EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY AND TRANSPORT

DIRECTORATE H - Nuclear Energy
Radiation Protection

TECHNICAL REPORT

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

FORSMARK Nuclear Power Station

National Environmental Radioactivity Monitoring

SWEDEN

9 to 12 February 2009

Reference: SE-09/02

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35
OF THE EURATOM TREATY

FACILITIES:	- Provisions for monitoring and controlling radioactive discharges and for surveillance of the environment during normal operations of the Forsmark NPP - Provisions for monitoring and controlling levels of radioactivity on the national territory - The national radiological early warning network
DATE:	9 to 12 February 2009
REFERENCE:	SE-09/02
VERIFICATION TEAM:	Mr V. TANNER (Head of team) Mr J.L. FRICHET Mr A. RYAN Ms C. HANOT
DATE OF REPORT:	30 October 2009

SIGNATURES:

V. TANNER J.L. FRICHET

A. RYAN C. HANOT

TABLE OF CONTENTS

TECHNICAL REPORT

1 ABBREVIATIONS

24/7	24 hours, 7 days per week
BEGe Detector	Broad Energy Germanium Detector
BSS	Basic Safety Standards
DG TREN	Directorate-General for Energy and Transport
EC	European Commission
EURDEP	EUropean Radiological Data Exchange Platform
FKA	Forsmark Kraftgrupp AB (Forsmark NPP operator)
FWHM	Full Width at Half Maximum
GM	Geiger-Müller (radiation detector)
GPS	Global Positioning System
HELCOM MORS	Helsinki Commission – Monitoring Of Radioactive Substances
HEPA	High Efficiency Particulate
HPGe	High Purity Germanium (gamma radiation detector)
IAEA	International Atomic Energy Agency
ISO	International Standardization Organization
MCA	Multichannel Analyser
MDA	Minimum Detectable Activity
NaI	Sodium Iodine (gamma radiation detector)
NaI(Tl)	Sodium iodide crystals doped with thallium
OSART	Operational Safety Review Team
NFA	National Food Administration
SGU	Swedish Geological Survey
FOI	National Defence Research Agency
UTC	Universal Time Coordinated
QA	Quality Assurance
SKB	Svensk Kärnbränslehantering AB (Swedish nuclear waste management organisation)
SKI	Swedish Nuclear Power Inspectorate
SMHI	Swedish Meteorological and Hydrological Institute
SSI	Swedish Radiation Protection Authority
SSM	Swedish Radiation Safety Authority
UPS	Uninterruptible Power Supply

2 INTRODUCTION

Article 35 of the Euratom Treaty requires that each Member State establish the facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with the Basic Safety Standards[1].

Article 35 also gives the European Commission (EC) the right of access to such facilities in order that it may verify their operation and efficiency.

For the EC, the Directorate-General for Energy and Transport (DG TREN), and in particular its Radiation Protection Unit (TREN H4), is responsible for undertaking these verifications.

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

- Liquid and airborne discharges of radioactivity into the environment by a site (and control thereof).
- Levels of environmental radioactivity at the site perimeter and in the marine, terrestrial and aquatic environment around the site, for all relevant pathways.
- Levels of environmental radioactivity on the territory of the Member State.

From 9 to 12 February 2009, a verification team from DG TREN visited the site of the Forsmark Nuclear Power Station located on the Swedish east coast about 4 km north of Forsmarks Bruk in Östhammar Municipality in Uppsala County. The aim of the verification was to check the operation and efficiency of the facilities and associated analytical laboratories for continuous monitoring of the level of radioactivity in air, water and soil in the vicinity of the Forsmark site and on the territory of Sweden. The verification scope also covered the on-site facilities monitoring liquid and aerial discharges of radioactivity into the environment.

During the verification activities addressing the monitoring of radioactive discharges from the Forsmark NPP, the EC team was accompanied by representatives of the Swedish Radiation Safety Authority (SSM) and Forsmark NPP. During the verification activities relating to monitoring of the environment in the vicinity of Forsmark, the EC team was accompanied by representatives of Forsmark NPP.

The present report contains the results of the verification team's review of relevant aspects of discharge control and radiological environmental surveillance on and around the Forsmark site, as well as elements of the national radiological surveillance put in place by the competent Swedish authorities.

[1] Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the health protection of the general public and workers against the dangers of ionizing radiation (OJ L-159 of 29/06/1996)

3 PREPARATION AND EXECUTION OF THE VERIFICATION

3.1 Preamble

The Commission's decision to request the execution of an Article 35 verification was notified to the Swedish Permanent Representation to the European Union by letter TREN.H4 CG/cd D(2008) 438119 dated 28 October 2008.

Subsequently, practical arrangements for the implementation of the verification were made through contacts with the Swedish Radiation Safety Authority (SSM).

3.2 Programme of the visit

A preliminary programme of verification activities under the terms of Article 35 of the Euratom Treaty was discussed and agreed upon with the Swedish competent authorities.

The programme encompassed verifications of discharge monitoring at Forsmark NPP, environmental monitoring in the vicinity of the NPP and selected parts of the Swedish national environmental radioactivity monitoring programme.

The verifications were carried out in accordance with the programme, a summary overview of which is attached as Appendix 2 to this report.

3.3 Documentation

In order to facilitate the work of the verification team, a package of information was supplied in advance by the Swedish authorities in response to a questionnaire from the Commission. Additional documentation was provided during and after the visit. All documentation received is listed in Appendix 1. The verification team notes the comprehensiveness of the documentation provided. The information thus provided has been extensively used for drawing up the descriptive sections of this report.

3.4 Representatives of the competent authorities and the operator

During the verification visit, the following representatives of the national authorities and the operator were met:

Ministry of the Environment, Stockholm

Ansi Gerhardsson	Deputy Director, Ministry of Environment

SSM Stockholm

Carl-Magnus Larsson	Head of Department of Radioactive Materials
Lynn Hubbard	Head of Section, Emergency Preparedness
Maria Lüning	Analyst, Environmental Control
Inger Östergren	Laboratory engineer
Lena Wallberg	Laboratory engineer
Christer Karlsson	Site Inspector, Forsmark
Ann-Christin Hägg	Analyst, Discharges
Simon Karlsson	Analyst, Emergency Preparedness
Jonas Lindgren	Analyst, Emergency Preparedness
Birgitta Ekström	Inspector, Forsmark
Johanna Sandwall	Head of Section, Operation and Decommissioning of Nuclear Facilities

Helene Asp	Head of Section, Environmental Assessment
Pål Andersson	Analyst, Environmental Assessment
Forsmark NPP	
Staffan Hennigor	Radiation Protection Manager
Erika Bohl Kullberg	Specialist in Radiology
Mattias Olsson	Specialist in Radiochemistry
Erik Kjellgren	Group Manager
Charlotte Lager	Chemist
Jan Ola Helmersson	Group Manager
Maria Berglund	Chemist
Anette Grundin	Chemist
Felix Kuffner	Group Manager Radiophysics
Tomas Larsson	Manager Waste Department
Lena Eriksson	Engineer Waste Management
FOI Stockholm	
Karina Lind	
SGU Uppsala	
Sören Byström	Senior Advisor Airborne Geophysics

4 LEGISLATION AND COMPETENT AUTHORITIES

4.1 Primary legislation and derived regulations

The legal framework in the field of environmental radioactivity monitoring is to be found in the Radiation Protection Act (SFS 1988:220), which aims to protect people, animals and the environment from the harmful effects of radiation, and in the Environmental Code (SFS 1998:808), which addresses environmental aspects of nuclear activities and lists nuclear activities among several other "environmentally hazardous activities". The Swedish Parliament has appointed the SSM to implement its environmental quality objective, *Säker strålmiljö* (Safe Radiation Environment).

The provisions of the Radiation Protection Act and the Environmental Code supply the general principles of the regulatory regime. These acts are supplemented by a number of ordinances and other secondary legislation containing more detailed provisions of concern for environmental radioactivity monitoring.

In accordance with the Radiation Protection Ordinance (SFS 1988:293) the Swedish Radiation Safety Authority has issued a number of regulations implementing the EU Council Directive 96/29/Euratom.

Human health and the environment shall be protected from the harmful effects of ionizing radiation both during the operation of a nuclear facility as well as in the future. Releases of radioactive substances may not lead to more severe impacts on human health and the environment beyond Swedish borders than is accepted within Sweden.

The limitation of releases of radioactive substances from nuclear facilities shall be based on the optimization of radiation protection and achieved by using the best available technique (BAT). The optimization of radiation protection shall include all facilities located within the same geographically delimited area. The possibility that radiation doses to the personnel can increase when releases to the environment are limited shall be taken into account during the optimization as shall the consequences of other waste management alternatives.

The effective dose to an individual in the critical group of one year of releases of radioactive substances to air and water from all facilities located in the same geographically delimited area shall not exceed 0.1 mSv. The effective dose, which includes the dose from external irradiation and the committed effective dose from internal irradiation, shall be integrated over a period of 50 years.

When calculating the dose to individuals in the critical group, both children and adults shall be taken into consideration. Dose coefficients that are to be used for intake and inhalation are specified in Appendix III in the Council Directive 96/29/Euratom. When the calculated dose is 0.01 mSv or more per calendar year, realistic calculations of radiation doses shall be conducted for the most affected area. The calculations shall be based on measured dispersion data and knowledge of the conditions within the most affected area for the period concerned.

The basis for the dose calculations and the methodology used to calculate the relationship between released activity and effective dose shall be presented to the SSM for examination. The reference values shall be established for each nuclear power reactor with respect to annual released activity of individual radioactive substances or groups of radioactive substances. The reference values shall be worked out by the licensees and submitted to the SSM for examination. The basis for the proposed reference values shall be attached to the notification.

Target values shall be established for each nuclear power reactor with respect to the release of individual radioactive substances or groups of radioactive substances and shall show the level to which the releases can be reduced over a specific period.

Quality assurance and documentation of environmental surveillance shall be provided in accordance with the principles of ISO 9000. The laboratories used for the environmental surveillance shall, at the request of the SSM, participate in comparative measurements (inter calibrations).

For nuclear power reactors, plans of action shall exist to limit the release of radioactive substances that can arise in the event of fuel failures. The strategy for avoiding the occurrence of fuel failures and the measures planned to limit radioactive releases to the environment in the event of a fuel failure shall be described in the plans.

In the event of a release of radioactive substances to air or water, which results in a dose to any individual in the critical group exceeding 0.01 mSv per month or if results from environmental monitoring show abnormally large quantities of radioactive substances, the SSM shall be notified as soon as possible.

Before new facilities are brought into operation or the operational conditions are modified so that new release pathways or new release sources arise, or an existing release pathway is modified, investigations shall be conducted to determine the size and composition of the release, the environmental and dispersion conditions as well as expected doses. These investigations shall be submitted to the SSM for examination.

4.2 Environmental radioactivity monitoring

The following legal texts cover the statutory requirements for environmental radioactivity monitoring:

- The Swedish Radiation Protection Authority's Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities (*SSI FS 2000:12)*
- Environmental Control Program (SSI Report 2004:15)
- Swedish Environmental Objectives: Partial Objectives and Action Strategies (*Regeringens proposition 2000/01:130*) including guidelines for the implementation of *a Safe Radiation Environment*

Environmental monitoring shall be conducted in the surrounding areas of nuclear facilities in accordance with programmes formulated by the SSM. The programmes contain regulations for sampling, sample preparation, analysis, evaluation and reporting as well as information on the type of samples and sample locations.

At the request of the SSM, separate environmental monitoring shall be conducted and the environmental consequences to the most affected area assessed, for all events resulting in an increased release of radioactive substances to the environment. Continuous measurements of gamma radiation shall be conducted in the environment around nuclear power reactors, research reactors and material testing reactors. Measurements shall be conducted on land at a distance of about one kilometre from the facility.

Meteorological conditions at nuclear power reactor, research reactor and material testing reactor sites shall be continuously recorded.

4.3 Radiological surveillance of foodstuffs

The following legal texts cover the statutory requirements for foodstuffs radioactivity monitoring:

- Swedish Food Regulation, Food Act *(SFS 2006:804)*
- Swedish Food Regulation, Food Decree *(SFS 2006:813)*
- The National Food Administration Regulation (LIVSFS 1993:36) on certain foreign substances in food
- The National Food Administration Regulation (SLVFS 2004:7) on amendments of the National Food Administration Regulation (LIVSFS 1993:36) on certain foreign substances in food

4.4 Discharge monitoring

The following legal texts cover the statutory requirements for discharge monitoring:

- The Swedish Radiation Protection Authority's Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities (*SSI FS 2000:12)*
- EU Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the health protection of the general public and workers against the dangers of ionizing radiation

Releases of radioactive substances from a nuclear facility to the air and water shall be controlled through measurements. The detection limits of the measuring instruments shall be selected so that the effective dose can be estimated for an individual in the critical group.

Releases to the air via the main stacks of nuclear power reactors, research and material testing reactors shall be controlled through continuous nuclide-specific measurements of volatile radioactive substances such as noble gases, through nuclide-specific measurements of continuously collected samples of iodine and particle-bound radioactive substances as well as through the measurement of Carbon-14 and Tritium.

Releases to the air from a facility for fabrication of uranium pellets and nuclear fuel bundles, for storage or other handling of spent nuclear fuel, and for storage, handling or final disposal of nuclear material or nuclear waste shall be controlled through nuclide-specific measurements of particle-bound radioactive substances in continuously collected samples and, where relevant, Iodine and Tritium.

Releases to water shall be controlled through the measurement of representative samples for each release pathway. The analyses shall include nuclide-specific measurements of gamma and alpha-emitting radioactive substances as well as, where relevant, Strontium-90 and Tritium. The SSM conducts control measurements on representative water samples from each pathway from the month before and after the outage period. The samples are analysed for gamma radiation.

Representative annual samples of releases to water from nuclear power, research or material testing reactors shall be submitted to SSM within three months after the end of the release year. The samples are analysed for nuclide-specific gamma and for tritium. The functioning of measuring equipment and release-limiting systems shall be regularly controlled and also in the event of any suspicion of a malfunction. Written instructions shall exist for the maintenance of the equipment. Any modification of regular systems for the monitoring of releases shall be approved in advance by the SSM.

Measuring and sampling equipment for the control of releases to air may be out of order for a period not exceeding 24 hours for maintenance or in the event of a malfunction without any special permission from the SSM. If the measuring equipment is out of order for a longer period of time, operation may continue, during non-office hours, until the Swedish Radiation Protection Authority has been contacted, on condition that the operation can be expected to be stable from the standpoint of releases. The reasons upon which this assessment was made shall be reported when the SSM is contacted. When the regular measuring equipment is out of order, other monitoring systems shall be used, to an adequate extent, in order to determine the released activity.

The measuring equipment may only be shut down, for other reasons, after special permission has been obtained from the SSM. The nuclear power reactor coolant shall be analyzed. The analyses shall include nuclide specific measurements of gamma and alpha-emitting radioactive substances as well as Strontium-90 and Tritium. If the possibility of diffuse leakage of radioactive substances is suspected, and it is not possible to determine such leakage by measurements, an investigation shall be conducted to determine an upper boundary for possible undetectable leakage to air and water from the facility.

4.5 Competent authorities

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. The authority took over the responsibilities and tasks from the Swedish Radiation Protection Authority (SSI) and the Swedish Nuclear Power Inspectorate (SKI) when these ceased to exist on 30 June 2008. SSM is therefore the competent authority according to the Radiation Protection Act (SFS 1988:220) and the Nuclear Activities Act (SFS 1984:3). The Swedish parliament has appointed SSM to implement its environmental quality objective *Säker Strålmiljö* (Safe Radiation Environment).

According to the Radiation Protection Ordinance (SFS 1988:293) SSM has the mandate to issue regulations in the field of radiation protection including environmental monitoring and discharge control. The SSM Regulations on the Protection of Human Health and the Environment from the releases of Radioactive Substances from Certain Nuclear Facilities (*SSI FS 2000:12*) include provisions on environmental monitoring in the vicinity of nuclear facilities. The environmental monitoring programme has been issued by the SSI (latest version, SSI report 2004:15, valid from 1st of January 2005). It specifies types of sampling, sample treatment, radionuclides to be measured, reporting, etc. Every year a basic programme involving spring and autumn sampling is conducted. Furthermore, certain samples are taken on a monthly and quarterly basis. In addition to the basic programme, extended sampling is also conducted every fourth year at most of the facilities. The extended programme focuses exclusively on samples taken in the marine environment.

National Board of Fisheries conducts the sampling of environmental samples outside the facilities. The samples are analysed by the facilities themselves or at an external laboratory.

National Defence Research Agency (FOI) operates a national air sampling network to detect particulate radionuclides in the air.

National Food Administration (NFA) 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. The responsibility of the NFA includes also radioactive contaminants in food. Food control at the local level is the responsibility of the relevant municipal committee(s), usually the Environment and Health Protection Committee. County administrations are responsible for co-ordinating food control within each county.

Swedish Geological Survey (SGU) carries out airborne radiation monitoring.

5 MONITORING OF FORSMARK NPP RADIOACTIVE DISCHARGES

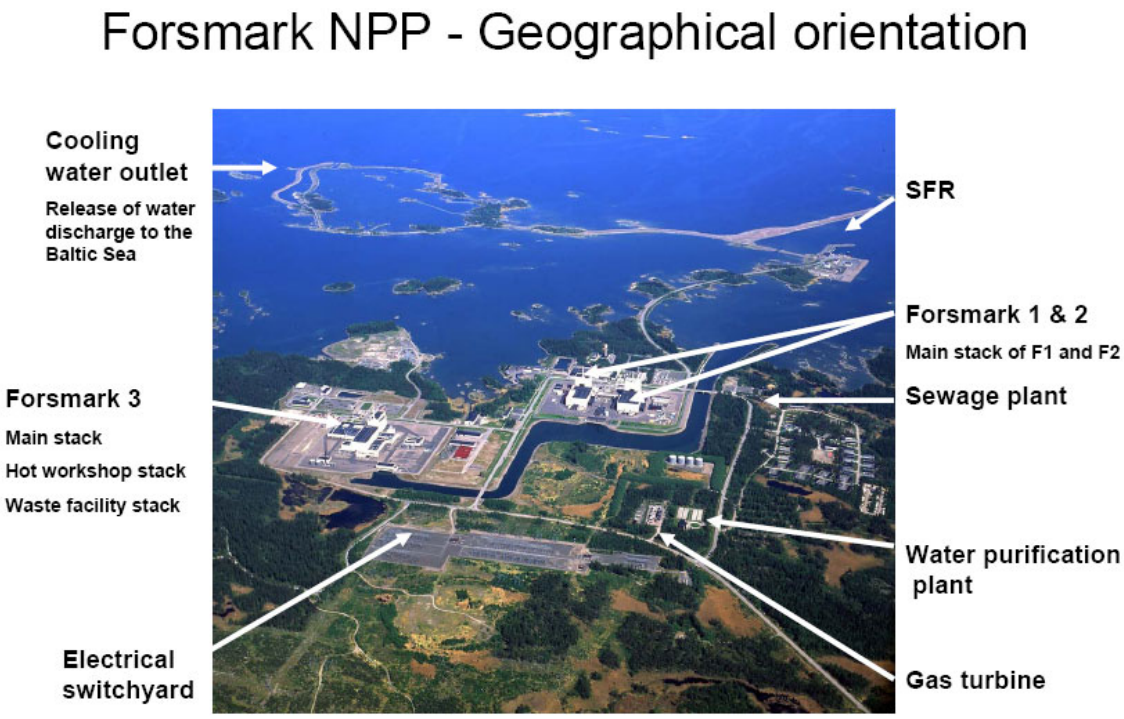
5.1 General description of the Forsmark NPP

Forsmark nuclear power plant is situated on the Swedish east coast about 4 km north of Forsmarks Bruk in Östhammar Municipality in Uppsala County. It is situated on the coastline of the Baltic Sea and uses sea water for cooling. The immediate surroundings with the villages Öregrund, Östhammar, Österbybruk, Gimo and Tierp are sparsely populated but the distance to large consumers of electricity such as the larger cities, Gävle, Uppsala and the whole Stockholm area is relatively short.

Discharges from the Forsmark NPP are mainly to the Baltic Sea. To study the effects of releasing heated cooling water into the sea an artificial "atoll", the Biotest Lake, has been constructed.

The plant consists of three nuclear power units, all of which are boiling water reactors (BWR). The power plant's industrial area also houses storage and workshop buildings necessary for the most common repair and maintenance work. Figure 1 provides an aerial picture of the Forsmark NPP area.

Figure 1. Forsmark NPP



The three nuclear power units were all designed by the former ASEA-ATOM (currently Westinghouse Electric). Construction of Forsmark 1 and 2 (F1, F2) started in 1971 and 1973 and they were put into commercial operation in 1980 and 1981 respectively. They currently have a net output of 1010 MWe each. The reactors produce saturated steam with a pressure of 7 MPa for direct use in the steam turbines (two turbine trains per reactor). The fuel in the reactor core is enriched uranium dioxide. The maximal thermal output in each unit is 2928 MW. Since the reactors have internal circulation pumps and fine motion control rods they are considered to be an early advanced boiling water design.

Forsmark 3 (F3) is similar to F1 and F2, although unit 3 has only one turbine train. Construction of the unit started in 1978 and it was put into commercial operation in 1985. Another difference between F1/F2 and F3 is that the latter is designed to withstand seismic events far greater than those foreseen to occur in Scandinavia. The physical separation is also more advanced. F3 has 700 fuel assemblies (676 in F1 and F2), which generate a nominal thermal output of 3300 MW. F3 currently has a net output of 1190 MWe.

Forsmark reactors produce close to 25 TWh per year, which is about one sixth of the Swedish electricity production. During the verification visit all units at the Forsmark site were in commercial operation.

A disposal site for low and intermediate level waste (SFR) is located in close vicinity to the Forsmark site. The license holder for the SFR facility is the Swedish Nuclear Fuel and Waste Management Co. (SKB) but the facility is operated by FKA. Discharges from the SFR-facility are regulated in the regulation of discharges from nuclear installations and included in the total discharges from the Forsmark site.

The Forsmark site also includes a shallow land burial site for short-lived very low level waste.

5.2 Regulatory limits for gaseous and liquid discharges

5.2.1 Description

SSM has not defined any radionuclide specific discharge limits. Limitation of releases is being implemented through the restriction of dose to the critical group members [3]. For each nuclear facility, e.g. each reactor at Forsmark, and for each radionuclide that may be released, specific release-to-dose factors have been calculated. The factors have been calculated for hypothetical critical groups, and take into consideration local dispersion conditions in the air and in the environment, local settlements, locally produced food as well as moderately conservative assumptions on diet and contribution of locally produced foodstuffs to the diet of the group. The latest release-to-dose factors are based on more realistic assumptions than earlier ones and are in line with the requirements in the EU BSS.

For nuclear power reactors, release-to-dose factors (mSv/Bq) have been calculated according to the Appendix III of the Council Directive 96/29/Euratom for 97 radionuclides that may be discharged to the marine environment and 159 radionuclides that may be emitted to air. The dose contributions from all monitored radionuclides are summed, and this sum shall not exceed 0.1 mSv for a calendar year. Facilities are required to notify SSM of any abnormal releases or if the dose limit of 0.01 mSv/month to any individual is exceeded.

Nuclear power plants are required to report to SSM on a regular basis the releases to air and water and the estimated doses to individuals.

5.2.2 Verifications

The verification team verified the regulations concerning the regulatory limits for gaseous and liquid discharges and noted the following:

- There appears to be no formalised policy for reporting values below MDA in Sweden and there has been no regulatory guidance on the required instrument sensitivity. In Forsmark the policy is to report zero if the measured value is below the MDA of the system.

Verification team recommends that SSM considers the benefits of revising its regulatory requirements for substitutions of analytical results below MDA by bringing these requirements in line with the Commission Recommendation 2004/2/Euratom and ISO standard 11929-7:2005.

5.3 Monitoring and sampling provisions for gaseous discharges

5.3.1 System description

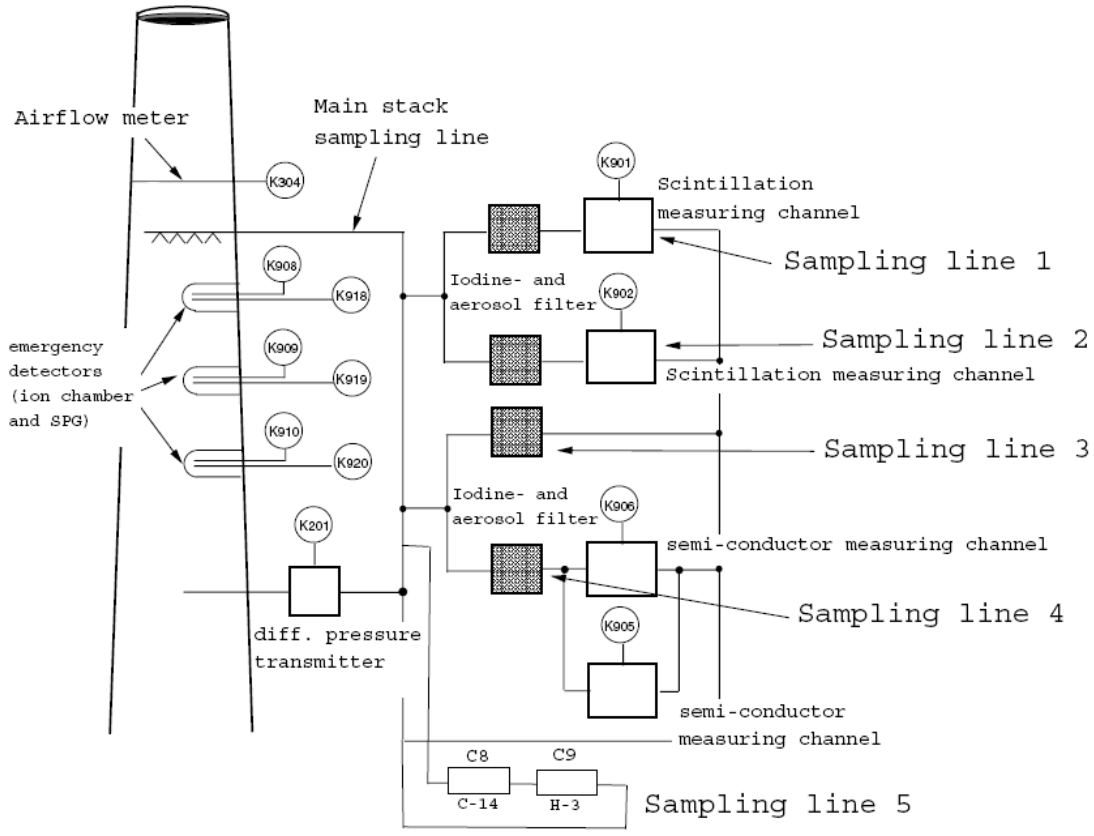
Allowed release points at Forsmark site for gaseous discharges are unit main stacks (3), waste building ventilation stacks (1), hot work-shop stack (1) and the emergency filter building stacks (3).

Main stack monitoring

Discharge from the main exhaust stacks is controlled by on-line measurements of total radioactivity, nuclide-specific on-line monitoring of noble gases and continuous sampling of aerosol particles and iodine. Also C-14 and tritium are continuously sampled.

From the main stack of each unit an isokinetic partial flow is directed proportionally through five parallel sampling lines (Figure 2). For each sampling line calibrated gas flow meters are used to determine the flow volume. Readings are recorded on each filter change to calculate the total filter flow volume. The total flow in the stack is measured using an annubar probe inside the stack that registers the difference between the static and dynamic pressure. The value is transmitted to the plant central computer system.

Figure 2. Main stack discharge monitoring



Sampling lines 1 and 2

Sampling lines 1 and 2 are used for collection of aerosols and iodine using combination filters (glass fibre filter attached to a carbon filter cartridge). The filters are changed and evaluated for gamma nuclides once a week (line 1) or once a month (line 2). The collected activity in the filters is continuously monitored by GM-detectors. If high values are measured sampling line 3 starts automatically.

The samples are to be evaluated within 24 hours after filter removal. At evaluation the results are corrected for decay during the sampling period. The filters are separated into the aerosol collecting part (glass fibre filter) and the iodine collecting part (carbon filter) before measurement on germanium detectors. The aerosol filters changed every month (line 2 or line 4) are also used for determination of Sr-90 and nuclide specific alpha. These measurements are done every 6 months on composite batch samples.

To get a continuous measurement of the total gamma activity discharge air is led into measuring chambers with NaI(Tl) detectors after the aerosol and iodine filters. Count rate values from these detectors are continuously displayed in the control room. The detector stability is continuously monitored using an attached check source. The computer system gives an alarm if the count rate values are too high or too low.

If the total activity measurement malfunctions, readouts from the nuclide specific measurement should be taken every hour or manual air samples should be taken every other hour for analysis in the laboratory. If the sampling for iodine and aerosols is malfunctioning, manual air samples should be taken within one day.

Sampling line 3

This line is an extra line intended for future needs. It is supplied with particle- and iodine filters and can be used if the sampling in line 1 or 2 is malfunctioning.

Sampling line 4

In this line the discharge is continuously evaluated for noble gas content by nuclide specific gamma measurements using germanium detectors after having passed filters that remove aerosols and iodine that otherwise would have interfered with the measurements. The on-line gamma detector evaluates the data every 6 hours. There are two electrically cooled HPGe-detectors, (553K905, 553K906) on F1 and F2 and two nitrogen cooled HPGE- detectors (553KB741, 553 KD742) on F3. The two detectors at each reactor have separate electronics and computer systems. They are both running in parallel giving redundancy to the monitoring system. If the nuclide specific measurement is out of order (the total activity measurement is running) manual air samples should be taken once every 24 hours. This should be noted in the reports and the results should be calculated conservatively.

Sampling line 5

The flow in this line is led through sampling equipment that collects C-14 and H-3. C-14 is continuously collected in NaOH and H-3 is continuously collected in water (MARC 7000 Tritium sampler and HAGUE 7000 Carbon sampler). Every fortnight the samples are changed and after a couple of days (decay time for short lived nuclides) they are measured using a liquid scintillation counter. If the C-14 and H-3 sampling is not working, there should be a stand-in measurement system operating within 7 days.

Main stack emergency monitoring

For emergency monitoring purposes there are detectors in the main stack that are able to measure higher doses than the on-line HPGe- and NaI-detectors. An ion-chamber and a Self Powered Gamma (SPG) - detector is connected to the control room for on-line continuous monitoring. To ensure that the detectors are working they are equipped with a Cs-137 background source. The systems will give an alarm when the signal is too low indicating that the systems might malfunction, or too high indicating an emission of radioactivity. These systems are able to cover a very wide dose rate range ($10 – 10^6$ Gy/h).

Emergency filter building stack monitoring

In case of a major emergency pressure release, steam from the containment can be led through an emergency filter (FRISK-system [1]) and vented to the atmosphere through the emergency filter building stack. The release through this stack is monitored with an on-line ionisation chamber and aerosol and iodine filters. Monitor readings are available locally and at the control room. There are alarms for high and low readings. The filters are changed annually.

Condenser off-gas monitoring system

Apart from the actual discharge monitoring Forsmark NPP has developed a system for monitoring gaseous activity in the condenser off-gas system in order to detect and locate possible fuel failures as early as possible. The system is based on three NaI-detectors and one electrically cooled HPGe detector. The NaI detectors monitor the total off-gas activity and the HPGe system collects the gamma spectrum of the condenser off-gas on 20 minute cycles for qualitative analysis. Spectrum data is analysed on weekly basis.

Monitoring at the waste handling facility

The exhaust stacks at Forsmark 3 waste handling facility and the hot workshop are monitored by having a partial flow pass through filters that collect aerosols and iodine. The filters are changed and measured weekly. The filters are continuously monitored using NaI-detectors and an alarm will go off if the activity concentration in the filters becomes too high.

5.3.2 Verifications

Verification team verified the following gaseous monitoring arrangements at F2:

- Noble gas monitoring computers located at the control room area. Two redundant systems collect the on-line data from the stack monitors, perform spectral analysis at 6 hour intervals and store the results into the plant database.
- Stack monitor display systems available at the operator panels in the control room (activity and airflow). Here the system stores the results on memory cards, which are archived for verification purposes. Alerts on high values are available at the plant control system.
- Condenser off-gas monitoring system
- Emergency filter building monitoring systems
- Main stack on-line monitoring systems
- Main stack off-line monitoring systems
- Main stack emergency monitoring system

Based on the verifications the team noted the following:

- The gaseous discharge monitoring system at F2 is very sophisticated, well equipped and adequately maintained. It appears to adequately meet the gaseous discharge monitoring requirements both in routine and emergency situations.

  Verification does not give rise to recommendations.

5.4 Monitoring and sampling provisions for liquid discharges

5.4.1 System description

At the Forsmark waste treatment facilities, radioactive waste water is collected in special tanks. The waste water is purified by an evaporator which gives almost pure water with most of the activity collected in a concentrate that is deposited in rock caverns of the underground repository SFR.

Water discharge is released to the cooling water outlet from F1 and F2 release tanks (00-342 T62/T64 and 30-342 TC61/TC62). Prior to release of water into the recipient a non-statutory pre-sample is taken and measured to control that the radioactivity is sufficiently low. For F1 and F2 this is done using a one litre sample flask on a 3" NaI-detector. At F3 the pre-samples are measured using a HPGe-detector. If the pre-sample indicates too high activity values the tank contents are redirected to the purification system (the verification team was informed that this has not happened for several years). The waste water release valves are normally locked closed. A key is provided by the shift manager after the tank activity has been confirmed to be below the activity limit.

During the discharge a proportional part (1/10000) of released water is collected in a special tank. The water from this sampling tank is analysed each month with regard to nuclide specific gamma emitters. Samples are filtered through a glass fibre filter. The particle fraction (on the filter) and the water fraction are measured separately. Water is distilled before measurement of H-3 and 20 ml water is evaporated to measure total alpha. From each monthly sample a part is acidified by HNO_3 and kept to form a weighted 6 months batch sample which is used for evaporation in order to carry out nuclide specific alpha analysis and phase separation for Sr-90 analysis.

As an extra security measure, on-line NaI-detectors monitor the pipes during discharge. If the dose rate is too high the valves close automatically and the water release stops. This measurement is connected to the central control room but the results are not used for statutory reporting.

Representative monthly samples (two from F1/2 waste facility and two from F3) are taken one month before the outage period and one month after the outage has ended. The samples are sent in to the SSM within two months after the monitored discharge month's end.

Representative annual samples of discharged water (for each release point) are sent to SSM within three months after the end of the year.

5.4.2 Verifications

Verification team verified the following liquid discharge monitoring arrangements at F3:

- Control room monitoring arrangements
- Arrangements at the statutory sampling station at the waste water treatment facility
- Arrangements at the waste water tank pre-sampling station at the waste water treatment facility
- Locking of the main release valves

Based on the verification the team noted the following:

- The arrangements for taking the statutory liquid discharge sample are sophisticated and well built. They appear to adequately meet the sampling requirements.

However,

- At the statutory sampling station the tank rinsing line valve is not locked. Opening this valve (346 VC16.V1) could accidentally dilute the statutory sample collected in the tank.
- There was no sampling instruction available at the release tank pre-sampling station.

  Verification team recommends making sure there is no possibility of accidental dilution of the contents of the statutory release sample.

  Verification team recommends making sure there is a written sampling instruction available at each sampling station.

5.5 Forsmark 3 discharge monitoring laboratory

5.5.1 Description

F3 analytical laboratory carries out the measurements of the plant discharge samples. The laboratory is well equipped and adequately staffed, but not accredited. It has two HPGe detectors (Canberra) for gamma spectroscopy and one Liquid Scintillation counter (Tri-Carb 2900TR) for C-14 and H-3 analysis. Statutory discharge samples are kept in a locked sample archive.

The laboratory participates in IAEA and joint Swedish-Finnish round-robin inter comparison exercises on a regular basis.

5.5.2 Verifications

Verification team verified the following analytical arrangements for discharge monitoring at the F3 laboratory:

- Sample preparation arrangements
- Counting room arrangements
- Sample archiving arrangements

Based on the verification the team noted the following:

- The laboratory is well staffed and equipped and therefore fully able to carry out its analytical tasks.

However,

- The laboratory has a control routine for HPGe detector stability (energy, efficiency and peak FWHM). It was noted that the efficiency stability test indicated unusually large variations in the BRAD detector efficiency.

Verification team recommends making sure the HPGe-detector efficiency stability test procedure at the F3 laboratory is adequate and the stability of each detector is thoroughly controlled.

5.6 Forsmark 1/2 discharge monitoring laboratory

5.6.1 Description

Forsmark 1/2 analytical laboratory carries out the measurements of the gaseous and liquid radioactivity discharge monitoring programme (liquid pre-samples, statutory samples, stack filters, condenser off-gas filters and gaseous samples) from units F1 and F2. The laboratory is in charge of maintaining the monitoring equipment located at the plants.

The laboratory has three HPGe gamma detectors (2 Canberra, 1 Nuclear Data) for gamma spectroscopy and one liquid scintillation counter (Tri-Carb 2900 TR) for total alpha/beta measurements. In addition the laboratory has two old alpha counters (Canberra and Tennelec), which are currently being replaced by a new system (Canberra α-Analyst). The laboratory has also portable gamma spectroscopy systems.

5.6.2 Verifications

Verification team verified the following analytical arrangements for discharge monitoring at the laboratory:

- Sample preparation arrangements
- Counting room arrangements
- Sample archiving arrangements

In addition special attention was paid to the changes implemented after the gaseous discharge monitoring incident, which took place at F1 in 2006. The verification team was informed, that after the incident a filter cross-checking procedure was put in place in all the Swedish NPPs. This procedure together with a new procedure for filter colour control should allow the laboratory personnel to detect any filter by-pass flow affecting the measurement results.

Based on the verification the team noted the following:

- The laboratory is well staffed and equipped and therefore fully able to carry out its analytical tasks.
- Corrective action has been taken in order to avoid the monitoring deficiencies encountered in 2006. It should be also acknowledged that these corrective actions have been implemented also in other Swedish NPPs.

Verification does not give rise to recommendations.

6 ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMMES

6.1 Forsmark NPP environment monitoring programme

6.1.1 Description

The environmental control programme determines impact to the environment by monitoring dose rates and the concentration of radionuclides in water and on the ground. The programme also provides reassurance that discharges are estimated correctly and that unusual discharges to the environment are recognised early.

The regulations [SSI FS 2000:12] include provisions on environmental monitoring. The environmental monitoring programme is issued by the SSM (latest version, SSI report 2004:15, valid from 1st of January 2005) and specifies type of sampling, sample treatment, radionuclides to be measured, reporting, etc. The site-specific monitoring programmes vary depending on the facility and are divided into a terrestrial and an aquatic part. The selection of environmental samples (biota and sediments) has been conducted in order to be representative of the area around the facility and preferably to be similar (or have a similar function in the ecosystem) for all facilities. Species which are part of the human food chain are also selected. Every year a basic programme involving spring and autumn sampling is conducted. Furthermore, certain samples are taken on a monthly and quarterly basis. In addition to the basic programme, extended sampling is conducted every fourth year at most of the facilities. The extended programme focuses exclusively on samples taken in the marine environment. The National Board of Fisheries conducts the sampling of environmental samples from outside the facilities.

The samples are analysed by the facilities themselves or at an external laboratory. The laboratory has to have an adequate system for quality assurance. To verify that the facilities comply with the programme, SSM conducts inspections and takes random sub-samples for measurements at the SSM or at independent laboratories.

Discharges from Forsmark are mainly to the Baltic Sea; therefore the water environment is thoroughly monitored with samples from various water living organisms from a large number of sampling sites. There are in total 27 sampling sites within 13 km from the plant. The land environment is also closely monitored: soil, vegetation and sludge are sampled as well as human foodstuffs such as milk, meat, vegetables and grain. There are 10 sampling sites for the land environment (excluding dosimeter sites (23 TLD's)), all within 12 km from the plant. All samples are measured for nuclide specific activity but also with regard to weight and appearance to determine if any effects to growth and reproduction occur.

The environmental control programme consists of two parts: an annual base programme and an extended programme performed every four years. The base programme makes it possible to detect short-term trends and covers a larger geographic area. Tables I-III summarise the content of the two programmes.

Table I Forsmark NPP water environment base programme

Sample type	Number of stations	Frequency	Number of samples	Number of samples / year
Diatomic algae	3	Monthly	1	36
Sediment	3	Quarterly/(autumn)	1	9
Algae	5	Autumn	1	5
Molluscs	4	Autumn	3	4
Fish	3	Spring/Autumn	4	9

Table II Forsmark NPP water environment extended programme

Sample type	Number of stations	Frequency	Number of sample types	Number of samples /4 year period
Algae	6	Each fourth year	3	10
Molluscs	8	-"-	3	9
Sediment	11	-"-	1	11

Table III Forsmark NPP land environment base programme

Sample type	Number of stations	Frequency	Number of samples	Number of samples / year
Natural vegetation	7	Spring/ Autumn	5	17
Cultivated vegetation	3	July+ Autumn	5	7
Animal samples	1	Autumn	1	1
Milk	1	Each fortnight (pasture season)	1	10-14
Sludge	4	Autumn	1	4
Dose measurements (TLD)	23	Quarterly		92

The National Board of Fisheries delivers most of the samples; staff from Forsmark picks up the milk samples at a nearby farm.

All radioactivity measurements are performed on dry materials. Most samples are burnt into ashes in ovens and thereafter measured in established geometries on germanium detectors in the laboratory for environmental samples.

Water sampling of the plant foundation drainage collection system is performed once a month. To verify that the drainage systems for each unit have not been contaminated, sludge samples are removed from pump holes every year after the outage period. The sludge is measured by nuclide specific gamma analysis.

For continuous evaluation of the gamma radiation in the vicinity, 23 TL-dosimeters (LiF-700) placed in little red boxes are placed within a radius of about one km from the plant. These are changed and evaluated quarterly.

Seven short link Gammatracer probes (Genitron Instruments operated with their own battery) are mounted in the surroundings and continuously monitor the dose rates. There is one mobile unit as well to be used in an emergency situation. The probes send data to the water tower where the signals are gathered and displayed in the Genitron software, accessible from computers at the plant. The system is intended for use in emergencies, not during normal operation. The batteries typically last for five years at normal background levels. GammaTracer has a built-in quality assurance system which continuously compares the two GM detectors to ensure that they are consistent and verifies other operating parameters. Any irregularity is logged in the probe's memory and flagged by a marker in the displayed area, once this is downloaded. The nature of the irregularity can then be investigated by the user.

6.1.2 Emergency monitoring arrangements

An emergency room is located on site where different equipment is kept for use in case of emergency. The monitoring equipment consists of one mobile short link Gammatracer unit (Genitron) and 4 portable air pumps with petrol engines for air sampling. There are also two personnel monitors to be used by the cleaning staff (for example). The room is locked and one key is kept in the emergency centre and another by the duty officer. A specific trailer would be used in case of emergency to pick up the equipment operated by the rescue team.

To be able to warn the staff in emergency situations dose rate monitors have been installed in the main entrance, security centre and the switchboard room as well as in the control room of each unit. Mobile units

are placed at nine assembly points in an emergency situation. The detectors are Automess Gamma-Alarm-Station 859.1 with a battery backup. They are calibrated annually and their function is tested once every six months with a known source. Calibration and functionality testing is documented in a log-book.

6.1.3 Meteorological station

The meteorological station consists of a meteorology tower about 1 km from the plant. There are measuring points for temperature at 2, 8, 24 and 100 m heights. The temperature difference between different heights is given for points above 2 m. Wind speed and direction are measured at 25, 50 and 100 m. Measurement data is transferred to a server in the emergency centre where it is processed using the Airviro computer system (SMHI, Sweden). Data can be reached through a web based application from every computer within the plant. For the transfer of data to the Swedish Meteorological and Hydrological Institute SMHI two cables are used; one fibre-optic and one copper.

6.1.4 Forsmark NPP environmental monitoring laboratory

The environment monitoring laboratory is located outside the controlled area. It has separate rooms for sample preparation and measurements of radioactivity. In the laboratory there are 2 HPGe-detectors (Canberra and Enertec). In case of emergency, this equipment can be taken out and used in the field.

Sample reception: sample identification and registration procedure

Deep frozen samples are received from the coastal laboratory in Öregrund, an independent agency. Most of the samples are already prepared. Upon reception, they are recorded in a binder and labelled with sampling information (date, type, station, sample collector, possible remarks).

Sample preparation and measurement

Samples are dried in two clay ovens at 80°C (except on-growth samples). When dried, samples are weighed and burnt into ashes in two other ovens at a maximum of 430°C. One oven is new and was being tested at the time of the verification. Ashes are then compacted and put into boxes labelled with sample date; this label information is cross-checked with the database. Samples are then measured for 80.000 sec on one of the HPGe-detectors and analysed with regard to the following radionuclides: Cr-51, Mn-54, Fe-59, Co-58, Co-60, Zn-65, Nb-95, Ag-110m, Sn-113, I-131 (milk), Cs-134, and Cs-137, this being the standard list of nuclides for analyses. Other nuclides are on the print-out of the measurement results.

Values are recorded on paper and stored in an interim fireproof archive for 18 months before being transferred to the central archive. Final results for each sample are filed both on paper and in the database.

Reporting obligations

Report on detected nuclides is sent to SSM in six month and annual reports with set parameters. The safety and environment department is responsible for sending reports to SSM. Every instruction for analysing nuclides is under the control of SSM. The laboratory is audited internally and externally (by SSM, IAEA OSART mission and WANO) on a three year basis.

Double samples on several sample types are gathered and sent to the SSM for independent analysis, thus allowing a double check sampling system.

Archiving

Written instructions are available for the staff on how to handle and archive samples. Treated samples are kept in an interim storage for 18 months before being transferred to the central archive for at least 10 years storage. Milk samples are freeze dried in a LABCONCO machine for storage. During the verification visit the main archive room was being modernized.

6.1.5 Verifications

The verification team verified the following arrangements of the environmental monitoring programme in place at Forsmark NPP:

- Overall structure of the programme
- Measurement equipment of the environment laboratory
- Sample preparation, measurement, reporting and archiving procedures at the laboratory
- Sampling of the Baltic sea water environment
- Site emergency room and the instruments ready for use in case of emergency
- Availability and distribution of the data collected by the weather station

The verification team noted that:

- Forsmark NPP environment programme is comprehensive and well implemented. The only remark is that the programme does not include monitoring of rain water radioactivity.
- The environment laboratory is well equipped and staffed, but has no formal accreditation.
- The laboratory database is user-friendly and shows records of analysed samples back to 1976 (3.600 samples).

The verification team suggests considering implementation of a rain water radioactivity monitoring programme.

The verification team suggests that the environment laboratory proceeds towards a formal accreditation.

6.2 National environment radioactivity monitoring programme

6.2.1 Introduction

SSM has implemented a national environmental radioactivity monitoring programme outlined in Table IV.

Table IV. National environmental monitoring programme overview

	Nuclides	Number of samples	Comments	Involved organisations
National monitoring				
Particles in air	γ (^{137}Cs, ^{7}Be)	5 stations	Weekly	FOI, SSM
Surface water	^{137}Cs, total-α, total-β, $^{234, 238}$U, ^{226}Ra	2 water plants	Spring and autumn	SSM
Drinking water	^{137}Cs, ^{90}Sr, ^{3}H, total-α, total-β, $^{234, 238}$U, ^{226}Ra	6 water plants	Spring and autumn	SSM
Consumption Milk	γ (^{137}Cs), ^{90}Sr	5 dairies	4 times/year	SSM
Mixed diet	γ (^{137}Cs), ^{90}Sr	3 hospitals	Spring and autumn	SSM
Game meat (moose and roe deer)	γ (^{137}Cs)	2 areas	Yearly	SLU, Gävle jaktvårdkrets, SSM
Reindeer meat	γ (^{137}Cs)	32 villages	Varying extent in different villages	SJV, SLV
Marine sediments open sea	γ (^{137}Cs)	16 stations	Every 5th year	SSM
Marine fish	γ (^{137}Cs)	8 areas	Yearly	SSM
Sea water	γ (^{137}Cs)	6 stations	Yearly	SSM
Regional monitoring				
Some municipalities have their own programs or offer the citizens to analyse their own samples of mainly game meat, mushrooms, fish, and berries.	γ (^{137}Cs)		In many occasions rather a service to citizens than a proper monitoring program. Some data are available through web site of SSM.	

Local monitoring				
Recipient control around nuclear sites. Precipitation, natural vegetation, cultured vegetation, meat, milk, sewage sludge, water, sediment, algae, molluscs, crustaceans, fish.	γ (^{54}Mn, ^{58}Co, ^{60}Co, ^{65}Zn, ^{110m}Ag, ^{137}Cs), ^{234}U, ^{235}U, ^{238}U (only Westinghouse site)	In total 184 sampling stations on six sites	Sampling frequency between once a fortnight and once a year plus an extended program every forth year.	Nuclear facilities and SSM
Mapping projects				
Agricultural soils and crops	γ (^{137}Cs)	1250 locations	2001-2010	NV, SLU, SSM
Airborne mapping of ground radiation	γ (^{137}Cs, K, U, Th)	surface covering	ongoing	SGU, SSM

6.2.2 External gamma dose rate monitoring

Sweden has an automatic network of 32 fixed gamma monitoring stations throughout the country. The main purpose of the network is to give an alarm if there is a significant increase above the natural background gamma radiation level and to give an instant overall picture of the radiation situation in Sweden.

The network is old and in need of modernisation. 28 new gamma monitoring stations will be installed among the existing weather stations in collaboration with the Swedish Meteorological and Hydrological Institute (SMHI). It is planned to use the old and new networks together for about 6 months. (Up to May 2009, 9 new stations have been installed.)

The measuring device of the old network consists of a pressurised ionisation chamber with a measuring range of 1-600 000 nSv/h ambient dose equivalent rate. The average normal background level in Sweden is 100-150 nSv/h. The results are stored locally on a microcomputer, which is equipped with a modem. There is also a local data display. The main computer in SSM in Stockholm calls each gamma station over the public network 12 times per day to collect data. The microcomputer at each station is equipped with an alarm function, which is triggered on a pre-set alarm criterion. The dose rate is continuously integrated over a twenty-four-hour rolling period. The alarm criterion is an integrated dose rate of 300 nSv/h above the preceding 24 hour average.

The system has shown a high degree of reliability which is important since many of the stations are in remote areas. In case of alarm, the station calls a personal pager, displaying the individual code of the station. The radiation protection officer on duty can then contact the station with a portable PC and a modem and obtain a reading. The system is sensitive, but in practise it has been difficult to distinguish between real detection and temporary dose rate increase after heavy rainfall.

The new system is based on Genitron detectors (GT XL 2-3); each station has two large and one small GM-tubes and one heated rain intensity detector (dripping bucket). Data transmission is wireless via GPRS. There is no local data display. However the data can be read out locally via an IR connection with the help of a laptop if necessary.

6.2.3 Air sampling programme

The National Defence Research Establishment (FOI) operates a national air monitoring network of six stations to detect particulate radionuclides in the air. The filters are exchanged twice a week, but can be exchanged more frequently in an emergency on request of SSM. In the case of a large increase of radioactive particles, the system is used to assess the time-integrated air concentration in order to predict inhalation doses and ground deposition. Priority is given to sensitivity rather than rapidity. Airborne particles are collected on fibreglass filters which are sent by mail to the FOI laboratory in Stockholm where they are analysed in a low-background high-resolution gamma spectrometer. The detection limit is of the order of 0.1-1 μBq/m^3.

The fixed stations are supplemented by a set of mobile stations which can be transported quickly to regions where additional sampling capacity is needed. Three trucks with trailers are available for quick transportation of the mobile stations.

In addition to the FOI stations there are about 20 mobile air-filter stations of different kinds operated by the county administrations (counties where NPPs are located), the nuclear power stations, FOI and SSM. Sweden does not have dry/wet deposition collectors.

The ASS 500 air sampler in Stockholm is situated on the roof of the FOI building in a small cabin. The laboratory is also equipped with two types of portable air-samplers from Senya Ltd. The "Liliput" model has a flow volume of 7 m^3/h with an average duration of 4 hours of battery operation. With the other model, the Dwarf 100, air flow between 120 and 140 m^3/h can be achieved with low pressure drop filters. No actual maintenance or service is needed on these devices; the pump lasts for some 25.000 hours and it is the only moving part of these devices.

6.2.4 Water sampling programme

Surface water

Surface water is monitored in the sparse network, i.e. two stations representing the southern and the northern region of Sweden. Water from the lakes Målaren and Storsjön are sampled as incoming water to the water plants in Norsborg and Östersund respectively. Ten to twenty litres of raw water is collected from the incoming water by the water plant personnel twice a year (spring and autumn). The samples are analysed at the SSM laboratory for Cs-137, total-α, total-β, U-234,238 and Ra-226.

Drinking water

Drinking water is also sampled at water plants, but in this case as the outgoing water. In addition to the water plants in Norsborg and Östersund, samples are taken at waterplants in Göteborg, Sandviken, Luleå and Kramfors. Ten to twenty litres of drinking water is collected by the water plant personnel twice a year (spring and autumn). The samples are analysed for Cs-137, Sr-90, H-3, total-α, total-β, U-234,238 and Ra-226. The analyses are conducted at the SSM and at the Studsvik facility.

Sea water

Sea surface water (10 litres at 1 m depth) is collected 1-2 times a year at six locations. The samples are specifically analysed for Cs-137 and H-3, in addition a gamma radiation analysis using the same nuclide library as for measurements of discharge waters is performed on a one litre subsample.

Rain water

Rain water is collected at meteorological stations. Each collector is 2 m in diameter. Samples are collected each week, compiled and sent to FOI for analysis once a month.

6.2.5 Soil sampling programme

Sea sediment samples are collected annually at four locations in the Baltic Sea as a complement to the sediment samples collected within the local recipient control around nuclear facilities. In addition every fifth year sediment samples in the open sea are collected at 16 locations around the Swedish coast. Sediment cores (10 cm diameter) are sampled and sliced into 1 cm thick layers directly on the sampling vessel. Samples are freeze dried and then analysed for Cs-137.

Cs-137 in agricultural soils is currently being mapped in Sweden. Top soils (0-20 cm) will be collected at approximately 1250 locations and analysed for Cs-137. At each location, 9 subsamples are taken within a 6 meter diameter circle of and then combined in a bulk sample. Crops at the same locations are also sampled (4 subsamples of 0.25 m^2 are combined into a bulk sample). This mapping project is coordinated with the national program for soils and crops where samples from the same locations are analysed for humus content, soil texture, pH, plant nutrient and trace elements.

6.2.6 Foodstuffs sampling programme

Milk

The sampling programme of dairy milk has been changed several times in order to fulfil the objectives in an optimal way. The latest change was done in 2005. One of the objectives is reporting according to the article 36 of the Euratom Treaty. Sampling is done at 5 dairies. In the year 2006 these dairies covered 65 % of the dairy milk production in Sweden and 78 % of the total intake of ^{137}Cs from milk consumption. The dairies are situated in Malmö, Jönköping, Kallhäll, Sundsvall and Umeå.

Sampling is done quarterly at the end of the dairy process where the filling of the containers intended for end consumer use is done. The sample quantity is 2 litres, of which one litre is used for the analysis.

All the samples from the dairies are measured for Cs-137 and K-40. Samples from Kallhäll and Umeå are measured also for Sr-90. The reason for measuring only two dairies for Sr-90 is that the variation in the concentration in milk in different parts of Sweden is as significant for Sr-90 as it is for Cs-137.

Mixed diet

Mixed diet is collected in hospital canteens at three locations, Stockholm, Gävle and Umeå. Sampling consists of all complete meals during a 24 hour period served to a patient without any dietary restrictions. Sampling is done twice a year, in the spring and autumn. Stockholm and Umeå represent the southern and northern region in the sparse network. Gävle is sampled in accordance with the Commission recommendation on the application of article 36 of the Euratom Treaty to monitor foodstuffs which are affected by the Chernobyl fallout. Cs-137, Sr-90 and K-40 are measured.

Other foodstuffs sampling

Sampling of various foodstuffs as a means of assessing the exposure of the population as a whole in accordance with the article 36 of the Euratom Treaty is not presently done.

Samples of elk meat from two locations in central Sweden affected by the Chernobyl fall-out are measured each autumn for Cs-137. Other data on e.g. roe deer is sporadically sent in to the SSM from other institutions.

Sampling of mushrooms, fresh water fish and berries is done at a local level in the districts most heavily affected by the Chernobyl fall-out and reported by the local authorities to SSM at irregular intervals.

Reindeer meat is sampled and measured according to the decision of the district veterinary office at slaughter to safeguard against that meat exceeding 1500 Bq/kg Cs-137 should reach the retail system. This data is reported to the SSM.

6.2.7 Verifications

The verification team verified the following arrangements of the national environmental monitoring programme:

- Structure of the programme
- Operational unit of the old dose rate monitoring network at SSM
- Test unit of the new dose rate monitoring network at SSM
- Monitoring provisions at FOI in Stockholm
- Gamma dose rate monitoring stations situated at Gävle and Alunda
- ASS 500 air sampling station situated at the local purification plant in Gävle

Verification team noted that the Gavle gamma dose rate station was not running any more.

> *Verification does not give rise to recommendations. Verification team supports the dose rate monitoring network modernisation project.*

6.3 Municipality radiation measurement programme

6.3.1 Description

In Sweden there is a municipality radiation measurement programme, which requires each municipality (typically the municipality rescue service) to perform dose rate measurements every 7th month at selected locations (900 in total, 2-4 locations each) and report the results to the SSM database. SSM has provided each municipality with the necessary hand-held measurement equipment.

6.3.2 Verifications

Verification team verified the arrangements for the programme. Based on the verification the team noted the following:

- The programme is efficient, cost-effective and appears to meet the surveillance objectives. SSM's approach of involving the local municipalities in routine monitoring not only widens the national monitoring programme but also provides the local emergency services valuable experience in using their radiation monitoring equipment.

Verification does not give rise to recommendations.

6.4 SSM analytical laboratory

6.4.1 Description

The SSM analytical laboratory carries out measurements of the statutory discharge samples from the NPP's, environmental samples, national monitoring samples and foodstuffs samples. There is also a programme for mixed diet monitoring and special programmes for monitoring wild food (elk, moose and reindeer). Sample logs are kept on paper; there is no database system. This has been considered sufficient since the number of incoming samples is fairly low.

The laboratory counting room is classified as a low-activity laboratory. It is equipped with four HPGe detectors and two total alpha/beta counters (Quantulus). After measurements the samples are archived for ten years.

The laboratory is not accredited, but there is an ongoing project on creating a quality system. On a regular basis the laboratory participates in inter comparison exercises organised by the IAEA and the EC. In addition there are round-robin discharge measurement exercises among the Swedish and Finnish NPP's.

6.4.2 Verifications

Verification team verified the analytical arrangements at the SSM analytical laboratory in Stockholm. Based on the verifications the team noted the following:

- The laboratory is small, but adequately equipped. It appears that it is able to carry out its analytical tasks during routine conditions, but would fall short of analytical capacity should the number of samples increase.
- The laboratory has no accreditation (in fact there is no accredited radiation measurement laboratory in Sweden).
- There is no sample management database in the laboratory.

In addition:

- Some of the measurement instructions were handwritten and there appeared to be no systematic documentation for the measurement procedures.

The verification team recommends that the SSM analytical laboratory creates a formalised system of measurement and calibration instructions as a part of a comprehensive quality system and thereafter proceeds towards a formal quality accreditation.

The verification team suggests SSM to consider setting up a computer database for sample management at the laboratory. This is particularly important if the number of incoming samples should increase for any reason.

6.5 Mobile monitoring systems

6.5.1 SSM mobile monitoring vehicles

SSM has three radiation monitoring vehicles and three monitoring trailers. The equipment is kept distributed across the country with trained staff on stand-by. Each system is equipped with two NaI detectors and one HPGe detector. The HPGe detectors mounted on trailers can be removed and installed on police helicopters for airborne surveillance. In addition there are several hand-held instruments, environment sampling equipment and portable air samplers. Several SSM staff members have been trained to use the equipment in order to ensure 24h measurement capability during an emergency situation. In addition SSM maintains capability to carry out plume sampling using jet airplanes operated by the Swedish Air Force.

6.5.2 SGU airborne monitoring systems

The Geological Survey of Sweden (SGU) carries out airborne measurements of the radioactivity in the ground. The spectrometer used measures the gamma radiation that arises in the decay of different radioactive elements. Airborne measurements started in 1968 to map the uranium deposits in Sweden. Nowadays, the surveys are carried out along straight lines with a nominal separation of 200-800 m over land. Survey altitude is 60 m and point distance 16 m. About 80% of Sweden is covered.

In the monitoring aircraft NaI and HPGe (100% relative efficiency) detectors are suspended in a "cage" in order to avoid vibrations of the plane. The 16 litre NaI detector measures the energy interval between 0.2 and 3 MeV in 256 channels.

Calibration measurements are made over large calibration plates (12 m diameter) with known concentrations. There is one plate for each of the elements (K, U and Th) and one with almost no activity. Data over large lakes makes it possible to get calibration factors to compensate for the cosmic radiation, aircraft influence and electronic noise in the system. An upward looking 4 litre detector is used to compensate for radon in the air.

6.5.3 Verifications

Verification team verified the following components of the mobile monitoring systems:

- One of the SSM mobile monitoring vehicles in Stockholm
- Airborne measurement equipment at SGU in Uppsala

Verification does not give rise to recommendations.

7 CONCLUSIONS

All verifications that had been planned by the verification team were completed successfully. The team wishes to indicate its appreciation of the quality and the comprehensiveness of the information supplied to them before the visit.

A summary overview of the verification findings and related recommendations will be compiled in the 'Main Findings' document that is addressed to the Swedish competent authorities through the Swedish Permanent Representative to the European Union.

The present Technical Report is to be enclosed with the Main Findings.

With respect to the radiological surveillance programmes related to the Forsmark NPP

(1) The verification activities demonstrated that the facilities necessary to carry out continuous monitoring of radioactive discharges from the Forsmark NPP are, in general, adequate. The Commission could verify the operation and efficiency of the facilities visited.

(2) The verification activities demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the air, water and soil around the Forsmark NPP are, in general, adequate. The Commission could verify the operation and efficiency of the facilities visited.

(3) However, in some areas the verification activities revealed room for improvement. These findings lead to recommendations that will be formulated in the Main Findings. These recommendations do not discredit the fact that the radiological surveillance of the Forsmark NPP is, in general, in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

With respect to the national radiological surveillance programmes

(4) The Commission could verify the operation and efficiency of the facilities visited.

(5) However, in some areas the verification activities revealed room for improvement. These findings lead to recommendations that will be formulated in the Main Findings. These recommendations do not discredit the fact that the radiological surveillance of the Swedish territory is in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

With respect to the national radiological early warning network

(6) The verification activities demonstrated that the facilities necessary to carry out continuous monitoring of ambient gamma dose rates in Sweden are generally adequate. The Commission could verify the operation and efficiency of these facilities.

Final remarks:

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

****

APPENDIX 1

RECEIVED DOCUMENTATION

Note: The list does not include various other documents that were asked for (and received) during the verification activities such as calibration certificates, standard operation procedures, quality assurance procedures, source records and measurement results, technical drawings, legislative texts, reports.

1. FILTRA MVSS Progress report No 5, ABB Atom, April 1987.
2. Strålsäkerhetsmyndighetens föreskrifter om arkivering vid kärntekniska anläggningar, Strålsäkerhetetsmyndighetens författningssamling, SSMFS 2008:38.
3. The Swedish Radiation Protection Authority's Regulations on the Protection of Human Health and the Environment from the release of Radioactive Substances from Certain Nuclear Facilities, Unofficial translation, December 15th, 2000.

APPENDIX 2

THE VERIFICATION PROGRAMME – SUMMARY OVERVIEW

EURATOM Article 35 Verification in Sweden

9 to 12 February 2009

PROGRAMME OF ACTIVITIES

Monday 9 February - Verifications in the Stockholm area

10:30 – 12:30 **Opening meeting at the Swedish Radiation Safety Authority (SSM)**

- Introductions
- Presentations
- Program of the verification visit

13:30 – 17:00 **Team 1: Verification of the environmental monitoring provisions at the SSM**

- Dose rate monitoring and other monitoring systems at SMM
- Automatic dose rate monitoring network data centre
- SSM radioanalytical laboratory
- Mobile monitoring systems

Team 2: Verification of the environmental monitoring provisions at the FOI

- High volume air sampler and other monitoring systems at FOI
- FOI radioanalytical laboratory

Tuesday 10 February - Verifications at the Forsmark NPP and surrounding area

09:30 – 10:30 **Opening meeting with the NPP personnel**

10:30 – 17:00 **Team 1: Discharge monitoring**

- Gaseous discharge monitoring systems at Forsmark 2

Team 2: Environmental monitoring

- Monitoring systems at the surrounding area (Gävle and Alunda)
- Airborne monitoring system (SGU Uppsala)

Wednesday 11 February - Verifications at the Forsmark NPP and surrounding area

09:30 – 17:00 **Team 1: Discharge monitoring**

- Liquid discharge monitoring systems at Forsmark 3

Team 2: Environmental monitoring

- Sampling arrangements
- Site meteorological systems
- TLD monitoring
- On-line dose rate measurements at the site area and vicinity
- Mobile monitoring systems

Thursday 12 February - Verifications at the Forsmark NPP laboratories

09:00 – 12:00 **Team 1: Discharge monitoring**

- Chemical and radiochemical laboratory at Forsmark 1
- Reporting arrangements and sample archive

Team 2: Environmental monitoring

- Operators laboratory for environmental samples
- Reporting arrangements and sample archive

13:00 – 13:30 **Closing meeting**

- Presentation of preliminary verification results