobile field laboratory of the Swedish armed forces and resources of the civil protection handled by the Swedish Civil Contingencies Agency (MSB). The latter resources include equipment for dose rate measurements, nuclide identification, radioactive source recovery and decontamination of personnel and equipment.

Civil protection units of all municipalities are equipped with instruments for dose rate measurements to facilitate correct handling of events involving radioactive material, e.g. road traffic accidents during transport of radioactive materials. In the three counties hosting nuclear power plants there are also premade plans for the use of these measuring capabilities in the event of a nuclear accident.

5.2 NATIONAL ENVIRONMENTAL MONITORING PROGRAM

The Swedish Radiation Safety Authority (SSM) runs an environmental monitoring program for ionising radiation. This task is assigned to the SSM in the Swedish radiation protection ordinance (2018:506) chapter 4, § 5. The overarching aim of the program is to follow the status and long and short-term trends in the environment regarding naturally occurring, as well as anthropogenic radiation. This is done in order to:

- Detect and follow unknown emissions of radioactive substances
- Follow-up of the Swedish environmental quality goal '*Safe radiation environment*'
- Provide a basis for reporting in accordance with international treaties and conventions
- Provide a basis for risk assessments, suggestions of important actions and research
- Provide a basis for information to the public

The design of the program is influenced by international treaties, conventions and recommendations, e.g. the 2000/473/Euratom recommendation on the application of Article 36 of the Euratom Treaty. The locations of the sampling points are indicated in Figure 1. Currently the program includes the following:

- Radionuclides on particulates in air (continuous sampling at 6 locations*)[5]
- Radionuclides in drinking water (sampling twice a year at 5 locations*)
- Radionuclides in surface water (sampling twice a year at 8 locations (6 marine, 2 fresh water)*)
- Radionuclides in consumption milk (sampling quarterly at 5 locations*)
- Radionuclides in mixed diet (sampling twice a year at 3 locations*)
- Radionuclides in game meat (moose) (sampling during hunting season from one area)
- Radionuclides in marine sediments (sampling at 16 locations every fifth year)
- Radionuclides in marine biota (annual sampling at 8 locations)
- Whole body content of Cs-137 in humans (2 reference groups yearly, other groups irregularly*)
- Gamma radiation at ground level (continuous measurement at 28 national locations*)
- Gamma radiation at ground level (continuous measurement at 90 locations around 3 nuclear facilities)

* indicates that the results are reported to the EU-commission through the REM or EURDEP platforms.

SSM is handling the national monitoring by

- deciding on the design of the sampling scheme;
- arranging sampling which mainly is performed by involved organisations themselves, i.e. dairies for milk, hospital kitchen for mixed diet, water treatment plants for drinking water, hunters for game meat etc.;
- carrying out sample measurements in the SSM laboratory (in some cases by ordering measurements from external laboratories);
- compiling results in a database;
- reporting relevant data according to international treaties and conventions.

Following monitoring, the results are analysed in order to perform risk assessments, inform the public etc. Results of the monitoring programme are made available to the public in several ways on the SSM public website. The results are presented and interpreted in text and diagrams[6,7] and the

[5] *The filter stations operated by FOI have in addition to filters also precipitation collected (at four stations) and charcoal traps for gaseous iodine (at five stations). This is also missing on the map on the next page.*

[6] The presentation of the air filter data can be found on:
https://www.stralsakerhetsmyndigheten.se/omraden/miljoovervakning/radioaktiva-amnen/radionuklider-pa-partiklar-i-luft/

[7] *Information of drinking water data:*

data itself is available for download from the same site. An interactive map over ground deposition of Cs-137 in Sweden after the Chernobyl accident is also available.[8]

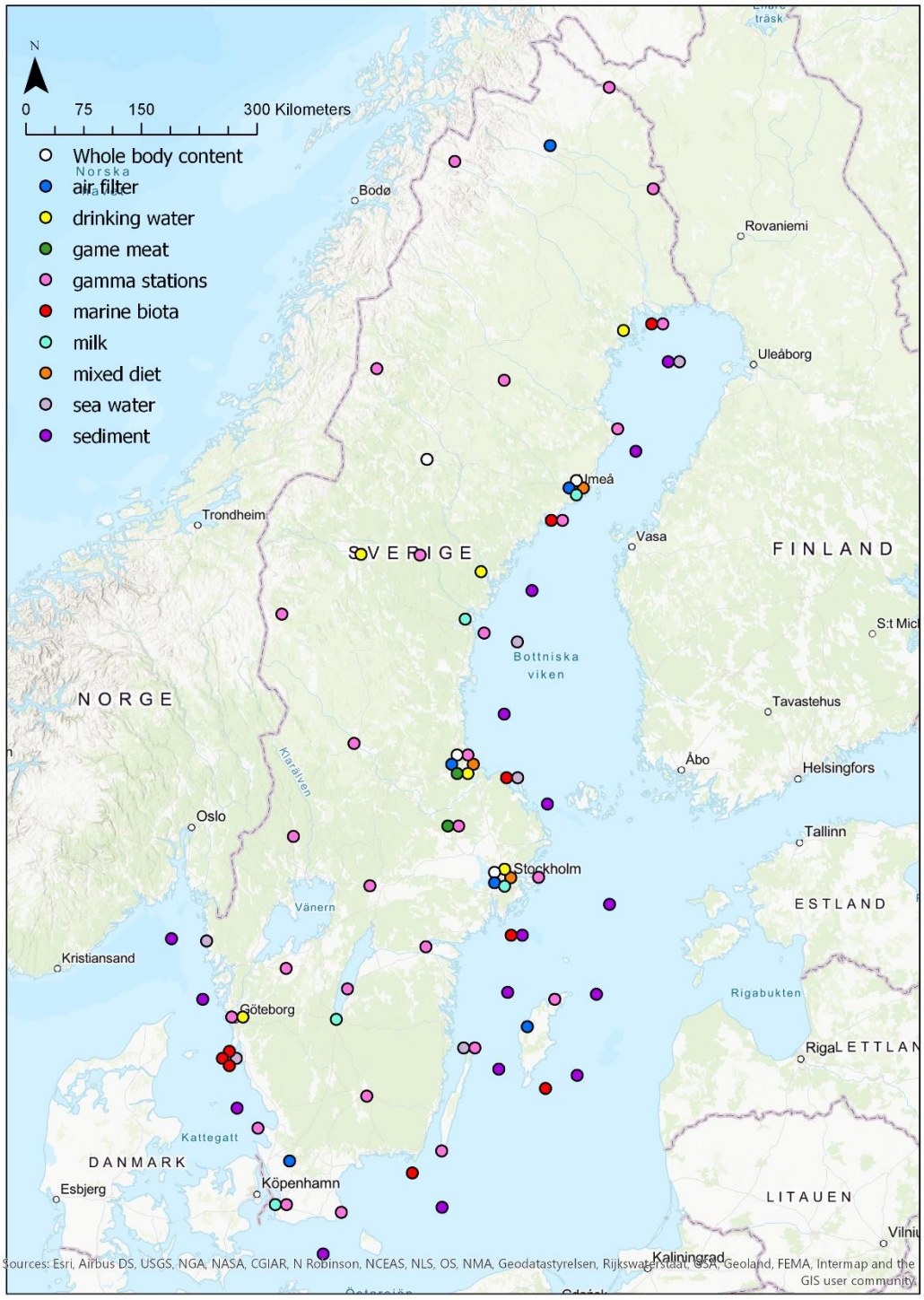

Figure 1. Sampling points within the Swedish national monitoring program for environmental radioactivity

https://www.stralsakerhetsmyndigheten.se/omraden/miljoovervakning/sokbara-miljodata/miljodatabasen/dricksvatten/

[8] *The Cs-137 deposition map can be found on:* https://ssm-kartor.maps.arcgis.com/apps/webappviewer/index.html?id=b0b123c9e99549f58d5d23a2436016ba

5.3 NATIONAL MONITORING OF AMBIENT RADIATION DOSE AND DOSE RATE

5.3.1 Automatic monitoring networks

The Swedish Radiation Safety Authority (SSM) manages two telemetric networks for monitoring external gamma dose rate – a nationwide network consisting of 28 monitoring stations (Fig. 2) and networks comprised of 30 monitoring stations in each of the three counties where the nuclear power plants of Sweden are located (Fig. 3-5).

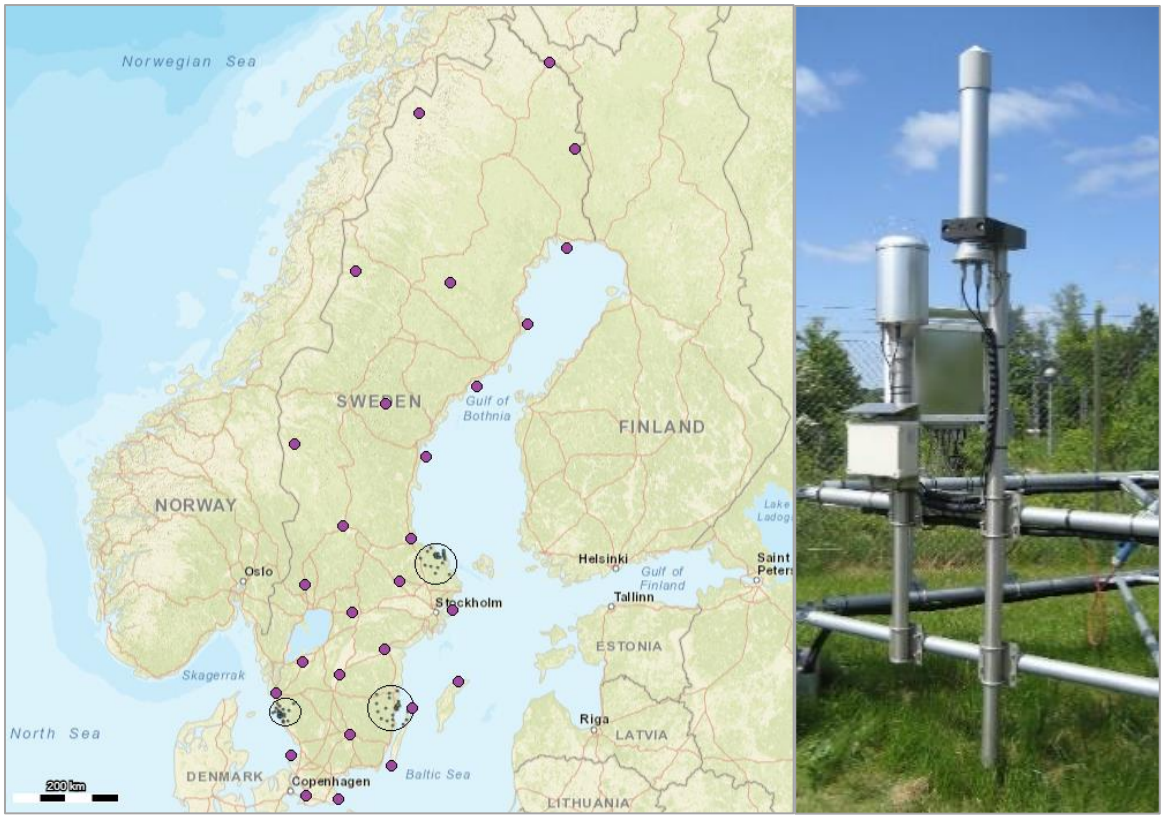

Figure 2. Nationwide network of monitoring stations (purple dots). Areas enclosed by circles indicate the location of the monitoring networks around the NPPs in Sweden. The insert depicts a monitoring station belonging to the nationwide network.

The monitoring stations operate autonomously and transmit data continuously to the network servers at the SSM. SSM administers the monitoring stations through dedicated software[9] and ensures that operations are maintained through collaboration with the county administrative boards in the NPP counties. In the NPP counties, personnel from the county administrative boards perform annual service trips to the monitoring stations.

[9] The administration software for the nationwide monitoring stations is *DataEXPERT10* (developed by Bertin GmbH, Germany) and the administration software for the stations in the NPP-counties is HIDACS (developed by Scanmatic AS, Norway).

Figure 3. Location of monitoring stations in Uppsala County (green dots). The insert depicts a monitoring station belonging the network in counties with NPPs.

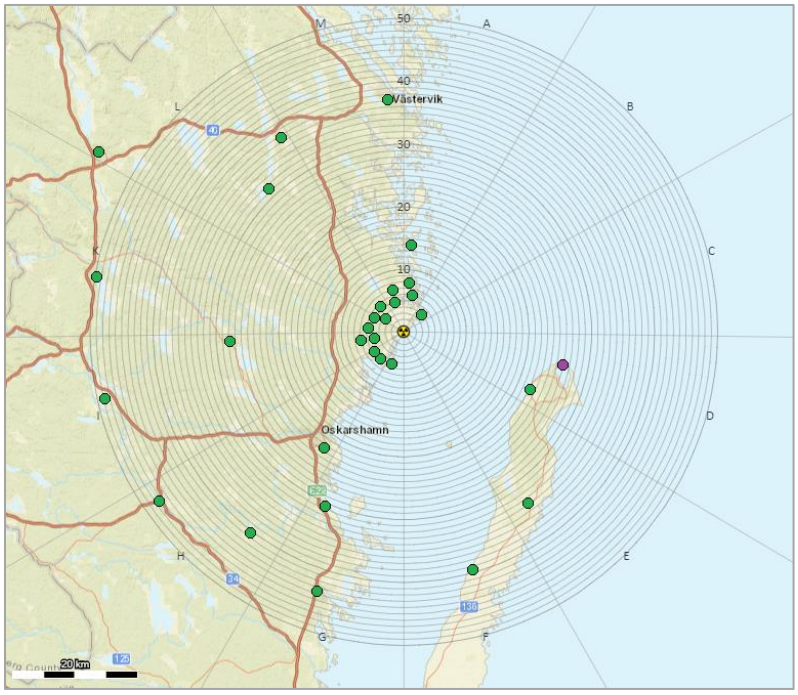

Figure 4. Location of monitoring stations in Kalmar County (green dots)

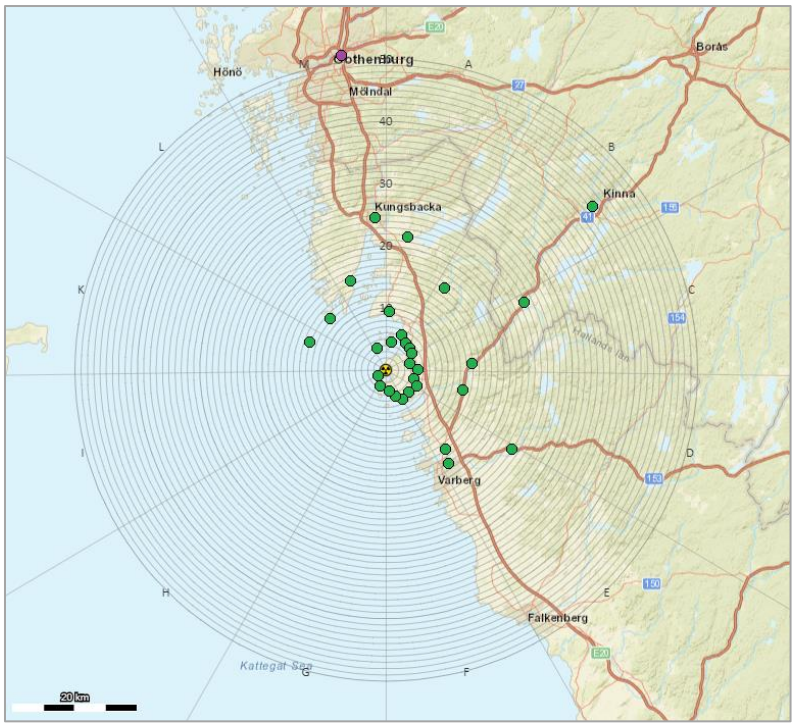

Figure 5. Location of monitoring stations in Halland County (green dots)

The main purpose of the nationwide network is to give an alarm if there is a significant increase above the natural background gamma radiation level[10] and to provide an instant overall picture of the radiation situation in Sweden. The purpose of the monitoring network in the counties with NPPs is to provide an early indication of gamma radiation levels and plume direction following a nuclear accident with a release of radioactivity to the environment.

Both networks monitor ambient dose equivalent rate ($\dot{H}^*(10)$) by means of monitoring probes equipped with three[11] energy compensated Geiger-Müller tubes, enabling a measuring range of 10 nSv/h – 10 Sv/h for each monitoring station. All monitoring stations use the GammaTRACER XL2-3 (Bertin GmbH[12], Germany) as a measuring device.

The monitoring probes of the nationwide network are mounted on weather stations managed by the Swedish Meteorological and Hydrological Institute (SMHI). SSM is responsible for its own equipment, but have the possibility to request help for simpler tasks by local supervisors of the weather stations. The weather stations provide an external power supply (12V/500mW) in addition to the integrated battery of the GammaTRACER XL2-3. The monitoring stations belonging to the network in NPP counties are all equipped with an external battery of 120 Ah combined with a 55W solar panel. The solar panel and the battery have been dimensioned in order for the station to operate continuously during all seasons of the year.

The XL2-3 probes belonging to the nationwide network have an internal GSM/GPRS module for wireless data transmission of monitoring data and probe parameters. The nationwide monitoring stations transmits data through the GMS-network managed by the Telia Company AB. All monitoring stations in the NPP counties are equipped with a data logger connected to a TETRA modem. These stations transmit their monitoring data and probe parameters in the form of SDS-packages[13] via the

[10] The average normal background level in Sweden is in the range of 100-150 nSv/h.
[11] Two redundant GM-tubes intended for low dose rates and one GM-tube intended for high dose rate levels.
[12] Formerly known as Saphymo GmbH (merged in 2016) and, before merge in 2006, Genitron GmbH.
[13] SDS: Short Data Service

Swedish TETRA-network RAKEL[14]. All monitoring stations store data locally in the probe (GammaTRACER XL2-3) and transmit data to servers at the SSM. The data transmitted to the SSM is stored in a SQL-compliant database (MS SQL server 2012). Stations in the NPP counties also store data locally on the data logger. This data can be viewed at any station via a display on the data logger.

All monitoring probes are configured to routinely transmit data once per hour and to switch to data transmission on a 10-minute basis if a pre-set alarm criterion is triggered. An alarm is triggered if the average dose rate exceeds 300 nSv/h, or if the integrated dose for two consecutive 24-hour periods differ by 20 %. All stations are equipped with rain sensors in order to help rule out elevated gamma radiation levels due to radon washout.

Once data has been transmitted to the servers at the SSM, it is automatically extracted from the databases associated with the administration software for the monitoring stations, and loaded into the database used by the SSM in-house software for spatially bound data (RadGIS 2.0, Radiation Geographical Information System). Further analysis can be performed in RadGIS 2.0 (e.g., visualization and comparison of data from different stations). RadGIS 2.0 also handles the export of monitoring data to EURDEP and can forward alarms from the stations to the duty officer at the SSM (either by email or RAKEL). No dedicated control centre exists for the telemetric networks for monitoring of external gamma dose rate. QA parameters and monitoring data sent by the stations are controlled and compared to historical data using either DataEXPERT10, Hidacs or RadGIS 2.0.

5.3.2 Passive monitoring networks

SSM does not carry out any measurements using field deployed thermoluminescent dosimeters (TLD). The management of field deployed TLDs, if used at all, is carried out by the county administrative boards in the NPP counties. The system with field deployed TLDs is still used to some extent, but will be fully removed in the close future since the monitoring stations surrounding each NPP produce similar information.

5.4 MONITORING OF RADIOACTIVITY IN THE ENVIRONMENT IN THE STOCKHOLM AREA

5.4.1 Air and atmospheric deposition

There are six large-volume (about 1000 m^3/h) air samplers for monitoring radioactivity in air permanently installed in Sweden. FOI operates the system. In the event of an increase in the amount of radioactive particles, the system is used to assess the time-integrated air concentration in order to predict inhalation doses and ground deposition. Typical sampling time is one week, i.e. priority is given to sensitivity rather than rapidity. The locations are Kiruna, Umeå, Gävle, Kista, Visby and Ljungbyhed (Table III and Fig. 6 below). The samplers are in-house design; glass fibre filters (type HB5773 from Hollingsworth) are used as filter media. The stations are maintained and monitored by local operators contracted by FOI. The filters are sent to the FOI laboratory for analysis by gamma spectroscopy on HPGe-detectors. Natural and anthropogenic gamma emitting radionuclides are assessed, but only Be-7 and anthropogenic radionuclides are reported if detected.

At five of the stations (Kiruna, Umeå, Gävle, Kista and Ljungbyhed) a small part of the air flow (12 m^3/h) downstream of the filter is passed through an active charcoal cartridge in order to collect gaseous iodine. The cartridges are changed weekly, but only analysed if particulate iodine has been detected in the filter. The Visby station does not have an iodine cartridge.

[14] Rakel, acronym for *RAdioKommunikation för Effektiv Ledning.* Rakel is managed by the Swedish Civil Contingencies Agency (MSB).

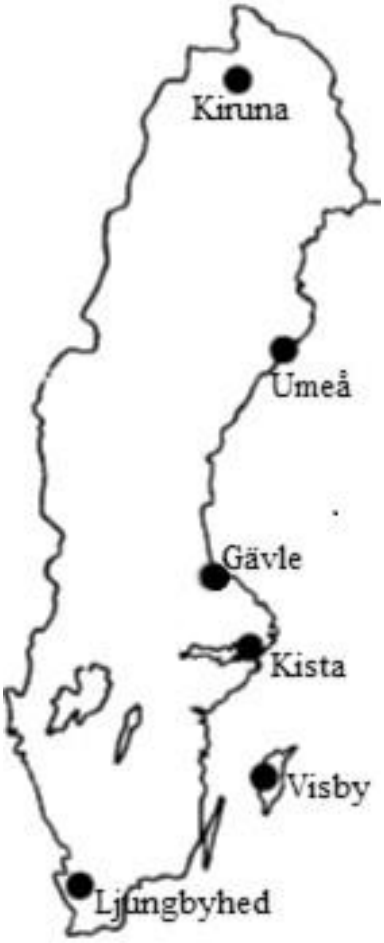

Figure 6. Locations of the FOI large-volume air filter and deposition collector stations

Table III. The Swedish high-volume particulate sampling stations

Location	Latitude	Longitude	Height above sea level	Frequency of filter change	Air flow (m^3/h)
Kiruna	67.84 N	20.42 E	415 m	2/week	~1000
Umeå	63.85 N	20.34 E	46 m	2/week	~1000
Gävle	60.67 N	17.19 E	7 m	2/week	~1000
Kista	59.40 N	17.95 E	30 m	6/week	~1500
Visby	57.61 N	18.32 E	59 m	2/week	~1000
Ljungbyhed	56.08 N	13.22 E	45 m	2/week	~1000

The air sampling stations at Kiruna, Gävle, Kista and Ljungbyhed (see map above) are equipped with a stainless steel funnel (1 m radius) to collect precipitation. Precipitation is passed through a column consisting of a filter part, an an-ion exchanger part and a cat-ion exchanger part. The columns are changed weekly and sent by mail to the FOI laboratory in Kista. Four samples are combined to a monthly sample by ashing. The samples are measured on HPGe detectors. From these measurements the total deposition is calculated. Natural and anthropogenic gamma-emitting radionuclides are assessed, but only Be-7 and anthropogenic radionuclides are reported if detected.

5.4.2 Surface water

Surface water is sampled as the incoming raw water to the water plant in Norsborg. The water is taken from Lake Mälaren, which is the third largest lake in Sweden.

Samples are taken manually by the personnel at the water plant by tapping 40 litres of water into plastic containers supplied by the SSM. The containers are pre-treated by the SSM with stable Cs in order to minimize adsorption of Cs-137 to the walls of the containers. The containers are then sent back to the SSM laboratory. Sampling is performed twice a year. The water is analysed for Cs-137, Ra-226, total-alpha and total-beta.

5.4.3 Ground water and drinking water

In Sweden, there are approximately 1700 municipal drinking water treatment plants and 3600 public/commercial drinking water treatment plants. The regulations in SLVFS 2001:30 provide that surveillance of radioactivity in drinking water is mandatory for all producers, if a source of artificial radioactivity is present in the water catchment area. If there is no source of artificial radioactivity in the catchment area, the regulation SLVFS 2001:30 provides that monitoring is mandatory only for drinking water produced from ground water. The sampling frequency is dependent on production volumes, and ranges from one sample every three years to 12 samples/year + 1 sample per 25 000 m^3 drinking water produced.

The drinking water producers themselves decide which certified laboratory to contract for analysis. The monitoring parameters include total alpha activity, total beta activity, tritium and radon. In the current situation, the SSM has judged that it is not necessary to analyse tritium in Sweden. If the screening values for total alpha or beta activity are exceeded, the SLVFS 2001:30 provides for nuclide specific analysis in order to calculate the indicative dose.

Every three years, the Swedish Food Agency compiles the monitoring data from the drinking water producers and reports to the EEA by Eionet, DG Environment. The most recent report contained data from years 2014-2016, i.e. before the implementation of SLVFS 2001:30 including the transposed Directive 2013/51/Euratom. Compilation of the monitoring data from years 2017-19 will start in 2020 and will be reported to the EEA by Eionet in 2021. This will be the first report including data for radioactive substances.

The regulation SLVFS 2001:30 also requires the drinking water producer to perform hazard analysis, for example to analyse their raw water (the sampling frequency is not defined).

Within the national environmental monitoring program, wherefrom data are reported according to Art. 35 and 36, there is one sampling station in Stockholm, i.e. the outgoing drinking water from the water plant in Norsborg. The water is taken from the Lake Mälaren, which is the source of drinking water for the people living around the lake. The water plant in Norsborg is one of the largest water plants in the Nordic countries. Samples are taken manually by the personnel at the water plant by tapping 40 litres of water into plastic containers supplied by the SSM. The containers are pre-treated by SSM with stable Cs in order to minimize adsorption of Cs-137 to the walls of the containers. The containers are then sent back to the SSM laboratory. Sampling is performed twice a year. The water is analysed for Cs-137, Sr-90, H-3, Ra-226, total-alpha and total-beta.

As all drinking water producers in the Stockholm area have to comply with SLVFS 2001:30 there is also additional sampling in the area, which is not reported under article 35. The water catchments in the Stockholm area are considered not to contain any artificial sources of radioactivity triggering a need for the water plants to measure anthropogenic radionuclides. Therefore, from a drinking water perspective, the focus of the surveillance should be ground water. The monitoring parameters include total alpha activity, total beta activity and Radon. In case of exceeding the screening levels for total alpha or total beta, nuclide specific analyses are required. The local health/environment authorities are responsible for the official control.

5.4.4 Soil and sediments

There is no sampling of soil or sediments in the Stockholm area included in the monitoring program.

There is no ongoing routine soil sampling in the national program. Soil was sampled and measured in a national survey of Cs-137 in agricultural soils and crops between 2001 and 2010. In total 1695 soil samples and 1235 coupled crop samples were collected in a statistically representative sample of the Swedish agricultural soils (SSM 2008/3025-4). Samples were taken in cooperation with the national soil survey so that all other relevant soil data are available for the same soils.

Radionuclides in marine sediments are included in the national programme (sampling at 16 locations every fifth year).

5.4.5 Terrestrial and aquatic biota and flora

There is no ongoing sampling of terrestrial biota or flora in the Stockholm area included in the monitoring program. Radionuclides in marine biota are included in the national programme (annual sampling at 8 locations).

5.4.6 Terrestrial fauna

The national program includes sampling of moose in the Gävle area, and currently there is a measuring project (rather than long term monitoring, although it might become one) regarding Cs-137 in wild boar in an area affected by the Chernobyl accident.

5.5 Monitoring of radioactivity in foodstuffs and feeding stuff in the Stockholm area

5.5.1 Milk

Milk is sampled as outgoing consumption milk from the dairy in Kallhäll. The dairy takes in milk from an area with a radius of approximately 250 km, mainly from around Lake Mälaren. 235 million kilograms of milk are processed yearly at the dairy, which is one of the largest in Sweden.

Samples are taken manually by the personnel at the dairy by tapping 2 litres of milk into a plastic container supplied by the SSM. The container is then sent back to the laboratory at SSM. Sampling is performed four times a year. The milk is analysed for Cs-137, Sr-90 and K-40.

5.5.2 Mixed diet

Mixed diet is sampled as all food served from the kitchen during 24 h to a normal person living at the caring centre Polhemsgården.

Samples are taken manually by the personnel in the kitchen by “feeding” a plastic container supplied by the SSM with the same food portions that are served to the persons living at the centre. The container is then sent back to the SSM laboratory. Sampling is performed twice a year. The mixed diet samples are analysed for Cs-137 and Sr-90.

5.5.3 Foodstuffs

No samples of individual foodstuffs from the Stockholm area are included in the monitoring program.

5.5.4 Feeding stuffs

No samples of individual feeding stuffs from the Stockholm area are included in the monitoring program.

5.6 Laboratories participating on the environmental radioactivity monitoring programme

5.6.1 Swedish Radiation Safety Authority

The SSM laboratory performs radioactivity analysis of milk, drinking water, surface water (fresh and marine), and mixed diet within the Swedish national monitoring program. The SSM laboratory has no accredited methods, but it follows the ISO17025 standard in most of its work. All methods are described in the quality handbook included in the SSM 360 documentation system. All calibrations are traceable to international standards for activity. The SSM laboratory regularly participates in proficiency tests and interlaboratory comparisons, for example in the IAEA-ALMERA proficiency tests.

Sample preparation

The laboratory has a sample preparation room where incoming samples are registered in a database. All samples are assigned with a unique sample code for tractability in the analysis and reporting chain. At the reception, all samples are checked to make sure the containers and packing are intact. If a broken parcel is discovered, the laboratory informs the provider and a new sample is sent to the SSM.[15]

Milk samples

After arrival to the laboratory, the sample is split into two aliquots: one for Sr-90 analysis and one for gamma spectrometry. The wet weight is noted. The milk samples are assumed to be homogenous in its content of radionuclides. The aliquot for gamma spectrometry is transferred to a Marinelli geometry and stored in a fridge until measurement. The aliquot for Sr-90 analysis is freezer-dried and ashed before radiochemical separation is done.

Drinking water and surface water samples

All water samples are pH adjusted to around 1 with concentrated HCl acid, except for the determination of Sr-90 where concentrated HNO_3 is used.

Mixed diet

After sample registration, the already mixed food is homogenized with a standard food processor for about 5 min. One aliquot is taken for Sr-90 analysis and stored freeze-dried until the radiochemical separation starts. For gamma ray analysis, one Marinelli beaker is filled and stored in a refrigerator until the sample is measured.

Descriptions of the methods can be found in the following SSM 360 documents:

- STYR2013-29 (Analys av gammastrålande nuklider med HPGe-detektor)
- STYR2012-13 (Analys av cesium i lågaktiva vattenprover)
- STYR2012-4 (Analys av tritium i vatten)
- STYR2012-14 (Analys av totalalfa/totalbeta och Ra-226 i vatten)
- STYR2012-3 (Analys av Sr-90 aktivitet i diverse provtyper)

At the laboratory the samples are measured for gamma-ray emitting radionuclides according to STYR2013-29 (Analys av gammastrålande nuklider med HPGe-detektor).

Equipment

The SSM laboratory has five HPGe gamma ray spectrometers of different manufacturers, which are used in the analysis. In the laboratory there are also two liquid scintillation counters (Wallac, 1220 Quantulus) for the tritium, Sr-90, and gross alpha/beta analysis according to methods referenced above.

All laboratory instruments and equipment are registered in the SSM 360 document management system. The inventories of the laboratory can be found in the document 15-2113 (RAL – Inventarielista). At the laboratory regular QA/QC procedures are followed according to the described procedures in STYR2015-10 (Kalibrering och kvalitetskontroll: LSC) and STYR2013-30 (Kontroller HPGe). The calibration procedures are described in STYR2015-10 for the LSC equipment and for the gamma spectrometers in STYR2013-31 (Kalibrering av HPGe).

After measurements, the results are processed in standard calculation sheets presented in the SSM 360 document STYR2016-3. The uncertainties and detection limits are calculated according to the

[15] This is described in SSM 360 document 16-474 (RAL - Loggbok för inkomna prover) and 16-699 (RAL – Lathund för provinsamling/provtagning).

GUM standard. The laboratory sends a measurement report to the responsible unit at the SSM, documented in the SSM 360 documentation system. The mixed diet and milk samples are discarded after measurement; other samples are archived for 6 months.

5.6.2 Swedish Defence Research Agency

The Swedish Defence Research Agency (FOI) laboratory maintains an extensive programme for sampling and measurement of radionuclides in air and precipitation. Sampling is performed at six national stations (see section 5.4.1). The stations are run by local operators and the filters are sent by regular mail to the FOI laboratory in Stockholm for analysis. Upon arrival at the laboratory, the filters and collection data are registered in a database and a short initial measurement is performed to assess the radiation levels. For final measurement, the individual filters covering a week from one station are combined to a composite sample by compression and measured on an HPGe-detector for 72-96 hours. All samples are archived.

Precipitation sampling is performed at four of the six national stations and, as for the air filters, the ion exchange filters are sent to the central laboratory. Four weekly filters from one station are combined to a 4-week sample. The ion exchange resins from the columns are ashed and measured on an HPGe-detector for 72-96 hours. All samples are archived.

The FOI laboratory in Stockholm is equipped with seven liquid nitrogen cooled HPGe-detectors (Ortec and Canberra) with relative efficiencies ranging from 21 to 89%. The software APEX™ and Genie™2000 from Canberra are used for analysis of spectra. Calibrations are performed with certified radioactive sources in a custom geometry, or with calibration sources made from filters spiked with an isotope solution. QC measurements are made monthly with a long-lived calibration source.

Results are saved in a local database and reported weekly to the SSM; results are also reported yearly as a printed report. Nuclides are reported as detected if the uncertainty <75%.

The laboratory participates regularly in proficiency tests organized by the IAEA and in national inter-comparison tests.

5.6.3 Other laboratories

In addition to the SSM and FOI laboratories, the following laboratories take part in monitoring of radioactivity in the environment in Sweden:

Laboratory	Sample
Nuclear power plant laboratories	Environmental samples from the plant vicinity
Private laboratories	Food and drinking water

5.7 EMERGENCY MONITORING

5.7.1 National Expert Response Organisation

In Sweden, the National Expert Response Organisation comprises government authorities, organisations and laboratories, which have expertise in radiological assessment and radiation monitoring. This organisation, maintained and led by the SSM, has as its main purpose to perform radiation measurements in response to radiological emergencies. Figure 7 lists the contracted authorities, organisations and laboratories that have capabilities encompassing laboratory analysis and field monitoring, mobile and airborne monitoring, weather forecasting and plume dispersion prognoses. In addition to the tasks belonging to the national expert response organisation, individuals engaged in this response organisation may also have a role in providing expert advice during the response.

Laboratories within the organisation do not have their employees on call, but through the contract with the SSM they are obliged to maintain competence through internal education and exercises and to keep radiation monitoring equipment ready for deployment. SSM provides the laboratories with

equipment and standardized monitoring methods. SSM also arranges frequent national exercises, inter-comparisons etc., with the aim to improve competence and quality of the measurements.

Expert Response Organisation

- Swedish Defence Research Agency, FOI (Umeå and Stockholm)
- Geological Survey of Sweden, SGU (Uppsala)
- Cyclife Sweden AB (Nyköping)
- Linköping University (Linköping)
- University of Gothenburg (Göteborg)
- Lund Unversity (Malmö)
- Swedish Meteorological and Hydrological Institute, SMHI (Norrköping)
- SSM (Stockholm)

Figure 7. Laboratories within the National Expert Response Organisation

5.7.2 Terrestrial monitoring

There are several different systems for mobile gamma spectrometry within the Swedish organisation for emergency preparedness. The systems are mainly used by the SSM and the laboratories within the National Expert Response Organisation. They consist of combinations of NaI(Tl)-detectors, $LaBr_3$-detectors and HPGe-detectors; most of them have electronics from EG&G Ortec (Digibase/DigiDart), while a few use detector packs from Radiation Solutions Inc. The Ortec-systems, as well as the software for data collection and analysis, NuggetW, are developed in-house by the SSM. The main system configurations used are:

- Three vehicles with 2×4 liter NaI(Tl) and a 120 % HPGe-detector (Fig. 9). These vehicles are stationed in Malmö, Stockholm (SSM) and Umeå.
- Three carriers with 1×4 liter NaI(Tl) and a 120 % HPGe-detector. These carriers are stationed in Malmö, Göteborg and Stockholm (FOI Kista).
- Six backpack systems with 1.5×1.5” $LaBr_3$-detectors (Fig. 8). These can be used by foot or mounted in rental cars. These systems were developed after the Fukushima accident to make sure mobile gamma spectrometry can be performed also in areas with high dose rates.

- Two systems with 1×4-liter NaI(Tl) mounted in pelicases for use in various platforms and also for transportation by airplane abroad if necessary.
- Two airborne systems used by the Geological Survey of Sweden, detailed below.

In addition to these systems, a new radiation monitoring system for mobile gamma spectrometry is currently undergoing development. The system will be based on a spectrometric gamma probe by Envinet GmbH (Sara-probe) and mainly used for detailed mapping of dose rates around the Swedish nuclear power plants in the case of a nuclear accident. It will replace the current system used by the County Administrative Boards in the NPP counties, which is currently based on measurement of dose rates using handheld instruments in discrete positions. The plan is to have the new system up and running in the beginning of 2021.

SSM has recently developed new GIS software for reporting, storing, extracting and visualising radiation monitoring data and environmental samples collected during an emergency. The new software, RadGIS 2.0, replaces RadGIS 1.0, which was developed in the 1990s. RadGIS 2.0 will be used by all Swedish organisations that perform radiation monitoring and sampling during a nuclear emergency.

Figure 8. SSM backpack monitoring system

Figure 9. One of three vehicles for mobile gamma spectrometry in Sweden

5.7.3 Airborne monitoring

The Swedish Geological Survey (SGU) has two complete airborne radiation monitoring systems (Fig. 10 and 11). Both systems are designed and approved by the EASA to fit the seat rails available in a Twin Commander 690 aircraft. The survey aircrafts, including pilots, are contracted from a private company (Wermlandsflyg Operations AB), which also conducts the ordinary airborne geophysical surveys for the SGU.

Each system consists of:

- 16L NaI downward plus 4L upward looking crystal package (RSX5)
- Mounting plate for NaI detector
- 100% HPGe detector (Ortec)
- Damped rack mounting for HPGe detector (SGU construction)
- Digidart (Ortec)
- Navigation system including display for navigator pilot (SGU construction)
- Data acquisition and analysis unit (solution provided by SSM with Nugget software)
- Electronics rack (SGU construction)

Survey altitude is 60 m above ground and survey speed about 67 m/s. The survey instruments are tested at least twice a year to make sure that they are functioning according to specifications. In the spring and in the autumn the instruments are tested in-house at the SGU laboratory; one system (alternating each year) is also tested in a short test flight in the autumn.

During survey flights the aircraft is manned by two pilots (one serving as navigator) and two system operators. One person is operating the data acquisition and the other one is managing contact with ground personnel and acting as a backup for the main survey operator. The normal flight time is four hours per flight. The aircraft operator has a permit to perform low altitude flights in Sweden down to 60 m above ground. Normally two flights per day are made and up to three in short periods. Operation on low altitudes is restricted to VFR (visual flight rules, i.e. requires good weather conditions). The processed data is delivered as ASCII files to the SSM via the RADGIS system or e-mail. The aim is to deliver the data within two hours after landing.

Figure 10. NaI and HPGe detectors of the SGU for airborne monitoring

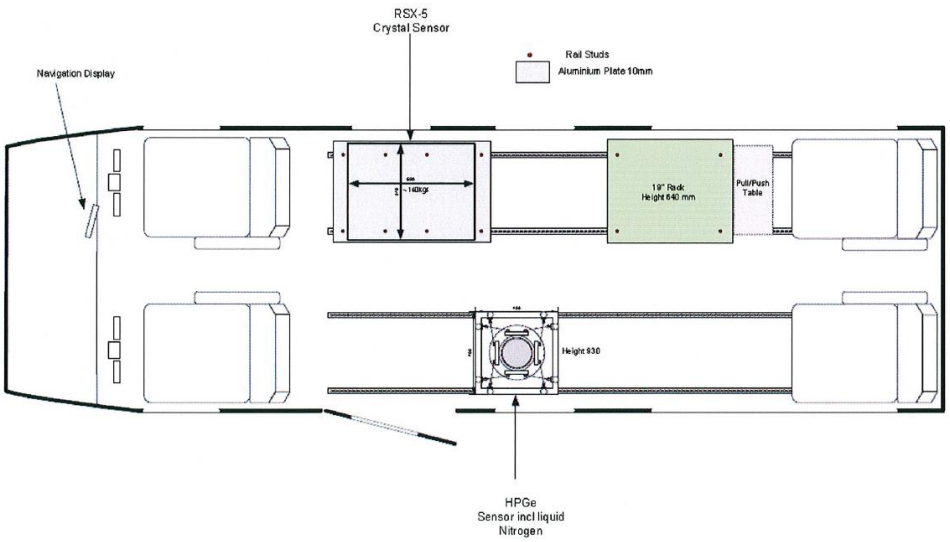

Figure 11. SGU survey installation in the aircraft

5.7.4 Civil protection services monitoring

The County Administrative Boards are responsible for protecting the public during and after a nuclear emergency, including monitoring. Monitoring of dose rates and collection of air samples for the purpose of public protective actions are performed by the local rescue services from municipalities within each county at predefined locations and routes. During a nuclear emergency, the County Administrative Boards coordinate response and monitoring activities with the national expert response organisation and government authorities. The county is testing the ability to measure every 7th month.

All municipalities have at least two dose rate instruments. These instruments are to be used for measuring after an accident. Most of these instruments are placed at the local fire & rescue service brigades and should be on the first truck that leaves the station (within 90 seconds).

The Swedish contingencies agency maintains CBRN detection teams, which have alpha/beta monitors, surface contamination monitors and nuclide identification equipment. In addition, they have equipment for securing small orphan radiation sources and for personnel decontamination. Teams are located in Stockholm and Goteborg, while there are equipment ready for a third team currently not located to a specific location. They can be rapidly deployed anywhere in Sweden. Figure 12 shows their main equipment for radiation measurements.

Figure 12. Civil protection CBRN detection team equipment for securing small radiation sources and for monitoring radiation

5.8 INFORMATION FOR THE GENERAL PUBLIC

Information on the national environmental radioactivity monitoring program is given at the SSM website[16]. At the website the SSM presents the monitoring programs together with the selected main results and interpretations of these. This includes text and figures, sometimes based on processed data such as mean values etc. Raw data from the monitoring program is also available through a web interface to the database, so that the public can reach the data and evaluate it themselves.

The update frequency of the website and database is mainly yearly updates. The dose rate readings received from the automatic monitoring systems are not available on-line on the SSM website, but they are made available at the EURDEP website with no delay.

[16] https://www.stralsakerhetsmyndigheten.se/omraden/miljoovervakning/

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 SWEDISH RADIATION SAFETY AUTHORITY

The verification team visited the Swedish Radiation Safety Authority (SSM)[17]. The SSM demonstrated to the verification team the mobile equipment used for emergency preparedness and presented two networks for gamma dose rate monitoring. The verification team visited also the radio-analytical laboratory of the SSM.

6.2.1 Mobile measurement systems

The SSM possesses and operates a wide range of mobile and portable measurement equipment for emergency preparedness purposes that are stationed in different areas of Sweden as described in paragraph 5.6.1 above. At the SSM premises one vehicle for mobile gamma spectrometry system with two NaI(Tl)- and one HPGe-detector is stationed. In addition, the SSM operates an impressive list of portable detectors for quantification and identification of radiation levels in an emergency situation. There are two to four exercises each year to test the functioning of the mobile measurement systems

No remarks.

6.2.2 Radio-analytical laboratory

The radio-analytical laboratory is not accredited in conformity with the ISO/IEC 17025 standard. However, the laboratory follows closely quality management procedures defined according to the national and international standards, as described in their internal quality manuals and work instructions. Well-established quality control of each measurement method and participation in the proficiency tests and inter-laboratory comparison exercises guarantee the quality of the measurement results.

Sampling is done by external organisations. Paper records and an Excel database (a part within the document management system 360°[18]) is used to register incoming samples.

[17] Solna Strandväg 96, 171 16 , Stockholm

[18] 360° case, document and records management. Tieto Corporation, Espoo, Finland.

There are adequate equipment and facilities in two sample preparation rooms (dryers, furnaces, evaporators, etc.) to treat the samples related to analyses of the environmental radioactivity monitoring programme, i.e. milk samples, drinking water, surface water and mixed diet. In addition to the samples of the national monitoring programme, there are samples analysed in the laboratory for research purposes. Measured samples from the national programme are stored for six months inside the locked cupboards located in the corridors of laboratory area.

The low background measurement room is well equipped to perform identification and quantification of gamma-emitting radionuclides by HPGe gamma spectroscopy.

At the time of the visit the two liquid scintillation counters used for alpha and beta counting were only partially operational. The laboratory was in process of writing an open call for tender for purchase of a new liquid scintillation counter.

The verification team noted the lack of space in the sample receipt and preparation areas. The laboratory staff explained that the extension work would require complete exchange of the ventilation system. There are no plans to extend the laboratory areas. Handling many contaminated samples would likely be problematic with the current layout of the lab. In an emergency situation, the sample receipt area is planned to be placed outdoors, using an emergency shelter.

The laboratory sample management is based on paper logbooks and Excel-sheets – there is no dedicated laboratory information management system (LIMS). The lab uses the document management system (SSM360°) for its electronic documentation, including the logbook for incoming samples. Sample codes are written on the samples by hand, there is no bar code system.

The verification team was informed, that the SSM laboratory staff consist of 4-5 persons; each staff member has not been cross-trained on all analysis techniques used in the laboratory. This may create lack of staff competence situations if the laboratory workload increases.

The laboratory working space is quite small. This would create sample management and storage problems in the event of increased number of incoming contaminated samples in a radiological emergency.

The verification team recommends that the SSM restore the liquid scintillation counting capability in the laboratory.

The verification team suggests to consider increasing the number of permanent staff trained to carry out the analytical work in the laboratory.

If the number of samples analysed in the laboratory further increases, the verification team suggests introduction of a LIMS system with sample bar coding for the sample management.

The verification team suggests that the SSM laboratory drafts an operational contingency plan for a situation where the number of incoming, possibly contaminated, samples significantly increases.

The verification team suggests that the SSM proceeds towards laboratory accreditation.

6.2.3 Dose rate monitoring networks

The SSM presented to the verification team the technical characteristics and introduced detectors of the two telemetry networks for monitoring gamma dose rate and precipitation. The nationwide network consists of 28 dose rate monitoring stations with Gamma TRACER XL2-3 as detecting unit. The stations are located based on the population density. Data is received via the GSM network every hour; in the event of an emergency 10 minute data polling can be used. The current gamma detectors have been operational for about 10 years; the SSM is planning to renew the current detectors with new ones in the near future.

The second network managed also by the SSM consists of 30 stations for monitoring the dose rate around each nuclear power plant in Sweden. The data from these networks is transmitted using the non-public TETRA communications network. Alarm threshold is 300 nSv/h.

The public has access to the real-time dose rate and precipitation monitoring data from the nationwide network via the EURDEP web platform. The dose rate data received from the networks is not available at the SSM own website. Data from the ring stations are not transferred to EURDEP.

The verification team recommends making the on-line dose rate monitoring data available for the public via the webpage of the SSM.

The verification team suggests making the data from the NPP ring networks available in EURDEP.

6.3 SWEDISH GEOLOGICAL SURVEY

The verification team visited the geophysics laboratory of the SGU[19]. The geophysics team presented their role and equipment within the nuclear emergency preparedness in Sweden. The SGU has an agreement with the SSM to support them in emergency situations. The SGUs role is to measure gamma radiation from fixed wing aircrafts (helicopters are not used) in order to identify individual sources of radiation, or map radioactive fallout. Since the Chernobyl accident in 1986, the SGU has been a part of Sweden's preparedness program for nuclear and radiological events.

The SGU laboratory has developed two complete systems for airborne radioactivity measurements that are certified to be used in the specific aircraft. The systems include both NaI and HPGe detectors (Fig. 10 and 11). The measurement methodology is very sophisticated, well established and tested twice a year. The availability of aircraft and flying personnel is very good, since the radiation measurements are carried out in the framework of airborne geological surveys.

The verification team commends the sophisticated methods and the technical design of the equipment used for airborne radioactivity monitoring in Sweden.

6.4 SWEDISH FOOD AGENCY

The verification team was informed about the food radioactivity monitoring arrangements at the Swedish Food Agency. The agency has a long history of monitoring Chernobyl Cs-137 in food, especially during the first years after the accident. It is responsible for the national regulations within this area, but it does not have a radio-analytical laboratory. The regulations include specific requirements regarding monitoring of Cs-137 in reindeer meat and radioactive substances in drinking water. Producers of all food products are responsible to make sure that their products meet the national limits regarding content of radioactive substances. Producers of food and drinking water buy the necessary analytical work from commercial laboratories, including foreign laboratories. In addition, monitoring of certain food stuffs are included in the national monitoring program run by the SSM, including milk, mixed diet and drinking water.

The Swedish Food Agency is responsible for the national monitoring program concerning Cs-137 in reindeer meat. This is a control and monitoring measure after the Chernobyl accident. Monitoring is carried out in abattoirs by external measurement using gamma detectors and by sampling of reindeer products. The Sametinget (the Sami parliament) is responsible for contracting the laboratory; currently the analyses are performed by a private laboratory called Radonova**.**

Currently the Food Agency does not run any other regular monitoring program regarding radioactivity in food.

No remarks.

[19] Villavägen 18, Uppsala

6.5 SWEDISH DEFENCE RESEARCH AGENCY

The verification team visited the FOI monitoring station and the laboratories in Kista[20]. During the visit, the team had access to the air filter station on the roof, the air filter preparation room (storage of samples), the preparation and the measurement laboratories and to the storage and archive room.

They system comprises one automatic filter and five manual filter high-volume air sampling devices (1000 m^3/h, for five of six stations) and four precipitation collectors. The local operators are in charge of filter exchange and daily maintenance. The air filters and ion exchange resins from the stations outside Stockholm are collected weekly, transported and analysed in the FOI laboratory. The air filter in Stockholm has a flow of 1500 m^3/h and is analysed daily on demand.

At arrival, fast screening with a NaI detector is carried out on air filters in order to detect high contamination levels, followed by overnight measurements with an HPGe detector. At this stage two filters per station are compressed into one sample (25% saved as ref. material). Six air filters from the station in Stockholm are prepared as a composite sample and measured together (even if the six individual samples still exist as entities). The combined sample covers 1 week. The prepared samples are measured for 3-4 days. Ion exchange resins from the deposition collectors are ashed in the laboratory and measured on an HPGe detector. The results are evaluated and reported to the SSM.

The FOI gamma-spectrometry laboratory in Stockholm is very well equipped to measure the gamma-ray emitting radionuclides in the air and deposition samples. With the in-house developed analysis methods, several samples can be pooled together. Both commercial and in-house prepared standards are available for efficiency calibrations; in addition Monte Carlo calculations can be used for efficiency calibration and coincidence summing corrections. Detector stability (energy, efficiency and resolution) is followed on paper logs.

All samples are archived after measurement. The FOI air sample archive contains air monitoring filters starting from the 1950's.

Currently the FOI air monitoring system does not include an alarm function. There used to be a NaI detector with an early alarm at the stations, but these are not functional anymore.

The air sampling stations have also an option to monitor gaseous radioactive iodine by directing 1% of the total airflow through an activated charcoal cartridge. The cartridge is not analysed on routine basis, only if particulate iodine is found in the air filters, or there a reason to suspect presence of iodine in air (reactor accident).

The FOI radiation laboratory is not accredited. All procedures are documented, and work instructions are available to the staff. Sample registers are kept on paper logbooks. The laboratory participates in intercomparison exercises organised by the IAEA and the EC (DG JRC).

The verification team noted that due to the large collection volume the air filters arriving at the FOI laboratory in the event of radioactive release affecting Sweden could be quite radioactive. Therefore, special measures can be needed in order to avoid laboratory contamination and to maintain low counting background.

The verification team noted that the air radioactivity concentration data from Sweden is not made available to the EURDEP system by the SSM after receiving data from FOI.

> *The verification team commends the extent and technical sophistication of the FOI air and deposition monitoring arrangements.*

[20] Gullfossgatan 6, Kista, Stockholm

The verification team suggests advance planning for the management of contaminated air filters in the event of a radiological emergency, in particular when planning the work arrangements at the sample preparation room.

The verification team suggests SSM to include the Swedish air radioactivity concentration data to the EURDEP system data exchange.

6.6 CIVIL PROTECTION AND SWEDISH CIVIL CONTINGENCIES AGENCY

All municipalities in Sweden are required to have radiation dose rate monitoring capability – typically there are two dose rate monitors in each municipality fire brigade. This arrangement facilitates simultaneous dose rate measurement in about 900 monitoring points throughout Sweden. Some of the monitoring equipment dates back to 1998, a renewal project is on-going. In addition, the MSB has two CBRN detection teams (Stockholm and Göteborg) with more advanced instrumentation, including contamination monitors, neutron detectors and nuclide identification capability.

The verification team visited the Civil protection and Swedish civil contingency agency fire brigade located in Farsta, Stockholm, where the Stockholm area CBRN detection team is based. The team is well equipped to monitor radiation and it can be activated quickly. The monitoring equipment are regularly tested with small test sources. In addition to monitoring, the team is able to carry out also personnel and equipment decontamination and small radioactive source recovery operations.

The verification commends the availability and organisation of the radiation monitoring systems at the civil protection services.

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 Stockholm 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 Stockholm 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 Stockholm 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, data availability and advance planning of emergency monitoring. Notwithstanding these recommendations, the verified parts of the monitoring system for environmental radioactivity in Stockholm 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 Swedish competent authority through the Sweden Permanent Representative to the European Union.

(6) The Commission services kindly request the Swedish 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 Sweden.

(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 SWEDEN (STOCKHOLM)

4 – 6 December 2019

Wednesday 4 December

09:30 Opening meeting

Swedish Radiation Safety Authority (SSM) *(Solna strandväg 96, Solna)*

- European Commission Art. 35 verification programme introduction
- Discussion on past verifications in Sweden by the Commission
- Overview of radioactivity monitoring arrangements in Sweden
- Overview of radioactivity monitoring arrangements in Stockholm
- Verification planning

11.00 Radioactivity monitoring arrangements in Stockholm

Swedish Radiation Safety Authority (SSM) *(Solna strandväg 96, Solna)*

- Dose (TLD) and dose rate monitoring
- Air sampling
- Dry/wet deposition sampling
- Soil sampling
- Water sampling
- Mobile monitoring systems
- Emergency monitoring systems
- Public information arrangements
- Automatic dose rate monitoring network

14.00 Swedish Geological Survey, Uppsala *(Villavägen 18, Uppsala)*

- Mobile radioactivity monitoring facilities

16:00 Swedish Food Agency *(at SGU office, Villavägen 18, Uppsala)*

- Food and water radioactivity monitoring

Thursday 5 December

09.30 Swedish Defence Research Agency *(Gullfossgatan 6, Kista)*

- On-site radioactivity monitoring facilities
- Laboratory facilities

14.00 Radioactivity laboratory in Stockholm

Swedish Radiation Safety Authority (SSM) *(Solna strandväg 96, Solna)*

- Laboratory facilities

Friday 6 December

09:30 Civil protection and Swedish civil contingencies agency *(Lingvägen 155 Farsta)*

- Emergency radioactivity monitoring facilities

14:00 Closing meeting

Swedish Radiation Safety Authority (SSM) *(Solna strandväg 96, Solna)*