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EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY

Directorate D - Nuclear energy, safety and ITER
D.3 – Radiation protection and nuclear safety

Technical Report of the Verification under the Terms of Article 35 of the Euratom Treaty

FINLAND

Loviisa NPP Discharge and Environmental Monitoring

and

National environmental radioactivity monitoring network in the vicinity

29 September - 2 October 2015

Reference: FI 15-03

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35

OF THE EURATOM TREATY

FACILITIES:	Monitoring of liquid and gaseous discharges at the Loviisa NPP National environmental radiological monitoring network in the vicinity of Loviisa NPP, together with elements of the national environmental radiological monitoring programme
LOCATIONS:	Helsinki, Loviisa
DATES:	29 September to 2 October 2015
REFERENCE:	FI 15-03
TEAM MEMBERS:	Mr S. Mundigl DG ENER (team leader) Ms K. Peedo DG ENER Mr A. Ryan DG ENER Mr T. Tollefsen DG JRC
REPORT DATE:	28 February 2016
SIGNATURES:	

S. Mundigl K. Peedo

A. Ryan T. Tollefsen

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1 INTRODUCTION

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

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

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

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

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[1] Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (OJ L-159 of 29/06/1996) which will be superseded by Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom (OJ L 13 of 17.1.2014, p. 1)

[2] Commission Communication Verification of environmental radioactivity monitoring facilities under the terms of Article 35 of the Euratom Treaty. Practical arrangements for the conduct of verification visits in Member States. (OJ C 155, 4.7.2006, p. 2–5)

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 PREAMBLE

The EC's decision to conduct an Article 35 verification was notified to Finland by a letter addressed to the Finnish Permanent Representation to the European Union. The Finnish Government subsequently designated the Radiation and Nuclear Safety Authority (STUK) to lead the preparations for this visit.

2.2 DOCUMENTS

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

2.3 PROGRAMME OF THE VISIT

The EC and STUK discussed and agreed upon a programme of verification activities, set out in Appendix 2, with due respect to the Commission Communication of 4 July 2006 setting out practical arrangements for the conduct of Article 35 verification visits.

During the opening meeting presentations were given by STUK on the national monitoring programme and their activities, whilst the verification team presented Article 35 and the programme for the verification.

Subsequently presentations were given by Fortum Power & Heat Oy concerning the monitoring of discharges at the Loviisa Nuclear Power Plant site.

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

The following representatives of the national authorities and other parties involved were met:

Radiation and Nuclear Safety Authority (STUK)

Mr Petteri Tiippana	Director General
Dr Tarja Ikäheimonen	Director, Department of Environmental Radiation Surveillance and Emergency Preparedness
Dr Pia Vesterbacka	Head of Environmental Surveillance and Measurement laboratory
Mr Kaj Vesterbacka	Head of Emergency Preparedness and Mobile Measurements laboratory
Ms Kaisa Vaaramaa	Senior Research Scientist, Environmental Surveillance and Measurement laboratory
Dr Maarit Muikku	Head of Emergency Preparedness and Mobile Measurements laboratory
Dr Päivi Kurttio	Head of Radon and Health laboratory
Mr Vesa-Pekka Vartti	Senior Research Scientist, Environmental Surveillance and Measurement laboratory
Mr Jukka Sovijärvi	Section Head, Radiation Protection, Nuclear Reactor Regulation
Dr Tuomas Valmari	Inspector, Radiation Protection, Nuclear Reactor Regulation
Mr Antti Tynkkynen	Inspector, Radiation Protection, Nuclear Reactor Regulation

Fortum Power and Heat Oy

Mr Timo Kontio	Manager, Radiation Safety, Fortum Loviisa NPP
Mr Miska Hirvelä	Radiation Protection Engineer, Fortum Loviisa NPP
Mr Roger Kvarnström	Senior Advisor, Radiation Safety, Fortum Loviisa NPP
Ms Laura Togneri	Laboratory Manager
Dr Reko Rantamäki	Manager, Radiation Safety Engineering, Fortum Nuclear and Thermal Power, Nuclear Engineering & Co-Owned Nuclear

Finnish Meteorological Institute (FMI)

Dr Jussi Paatero	Research Manager

3 RESPONSIBLE ORGANISATIONS AND THEIR MONITORING PROGRAMMES

3.1 RADIATION AND NUCLEAR SAFETY AUTHORITY (STUK)

STUK's operations are based on the Act on Radiation and Nuclear Safety Authority. The first section of the Act defines STUK's mission and position: "The Radiation and Nuclear Safety Authority operates under the Ministry of Social Affairs and Health with the purpose of preventing and limiting the adverse effects of radiation, controlling the safety of the use of radiation and nuclear energy, and engaging in associated research, education and communications".

STUK also offers expert services to clients both within Finland and abroad in the field of radiation and nuclear safety, as well as safeguards.

At the end of 2014, STUK had 324 employees, 60% of who were men. A little over 80% of STUK's employees have a M.Sc. or M.A. degree. The average age of the employees is approximately 48 years.

The Director General, currently, Mr Petteri Tiippana is appointed by the Government.

The environmental radiation surveillance programme includes continuous and regular monitoring of radiation or radioactivity in air, soil, water, foodstuffs, and in the human body. On-line surveillance is based on monitoring of external dose rate in a network of about 300 automatic stations. A detailed description of STUK's activities can be found on their web-site; www.stuk.fi.

Radiological surveillance of foodstuffs is performed by STUK as a part of the environmental radiation surveillance programme in Finland.

STUK maintains and develops emergency preparedness with the aim of ensuring safety of all members of the public and workers in radiological and nuclear emergencies. STUK is the national contact point in nuclear emergencies, and is responsible for all drafts of recommendations for protective actions. STUK is responsible for informing neighbouring countries and international organisations in emergency situations.

In the case of a radiological emergency, STUK is the central laboratory performing radiological surveillance and measurements. There are two additional places in addition to Helsinki (Ylöjärvi and Kuopio), which are able to make gamma spectrometric measurements depending on the situation. The laboratories in Helsinki are STUK's own laboratories; the laboratory in Ylöjärvi is run by PvTT and the laboratory in Kuopio by FMI.

STUK has provided spectrometers to some 30 local foodstuff and environmental laboratories in Finland to be used in the case of a radiological or nuclear emergency to monitor radioactivity in foodstuffs and drinking water, as well as in environmental samples at a local level. In normal circumstances, the laboratories use the spectrometers to measure radon in drinking water and perform test measurements according to instructions given by STUK.

At the request of the Government of Finland, an international team of senior safety experts met representatives of the Radiation and Nuclear Safety Authority of Finland (STUK) from 15 to 26 October 2012 to conduct an Integrated Regulatory Review Service (IRRS) mission. The purpose of the peer review was to review the Finnish regulatory framework for nuclear and radiation safety. As recommended by the IAEA Nuclear Safety Action Plan, special attention was given to regulatory implications in the Finnish framework for safety of the lessons learned from the TEPCO-Fukushima Dai-ichi nuclear power plant accident.

The review compared the Finnish regulatory framework for safety against IAEA safety standards as the international benchmark for safety. The mission was also used to exchange information and experience between the IRRS review team members and the Finnish counterparts in the areas covered by the IRRS. The IRRS review team identified a number of good practices and made recommendations and suggestions that indicate where improvements are necessary or desirable to continue enhancing the effectiveness of regulatory functions in line with the IAEA safety standards.

The follow-up mission was made in 2015. The IRRS team concluded that Finland's Radiation and Nuclear Safety Authority (STUK) had strengthened its oversight and made significant progress, addressing 26 of 29 of the findings issued by the 2012 mission. This is a significant accomplishment in less than three years, demonstrating commitment to an effective implementation of the IAEA Safety Standards.

3.2 Finnish Defence Forces' Technical Research Centre (PvTT)

PvTT, which operates under the Ministry of Defence is in charge of providing the technological and scientific research, development, testing and trialling services that are required by the Defence Forces and the country's defence. PvTT co-operates with STUK in environmental radiation surveillance by performing monitoring of airborne radioactivity at one monitoring station using the collection equipment and analysis software developed by STUK.

This organisation was not included in the verification.

3.3 Finnish Meteorological Institute (FMI)

The main objective of the Finnish Meteorological Institute is to provide the Finnish nation with the best possible information about the atmosphere above and around Finland, for ensuring public safety relating to atmospheric and airborne hazards and for satisfying requirements for specialised meteorological products. In the national programme of environmental radiation surveillance; FMI performs the surveillance of airborne total beta activity in Finland. FMI operates under the Ministry of Transport and Communication.

This organisation was not included in the verification.

4 LEGAL FRAMEWORK FOR ENVIRONMENTAL RADIOACTIVITY MONITORING

4.1 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

On the national front the following legislative acts cover environmental radioactivity monitoring:

- Radiation Act and Radiation Decree (592/91, 1512/91) enacting STUK as the facility to carry out monitoring of environmental radioactivity as described in the Euratom Treaty.
- Act and Decree on STUK (1069/83, 618/97) enacting STUK to monitor radiation in the environment and to maintain preparedness to respond to radiological emergencies.
- Rescue Act (379/2011) enacting STUK to carry out radiation surveillance in the environment.

The most important international legal requirements and other important guidance documents, which are relevant to environmental radiation monitoring, are:

- EU Commission Recommendation 2000/473/EURATOM 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. (EU Official Journal L-191, 27/07/2000);
- HELCOM Recommendation 19/3, Manual for the marine monitoring in the COMBINE programme of HELCOM;
- HELCOM Recommendation 26/3, Monitoring of radioactive substances.
- EURATOM Treaty, Articles 35 and 36, enacting EU Member States to monitor environmental radiation in their territories.
- IAEA Safety Standards, Environmental and Source Monitoring for Purposes of Radiation Protection, Safety Guide No. RS-G-1.8, 2005.

4.2 LEGISLATIVE ACTS REGULATING THE RADIOLOGICAL SURVEILLANCE OF FOODSTUFFS

The competent authorities in the surveillance of foodstuff safety are the Finnish Food Safety Authority (EVIRA) and the regional and municipal food safety authorities. Their tasks and responsibilities are stipulated in the Food Act (23/2006). Regarding the radiological surveillance, STUK is the national reference laboratory providing laboratory services to the competent authorities. Provisions on the criteria for assessing the radiation safety of food are laid down in the Radiation Act (592/1991).

4.3 LEGISLATIVE ACTS REGULATING DISCHARGE MONITORING

Discharge monitoring is regulated by the following:

- Nuclear Energy Act and Nuclear Energy Decree (990/1987, 161/1988)
  http://plus.edilex.fi/stuklex/en/lainsaadanto/19870990?toc=1,
  http://plus.edilex.fi/stuklex/en/lainsaadanto/19880161?toc=1
- Laki ydinenergialain muuttamisesta (676/2015) (not available in English yet)
  https://www.finlex.fi/fi/laki/alkup/2015/20150676
- Valtioneuvoston asetus ydinvoimalaitoksen turvallisuudesta, (717/2013),
  http://plus.edilex.fi/stuklex/fi/lainsaadanto/20130717?toc=1, (not available in English yet)
- YVL C.3 Limitation and monitoring of radioactive releases from a nuclear facility,15.11.2013, ISBN 978-952-309-097-2, http://www.finlex.fi/data/normit/41782-YVL_C.3e.pdf
- YVL C.6 Radiation monitoring at a nuclear facility, 15.11.2013, ISBN 978-952-309-103-0,
  http://www.finlex.fi/data/normit/41742-YVL_C.6e.pdf

5 LOVIISA NPP SITE AND ITS RADIOLOGICAL SURVEILLANCE PROGRAMME

5.1 SITE DESCRIPTION

Loviisa NPP is located on the island of Hästholmen on the Baltic Sea. The approximate position is 60°22' N 26°21'E. The island is connected to the mainland by an approximately 200 m long elevated road. The main gate and accommodation facilities are located on the mainland. The site belongs to the municipality of Loviisa and is 12 km from Loviisa centre. The site is located 80 km from the capital Helsinki. As of 2011, there are 44 permanent residents within 5 km from the plant and 12 423 permanent residents within 20 km from the plant. There are also 3054 vacation buildings within 20 km from the plant.

The site area includes a repository for low- and intermediate level waste as well as an interim storage for spent nuclear fuel.

Loviisa NPP includes two VVER-440 model 213 pressurised water reactor units (LO1 and LO2). Light water is used as coolant and moderator. The maintenance outage is scheduled annually. The LO1 and LO2 units have separate reactor buildings but a common turbine building.

Commercial operation started on 9 May 1977 (LO1) and 5 January 1981 (LO2). Both units are currently operational. The nominal thermal power of both units was increased from the original 1375 MW to 1500 MW during 1996-1998. After turbine modifications in 2000 (LO1) and 2002 (LO2) the net electric power was increased to 488 MWe per unit. The original values were 440 MWe (LO1) and 465 MWe (LO2).

5.2 RELEASE LIMITS

According to Government Decree 717/2013, the limit for the dose constraint to an individual in the population, arising from normal operation of a nuclear power plant in any period of one year, is 0,1 mSv. Based on this limit, release limits for radioactive materials during normal operation of a nuclear power plant are defined. Detailed requirements concerning the calculation methods used for assessing the radiation exposure of the population are specified in the Guide YVL 7.2 (http://www.finlex.fi/data/normit/9591-YVL7-2e.pdf) which is to be replaced in the near future by a new guide YVL C.4 (http://www.finlex.fi/fi/viranomaiset/normi/555001/42196). When calculating the radiation dose to an individual in the population caused by releases of radioactive materials, the analysis is based on the average radiation exposure of the most exposed group. This group presents a hypothetical group of individuals in the population, who, based on their residence and life style, are estimated to receive the highest radiation exposure arising from releases according to the calculations.

Release limits for radioactive materials for the Loviisa NPP are defined in the technical specifications (LO1/LO2, 6.2.2013) concerning the operation of the plant units.

Noble gases (^{87}Kr equivalent) atmospheric (stack)	$1.4 * 10^{16}$ Bq/a	A_{stack}
Noble gases (^{87}Kr equivalent) atmospheric (roof)	$4.4 * 10^{14}$ Bq/a	A_{roof}
Iodines (^{131}I equivalent) atmospheric (stack)	$2.2 * 10^{11}$ Bq/a	B_{stack}
Iodines (^{131}I equivalent) atmospheric (roof)	$1.4 * 10^{10}$ Bq/a	B_{roof}
Nuclides other than tritium, (sea)	$8.9 * 10^{11}$ Bq/a	C

$A_{stack} + A_{roof} + C \leq 1$

$B_{stack} + B_{roof} + C \leq 1$

A, B and C are ratios of realised releases vs. release limits. The ratio A considers the whole body dose whilst B is the dose for the thyroid or any other individual organ.

A separate release limit for tritium to the sea is 1.5 * 10^{14} Bq/a corresponding to a dose <0.001 mSv/a.

5.3 STATUTORY DISCHARGE MONITORING PROGRAMME

The normal release routes include:

- the main ventilation stack which is divided in two (separate route for each plant units)
- release tanks for process water releases
- laboratory building release tanks

In case of a primary to secondary side leak in the steam generators, radioactivity may be found in the secondary circuit. Thus the ejector exhaust gas route and the sewage water system are considered potential release routes. Also the outlet air from the maintenance waste repository is monitored.

The table below summarises the types of releases, the location and the monitoring carried out.

Release type	Location	Monitoring principle	Remarks
Air discharge, primary side	Ventilation stack	Continuous noble gas, aerosol and iodine monitoring	Two redundant monitoring units / reactor unit
		Continuous collection of aerosol and iodine sample. Weekly noble gas sampling	Aerosol and iodine sample filters are routinely changed weekly by RP staff. Noble gas sampling by radiochemistry staff. All samples are analysed at plant's radiochemistry laboratory
		^{14}C and ^{3}H monitoring: monthly analysis	Samples are collected by radiochemistry staff monthly
		$^{89/90}Sr$ monitoring	Quarterly combined sample from the aerosol filters

Release type	Location	Monitoring principle	Remarks
Liquid discharge, primary side	Process water control tank	Continuous total gamma-activity measurement on release route	The total gamma-activity measurement operate release route shut-down valves in case of monitor failure or if activity concentration exceeds predefined alarm limit
		Water sampling from control tank before release	Sample is taken by operators and analysed in radiochemistry laboratory. Permission for release is given if activity concentration of most important radionuclides is below pre-defined limits
		^{3}H and alpha monitoring	Monthly composite sample is analysed in radiochemistry laboratory
		$^{89/90}Sr$	Sr-nuclides are analysed from a quarterly composite sample.
Liquid discharge, laboratory building	Laboratory building	Continuous monitoring of release route total gamma activity	The total gamma-activity measurement operate release route shut-down valves in case of monitor failure or if activity concentration exceeds predefined alarm limit
		Proportional sampling from discharged liquids	During the release a proportional sample is taken from the outlet water. The sample is analysed in radiochemistry laboratory
Air discharge secondary side	Turbine hall, main ejector exhaust	Continuous monitoring of noble gases.	One monitor / exhaust line
		Continuous collection of aerosol and iodine sample	Samples are analysed in radiochemistry laboratory on a 2 week frequency
Liquid discharge secondary side	Turbine hall, flushing waters of resins	Sampling prior release	Samples are analysed in radiochemistry laboratory

Release type	Location	Monitoring principle	Remarks
Air discharge, waste repository	Repository ventilation outlet	Continuous sampling of aerosols and iodine	Monthly analysis of sample filter in radiochemistry laboratory

Calibration, maintenance and follow up of the monitoring system operation are assured by four separate means:

1. Continuous follow up

The measurement data is sent to the plants process computer and analog signals to the main control room. The monitors are equipped with self-diagnostics and all faults cause alarms in the control room. Some monitoring devices are equipped with automated process control, thus a monitor failure will cause actuation of process components to bring the process in a safe state (i.e. a monitor failure during liquid releases would close the outlet line). The control room operators monitor the alarms continuously.

2. General operational check

A general operational check includes periodical inspection of the monitoring trends and mainly that the outward appearance of the monitor is in good condition. For the safety related release monitors, this is done every two weeks.

3. Operational test

The operational status of the monitor is checked with a radiation source periodically. The aim is to check that the device reacts to radiation as assumed (alarm function and actuation of automatic process operation). For the safety related release monitors this is done every four weeks.

4. Calibration check

The measurement accuracy is periodically checked with a standard calibration source. For the safety related release monitors this is done twice a year.

In case of faults the required repair time is defined in the plant's technical specifications based on the safety significance.

5.4 METEOROLOGICAL STATION

The meteorological station is located 1.6 km north-west from the NPP. The weather mast is 150 m high and is located 11.5 m above sea level.

Wind speed and direction are measured at heights of 30, 103 and 143 metres. Temperature is measured at heights of 10, 40, 100 and 140 m. Stability class is determined based on temperature difference between 10 and 40 m as well as between 100 and 140 m. Temperature, air pressure, relative humidity as well as the amount of rainfall and rain duration are measured at the ground level (2 m).

Sensors:

- Wind speed and direction: Gill Instruments Ltd.: Solent 3-axis ultrasonic anemometer 1012s (30 and 103 m) and Metek USA-1 3D ultrasonic anemometer (143 m)

- Air pressure: Vaisala DPA 21
- Rain gauge: Vaisala RG 13 H
- Rain detector: Vaisala DRD 11 A
- Air temperature: Vaisala DTS 12G, DTS 12A
- Air humidity: Vaisala HMP 35D

There is an on-going project to modernise the current meteorological station described above.

6 NPP LIQUID AND AERIAL DISCHARGE MONITORING

6.1 AERIAL DISCHARGES

For each NPP unit there are two different sampling monitors in the ventilation stack: MGP PING 205 and MGP NGM 203.

PING 205 consists of a two channel measurement system - one channel for continuous monitoring of aerosols, iodine, noble gases and the other for samples analysed in the laboratory (aerosol and iodine sampler, PI-sampler). Sample volume in each channel is 35 l/pm and the total volume is 70 l/pm. Samples from the stack are taken through a multi-nozzle sampler, which is designed for isokinetic sampling. A real time particulate detector has silicon detectors to recognise alpha, beta and gamma radiation emitted by the particulates deposited on the filter paper. For iodine measurement there is a NaI scintillation detector, which measures molecular or organic iodine trapped in an active charcoal absorbent cartridge. Noble gas measurement is done with silicon detectors, which measure the beta activity from a 300 cm^3 volume passing through the sample chamber. All detectors are shielded with 50 mm of lead. Each monitor has two sample pumps, one operating and the second in reserve.

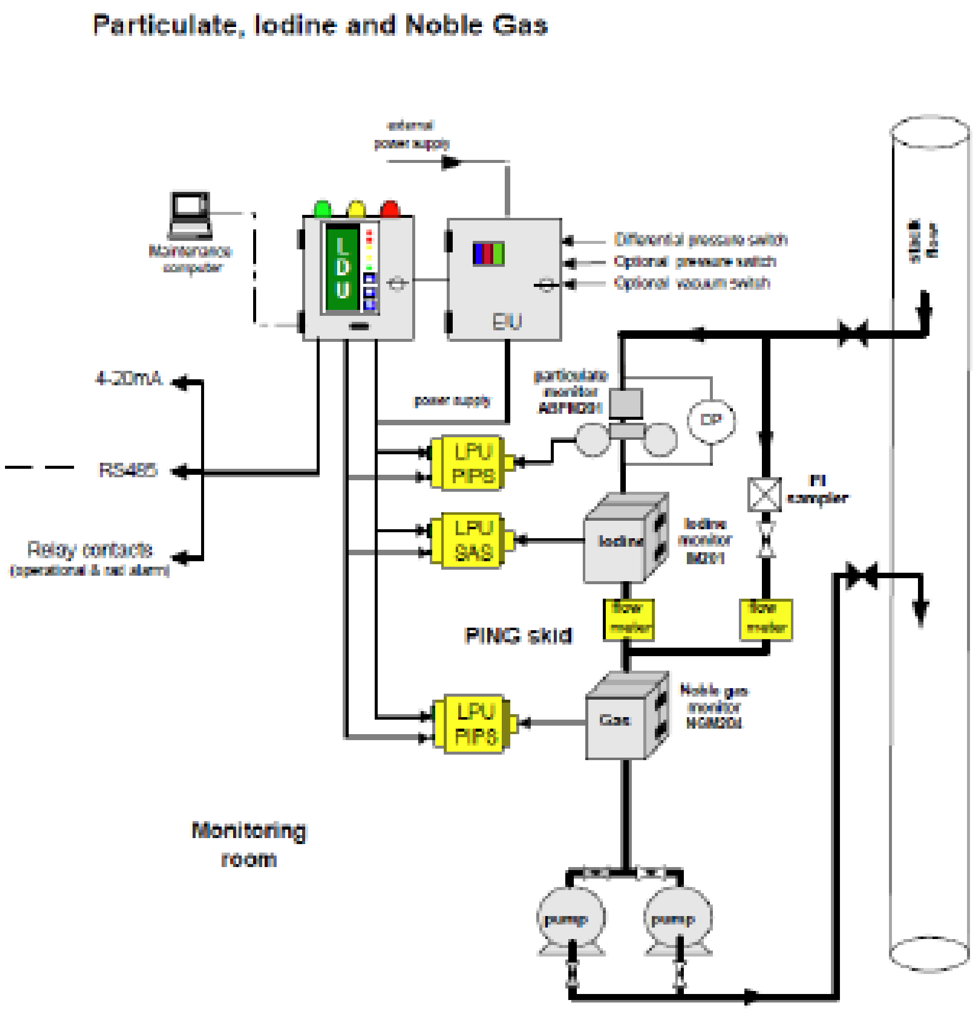

Figure 1 Particulate, iodine and noble gas monitor PING 205

Measurement range for particulate detection is 1 - 10^6 Bq/m^3 for β and 10^2 - 10^4 Bq/m^3 for α with energy ranges of 80 keV - 2 MeV and 4.2 MeV – 5.5 MeV. Integration time for 100 Bq/m^3 β volumetric activity is 15 minutes.

For iodine the energy range is 100 keV to 3 MeV but the controlled energy window is 310 - 410 keV. Measurement range is 3.7 – 3.7 * 10^6 Bq/m^3 and the integration time for step from 0 to 100 Bq/m^3 60 minutes.

Noble gas measurement energy range is from 80 keV to 2 MeV. Measurement range is 3.7 * 10^4 – 3.7 * 10^9 with ^{133}Xe and the integration time for 3.7 * 10^4 Bq/m^3 is 15 seconds in 0,1 µGy/h ^{137}Cs background.

NGM 203 is a high range noble gas measurement monitor, which has the same type of multi-nozzle sampler and sample piping as the PING 205. Piping in the stack room is insulated and heated to reduce condensation in the sampling line. The monitor itself only has one channel, which is similar to the PING 205 PI-sampler. There is one sample pump and the sampling volume is 35 lpm. Real time noble gas measurement is 50 mm lead shielded and the detector is based on an ionisation chamber.

Noble gas measurement energy range is 5 keV to 3 MeV and the range for ^{85}Kr and ^{133}Xe activity is 3.7 * 10^6 to 3.7 * 10^{16} Bq/m^3.

The PI sampler consists of an aerosol filter paper and charcoal cartridge, which are analysed weekly. Activities are measured in parallel from the NGM 205 and the NGM 203 PI samplers and discharges are specified conservatively by multiplying the higher activity concentration by the stack total outlet air volume. The total volume is measured with an anemometer, which is located in the centre of the stack channel.

For measuring possible discharges from the secondary circuit there are two NGM 204 noble gas monitors in the main ejector outlet lines with the same kind of PI-samplers as the stack monitors and the filters are changed fortnightly. NGM 204 noble gas measurement is similar to PING 205 noble gas measurement.

Measurement trends are followed daily by either the main control room or RP personnel. There is an operational test performed with a test source every month and a calibration check, which is done twice a year by RP staff. Measurement data from all measurements is delivered to the main control room; the severe accidents control room and the process computer.

In addition to sampling monitors there are two gamma dose rate monitors for accident situation use in the ventilation stack per plant unit. Measurement techniques are based on ionisation chambers and the measurement ranges are 0.01 - 10^7 and 1 - 10^8 mSv/h.

6.2 LIQUID DISCHARGES

Liquid discharges are released through control tanks. Prior to a release the water of a control tank is analysed in the radiochemistry laboratory. Permission for the release is given only if pre-defined activity concentration limits are complied with.

In addition there is an MGP GLM 201-1 off-line gamma liquid monitor in the discharge line designed to measure gamma volume activity of a liquid stream flowing through it. The volume of the measurement chamber is 4.4 l and NaI detector size is 1.25" * 1". Energy range is 150 keV to 2.2 MeV and the measurement range is 10 - 10^6 kBq/m^3 for ^{60}Co energies. The detector chamber is shielded with 50 mm of lead and the sample flow is generated through process pressure. Malfunction or exceeding a threshold level during discharge closes certain valves automatically which has the effect of stopping the discharge.

The discharges from the laboratory building are monitored with an on-line monitor with process control. If the activity level is acceptable for discharge, the valve in the discharge line is opened. The monitor type is GIM 204 with a 3" * 2" NaI detector. Measurement range has been modelled with Monte Carlo simulation and the range in the current position is 10 - 10^6 kBq/m^3.

6.3 OPERATOR'S LABORATORY FOR ANALYSIS OF DISCHARGE SAMPLES

The radiochemical analyses in Loviisa NPP are done in a laboratory situated in the controlled area. Samples from different systems of the power plant are pre-treated and analysed within the facilities. The laboratory has separate rooms for sample preparation, storage and measurements.

Nuclide specific gamma measurements are conducted with four HPGe detectors (Canberra) with an APEX Laboratory Suite analysis programme. There are two detectors with relative efficiencies of 20-25% (for active samples) and two with 60-65% (for release samples). There is an additional HPGe detector (rel. eff 10 %) in the emergency centre, which can also be used.

A liquid scintillation counter (HIDEX 300 SL) is used for tritium, ^{14}C and total-alpha measurements.

A proportional counter (Berthold LB770) is used for total-alpha and -beta measurements of the aerosol filter taken from the stack.

All measurement results are stored in the LIMS-system (Laboratory Information and Management System) of the laboratory. Calculations of the releases are done within the LIMS system. Results below the required MDA are reported.

6.3.1 Sample reception

Samples are mainly taken by the laboratory staff, the radiation protection personnel or the operational personnel. Most of the samples are scheduled in the work maintenance system (LOMAX). The samples are registered in the LIMS system when they arrive in the laboratory. Information for the sampling point, time, date and the person who has taken the sample are registered. This information is also written on the sample bottle or filter envelope and dedicated containers (marked with the sampling point and/or time/date) are used to make sure the sample can be identified all through the measuring process.

6.3.2 Sample analysis - aerial discharges

Nuclides in the exhaust air are captured on aerosol and charcoal cartridge filters mounted in a filter cartridge. The filters (glass fibre and charcoal cartridge) are removed from the filter cartridge and brought to the laboratory. The filters are analysed as soon as possible with the HPGe-detectors. The MDA requirements of 1 mBq/m^3 for ^{60}Co and ^{137}Cs and 4 mBq/m^3 for ^{131}I are reached. The aerosol filters are stored for total alpha and beta analyses that are preformed every three months. The MDA requirement of 1 mBq/m^3 for total-alpha is achieved.

A 4.3 litre air sample is taken from the stack exhaust air every week to determine the noble gas releases of the plant. The air tight Marinelli beaker is measured straight after sampling to identify any short lived nuclides and overnight to achieve the required MDA (10 kBq/m^3) for ^{85}Kr.

Tritium and ^{14}C are collected in molecular sieves located in the stack; the sieves are changed twice a week or up to every 2 weeks, depending on the humidity of the air. All hydrogen and carbon products in the air are burnt into carbon dioxide and water in a furnace (with catalyser) and are trapped in the molecular sieve. The sieve is treated in the laboratory to achieve separate tritium and

^{14}C samples for liquid scintillation. The MDA requirements of 0.1 kBq/m^3 for tritium and 10 Bq/m^3 for ^{14}C are achieved. The analysis frequency will be shortened if there is an indication of changes in the release amounts.

6.3.3 Sample analysis - liquid discharges

A sample from the release water tanks is brought to the laboratory before the intended release. The sample is acidified to ensure the potential alpha-emitters will not adsorb into the container walls. A gamma measurement of a 1 litre sample is made and the required MDA of 1 kBq/m^3 for all significant gamma nuclides is achieved. After the gamma measurement, if the activity level is below 4000 Bq/l permission to release is given by the laboratory to the operational personnel. If it is above the limit mentioned, only the radiation protection manager can give the permission. After the discharge, the operational personnel return the permission paper with the exact time and amount of the release and a final release report is generated in the LIMS system. A proportional sample is taken into a monthly composite sample container. The composite sample is measured by liquid scintillation for tritium and total alpha activities.

The waters originating from the laboratory building are collected in separate tanks. A proportional amount of the released water is collected in a collection tank and a sample is brought to the laboratory for analysis every 1-2 weeks. A gamma measurement is made and the sample is acidified before storing. To analyse the tritium and total alpha activities from this release route, proportional samples are made and analysed by liquid scintillation. Release reporting is done in the LIMS system.

The required MDAs of 50 kBq/m^3 for tritium and 1 mBq/m^3 for total alpha are achieved. Tritium is measured from a sample that has not been acidified.

6.3.4 $^{89/90}Sr$ analyses

Subsamples from all release water composite samples and aerosol samples from the stack are sent to an accredited laboratory for strontium analyses. There is a continuous contract with STUK for this.

6.3.5 Statutory accounting and reporting

The results are stored in the laboratory LIMS-system. Analytical results (raw data and evaluated results) of measurements are archived. Results that are below the required MDAs are also reported. Any nuclide result that has been obtained in the measurement is reported, even if the result is below the required MDA stated in YVL C.3. Release reports are compiled for every quarter year and sent to STUK. An annual report is also compiled. Samples are not stored after the final results have been reported.

6.3.6 Quality assurance and control

The laboratory is not accredited, but nevertheless has implemented a quality system which is built on the ISO/EN 17025:2005 standard to the appropriate extent.

For the gamma-detectors, background and quality control measurements are done on a weekly basis. An ^{152}Eu source is used for the weekly QA check. These results are stored in the APEX system. ^{60}Co, ^{57}Co, ^{133}Ba and ^{137}Cs are used for energy calibration and a certified multigamma solution is used for efficiency calibration measurements. All the detectors are characterised, so in the future, the efficiency calibrations could be calculated with LabSOCS (Canberra).

For the liquid scintillation counter, quality control samples (background and standard within the same sample matrix) are always measured along with the actual samples. These QA results are stored in the LIMS system. Unquenched standard samples (background, tritium and ^{14}C) are measured every fortnight to ensure the proper functionality of the instrument.

For the proportional counter, background and quality control samples (^{241}Am and ^{90}Sr) are measured before every measurement campaign to ensure the correct functionality of the instrument.

The laboratory participates in an annual intercomparison exercise within Finland, where fresh reactor water from either Loviisa or Olkiluoto is sent to the Finnish radiochemistry laboratories. Gamma and tritium measurements are made. The laboratory also takes part in other (inter)national intercomparisons, when applicable.

7 ENVIRONMENTAL MONITORING PROGRAMME AROUND THE NPP

7.1 MEASUREMENTS PERFORMED BY THE OPERATOR

The NPP operates 28 ambient gamma dose rate meters, four air samplers, four deposition samplers and ten Thermo Luminescent Dosimeters (TLDs), which are located within a 5 km radius from the NPP.

The gamma dose rate meters are of the type Saphymo Gamma Tracer XL2-3, the technical specs are the same as those in the nationwide monitoring network. Seven probes are located on Hästholmen Island, seven in a 2 km radius from the NPP and 14 in a 5 km radius from the NPP. Data from the probes is sent by wireless transmission to two receivers, which are located at the weather and telecommunication mast. There are two parallel servers, from which measurement results are directed into the NPP process computer. Measurement data from probes at 2 and 5 km radius is also sent to STUK.

Four air samplers (IVO/100 m^3/h with Whatman glass fibre and activated carbon loaded filters) are running continuously and one sampler is in reserve. Filters are changed fortnightly during normal operation, and once per week during outage time. Filters are sent to STUK where the analysis is done.

There are two large and two small deposition samplers, with one small sampler in reserve. The large samplers are 1 m^2 with a 30 l container and the small 0.07 m^2 with a 10 l container. The larger sampler was made by the NPP and the smaller one is of the type JL-300 THERMO. Containers are changed when needed but at least once a month for large samplers and quarterly for small ones. Samples are sent to STUK for analysis.

Quarterly, tap water samples (2 * 20 litres) and twice a year, sludge samples from the NPP water purification plant are also sent to STUK for analysis.

TLDs are changed quarterly and analysed by the NPP dosimetry laboratory. There are four H*(10) calibrated LiF crystals in each dosimeter and the results are derived from the mean value of the different crystals. Results are reported to STUK quarterly.

An overview map below (fig 2) indicates the on-site and off-site sampling/monitoring locations and respective media sampled and/or monitored at these locations.

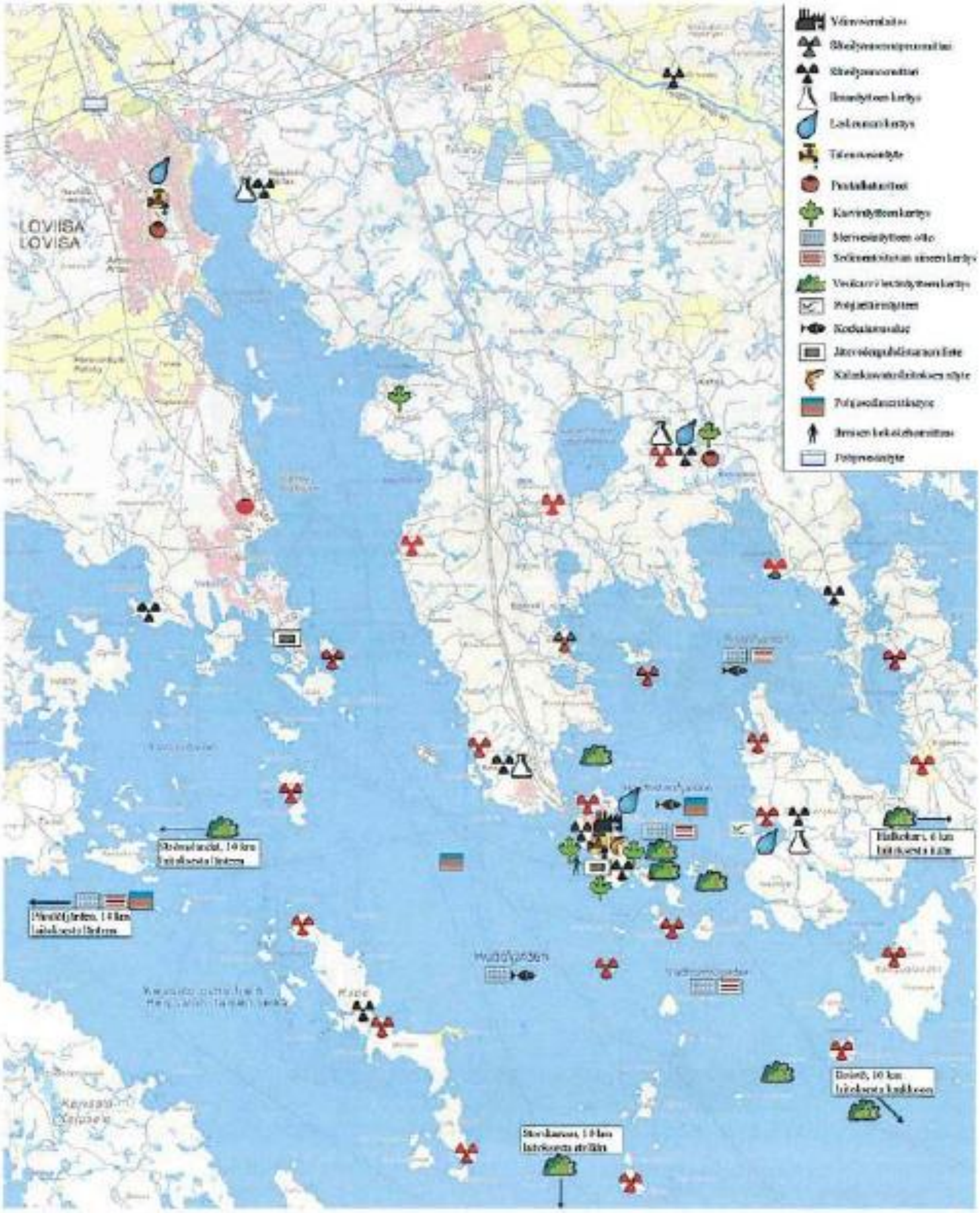

Figure 2: Sampling points and detector locations of the environmental monitoring program in the vicinity of Loviisa NPP

7.2 MEASUREMENTS PERFORMED BY THE REGULATORY AUTHORITY

In the 2012 IRRS evaluation a recommendation was made that STUK should withdraw from the practice at that time of conducting the environmental monitoring programmes in the vicinity of the nuclear facilities based on commercial contracts with the licensees. Based on the recommendation STUK proposed a change in the Nuclear Energy Act (676/2015).

Until the end of June 2015, STUK had been providing environmental radiation monitoring services to the licensees in the environment around the nuclear power plants (off-site). The licensee did not perform their own measurements of off-site radiation but only carried out on-site monitoring e.g. measurements of radioactive releases.

After a change in the legislation STUK withdrew from the practice of conducting environmental monitoring as a commercial service and now performs the off-site environmental monitoring as an independent regulatory activity.

The facility licensee continues to have full responsibility for safety including discharge monitoring, sampling of air, deposition and assessment of radiation doses to the public. The licensee is also responsible for the annual analysis of the results and reporting to STUK. The results, including conclusions relating to compliance with specified limits, increases in environmental concentrations, as well as an assessment of the impact on the public and the environment, is provided to the regulator at intervals specified by the regulator. To assess the reports submitted by the licensee and to validate the results, the regulator is required to implement an independent monitoring programme.

These arrangements are based on the fact that STUK is the only body in Finland having laboratories where very low level radiation can be measured. STUK has the facilities and necessary equipment for such measurements, coupled with competence and expertise for radiation measurements in an accredited laboratory and the associated environmental sampling.

The roles and responsibilities of the regulator and operator will be appropriately defined in YVL Guide C.7 which is currently in preparation.

The Loviisa nuclear power plants environmental monitoring program is revised every five years on the basis of previously obtained experience. The programme presented below came into force at the beginning of 2012 (now performed as an independent regulatory activity). Methods, equipment and QA systems are same as within the national environmental radioactivity monitoring programme.

The table below summarises the monitoring programme (objects, measurement types, measurement/sampling frequencies and analyses carried out).

Monitoring object	**Type of measurements or samples and number of measurements or sampling stations**	**Measuring or sampling frequency**	**Analyses and frequencies**
External radiation	a) Environmental dose rate meters at Loviisa (17) at 0 - 10 km from the power plants	Continuous measurement and recording	Dose rate, min., max., mean, analogue plotter charts and/or digital hourly average values
	b) TLD dosimeter stations at Loviisa (10) at 0 - 10 km from the power plants	Continuous measurement	Gamma dose, 4 times a year
	c) Supplementary gamma spectrometric measurements	Once every two years	Gamma spectrum, once every two years

Monitoring object	Type of measurements or samples and number of measurements or sampling stations	Measuring or sampling frequency	Analyses and frequencies
Airborne radioactive particles and iodine	a) Air sample collectors at Loviisa (4) at 0 - 10 km from the power plants. The collectors can collect airborne radioactive particles and iodine (also iodine in the form of organic compounds)	Continuous collection. Filters replaced twice a month; at one station once a week during refuelling	Gamma emitters, twice a month (once a week)
	b) Supplementary monitoring performed with a portable air sample collector	Once a week during refuelling	Gamma emitters, once a week during refuelling
Deposition	Deposition collectors at Loviisa (4), at 0 - 10 km from the power plants	Continuous collection	Gamma emitters 4 - 12 times a year; ^{89}Sr and ^{90}Sr, 2 times a year
Soil	Soil samples are drawn from the area of assumed maximum deposition to determine the accumulation of long-lived radionuclides	Once every four years	Gamma emitters and ^{90}Sr, vertical distribution
Terrestrial wild plants, natural products and game	a) Reindeer lichen from 1 sampling site close to the power plants and reference sample	Once a year	Gamma emitters, once a year
	b) Hair moss from 1 sampling site at Loviisa and reference sample	Once a year	Gamma emitters, ^{89}Sr and ^{90}Sr, once a year
	c) Pine needles from 1 sampling site close to the power plants and reference sample	Once a year after the refuelling	Gamma emitters, once a year
	d) Ferns from 1 sampling site close to the power plants and reference sample	Once a year after the refuelling	Gamma emitters, once a year
	e) Wild berries, mushrooms and game found in the vicinities of the power plants	Once every four years simultaneously with the soil sampling	Gamma emitters

Monitoring object	Type of measurements or samples and number of measurements or sampling stations	Measuring or sampling frequency	Analyses and frequencies
Grazing grass	Collective sample representing farms producing milk, at 0 - 10 km from the power plants and reference sample	Twice a growing season	Gamma emitters, twice a growing season
Milk	a) Sample representing farms producing milk, at 0-10 km from the power plants	Once a week	^{131}I and gamma emitters, once a month
	b) Sample representing the whole production of the local dairy (at Loviisa at 0 - 40 km distance from the power plant)	Once a week	Gamma emitters, once a month and ^{131}I if needed; ^{89}Sr, ^{90}Sr, one times a year
Garden produce	a) Lettuce grown at 0 - 10 km from the power plants	Once a growing season	Gamma emitters, once a year
	b) Apples grown at Loviisa at 0 - 10 km from the power plants	Once a year	Gamma emitter, once a year
	c) Root vegetable grown at Loviisa at 0 - 10 km from the power plants	Once a year	Gamma emitter, once a year
Grain	Grain (e.g. oat and wheat) samples, grown at less than 20 km from the power plants	Once a year	Gamma emitters, once a year; ^{89}Sr and ^{90}Sr, only from wheat
Meat	Meat samples from livestock raised at less than 40 km from the power plants. The samples represent the grazing season and the fodder season	Twice a year	Gamma emitters, twice a year
Drinking water	Samples of drinking water or raw water from the power plants and from the town of Loviisa	2 - 4 times a year	Gamma emitters 2 - 4 times a year; ^{89}Sr and ^{90}Sr, once a year from both places

Monitoring object	Type of measurements or samples and number of measurements or sampling stations	Measuring or sampling frequency	Analyses and frequencies
Ground water	Samples of ground water near the town of Loviisa	Once a year	Gamma emitters once a year
Sea water	Samples from 5 stations in the surrounding sea areas of the power plants	2 - 4 times a year	Gamma emitters, ^{3}H, ^{89}Sr and ^{90}Sr, 2 - 4 times a year (Sr only from 2 stations)
Bottom sediments	a) Sinking matter collected by sediment traps at 4 stations in the surrounding sea areas of the power plants	Continuous collection	Gamma emitters, 4 times a year; ^{238}Pu and ^{239},^{240}Pu, once a year from 2 stations
	b) Sediment samples are taken from top of the sediment (0-10 cm) 2 - 4 stations in the surrounding sea areas	Once a year	Gamma emitters, once a year
	c) Sediment samples are taken from 1 - 2 stations in the surrounding sea areas	Once every four years	Gamma emitters, ^{90}Sr, ^{238}Pu and $^{239,240}Pu$, vertical distribution
Aquatic indicator organisms	a) Periphyton collected sampling plates close to the cooling water outlets of the power plants	Continuous collection during the growing season (May- November)	Gamma emitters, 7 times a growing season
	b) *Fucus vesiculosus* from 5 sampling sites at Loviisa	Twice a year	Gamma emitters twice a year; ^{89}Sr, ^{90}Sr, ^{238}Pu and $^{239,240}Pu$, from 2 sites once a year
	c) Submerged seed plants *Myriophyllum spicatum* and *Potamogeton pectinatus* from 1 sampling site at Loviisa	Once a year	Gamma emitters, once a year
	d) Crustacean *Saduria entomon* at Loviisa from one sampling site	Once a year	Gamma emitters, ^{89}Sr and ^{90}Sr, once a year
Wild fish	Pike, perch, roach and Baltic herring from two sampling areas at Loviisa	Once a year (May to October)	Gamma emitters, once a year; ^{89}Sr and ^{90}Sr, one perch and Baltic herring sample once a year

Monitoring object	**Type of measurements or samples and number of measurements or sampling stations**	**Measuring or sampling frequency**	**Analyses and frequencies**
Farmed fish	Young salmon and other fish from the fish farm at Loviisa	5 times a farming season	Gamma emitters, 5 times a year
Sludge	a) sludge samples from the sewage treatment plant at Loviisa	2 times a year, once a week during refuelling	Gamma emitters
	b) sludge samples from the sewage treatment plant at Loviisa power plant	2 times a year	Gamma emitters
	c) sludge samples from the sewage treatment plants at Kotka and Porvoo	Once a year	Gamma emitters
Radioactivity in man	5 to 10 persons living 1 - 10 km from either power plant	Once a year	Gamma emitters

8 NATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

8.1 INTRODUCTION

Finland carries out a comprehensive environmental monitoring programme which is summarised in the table below. In addition to the continuously running programme summarised below, environmental monitoring includes thematic investigations every 5 - 10 years. Current ongoing thematic investigations are radon in outdoor air, radon in kindergartens and schools, radon in new residential buildings, radioactivity in meat, eggs, natural products, building materials, sawn timber and in biomass material. In addition, radioactivity in man is measured in the area where deposition from Chernobyl was most important.

Media	Monitoring places	Monitored quantity	Frequency	Responsible organisation
Ambient dose rate	255 automatic stations	Dose rate, µSv/l	Continuous, 10 min. interval	STUK
Airborne radioactivity	Helsinki, Kotka, Imatra, Ylöjärvi, Kuopio, Rovaniemi, Kajaani, Sodankylä, Ivalo (9 stations)	Gamma emitting radionuclides	From 1/day to 1/week	STUK, PvTT, FMI
Airborne total beta-activity	9 stations	Total beta-activity	1/day or 1/week	FMI
Fallout of radionuclides	Helsinki, Kotka, Imatra, Ylöjärvi, Kuopio, Rovaniemi, Kajaani, Sodankylä, Ivalo (9 stations)	Gamma emitting radionuclides, ^{90}Sr	Gamma, 4/year ^{90}Sr, 2/year	STUK
Radionuclides in surface water	Kymijoki, Oulujoki, Kemijoki, Kokemäenjoki	Gamma emitting radionuclides	2/year	STUK
Radionuclides in drinking water	Helsinki, Turku, Tampere, Oulu, Rovaniemi	Gamma emitting radionuclides, ^{3}H, ^{90}Sr	2/year	STUK
Radionuclides in milk	Riihimäki, Joensuu, Jyväskylä, Seinäjoki, Oulu (dairies)	Gamma emitting radionuclides, ^{90}Sr	Gamma, 12/year ^{90}Sr ,4/year	STUK
Radionuclides in foodstuffs	Helsinki, Tampere, Rovaniemi, (Main hospitals + foodstuffs on the market)	Gamma emitting radionuclides, ^{90}Sr	2/year	STUK
Radionuclides in sludge	Helsinki	Gamma emitting radionuclides	4/year	STUK
Radionuclides in human body	Helsinki, Tampere, Rovaniemi	Gamma emitting radionuclides	1/year	STUK
Indoor radon	Whole of Finland	^{222}Rn	Continuous	STUK
Radioactivity in the Baltic Sea	See Section 8.10			STUK

8.2 EXTERNAL GAMMA DOSE RATE MONITORING

Finland has an automatic nationwide monitoring network for external dose rate which has two main functions: alarming and providing the radiation situation. The network has 255 stations equipped with GM-tubes. The maintenance and development of the network is carried out by STUK in close co-operation with local emergency authorities. The map below shows the locations of the stations.

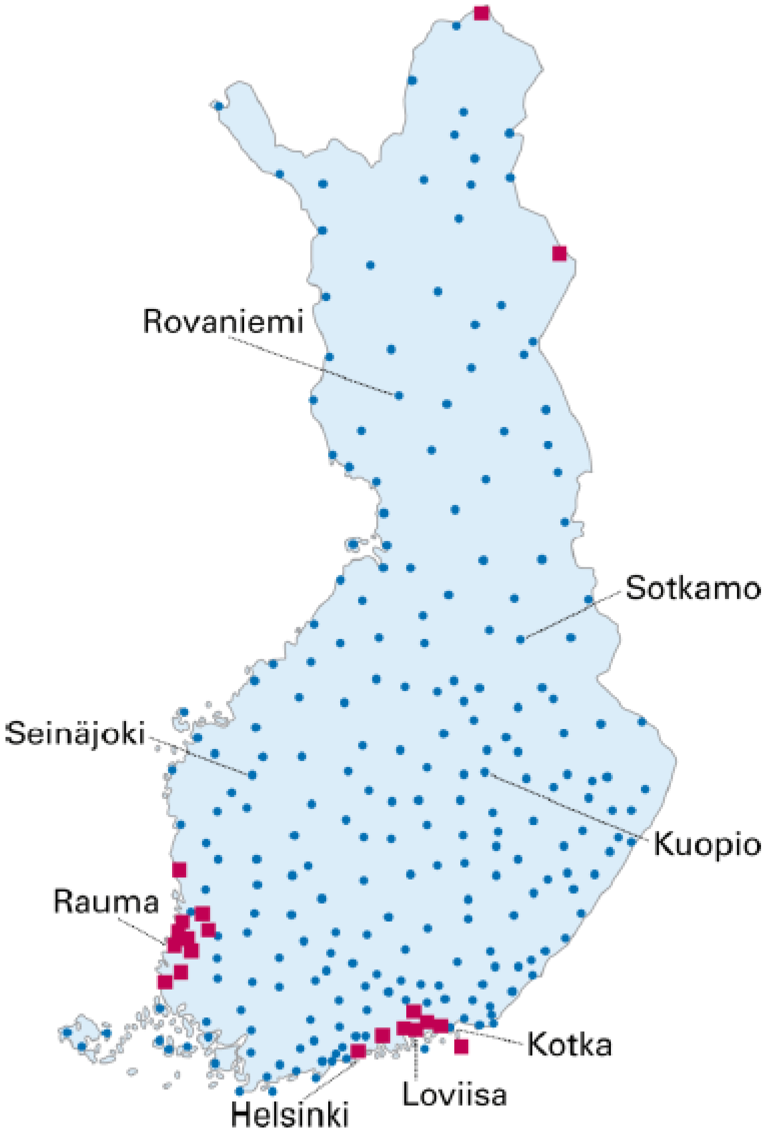

Figure 3: Network of automatic dose rate monitoring stations. Red squares indicate stations that have both a GM detector and a $LaBr_3$ spectrometer.

8.2.1 Monitoring devices

The monitoring network was renewed between 2005 and 2007. The monitoring stations are manufactured by Envinet GmbH. Dose rate probes are manufactured by Envinet and Saphymo GmbH (previously Genitron). Technical specifications are listed below.

Envinet IGS421A1-H	
Measuring range	0.01 µSv/H-10 Sv/h
Measured value	Gamma dose rate H*(10)
Number of GM-tubes	3, two for low dose rate and one for high dose rate
Operating temp.	-40 - +60 C
Connector interface	RS232
Internal memory	77 results

Genitron GammaTracer XL3	
Measuring range	0.01 µSv/h-10 Sv/h
Measured value	Gamma dose rate H*(10)
Number of GM-tubes	3, two for low dose rate and one for high dose rate
Operating temp.	-40 - +60 C
Connector interface	RS232
Internal memory	12800 results

The monitoring station has a Linux based computer. The computer gives a possibility to connect different types of detectors to the monitoring station. Currently STUK is using probes equipped with GM-tubes, rain detectors and detectors with nuclide identification capability. The software for the monitoring stations is either bought from different companies or developed in-house. Flexibility of software and detectors is very important when operational use of 20 years needs to be achieved.

The probes that are used in monitoring stations have three GM-tubes, two of the GM-tubes are for low dose rate and one for the high dose rate. This gives better statistics at background level. It also enables to recognise GM-tube failures.

Each monitoring station sends its results automatically every ten minutes to three different locations, namely STUK, a back-up system and the regional emergency response centre. Communication is done using a secure Tetra radio network (VIRVE) dedicated only for the Finnish authorities. Due to this 10 minute reporting interval, the radiation situation will be almost real-time from the whole of Finland.

Each monitoring station has an individual alarm threshold limit which is the 7 day smoothed average background at the monitoring station plus 0.1 µSv/h. If it is raining during the alarm, the alarm limit is the background plus 0.15 µSv/h.

Monitoring stations around the Finnish nuclear power plants are equipped with $LaBr_3$ spectrometers, installed during 2010 and 2011. They operate at the same 10 minute monitoring interval like the GM-detectors. Spectra are sent to STUK where they are analysed automatically for 65 different gamma energies. If any of these nuclides are identified, STUK's expert on duty is alerted. The detection level for example for ^{131}I is 35 Bq/m^3 in a 10 minute measurement.

8.2.2 Data management and control centre

Data coming from monitoring stations is managed and presented by the USVA system which is a closed system for STUK, the Finnish Defence Forces, the Finnish Meteorological Institute and the

Ministry of the Interior. One of the main tasks of the USVA is to create and distribute the radiation situation to defined authorities.

10 minute average and one minute pulse counts from individual GM-tubes are stored in an SQL database. Users can view the results on a map, create time series and reports. The system creates alarms if the dose rate exceeds the 7 day average background of the monitoring station by 0.1 µSv/h. The alarm is sent to the STUK's expert on duty. An alarm is also sent to the emergency response centre, which orders the rescue service to the alarming monitoring station to make measurements using hand held meters.

8.3 AIR MONITORING PROGRAMME

STUK operates eight sampling stations for nationwide monitoring of airborne radioactive substances whilst the Defence Forces has one station, which are shown on the map below.

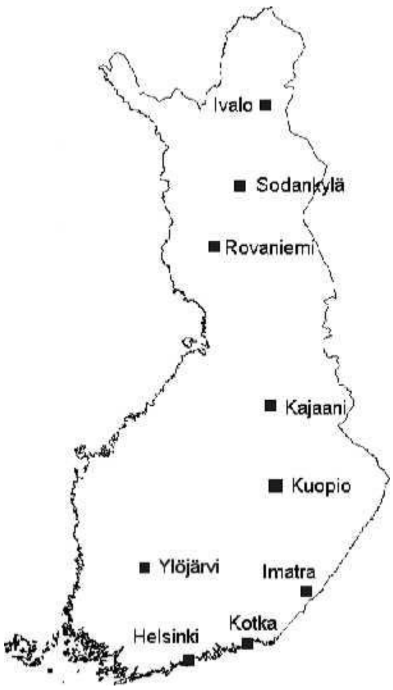

Figure 4: Stations for monitoring of airborne radioactivity and atmospheric deposition. The Ylöjärvi station is operated by PvTT.

Kotka, Kajaani and Rovaniemi have Snow White air samplers (~900 m^3/h), whereas Imatra, Kuopio, Sodankylä and Ivalo have Hunter (~150 m^3/h). The automatic sampler located at STUK headquarters is called Cinderella (~500 m^3/h).

Sampling is performed using a specially designed sampler which filters large amounts of air. Airborne radioactive substances are deposited on glass fibre filters whereas charcoal filters are used for gaseous effluents such as iodine. The samplers are manually operated but one station located at STUK's headquarters in, Helsinki, is fully automated. The automatic station filters radioactive substances from the air, changes the filter, prepares the filter for on-site high-resolution gamma ray analysis and reports the data on web pages.

All samplers are manufactured by the Finnish company Senya Ltd. The Hunter model filter is changed twice a week (Monday and Thursday), Snow White once a week and Cinderella once a day.

Four samplers (Helsinki, Kotka, Kajaani and Rovaniemi) are equipped with continuous monitoring of the glass fibre filter by a $LaBr_3$ spectrometer. The spectrometer operates in the same way as the spectrometer connected to an external dose rate monitoring station. The detection level depends on different parameters but the detection level for ^{131}I is around 1mBq/m^3 with a 10 minute measuring interval.

The glass fibre filters are measured in the laboratory with a high-resolution gamma spectrometer. Nuclide specific minimum detectable concentrations (µBq/m^3) depend on the filtered air volume, the activity of other radionuclides in the sample, the measuring time and decay time before the measurement, detection efficiency and the background shield. Detection limits are typically a billion times smaller than the concentrations that may lead to protective action being taken. The gamma spectrometry method is accredited by FINAS (FINAS T167).

8.3.1 Monitoring of total beta-activity in air

As part of the Finnish national radiation surveillance programme the Finnish Meteorological Institute (FMI) has been measuring beta and alpha radioactivity instrumentally from air filters and precipitation samples since 1960. In addition to radiation monitoring the results have been used in meteorological and air quality studies.

Currently FMI collects daily samples at three stations and weekly aerosol samples at eight stations as shown on the map below.

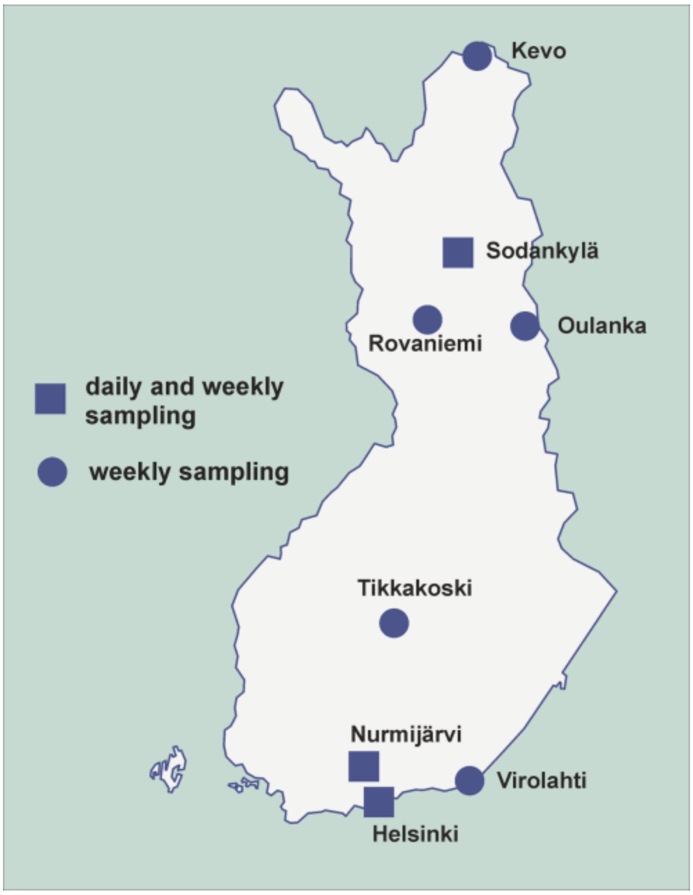

Figure 5: FMI stations for monitoring of airborne total beta-activity.

Daily aerosol samples are collected with high-volume samplers. The filter material is glass fibre (Munktell MGA; Ø 24 cm). The samplers have a capacity of 3500 m^3 per day and they collect particles with an aerodynamic diameter less than 10-15 µm depending on the wind speed. The air flow is measured with a rota meter. The filters are changed daily at 06.00 UTC.

Weekly aerosol samples are obtained from the instruments continuously monitoring aerosol beta activity. The equipment uses two rectangular paper filters (Whatman 42) or glass fibre filters (Whatman GF/A) with a filtering area of 120 mm x 140 mm. The weekly air volumes are 800 m^3 and 4000 m^3 for paper and glass fibre filters, respectively. The air flow is measured with a mass flow meter. The filters are changed every Monday at 06.00 UTC.

All filters are measured in the laboratory with an automatic alpha/beta analyser. The detector arrangement of the instrument consists of five gas flow proportional counters with 25 cm x 25 cm windows. The flow gas is P-10, a mixture of argon (90 %) and methane (10 %). The filters are attached to holders which are carried one by one beneath the upper detector assembly with the exposed side of the filter facing upwards. The sample identification data is read from a bar code attached to the sample holder. Next, the lower detector assembly moves upwards, so that the filter is lightly pressed between the counters. The uppermost and undermost counters (I and V) are used for anticoincidence shielding. The counter III detects alpha particles from the filter surface. The two remaining counters, II and IV, are for beta particles. Pulses from the detectors are counted and the movements of the sample changer are controlled with an add-on board in the microcomputer.

The counting efficiency for alpha particles (^{210}Po) is 42 % and for beta particles (^{210}Bi) 76 %. Each filter type has its own background sample (an unexposed filter), which is measured at least twice per measuring sequence. Similarly three reference samples (^{242}Pu, ^{90}Sr and ^{55}Fe) are measured at least once per measuring sequence to monitor the stability of the instrument.

The total alpha and beta activities of all the aerosol samples are measured five days after the end of sampling, when the short-lived ^{222}Rn progeny has decayed into ^{210}Pb and the ^{220}Rn progeny has decayed into stable lead.

The measured net count rates are divided with counting efficiencies and air volumes to obtain total beta activity concentrations using Microsoft Excel. The data is stored on PCs.

The data have been published in:

- the FMI's yearbook series "Observations of Radioactivity" up to 1982
- the FMI's report series "Publications on Air Quality" for the years 1983-1997
- the FMI's report series "Air Quality Measurements" for the years 1991-2000
- the report series STUK-B-TKO of STUK - annually since 1999

8.4 MONITORING OF ATMOSPHERIC DEPOSITION

Radioactive substances can be deposited into the environment as dry deposition or with rain as wet deposition. The results of the analyses of the deposition samples as Becquerels per unit area form a basis for transfer studies of the deposited radionuclides both in terrestrial and aquatic environments.

Deposition samples are collected continuously at nine sites in Finland and the samples are taken from the sampling devices usually monthly for analysis. The device is made of stainless steel with a collecting area of 0.07 m^2 and it does not separate wet and dry deposition from each other, but collects them together. In order to facilitate sampling in wintertime, there is a small heating resistor inside the collector that melts the snow and ice accumulated in the funnel thus ensuring it is included in the sample. At two stations STUK has separate sampling devices for tritium determinations. For emergency purposes STUK has one sampler which separates wet and dry deposition from each other. Its collecting area is 0.5 m^2 and it is located at STUK's headquarters in Helsinki.

All the samples are analysed for gamma-emitting radionuclides, ^{90}Sr is analysed on semi-annual combined samples. Known amounts of stable Sr and Cs carriers are added to the samples, and the samples are acidified with nitric acid. The samples are concentrated by evaporating them under infrared thermal lamps, and the residues are ashed. The ashed samples are analysed for gamma-emitting radionuclides with gamma spectrometers. Strontium is separated by an extraction chromatographic method, and thereafter ^{90}Sr is determined via its daughter nuclide ^{90}Y, measured with a low background proportional beta counter. Tritium is analysed once a month in samples from Helsinki and Rovaniemi. The tritium samples are distilled and then measured with liquid scintillation spectrometry.

8.5 WATER MONITORING PROGRAMME

8.5.1 Surface water

Finland is characterised by countless lakes and rivers forming water courses which finally discharge into the Gulfs of the Baltic Sea, to the Archipelago Sea or to the Arctic Ocean. In the surveillance programme water samples are analysed from four large rivers: Kymijoki, Kokemäenjoki, Oulujoki and Kemijoki, representing water which is discharged from three large drainage basins in Finland (fig 6). The river Kokemäenjoki was included in 2009 as a new sampling site in the monitoring programme.

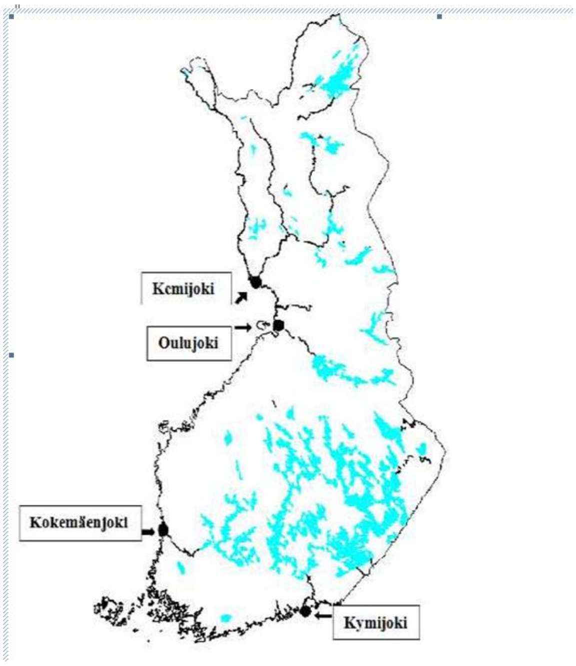

Figure 6: Discharge points of the four rivers included in the monitoring programme

The samples are taken by regional Environment Centres in connection with the sampling for their own purposes two times a year according to the hydrological cycle of the lakes and rivers in Finland.

In the laboratory, known amounts of Sr and Cs carriers are added to the samples, which are acidified with nitric acid. The samples are concentrated by evaporating them under infrared thermal lamps, after which the dry residues are ashed. Gamma-emitting radionuclides are analysed with gamma spectrometers on the ashed samples. Strontium is separated by an extraction chromatographic method, and ^{90}Sr is measured with a Quantulus liquid scintillation counter.

8.5.2 Drinking water

Both ground water and surface water is used for drinking water in Finland. The share of ground water is continuously increasing, and up to 2020 it is expected to be close to 70%. About 90 % of Finnish people get their drinking water from the public water supply.

Drinking water samples are taken twice a year from five sites in Finland: Helsinki, Tampere, Rovaniemi, Oulu and Turku (see map below). In three places (Helsinki, Tampere, Rovaniemi) samples are taken directly from the tap in connection with the sampling of diet samples. In two places (Oulu and Turku) samples are taken by water treatment plants and delivered to STUK.

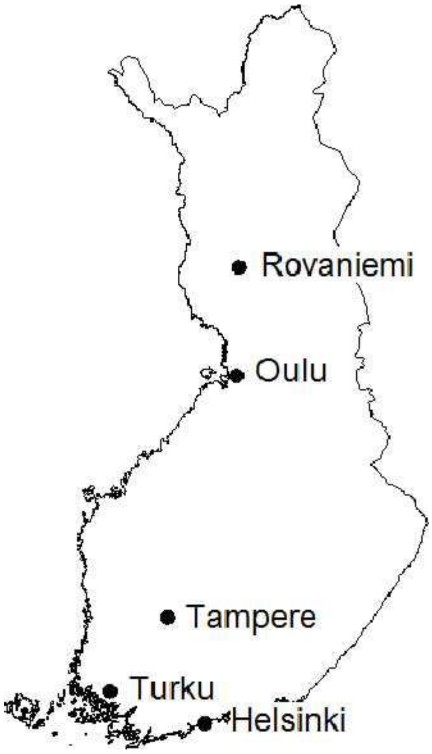

Figure 7: Sampling sites for drinking water monitoring.

Gamma-emitters, ^{90}Sr and tritium are determined on the samples. A subsample from each of the samples is taken first for the tritium determination. It is determined after distillation by measuring directly with a Quantulus liquid scintillation counter.

The samples are concentrated by evaporation and ashed to remove organic material. Gamma emitters are determined with semiconductor detectors. ^{90}Sr is analysed using the extraction chromatographic separation method with Sr-specific Triskem® resin and measured with a Quantulus liquid scintillation counter.

8.6 SOIL AND BIOTA MONITORING PROGRAMME

No soil sampling is included in the national surveillance programme in Finland. This is due to the fact that deposition samples are collected separately and therefore there is no need for soil samples.

Soil samples are collected once every four year as part of the environmental monitoring in the vicinity of the Loviisa and Olkiluoto NPPs.

Terrestrial and aquatic biota and flora is collected and monitored on a continuous basis only in the vicinity of the domestic nuclear power plants and in the Baltic Sea.

8.7 FOOD MONITORING PROGRAMME

The programme encompasses milk, mixed diet and other foodstuffs.

8.7.1 Milk

The dairy milk sampling sites in the monitoring programme are chosen to provide representative information about the radioactivity in milk produced in Finland. The sites represent different levels of deposition. The milk is also monitored in order to estimate the internal radiation dose to people via milk.

Figure 8: Sampling sites for milk monitoring

The samples are collected from Finnish dairies in Joensuu, Jyväskylä, Oulu, Riihimäki and Seinäjoki (Fig. 8). Weekly samples (1 litre/week) from each sampling site are taken during one- two days in the dairy. The samples are sent to STUK weekly or monthly. Weekly samples are frozen, and then bulked monthly for analysis. The monthly samples (4-5 litres) are evaporated.

The samples are evaporated under infrared thermal lamps and ashed before the analysis. The concentration of ^{137}Cs is determined by gamma spectrometric measurements on monthly samples. Strontium is determined from quarterly bulked samples by separating strontium by an extraction chromatography method and thereafter measuring ^{90}Sr with a liquid scintillation counter.

8.7.2 Mixed diet

The mixed diet samples are collected once a year at institutional kitchens in hospitals in Helsinki, Tampere and Rovaniemi. Sampling is carried out in autumn in order to include the new season's produce in the sampling. The institutional kitchens collect all the meals with bread and drinks during one day, drinks and solid food separately. The daily energy content of the total meals is approximately 8300-9200 kJ.

The solid food samples collected during a day are combined into one sample, which is dried and homogenised. The ^{137}Cs content of the dried daily samples is determined by gamma spectrometry measurement. After ^{137}Cs has been determined, the samples are ashed and combined into weekly samples for ^{90}Sr analysis. Strontium is separated from the samples by an extraction chromatographic method, after which ^{90}Sr is measured with a liquid scintillation counter.

The drinks collected during a day are evaporated under infrared thermal lamps and ashed. ^{137}Cs is determined by gamma spectrometry measurement from the ashed drink samples. Strontium is separated from the samples by an extraction chromatography method, after which ^{90}Sr is measured with a liquid scintillation counter.

8.7.3 Other foodstuffs

The foodstuffs on the market are acquired from grocery shops in the same cities as the daily diet samples. The sampling time is between summer and autumn. Wild game, wild berries, wild mushrooms and fish are chosen as samples in order to determine concentrations of ^{137}Cs. The foodstuff samples are collected once a year. Samples are dried before gamma spectrometry measurements.

8.8 MONITORING OF RADIOACTIVITY IN SLUDGE

In 2009, the programme for the surveillance of environmental radiation was expanded to monitor the occurrence of artificial radionuclides in sludge from the Viikinmäki wastewater treatment plant in Helsinki. Sludge is a sensitive indicator of radionuclides that enter the environment since many radionuclides in wastewater are enriched during the water treatment process. Sludge from the Viikinmäki wastewater treatment plant has been found to contain radionuclides that originate, for instance, from the Chernobyl accident, medical use of radioisotopes and natural sources. Investigating sludge also provides useful information about the transfer of radionuclides in the environment.

The Viikinmäki wastewater treatment plant in Helsinki was commissioned in 1994. The plant processes the wastewater of Helsinki, eastern and central parts of Vantaa, Kerava, Tuusula, Järvenpää, Sipoo, the southern part of Mäntsälä and Pornainen. In 2014, about 261,000 m^3 of wastewater per day flowed through the plant. The plant produced 64,400 tonnes of dried waste sludge in 2014.

8.8.1 Sampling

Samples of undigested sludge and dewatered sludge from the wastewater treatment plant are collected four times a year and analysed for gamma-emitting radionuclides. Samples are collected in February, May, August and November. Both types of samples are collected on the same day.

8.8.2 Pre-treatment and analyses

In the laboratory, the samples of undigested sludge are dried in a drying oven and ground into powder. The samples are not pre-treated in any other way. The samples are then analysed by gamma spectrometry for gamma-emitting radioactive substances.

The samples of dewatered sludge are analysed for gamma-emitting radioactive substances without any pre-treatment. Measurements are carried out as soon as possible after the samples have arrived in the laboratory in order to detect any short-term nuclides. The percentage of dry material in the samples is determined after the measurements.

8.9 MONITORING OF RADIOACTIVITY IN MAN

There are two whole-body counting systems at STUK. One is a permanently installed in the laboratory in Helsinki; the other is a mobile unit. The stationary, so called scanning bed system is installed inside an 80 tonne iron room and consists of two HPGe-detectors. The mobile unit weighs about 2.5 tonnes is installed in a truck. With this mobile system measurements can be done even far from Helsinki. The mobile system includes a measurement chair and in front of that is a sensitive HPGe -gamma detector. The amount of radioactive substances to be measured is usually small and the chair is made of lead to reduce the disturbing background radiation from the environment. Today ^{137}Cs is the most important man-made radionuclide transported via foodstuffs to man. The minimum detectable amounts of ^{137}Cs for the stationary and mobile systems are about 30 Bq and 50 Bq, respectively. The measurement results are stored in the Access and LIMS databases.

8.9.1 Groups of people measured

The measurements are done in Helsinki, Rovaniemi and Tampere. A reference group of persons working at STUK in Helsinki has been monitored since 1965. The Rovaniemi group has been followed since 1999 and in 2001 a group from Tampere has been added to the measurement program. The Tampere group includes children and teachers from a local school. In Helsinki and Rovaniemi both the groups from schools and persons from STUK are measured. Schools were chosen because different age groups are easily available among schoolchildren and teachers. All persons measured are volunteers. They are interviewed for information on eating habits and consumption of certain foodstuffs known to contain rather high concentrations of ^{137}Cs. Based on the results of these measurements the mean internal radiation dose from artificial radioactive substances can be estimated.

8.9.2 Results

The results are presented in STUK's annual report for adults (older than 14 years) in Helsinki, Rovaniemi and Tampere. In 2015 the Helsinki group consisted of 39 persons, the Rovaniemi group 44 and the Tampere group 35. In Helsinki the highest content was 573 Bq and 22 persons were below the detection limit of 50 Bq. In Rovaniemi the highest content was 540 Bq and in Tampere 1330 Bq. The influence of the atmospheric nuclear weapons tests and the Chernobyl accident on the body caesium content is clearly visible. The mean internal radiation dose from ^{137}Cs in 2015 was estimated at 0.01 mSv/person, or less than 0.3% of the total mean annual radiation dose 3.2 mSv.

8.10 MONITORING OF RADIOACTIVITY IN THE BALTIC SEA

All the Baltic Sea countries have ratified the Helsinki Convention, the Convention on the Protection of the Marine Environment of the Baltic Sea Area. The Helsinki Commission (HELCOM) co-ordinates the international co-operation, which focuses on the implementation of the Convention. Recommendation 26/3 of the HELCOM defines the programme for monitoring the occurrence, transport and amounts of radionuclides in the Baltic Sea. All the Baltic Sea countries contribute to the monitoring with their own national programmes. The Finnish contribution consists of about 120 annual samples from seawater, bottom sediments, fish and other biota, analysis of radioactive substances and reporting of the results to the HELCOM database. STUK is responsible for the Finnish part of the programme. The results are published in Joint Reports every five years. In addition, STUK maintains a discharge register, to which the Contracting Parties report annually discharge data from all nuclear facilities operating in the Baltic Sea area.

8.10.1 Sampling, pre-treatment and analysis

The sampling stations or areas for seawater, bottom sediments, fish and other biota are shown in Figure 9. Seawater samples are taken once a year from 15 sampling stations, sediment samples (entire depth profile) from 6 sampling stations, fish (pike and Baltic herring) from 6 sampling areas and other biota *(Fucus vesiculosus, Macoma baltica and Saduria entomon; 3* samples) from 2 sampling areas. The samples are taken on board the Finnish Research Vessel *Aranda*, or in the coastal areas by the staff of STUK or local fishermen.

The methods used in sampling, pre-treatment and analysis are accredited by FINAS (Accredited testing laboratory T167), and described in the Quality Manuals of STUK and Environmental radiation surveillance and Emergency Preparedness (VALO, in Finnish). Seawater samples (30 L) are taken with large seawater samplers, sediment samples with a Gemini Twin Cores sampler. The guidance quantities for samples are 5 kg fresh weight for fish, 2 kg for Fucus, and 200 g for *Macoma* and *Saduria.*

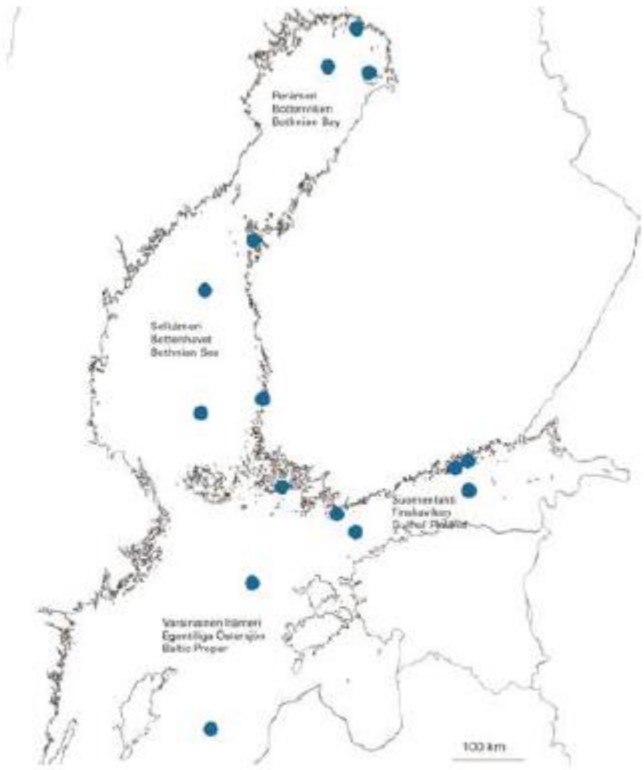

Figure 9: Sampling stations and areas for seawater, bottom sediments, fish and other biota

8.10.2 Assessed radionuclides

The radionuclides to be analysed are defined in the Guidelines related to HELCOM Recommendation 26/3 summarised below.

SAMPLE	OBLIGATORY	VOLUNTARY
A. Water (results in Bq m^{-3})	Radiocaesium (*) (^{90}Sr **)	^{3}H, ^{99}Tc; ^{239}Pu; ^{240}Am, ^{241}Am, γ-emitters
B. Sediments (results in Bq kg^{-1} dry weight and Bq m^{-2})	γ-emitters (***)	^{90}Sr, ^{239}Pu, ^{240}Pu, ^{241}Am, natural radionuclides (e.g. ^{210}Po)
C. Fish (results in Bq kg^{-1} fresh weight)	γ-emitters (***)	^{90}Sr, natural radionuclides (e.g. ^{210}Po)
D. Aquatic plants (results in Bq kg^{-1} dry weight)	γ-emitters (***)	^{90}Sr, ^{99}Tc, ^{239}Pu, ^{240}Pu, ^{241}Am, natural radionuclides
E. Benthic animals (results in Bq kg^{-1} dry weight)	γ-emitters (***)	^{90}Sr, ^{99}Tc, natural radionuclides (e.g. ^{210}Po); ^{239}Pu, ^{240}Pu, ^{241}Am

(*) ^{137}Cs and ^{134}Cs, if possible
(**) regularly, on a carefully selected number of samples
(***) ^{40}K, ^{37}Cs and other γ-emitters identified in the γ-spectrum

8.10.3 Recording of data

The results are stored in the LIMS at STUK, and reported to the HELCOM database once a year before September 1.

8.11 LABORATORIES PARTICIPATING IN THE NATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

The concentrations of radioactive substances in the environment and foodstuffs are constantly monitored by STUK. In a fallout situation, a sampling and analysis programme for assessing the situation is planned by STUK together with the national food authorities. In addition to STUK, the programme comprises about 30 local laboratories committed to measuring radioactivity in foodstuffs and drinking water shown on the map below.

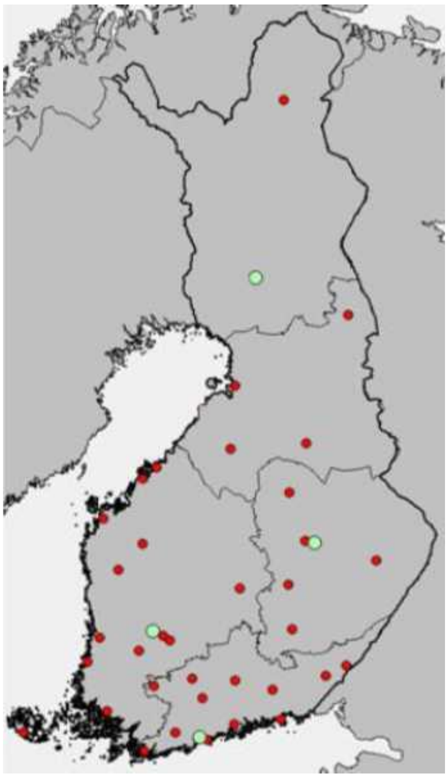

Figure 10: Local food and environmental laboratories in Finland

STUK has delivered equipment for municipal laboratories comprising a NaI-crystal detector with background lead shield. With this equipment local authorities can perform simple gamma analysis. Currently this system is accredited for ^{137}Cs measurements in foodstuffs and ^{222}Rn measurements in drinking water. Detection limit for ^{137}Cs and ^{222}Rn is 30 to 50 Bq/kg. STUK arranges training for local laboratories to maintain measuring skills. Laboratories regularly make measurements and report the results to STUK.

8.12 MOBILE MEASUREMENT SYSTEMS

Three mobile measurement systems are available, Sonni, Härkä and Vasikka.

8.12.1 SONNI - Mobile measurement vehicle

STUK has a mobile monitoring laboratory called SONNI equipped with state of the art measurement, environmental sampling, positioning and communication equipment. Measurement and analysis results are available at STUK almost in real time through wireless broadband networks.

SONNI is a 4x4 van equipped with the following systems:

- Ambient gamma dose rate measurement equipment
- In-situ gamma spectroscopy equipment (large NaI detectors and an electrically cooled HPGe-detector)
- 2 air sampling systems with flowmeters
- Alpha-beta spectroscopy equipment (without chemical treatments)
- Data management systems with GPS positioning for transferring data to the LINSSI-database

The mobile equipment is mainly used for emergency monitoring purposes, but possible other applications include complimentary environmental measurements and radiological surveillance for example at major public events.

When the mobile laboratory is operated in the field it usually has a crew of four persons. The systems have advanced automation, so the operating personnel do not need to be trained to an expert level. This allows STUK to have a pool of staff trained for mobile operation.

The mobile equipment base at STUK includes also equipment for four 3-person foot patrols, equipped to carry out gamma dose rate, in-situ spectroscopy, gross beta activity measurements and air sampling using portable air samplers (airflow 10 m^3 per hour). There is also a possibility to perform iodine assessment on thyroid and milk using portable gamma spectroscopy systems.

8.12.2 HÄRKÄ - Mobile measurement vehicle

In 2014, a new maintenance and radiation measurement vehicle Härkä was completed. The vehicle is used to carry out maintenance on the equipment of the stationary environmental radiation monitoring network. The vehicle is equipped with highly sensitive spectrometers, which measure radiation continuously while the vehicle is moving. In this way STUK can collect radiological data and chart the basic radiological situation in various parts of Finland. The car can also be used in nuclear security events.

8.12.3 VASIKKA - Measurement backpack

STUK has a measurement backpack called VASIKKA consisting of a $LaBr_3$ gamma spectrometer, which is used also for detecting neutrons. Data is collected using a computer with integrated modem and GPS. Data can be displayed on a remote data terminal PDA (smart phone). Full online data transfer to the SNITCH reach back system at STUK operates if sufficient data network is available. The system has a fast response time (4 second measurement interval). Expertise on radioactivity measurements is not necessarily needed.

9 VERIFICATIONS

9.1 INTRODUCTION

The purpose of this Article 35 verification was to verify the national monitoring system for environmental radioactivity in Finland, the liquid and aerial discharge monitoring at the Loviisa nuclear power plant, and the environmental monitoring programme around Loviisa nuclear power plant.

The verification team visited the laboratories of the Radiation and Nuclear Safety Authority (STUK), the airborne radioactivity monitoring equipment at STUK headquarters, and mobile radiation monitoring equipment at STUK. Further to this, the verification team verified the installations for discharge monitoring at Loviisa NPP, the Loviisa NPP radiochemical laboratory for analysis of discharge samples, and the installations for on-site and off-site environmental monitoring at Loviisa NPP.

9.2 STUK LABORATORIES

Apart from the air analysis carried out by FMI the STUK laboratories in Helsinki are responsible for performing all analysis related to the national monitoring system for environmental radioactivity in Finland. A summary of monitored media, monitoring places, monitored quantity and frequency is given in Chapter 8.1.

The environmental radiation surveillance programme includes continuous and regular monitoring of radiation or radioactivity in air, soil, water, foodstuffs, and in the human body. On-line surveillance is based on monitoring of external dose rate in a network of 255 automatic stations. A detailed description of STUK's activities can be found on their web-site; www.stuk.fi.

Radiological surveillance of foodstuffs is performed by STUK as a part of the environmental radiation surveillance programme in Finland.

In the case of a radiological emergency, STUK is the central laboratory performing radiological surveillance and measurements.

In addition, STUK performs, as the independent regulatory authority, the measurements related to the environmental monitoring programme around Loviisa nuclear power plant. A summary of monitored media, monitoring places, monitored quantity and frequency is given in Chapter 7.2.

The verification team visited the laboratories of STUK's Department of Environmental Radiation Surveillance and Emergency Preparedness, which is responsible for the above mentioned measurement programmes. All laboratories of the entire department are accredited according to ISO 17025 (under the Finnish accreditation body FINAS).

The wide range of accredited measurement methods means that laboratory staff need to have a good knowledge of the very extensive list of procedures and work instructions available on the local network drive. To facilitate and speed up the integration of new laboratory personnel, there exist, in addition to the hands on training, a well arranged sequence of main procedures with which they have firstly to get familiarised.

Annually around 1500 analyses are carried out. The receipt area for air filters from the national monitoring sites was visited. QR codes on the plastic bags containing the filters are used for identification. Filters are stored indefinitely after analysis.

The gamma spectrometry measuring room was constructed using special materials in order to reduce background radiation; additionally the temperature and humidity are carefully controlled. Overall 15 detectors are available, some of which came from STUK's office in Rovaniemi when it closed. Liquid nitrogen is recycled using Ortec's Möbius system which also gives a digital readout of the counting time remaining before refilling is necessary, generally it is only necessary to refill once per year.

Continuous operation of the laboratories, in case of the absence of a colleague, is ensured through frequent rotation of laboratory staff, typically every five years, to acquire knowledge in other measurement methods.

STUK uses a laboratory management system to track each sample from sampling to reporting of the analysis result. The current system LIMS, using fixed personal computers and working records on paper, will soon be replaced by a new system called NAMIT using tablets.

> *Verification does not give rise to recommendations. The verification team recognises that STUK's performance in monitoring environmental radioactivity requires a very high level of staff competence. This high level of competence is achieved through an appropriate programme of education, training and retraining. The verification team stresses the importance of maintaining the current level of staff and to pursue the policy of adequate education, training and retraining.*

9.3 AIRBORNE RADIOACTIVITY MONITORING EQUIPMENT AT STUK HEADQUARTERS

Air samplers

STUK acquired a 2nd generation Cinderella air sampler in May 2015, which is located on the roof of their headquarters. The flow rate is between 300 and 600 m^3/h, and the Whatman GF/A filters measure 460 * 285 mm. It monitors radionuclides collected on the filter in real-time, changes the filter and performs on-site HPGe measurement on the filter automatically. Currently the machine operates on a 24h cycle but the frequency can be changed to 1, 6 or 8 hours. A total of 15 filters are used daily and stored for 24hrs, prior to being measured by gamma spectrometry for 24 h. Results for day N are received on day N+2 and checked prior to publication on STUK's website. Contrary to the Hunter and Snow White air samplers at other sites, the Cinderella is not equipped with active charcoal filters for gaseous iodine.

Additionally a Hunter JL-150 air sampler was located on the roof of STUK's headquarters.

Fallout samplers

Three deposition samplers were seen on the roof of STUK's headquarters. The larger stainless steel cone is intended for tritium determination, whereas the smaller is a classic deposition collector. A Pirkko deposition sampler can distinguish between wet and dry deposition, a mechanical arm linked to a rain detector pivots a cover over the dry deposition collection area in the event of rainfall.

> *Verification does not give rise to remarks.*

9.4 MOBILE RADIATION MONITORING EQUIPMENT

Emergency preparedness

A Mercedes 4*4 van, called SONNI (bull in Finnish) is permanently on standby at STUK's headquarters for monitoring in the event of a radiological emergency. Additionally it can be dispatched where an incident occurs at a border, or may be used for security purposes at large events. Every year it is used for monitoring around one of Finland's NPPs, Olkiluoto or Loviisa. It plays no role in the routine monitoring programme, for which other suitably equipped vehicles are used.

Generally the personnel which have been trained for routine monitoring and sampling in the field are used to crew the vehicle. No in-depth knowledge is required as the data, in addition to being stored on board, is relayed back to headquarters, almost in real time where it can be analysed by specialists.

Two NaI and one HPGe detectors are installed, the former having greater sensitivity, whilst the latter allows identification of specific radionuclides. The Ortec HPGe detector, which has a built-in GPS, is chiefly used for in-situ measurements. Coupled to a notebook for data storage it also relays the measurement results to STUK's control centre in real time. Mounted on the roof of the vehicle are 2 "horns" for air sampling, using either fibreglass or membrane filters. Analysis is done using alpha spectrometry, with the software having been developed in-house.

A supply of 1 litre plastic bottles, with lids, is carried and may be used for all sample types, typically, water, soil, foodstuffs or vegetable matter.

Border services are equipped with GPS enabled backpacks which, coupled with a Panasonic Toughbook, are used for gamma and neutron measurements with a spectrum generated automatically every 4 seconds, though this can be increased to between 40 and 400 seconds for better resolution. The information can be displayed on a smartphone and communicated to STUK.

In addition to a fixed whole body counter at STUK's headquarters a mobile unit is available for deployment in the event of an emergency. Routinely this is used for monitoring of reindeer herders in Northern and central Finland where even today higher concentrations of ^{137}Cs are encountered.

Routine monitoring

The "Härkä" vehicle used for routine servicing of the gamma and air sampling network is equipped with 4 NaI detectors which allow measurements to be performed whilst driving. Furthermore a Lilliput portable air sampler is carried on-board, which in addition to routine air sampling may be equipped with a charcoal cartridge for testing the presence of gaseous iodine.

Verification does not give rise to remarks.

9.5 AVAILABILITY OF RADIOLOGICAL INFORMATION TO THE PUBLIC

In addition to the results obtained from the Cinderella air sampler which are made available to the public online through STUK's website, an interactive map, showing the locations of the gamma dose rate monitoring stations gives an overview for the whole country, whilst users can click on a specific station to view in detail the dose rate measured.

Verification does not give rise to remarks.

9.6 DISCHARGE MONITORING AT LOVIISA NPP

Liquid and aerial discharges are monitored using online samplers, and by analysis of samples in the NPP laboratory.

9.6.1 Liquid discharge monitoring

The team visited two control tank rooms, one for releases of process water and the second one for releases from the radiochemistry laboratory and laundry area. A detailed description of the liquid discharge monitoring systems is given in section 6.2. The team's visit, where detailed explanations were given, showed that all systems were operational and together form a comprehensive monitoring arrangement for liquid discharges from the controlled areas of the NPP.

Four tanks collect process waste water which has to be analysed prior to the discharge authorisation being granted. Each tank has a sample point ~ 1m above floor level. Sampling takes place after the tank is filled; this is to guarantee the homogeneity of the sample. The operator assumes that the filling of the tank mixes the water in the tank sufficiently to guarantee that the sample taken is representative. The verification team noted that in other plants the content of the tank is actively stirred before sampling. Sample bottles are rinsed 3 times and the tap remains open for up to 5 minutes prior to a sample being taken. Following an internal audit a funnel was placed under each tap in order to reduce drips. The non-sampled water is returned to the discharge tanks.

Where the measured activity of a sample is below the discharge limits permission is given by e-mail from the radiochemistry laboratory to the control room for the discharge of the tank's contents. In case of an elevated activity the radiation protection manager must countersign the protocol. Only one tank is discharged at any given time.

An on-line gamma detector is installed at the release outlet line and is remotely monitored from the control room during the discharge process to the environment. If elevated activity levels are detected, the discharge process is stopped automatically.

Waste water from the analytical laboratories and the laundry area is collected separately in two tanks. Samples are drawn off at the rate of 0.4 l/m^3 and collected in a proportionate collection tank (~ 100 litre capacity) which is analysed fortnightly under normal operation for gamma emitters. During outages the frequency is increased to weekly. The discharges from the laboratory building are monitored on-line with a NaI detector installed on the discharge line.

> *A key aspect of monitoring routine discharges to the environment is that the samples taken for analysis are representative of the actual discharge. The verification team notes with satisfaction that the Loviisa NPP has entered into a re-examination of the representativeness of samples taken for monitoring liquid effluent discharges. The verification team asks that the Commission Services be informed, within three months, about the outcome of these investigations and the actions taken to ensure the representativeness.*

9.6.2 Aerial discharge monitoring

The systems in place for the on-line monitoring and air sampling systems at the NPP common air exhaust stack are presented in section 6.1. All systems were operational when visited by the verification team and together form a comprehensive monitoring arrangement for gaseous discharges. The operational performance of the system is ensured by regular testing and calibration of each measurement system. An overview of the on-line monitoring systems was shown on the plant's process computer, which is replicated in the control room.

Differences in the distance which gases have to travel could lead to divergences in the representativeness of samples between the two units. This aspect is under investigation by the operator.

Four collection methods are routinely employed for sampling the air discharged through the common ventilation stack for the 2 units:

- Weekly air sample in a Marinelli beaker for identification of gamma emitting noble gases by gamma spectroscopy
- Aerosol filter, analysed regularly for gamma ray emitters and every three months for total α/β by proportional counter ($^{89/90}$Sr analysis of the aerosol filters are carried out by STUK)
- Active carbon filter for identification of radioactive iodine by gamma spectroscopy
- ^{3}H and ^{14}C collected in a molecular sieve. Sampled and analysed fortnightly by liquid scintillator

In cases where the effluent air contains higher activities, smaller air samples (µl-ml) can be extracted (with a syringe) from dedicated sampling points.

> *A key aspect of monitoring routine discharges to the environment is that the samples taken for analysis are representative of the actual discharge. The verification team notes with satisfaction that the Loviisa NPP has entered into a re-examination of the representativeness of samples taken for monitoring gaseous effluent discharges. The verification team asks that the Commission Services be informed, within three months, about the outcome of these investigations and the actions taken to ensure the representativeness.*

9.7 LOVIISA NPP LABORATORY FOR ANALYSIS OF DISCHARGE SAMPLES

The verification team visited the radiochemical laboratory of the Loviisa NPP, where in addition to the process samples the analyses of the aerial and liquid discharges samples are also carried out, as described in section 6.3. The $^{89/90}$Sr analyses on water discharge and aerosol filters are performed by STUK.

Though no formal ISO accreditation is held the laboratory follows validated measurement methods, up to date instructions and appropriate quality control procedures using reference standards on a regular basis to ensure the performance of the analytical results obtained during routine measurements. All sample information is recorded in the laboratory database. The laboratory participates regularly in interlaboratory comparison exercises at the national level, where samples of fresh reactor water are analysed for short lived radionuclides in the laboratories of Loviisa NPP and Olkiluoto NPP in Finland; thereafter the results of both laboratories are compared with each other. In addition the laboratory has participated in some interlaboratory comparisons at Scandinavian (Nordic co-operation) and international (IAEA) level, principally involving higher activity samples. Annual audits are carried out, both by Fortum experts and by the regulatory authority, STUK.

Personnel

The Radiochemistry section, part of the Loviisa NPP Operations unit is currently staffed by a laboratory manager, a senior advisor and 4 staff members. Staffing can be critical at certain times (e.g. more than 1 person on leave) and in such cases analyses have to be prioritised, or senior personnel enlisted to ensure adequate coverage. In addition to radioactive release monitoring, which is the focus of this report, it also has the responsibility for implementing process monitoring (detecting fuel leakages, corrosion in the primary circuit etc.). The breakdown between release and process monitoring and is roughly 50/50.

The team were shown the 28 page booklet which details all the necessary training to be followed before a new staff member would be entrusted with analysing samples.

Sample receipt and preparation

All samples arrive at a sample receipt area where staff register and upload details of the sample to the LIMS system by scanning the labels. In the future staff taking the samples may perform this operation. Where necessary, sample pre-treatment, e.g. acidification, is carried out before the sample goes for further treatment or analysis.

Gamma spectrometry

Currently almost 10 000 measurements are performed each year, using four HPGe detectors which are cooled by piped liquid nitrogen. Two detectors with 20-25 % relative efficiency are used for active samples from the process monitoring, whereas the two 60-65 % relative efficiency units are destined for the analysis of release samples. Analyses of the spectrum and control card evaluations for quality control purposes are carried out by the APEX analyses programme.

All detectors were well labelled with calibration data etc. and colour coded – green (measuring), blue (available) and red (error/out of service). A book was available nearby to note any calibration issues. Approval must be sought from the laboratory manager, who records any remedial actions taken, to proceed with further measurements.

An emergency laboratory has been available since the 1980's, located outside the control area, equipped with a 10% extended energy range electrically cooled HPGe detector. This detector may also be used for long term measurement of release samples, though this was not visited as the apparatus was under repair.

Proportional counting

Total alpha and beta measurements on aerosol filters from the ventilation stack amount to around 200 analyses annually. Aerosol filters are analysed with the Berthold LB 770 10 channel low level α/β counter. The counter may also be used as a back-up method for total alpha measurements on water samples.

Where more precise nuclide specific alpha and beta analyses are required these are purchased from other laboratories.

Liquid scintillation counting

A Hidex 300 SL counter which performs around 200 measurements per year is used for total alpha measurements on release waters and analysis of the following beta emitters:

- ^{3}H and ^{14}C from the stack collection system
- ^{3}H from primary and secondary side
- ^{63}Ni from spent resins

Each well was colour coded for specific sample types.

Where more precise nuclide specific alpha and beta analyses are required these are purchased from other laboratories.

Verification does not give rise to recommendations. It is key that Loviisa NPP continues to ensure that routine analysis can be adequately guaranteed. The verification team notes that the laboratory of the Loviisa NPP has only limited possibility to exchange experience and *compare performance with other similar laboratories. The verification team therefore recommends exploring possibilities for experience exchanges with other laboratories, also with reference laboratories, and increased access to national and international intercomparison exercises, particularly for lower activity samples.*

9.8 ON-SITE AND OFF-SITE ENVIRONMENTAL MONITORING AT LOVIISA NPP

The NPP operates 28 ambient gamma dose rate meters, four air samplers, four deposition samplers and ten Thermo Luminescent Dosimeters (TLDs), which are located within a 5 km radius from the NPP.

The verification team visited selected gamma dose rate meters, air samplers, deposition samplers and Thermo Luminescent Dosimeters at a number of sampling sites, both on-site at Loviisa NPP and off-site. At the $LaBr_3$ ambient dose rate station situated on the grounds of the fire & rescue services in Loviisa town a demonstration, using a small sealed radioactive source was performed. The signal, seen on a laptop computer was quickly followed by the STUK duty officer present being alerted on his mobile phone.

The meteorological station located 1.6 km north-west from the NPP was visited. There is an on-going project to commission a modernised meteorological station to replace the existing station which is described in detail in section 5.5.

The verification team notes that all samples defined in the environmental monitoring programme around Loviisa nuclear power plant (as detailed in Chapter 7.2) are taken exclusively by STUK. This programme is currently under review. The sampling procedure is accredited and includes standardised sampling protocols.

The verification team accompanied the STUK team taking environmental samples around Loviisa NPP. On a boat trip, sampling of seawater, fish, sediment and periphyton was demonstrated. The programme for soil sampling and sampling of forest flora such as bear moss was also shown. The verification team also visited STUK's local sampling laboratory, which is close to Loviisa NPP, in which environmental samples are prepared before they are sent to the STUK laboratories in Helsinki for analysis.

Verification does not give rise to recommendations. The verification team takes note of the fact that STUK conducts the programme of environmental radioactivity monitoring around Loviisa nuclear power plant. The verification team supports the review of the environmental monitoring programme around Loviisa NPP which STUK, in close contact with Fortum Power & Heat Oy, the operator of Loviisa Nuclear Power Plant, has started.

10 CONCLUSIONS

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

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

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

(2) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of liquid and gaseous radioactive discharges at the Loviisa NPP site are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.

(3) The verification activities that were performed demonstrated that the facilities necessary to carry out the environmental monitoring in the vicinity of the Loviisa NPP are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.

(4) The recommendations are detailed in the 'Main Conclusions' document that is addressed to the Finnish competent authority through the Finnish Permanent Representative to the European Union.

(5) The Commission Services ask the Finnish competent authority to inform them*, within three months,* of any developments and actions taken as a result of this report.

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

APPENDIX 1

REFERENCES & DOCUMENTATION

1. **Reply to the** preliminary information questionnaire addressed to STUK, received on 10/9/2015.

2. Surveillance of Environmental Radiation in Finland Annual Report 2014
(STUK-B 190 / September 2015)

APPENDIX 2

THE VERIFICATION PROGRAMME

Day/date	Time	Team 1	Team 2
Tuesday 29 September	10:15 – 11:15	Opening meeting with National authorities in Helsinki	
	11.15 – 18.00	Airborne radioactivity monitoring equipment at the STUK headquarters Mobile radiation monitoring equipment at STUK	STUK *Laboratories* Visit to laboratories dealing with analysis of environmental samples from the vicinity of NPP
Wednesday 30 September	8.30 – 9.00	Verification of ambient dose rate station and the $LaBr_3$ detector of the national monitoring programme on the road to Loviisa	
	9.00 – 10.00	Opening meeting with Loviisa NPP representatives	
	10.00 – 13.00	Verification of liquid discharge monitoring	Verification of operator's and regulator's on-site and off-site environmental monitoring and stations of national monitoring programme in the vicinity
	13.30 – 15.30	Verification of gaseous discharge monitoring	
Thursday 1 October	8.30 – 15.00	Visit to laboratories dealing with analysis of discharge samples	Verification of operator's and regulator's on-site and off-site environmental monitoring and stations of national monitoring programme in the vicinity, demonstration of sampling e.g. sludge and periphyton
	15.00 – 15.30	Closing meeting/debriefing with NPP representatives	
	15.30	Departure for Helsinki	
Friday 2 October	9.00 – 11.00	Closing meeting/debriefing with national authorities	

EC Team

Team 1: Alan Ryan, Kersti Peedo (both DG ENER)

Team 2: Stefan Mundigl (DG ENER, team leader), Tore Tollefsen (JRC)