EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY AND TRANSPORT

Directorate H – Nuclear Energy
Radiation protection

TECHNICAL REPORT

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

SLOVENIAN NATIONAL MONITORING NETWORK FOR ENVIRONMENTAL RADIOACTIVITY AND KRŠKO NUCLEAR POWER PLANT

SLOVENIA

12 to 16 June 2006

Reference: SI-06/5

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

FACILITIES	Installations for monitoring and controlling radioactive discharges and for surveillance of the environment in Slovenia during normal operations of the Krško nuclear power plant site; monitoring network for environmental radioactivity in Slovenia
SITES	Krško, Ljubljana, Zagreb, Brežice, Predmeja, Portorož, Koper
DATE	12 to 16 June 2006
REFERENCE	SI-06/05
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DATE OF REPORT	24 October 2007

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ABBREVIATIONS

a.s.l.	above sea level
AMES	Automatic Measuring Systems, Ljubljana
BSS	Basic Safety Standards
cpm	counts per minute
DAC	Derived Air Concentration
DG TREN	Directorate General Energy & Transport
EARS	Environmental Agency of the Republic of Slovenia
EC	European Commission
EIMV/TPP	Milan Vidmar Electric Power Research Institute / Thermal Power Plant
EML	Environmental Measurements Laboratory, US. Department of Energy
EURDEP	European Radiological Data Exchange Platform
FWHM	Full Width at Half Maximum
Ge(Li)	Germanium, lithium drifted (gamma radiation detector)
GM	Geiger-Müller (radiation detector)
HIRS	Health Inspectorate of the Republic of Slovenia
HPGe	High Purity Germanium (gamma radiation detector)
HASL	Health And Safety Laboratory, New York
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IMI	Institut za Medicinska Istraživanja i medicinu rada (Institute for Medical Research and Occupational Health, Zagreb)
IPA	Instrument Performance Assessment
ISDN	Integrated Services Digital Network
ISO	International Standardization Organization
JRC	Joint Research Centre (European Commission)
JSI	Jožef Stefan Institute (Ljubljana)
LRE-RBI	Laboratory for RadioEcology – Ruđer Bošković Institute
LMR	Laboratory for Radiation Measuring Systems and Radioactivity Measurements (at JSI)
LSC	Liquid Scintillation Counter (radiation detector)
MCA	Multichannel Analyser

MDA	Minimum Detectable Activity
MW	Megawatt
NaI(Tl)	Sodium Iodide, Thallium activated (gamma radiation detector)
NEK	Nuklearna Elektrarna Krško, d.o.o. (Krško NPP operator)
NIM	Nuclear Instrumentation Module
NPP	Nuclear power plant
OJ	Official Journal
PIPS	Passivated Implanted Planar Silicon (alpha/beta radiation detector)
PSTN	Public Switched Telephone Network
QA / QC	Quality Assurance / Quality Control
RBI	Ruđer Bošković Institute (Zagreb)
RPNS	Radiation Protection and Nuclear Safety
SMS	Short Message Service
SNSA	Slovenian Nuclear Safety Administration
SOP	Standard Operating Procedure (in QA)
SRPA	Slovenian Radiation Protection Administration
TCP/IP	Transmission Control Protocol/Internet Protocol
TLD	Thermoluminescence Dosimetry
TSL	Tritium-Strontium Laboratory (at JSI)
UPS	Uninterruptible Power Supply
WHO	World Health Organisation
ZVD	Zavod za Varstvo pri Delu d.d. (Institute of Occupational Safety, Ljubljana)

1. INTRODUCTION

Article 35 of the Euratom Treaty requires that each Member State shall establish 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 (BSS)[1].

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

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

For the purpose of such a review, a verification team from DG TREN visited the Krško NPP and different sites located in Slovenia, which are part of the national monitoring system for environmental radioactivity. The visit included meetings with representatives of the Ministry of the Environment and Spatial Planning, the Ministry of Health, and of organisations under their responsibilities. Two analytical laboratories in Zagreb performing various measurements (for the operator and the regulator) in the context of the monitoring of environmental radioactivity (Krško NPP and surroundings) were also included into the verification.

The present report contains the results of the verification team's review of relevant aspects of the environmental radiation surveillance in Slovenia The purpose of the review was to provide independent verification of the adequacy of monitoring facilities for air, soil, water and foodstuffs.

With due consideration to the scope of the verification mission and taking into account the relatively short time available for the execution of the programme, it was agreed that emphasis would be put on:

- The structure of the national environmental monitoring and sampling programme,
- The analytical laboratories,
- On-line automatic monitoring systems,
- The environmental radioactivity monitoring programme in the surroundings of the Krško-NPP (offsite monitoring),
- The Krško Nuclear Power Plant (on-site monitoring of environmental radioactivity and discharges).

The present report is also based on information collected from documents referred to in Appendix 1 and from discussions with various persons met during the visit, listed in section 2 below.

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

2. PREPARATION AND CONDUCT OF THE VERIFICATION

2.1. INTRODUCTION

The Commission Services' decision to request the conduct of an Article 35 verification was notified to the Slovene Government on 20 February 2006 (letter referenced TREN/H.4 CG/ab D(2006)202587 addressed to the Permanent Representative of Slovenia to the European Union). The Slovene Government subsequently designated the Slovenian Nuclear Safety Administration (SNSA) to lead the technical preparations for this visit.

2.2. PREPARATORY DOCUMENTS

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

2.3. PROGRAMME OF THE VISIT

EC and SNSA discussed and agreed upon a programme of verification activities, based on a draft Communication by the EC, setting out the framework and modalities within which Article 35 verifications may be conducted.

A summary overview of the programme of verification activities is provided in Appendix 2. The verifications were carried out in accordance with the programme. The EC team was divided into two teams. One team carried out the verification of the discharge monitoring at the NPP and the laboratories in Zagreb; the other dealt with environmental monitoring and the laboratories in Ljubljana.

2.4. REPRESENTATIVES OF THE SLOVENIAN COMPETENT AUTHORITIES AND THE ASSOCIATED LABORATORIES

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

Slovenian Nuclear Safety Administration:

Dr. Andrej Stritar	Director
Maksimiljan Pečnik	Head of Division on Radiation Safety and Materials
Dr. Milko Križman	Coordinator
Dr. Barbara Vokal Nemec	Deputy coordinator, Head of Section of monitoring
Dr. Helena Janžekovič	Inspector Counsellor
Dragan Mitić	Physicist
Michel Cindro	Physicist
Dušan Peteh	Electronics engineer

Slovenian Radiation Protection Administration

Dr. Tomaž Šutej	Inspector Counsellor
Dr. Nina Jug	Physicist

Jožef Stefan Institute, Ljubljana

Dr. Matjaž Korun	Head of Laboratory for gamma spectrometry
Denis Glavič-Cindro	Quality manager
Dr. Marijan Nečemer	Researcher
Urška Repinc	Researcher, Quality manager
Dr. Ivan Kobal	Head of Laboratory for strontium and tritium

Institute of Occupational Safety, Ljubljana

Dr. Gregor Omahen	Head of Centre for physical measurements
Urban Zdešar	Head of Laboratory for dosimetry
Peter Jovanovič	Physicist

Krško Nuclear Power Plant, Krško

Borut Breznik	Head of Radiation Protection department, Head of Radiological laboratory
Aleš Volčanšek	Engineer for radiation protection
Željko Kovač	Head of Chemistry department, Head of Radiochemistry laboratory
Ljerka Djurdjek	Lead engineer for analytical chemistry and radiochemistry

Ruđer Bošković Institute, Zagreb (Croatia)

Prof. Tarzan Legović	Director of Department for marine and environmental research
Dr. Stjepan Lulić	Head of Laboratory for radioecology
Dr. Dubravko Risović	Quality manager
Dr. Delko Barišić	Senior research associate
Dr. Bogomil Obelić	Head of C-14 laboratory

Institute for Medical Research and Occupational Health, Zagreb (Croatia)

Dr. Gordana Marović	Head of Radiation protection unit
Dr. Zdenko Franić	Senior research associate
Jasminka Senčar	Physicist

AMES, Automatic Measuring Systems, Ljubljana

Martin Lesjak	Director
Dr. Primož Mlakar	Senior researcher

Environmental Agency of the Republic of Slovenia, Ljubljana

Dr. Silvo Žlebir	Director
Jože Knez	Head of Office for monitoring

The verification team acknowledges the co-operation it received from all individuals mentioned.

3. BACKGROUND INFORMATION

3.1. INTRODUCTION

Slovenia has a nuclear programme and therefore monitoring of radioactivity in the environment is well justified.

Monitoring of radioactivity in environment and foodstuffs includes surveillance of artificial radiation and artificial radionuclides. Exposure to natural radiation is controlled only if there is reason to suspect that natural radionuclides may cause unusually high exposure to the public (e.g. indoor radon and natural radionuclides in drinking water).

The regular monitoring programme of environmental radioactivity covers the following segments of biosphere: air, ground (soil, external radiation), surface waters and precipitation. Originally defined by the Ministry of Health it is still performed on the same basis. The programme is financed by the Slovenian Nuclear Safety Administration. An overview is presented in Appendix 3.

The geographical distribution of sampling points for environmental monitoring fits the concept of integral monitoring networks of the former state of Yugoslavia.

3.2. RESPONSIBLE ORGANISATIONS

In the past the environmental radioactivity monitoring exclusively belonged to the domain of health, namely to the Yugoslavian Federal Ministry of Health (1959-1991) and then (1991-2002) to the Slovenian Ministry of Health.

According to the new act on radiation protection and nuclear safety, in force from 2002, the environmental radioactivity monitoring in Slovenia is the matter of competence of three ministries, i.e. the ministry responsible for the environment, the ministry responsible for health and the ministry responsible for agriculture.

Principal bodies in the field of environmental radioactivity monitoring are the Slovenian Nuclear Safety Administration (SNSA) within the Ministry of the Environment and Spatial Planning and the Slovenian Radiation Protection Administration (SRPA) within the Ministry of Health. The Ministry of Agriculture, Forestry and Food (Directorate of Food Safety) is the competent authority for monitoring and control of fodder/feeding stuffs). A complete overview is given in the organisational scheme in Appendix 4.

SNSA is a national competent authority founded in 1987, taking over the competences of the Inspectorate of Energetics with the main tasks on nuclear safety issues, including radiation protection in nuclear installations. With the new act RPNS (2002) SNSA took also the responsibilities for radiation protection in industry, research and education and took part in the national monitoring of environmental radioactivity.

The Slovenian Radiation Protection Administration (SRPA) is a national authority within the Ministry of Health. It was founded in 2003 and took over the competences of the Health Inspectorate of the Republic of Slovenia (HIRS) in the field of radiation protection. HIRS is a national competent authority within the Ministry of Health.

SRPA performs regulatory, administrative, control and development tasks related to practices involving radiation and use of radiation sources in medicine and veterinary medicine; protection of people against ionising radiation; systematic survey of exposure of both living and working environments to natural radiation sources; monitoring of radioactive contamination of foodstuffs and drinking water; and auditing and authorisation of radiation protection experts.

Monitoring of foodstuffs and drinking water has been within the competence of SRPA since its foundation in 2003. The annual monitoring programme is financed by the SRPA. Previously monitoring of foodstuffs and drinking water was within the competence of the Ministry of Health directly (1967-2002).

The Health Inspectorate of the Republic of Slovenia (HIRS) performs regulatory inspections in the field of health and hygiene safety of foodstuffs. Within its competences HIRS carries out control of radioactivity of foodstuffs that are imported to Slovenia from third countries according to regulations governing this field. Inspectors check such food samples at the border with their own equipment.

Monitoring of feeding stuffs is – according to the RPNS act (2002) - governed by the Ministry of Agriculture, Forestry and Food. The programme covers natural feeding stuffs (hay, silage) and concentrated fodder with additives.

4. LEGAL PROVISIONS FOR ENVIRONMENTAL RADIOACTIVITY MONITORING IN SLOVENIA

The most important legal text dealing with environmental radioactivity monitoring in Slovenia is the Act on Radiation Protection and Nuclear Safety (RPNS), (OJ RS, No. 67/2002, 102//2004) with the following content:

Article 123: Monitoring radioactivity in the environment

(1) The monitoring of radioactivity in the environment shall be ensured by:
- the ministry responsible for the environment, air, waters and the ground, as well as for some products,
- the ministry responsible for health, foodstuffs and drinking water, and
- the ministry responsible for agriculture and animal feed.

(2) On the basis of the results of the monitoring of radioactivity in the environment:
- trends of population exposure due to radioactivity of the environment shall be established,
- the provision of data needed for prompt action in the case of a sudden increase of radioactivity in the environment shall be ensured, and
- an evaluation of the doses received by the population will be drawn up.

(3) The monitoring of radioactivity in the environment shall include permanent and occasional measurements of:
- open air radioactivity levels,
- external gamma radiation,
- the presence of radio-nuclides in surface waters and subterranean waters,
- radioactivity of the ground and of precipitation and
- radioactivity of drinking water, foodstuffs, animal feed, and individual products.

(4) The report on the monitoring of radioactivity in the environment shall include information on the radioactivity of the air, waters, ground, foodstuffs, animal feed and specific products referred to in the previous paragraph, as well as information obtained by emergency monitoring in the case of increased radioactive contamination referred to in Article 90 of this Act.

(5) The minister responsible for the environment, the minister responsible for health and the minister responsible for agriculture shall determine the basis for the monitoring of radioactivity in the environment, the conditions applying to those carrying out the monitoring, the methodology used in the taking of measurements and samples, as well as the criteria for the qualifications of persons carrying out the monitoring, the quality of the equipment, the method to be used for the regular informing of the public and the scope and method for the drawing up and the adoption of an annual monitoring programme.

Article 124: Operational monitoring of radioactivity

(1) Operational monitoring of radioactivity shall entail:
- emission monitoring of the radioactivity of a radiation or nuclear facility, including monitoring of authorized emissions of radioactive substances into the environment,
- imission monitoring of radioactivity and the monitoring of the radioactivity of foodstuff and feeding stuff as the result of the environmental effects of the radiation from a radiation or nuclear facility.

(2) Operational monitoring of radioactivity must be ensured by the operator of a radiation or nuclear facility.

(3) In addition, the operator referred to in the previous paragraph must carry out the monitoring of the effects of the steps prescribed in the case of an emergency in order to remove the consequences thereof.

(4) The minister competent for the environment, in agreement with the minister competent for health, shall prescribe the method to be used for and the scope of operational monitoring of radioactivity, the methodology of sample taking and measuring as well as of reporting on the operational monitoring of radioactivity, the quality of the equipment used and the conditions which must be fulfilled by those carrying out the monitoring in accordance with this Article, as well as any credentials required.

In addition Articles 71, 79 and 80 provide requirements for discharge monitoring and environmental surveillance with regard to construction and operating licences of nuclear facilities.

A detailed list of legislative acts and guidance documents dealing with environmental radioactivity monitoring in Slovenia is presented in Appendix 5.

5. THE KRŠKO NUCLEAR POWER PLANT SITE

5.1. INTRODUCTION

The Krško Nuclear Power Plant which is owned by Nuklearna Elektrarna Krško, d.o.o. (NEK), is the only nuclear power plant in Slovenia. It is co-owned by Slovenia and Croatia and is situated on the left bank of the Sava River, about 90 km east of Ljubljana and 38 km west of Zagreb. Its geographical co-ordinates are 45°55’15” N and 15°30’54” E. The distance from the centre of Krško town is 3 km.

The plant is equipped with a Westinghouse pressurized light water reactor with 2000 MW thermal power (725 MW_{el}). Plant construction started in 1975 and commercial operation began in January 1983.

5.2. DISCHARGE MONITORING

5.2.1. General

Radioactive discharges from the Krško NPP are regulated by the following authorisations:

- The site licence for the Krško Nuclear Power Plant (issued 8.8.1974) provides the basic limits for total discharges.
- The initial operating licence (No. REI 31-04/83-5, issued 6.2.1984) provides limits for specific radionuclides or radioisotope groups.
- Plant internal technical specifications (essentially the Radiological Effluent Technical Specification (RETS) and the Off-site Dose Calculation Manual) provide detailed guidance on discharge management.

Discharge limits are defined for particular radionuclides or groups of radionuclides for liquid and gaseous discharges. In principle, the limits are based on the annual effective dose constraint to members of the public during normal operation. In the site licence it is stated that the annual (calendar year) effective dose at 500 m distance from the reactor and beyond due to radioactivity releases during normal operation has to be less than or equal to 50 μSv.

Discharge monitoring is carried out the by the plant operator and its contracted laboratories; there is no regulatory requirement for an independent control programme by the authorities.

Internally, the operation of the plant and its radioactive discharges are regulated according to technical specifications. These are in the process of being updated with the NEK documents Radiological Effluent Technical Specifications (RETS) and the Offsite Dose Calculation Manual (ODCM). They are based on the guidance document "Standard Radiological Effluent Controls for Pressurized Water Reactors" (NUREG-1301, U.S. Nuclear Regulatory Commission, April 1991). The RETS document is a licence based document and currently is in the process of approval by SNSA (foreseen for June 2006).

Besides the laboratories of the Krško NPP itself, also other institutions are involved in discharge monitoring on contract basis. At the moment these are the following:

- **Ruđer Bošković Institute – RBI** (Zagreb) (see the laboratory description under 7.2)
  - For analysis of gamma emitters, H-3, Sr-90, Fe-55 and total alpha/beta in liquid discharges, samples are collected by the Krško NPP and delivered by Ekoteh-Dozimetrija to the Laboratory for radioecology of the Ruđer Bošković Institute (LRE-RBI) together with the sampling forms.
- **Jožef Stefan Institute – JSI** (Ljubljana) (see the laboratory description under 7.5)
  - Traps of airborne effluents (H-3 and C-14 from NPP stack) are collected and delivered by Krško NPP to the JSI Tritium-Strontium Laboratory (TSL) together with the sampling forms.
  - Aerosol filters from the NPP stack are sampled by NPP staff and delivered by mail from the Krško NPP to the JSI Laboratory for Radiation Measuring Systems and Radioactivity Measurements (LMR). Upon receipt of the filters (and the corresponding detailed sample forms), a reception form is filled in and signed. After gamma-ray spectrometry measurement at LMR, the sample (with the form) is transferred to the Tritium-Strontium Laboratory (TSL).
- **Institute for Medical Research and Occupational Health** (Zagreb) (see the laboratory description under 7.3)
  - Filters from the NPP Krško Decontamination Building are collected by the NPP Krško. Filters and sampling forms are sent from the NPP Krško to the IMI Radiation

protection unit by express delivery.

5.2.2. Liquid discharges

Liquid discharges are either continuous or batch discharges. Monitoring is carried out either by combination of online instrumentation or by sampling (see Table 1 in Appendix 6). The liquid radioactive waste effluent line and the steam generator blow-down effluent line are equipped with online monitors capable of automatically terminating the release. The service water effluent line and the component cooling water systems have radioactivity monitors with alarms, but without automatic termination.

There is no actual monitoring of liquid releases from the decontamination building. The small amounts of active water generated in this building are collected in a sump and transferred to the plant controlled area in drums for treatment at the plant active liquid treatment system.

Table 2 in Appendix 6 provides an overview of the liquid sampling and analysis programme.

The control of liquid effluents is provided to ensure that the concentration of radioactive materials released in liquid waste effluents (through the discharge canal) to unrestricted areas will be less then 1/3 of the concentration levels specified for surface waters in the Decree on dose limits, radioactive contamination and intervention levels. This limitation provides additional assurance that the levels of radioactive materials in water bodies in unrestricted areas will result in: (1) very low radioactivity concentration during releases, and (2) total radioactivity complying with the limiting quantities of radioactive material as specified in the Initial Operating Licence. The concentration limit for tritium in the discharge canal is based on the limit for surface water. The concentration limit for dissolved or entrained noble gases is based upon the assumption that Xe-133 is the controlling radioisotope and its DAC in air (submersion) was converted to an equivalent concentration in water using the methods described in International Commission on Radiological Protection (ICRP) Publ. No. 2.

Discharge samples are collected by the NPP staff. In addition to individual tank samples, a composite sample is prepared for each month and sent for measurement, currently to Zagreb at the Ruđer Bošković Institute. A one litre sample is taken from the waste storage tank after, at least, one hour of stirring.

The tank discharge line has a protection system for high activity. A detector count rate above 8500 cpm initiates a discharge shutdown and an alarm in the control room. Discharge to the river is allowed only if the water flow is less than 1500 m^3/sec. This is to prevent contamination of agricultural land during floodings.

5.2.3. Gaseous discharges

Concentrations of gaseous discharges are limited to levels indicating that the annual dose due to radioactive materials released in gaseous effluents from the site to areas at and beyond a 500 m distance from the reactor shall be limited to the value of 1 mSv.

Gaseous discharges are monitored using online instrumentation and/or filter sampling (see Table 3 in Appendix 6). Table 4 provides an overview of the gaseous sampling and analysis programme. The main systems are presented below.

Containment control system

The temperature-controlled system includes on-line noble gas (possibility to take samples in Marinelli beakers), particle- and iodine-monitors and a filter placement for off-line sampling. The off-line sampler has a rolling filter paper with a 6 months change interval.

A separate automatic sampling system for a post-accident situation is also available. This system is switched on in case of an accident in order to be able to measure high activities inside the containment (iodine and particulates). The system is not used under normal circumstances.

Decontamination building

The air exhaust flow in the decontamination building ventilation system is some 28 000 m^3 per day. The monitoring system samples the particulate and gaseous activity in the air exhaust. There is also an alarm to the control room (with automatic shut down function) for high activity in the exhaust.

Steam generator blow-down system

There are two sampling points in the steam generator blow-down system. The blow-down system is also equipped with a monitor with an automatic shut down function in case of high activities. A 3 litre sample is taken daily and analysed in the laboratory.

Turbine ejector

In the turbine ejector there is a high activity monitor, but no automatic shutdown. In addition there is an exhaust sampling system for post-accident situations.

Radioactive waste storage building

Six portable pumps are available for air sampling from the waste storage building, Continuous sampling is performed. Filters are changed weekly.

5.2.4. Discharge control at control room

The control room has readings on secondary side particulate and iodine activity detectors and from the liquid monitors. Data are collected on the plant computer and also recorded on paper. Post-accident system readings are also available, as well as data from plant area monitors and from the meteorological equipment.

5.2.5. Reporting

Annual discharged activities into the environment are limited for particular radionuclides or a particular group of radionuclides, separately for liquid and for gaseous discharges. Krško NPP is required to:

- Report its monthly, quarterly and annual discharges of activity into the environment (source term) to the Slovenian Nuclear Safety Administration (SNSA) and the Slovenian Radiation Protection Administration (SRPA).

- Produce an annual report with the results of the environmental radiological monitoring programme in the region around the Krško-NPP (impact assessment). This report is addressed to the Slovenian Nuclear Safety Administration (SNSA) and the Slovenian Radiation Protection Administration (SRPA).

- In the occurrence of released activity and/or concentration exceeding the limits defined in the Technical Specifications (RETS), to inform the Slovenian Nuclear Safety Administration within 15 days, explaining the reasons of the event.

5.3. ON SITE ENVIRONMENTAL RADIOACTIVITY MONITORING

5.3.1. General

On-site environmental monitoring is managed by the power plant operator. Some samples are taken by the operator and transferred to a contractor's laboratory (currently JSI, contract on annual basis), others are taken by staff from the contracted laboratory itself. An overview including a map is given in Appendix 7.

5.3.2. Air radioactivity

Within the site perimeter five air pumps are installed. Glass fibre filters are changed weekly, iodine cartridges 2-weekly. The devices are maintained by the NPP maintenance department, for filter and cartridge change two staff members are trained. Two spare pumps are available. Power is supplied via the specific NPP grid.

Besides these manual devices an automatic air monitoring station of the type 'AMS02' made by the Austrian company Bitt Technology is installed in the NW of the site. The station contains a NaI(Tl) detector for low resolution gamma measurement of gamma emitters and a PIPS detector for alpha/beta monitoring in aerosols, a NaI(Tl) detector for low resolution gamma measurement of 'special' elemental iodine filters and a NaI(Tl) detector for gamma measurement in charcoal in a Marinelli beaker for organic iodine. The device is set-up in a container near the meteorological mast and is on-line connected to the NPP surveillance system. This station was provided to the SNSA by the IAEA through TC project. It is considered by SNSA to be part of the 'independent operational control' of the NPP. Data are transmitted automatically to SNSA. It is foreseen to transmit them to the Radiation Protection Unit of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management as well.

5.3.3. Dose rate and dose

Several ambient gamma dose rate monitors are set up within the site perimeter, near the meteorological tower: One (made by the Slovenian company AMES, with two separate gamma probes of different sensistivity) is operated by the NPP and has an on-line connection to the NPP system. The other one (made by the Finnish company ALNOR/RADOS) is a part of the national system and is connected to the data centre at SNSA in Ljubljana. All detectors are placed at the height of about 1.25 m. Data communication devices and a PC for presentation of the NPP-system data are located in a nearby building. The NPP data centre contains data from stations off-site the NPP but owned by NEK as well. The AMES detectors are serviced by AMES four times per year.

At the site perimeter ('fence') 6 locations have been selected for TLDs. At all these locations devices from the NPP operator and JSI are placed in parallel. The dosimeters are analysed by the respective owner. The probes are changed and read four times a year.

5.3.4. Precipitation

A precipitation sampler (ombrometer) which is operated by the NPP is located close to the meteorological mast and the dose rate detectors.

5.3.5. Surface water

Water from the River Sava is pumped up near the liquid discharge release point. The automatic system uses a peristaltic pump. Every 4 minutes a defined water volume is pumped to 4

containers plus a separate container for the 'weekly' sample. The sampling line length is ca. 20 m. The weekly sample is manually filtered by NPP staff; filter and liquid is transported to the NPP laboratory; every Friday 2 dl are taken for a monthly H-3 determination in a composite sample.

5.3.6. Ground water

For ground water sampling for radioactivity monitoring only one well is used (No. E1). The well has a depth of some 10 m; the location was selected by a hydrologist (water flow direction changes depending on water table). Formerly, sampling was performed from a well in an apple orchard just outside the fence, but the location was changed due to access considerations (avoiding potential tampering of the sampling site). The well is maintained and quarterly sampled by RBI; samples are analysed for gamma emitters, Sr-89/Sr-90 and H-3.

5.3.7. Meteorological information

Meteorological information such as wind speed, temperature and humidity is collected on a 70 m high mast, located close to the fence on the west side of the reactor. Wind speed and direction are monitored at 3 heights (10m, 40m and 70m), while temperature and humidity at 4 heights (including also the height of 2m), and additionally also solar radiation, atmospheric pressure and atmospheric stability.

Altogether there are four meteorological stations and a SODAR (SOnic Detection And Ranging) device near the NPP transmitting data to the NPP, which in turn is connected to SNSA.

5.4. OFF SITE ENVIRONMENTAL RADIOACTIVITY MONITORING

5.4.1. General

The NPP operates both, a continuous off-site monitoring system (dose rate monitors in selected locations) and a system based on sampling and laboratory analysis. Some samples are managed by the utility itself, others by contracted laboratories.

An overview over the various sample types and sampling locations including a map is given in Appendix 8.

5.4.2. Air

Air (aerosols on glass fibre and gaseous radionuclides on charcoal) is collected using old equipment at seven stations. The contractor (currently JSI) changes the charcoal cartridges every 15 days and the glass fibre filters monthly. The samples are transferred to the laboratory for analysis. Details are given in Appendix 8, Table 4.

5.4.3. Dose rate and dose

Ambient gamma dose rate is monitored in 13 locations circularly distributed around the facility mostly at distances of 2-5 km, including an 'altitude' station at Libna. All the stations are measuring continuously and are transferring automatically data to the NPP's network.

In a circular area of 10 km around the NPP 67 locations have been selected for the placement of TLD detectors (maintained by JSI), and 10 locations are situated in Croatia (maintained by IMI). Change of devices and analysis takes place every half year.

Details are given in Appendix 8, Table 5.

5.4.4. Surface water

Surface water (water plus suspended material as well as filtered water) is sampled at three locations (Krško, Brežice and Jesenice na Dolenjskem) with differing intervals. Analysis is performed by the contracted laboratory (JSI) with regard to gamma emitters, Sr-89/Sr-90, as well as tritium. Details are given in Appendix 8, Table 1.

5.4.5. River sediment and water biota

Some sediment and biota samples are taken from the River Sava at several locations upstream and downstream of the NPP. The samples are taken by the contractor (ZVD) and analysed for gamma emitters and Sr-89/Sr-90. For one station also H-3 in water is determined. Details are given in Appendix 8, Table 2.

5.4.6. Drinking water

Drinking water is sampled at taps in Krško and Brežice. In addition, wells of the public water supply systems of several locations are monitored, applying daily samples and monthly analysis for gamma emitters, Sr-89/Sr-90 and H-3. Contractor is JSI. Details are given in Appendix 8, Table 3.

5.4.7. Food and milk

Milk samples are collected from three farms (Pesje, Drnovo and Skopice) in monthly intervals. The contractor (JSI) determines gamma emitters, Sr-89/Sr-90 and (for samples taken during the grazing period) I-131. Other food samples such as fruit, vegetables, cereals, meat and eggs are taken once yearly at selected locations. They are analysed for gamma emitters and Sr-89/Sr-90 by the contracted laboratory. Details are given in Appendix 8, Table 7.

5.4.8. Soil and vegetation

Soil is sampled semi-annually at three locations by the contractor (JSI). For undisturbed soils the associated vegetation cover is also sampled. Generally, a four step depth profile is taken. After cutting any vegetation in an area of 1x1 m close to the ground and digging a 50 cm deep base hole several layers of soil of various areas and depths (2, 5, 10, 15 and 30 cm) are collected. A 31x31 cm frame serves as marking tool. Details are given in Appendix 8, Table 6.

5.4.9. Precipitation and atmospheric deposition

Precipitation is sampled at three locations using stainless steel collectors. The samples cover one month and are transferred to the contracted laboratory (JSI) for analysis of gamma emitters, Sr-89/Sr-90 and H-3.

In addition, for emergency preparedness reasons 'sticky plates' are set up at seven locations (e.g. Vihre and Stara vas). These are plates of some 40x40 cm, covered with some mm of vaseline. The plates are exposed and thus collect dry (and to a certain extent also wet) deposition. They are returned to the contracted laboratory (JSI) on a monthly basis. There, the vaseline cover is removed, measured and stored for any measurement that may be advisable after a nuclear or radiological event. The cleaned plates are again covered with vaseline and re-used.

6. NATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING

6.1. INTRODUCTION

The national environmental radioactivity monitoring programme comprises a laboratory based national monitoring system for air, soil, surface waters, precipitation, drinking water, foodstuffs and feeding stuffs, and an automatic national monitoring network. The responsibilities on governmental level lie with the Ministry of the Environment, the Ministry of Health (drinking water and foodstuffs) and the Ministry of Agriculture, Forestry and Food (feeding stuffs).

6.2. AUTOMATIC (ON-LINE) MONITORING SYSTEMS

6.2.1. General

The automatic national monitoring network comprises (in June 2006) overall 59 gamma dose rate probes and two automatic aerosol monitoring stations. Maps in Appendix 9 show the locations of the stations.

The system is managed in co-operation between the Slovenian Nuclear Safety Administration (SNSA) and the Environmental Agency of the Republic of Slovenia (EARS). It was recently upgraded within an EU Phare project. The locations of the gamma probes were selected as ones being already equipped with meteorological instrumentation.

The Krško Nuclear Power Plant operates its own gamma dose rate monitoring system. Additionally, five dose rate monitors are installed near thermal power plants.

6.2.2. Network data centres

The system is run on two independent industrial standard personal computers for enhanced reliability. One subsystem consists of two database servers running at the Slovenian Nuclear Safety Administration (SNSA) in Ljubljana, the other consists of two communication and two database servers at the Environmental Agency of the Republic of Slovenia (EARS), also in Ljubljana. The EARS central unit polls the measuring sites and stores data locally. Data are analysed and prepared for expert and public use and archived. The default communication interval is 30 min. In some stations gamma dose rate measurements are checked every 5 minutes.

Quality assurance is performed by the main data collection centre at the EARS. SNSA is authorised for international data exchange (e.g. to the European EURDEP system).

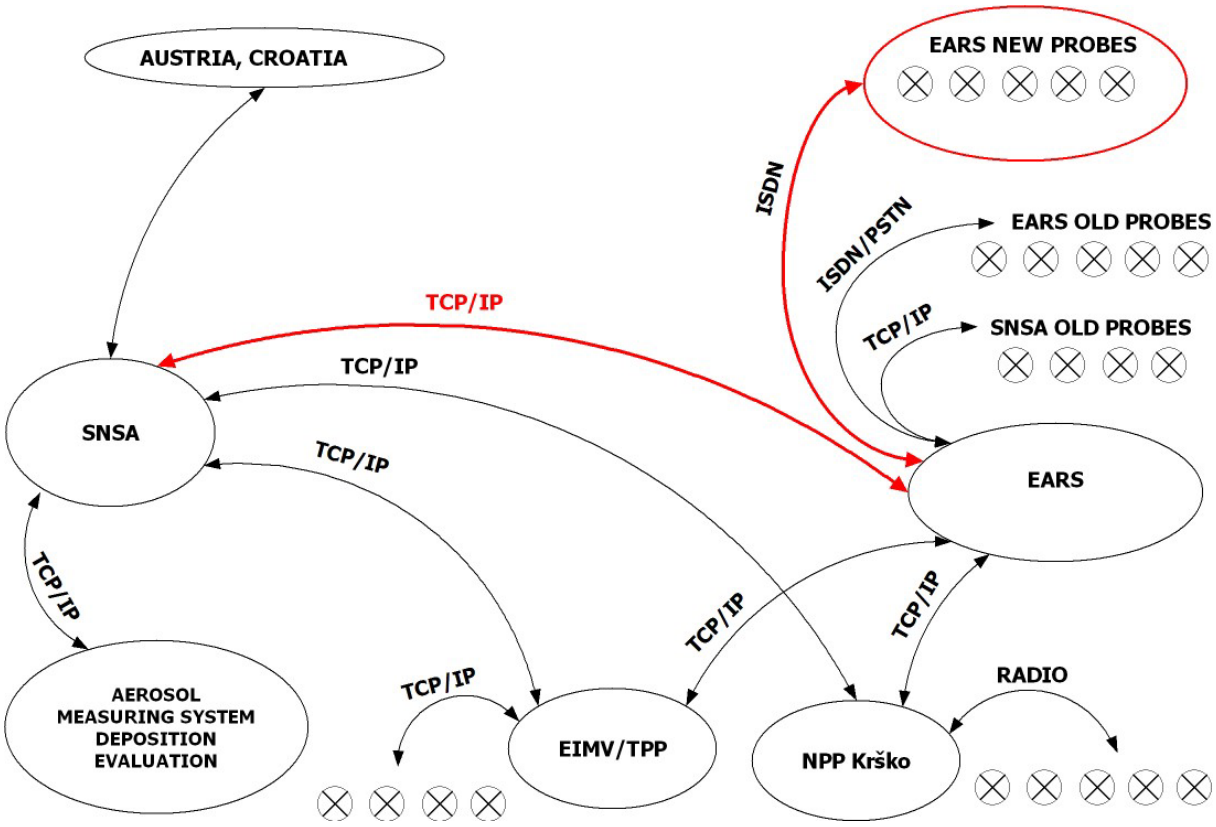


Figure 1: Data transmission pathways in Slovenian early warning systems

6.2.3. Ambient gamma dose rate

Ambient gamma dose rate is measured continuously by an automatic network consisting of several sub-networks. The following types of probes are used:

- AMES MFM 202A/203 (two GM tubes, measuring range 0.05 µSv/h to 1 Sv/h; battery backup for 2 days)
- ALNOR RD02-L (two GM tubes, measuring range 0.01 µSv/h to 10 Sv/h; UPS backup for 15 days)

The detector locations are shown in Appendix 9, Figure 1.

6.2.4. Air radioactivity

Automatic air radioactivity monitoring stations are situated in Brinje and Drnovo and are of the type Bitt AMS-02 and AMS-01 respectively, with alpha and beta measurement on aerosol filters using a PIPS detector. Drnovo station has an electrically cooled high resolution HPGe gamma spectrometry system for measuring the aerosol filters. Brinje station has a low resolution gamma spectroscopy system for measuring the filters. Both stations have also low resolution gamma spectrometry on special filters for elemental iodine and on activated charcoal for organic iodine using NaI(Tl) detectors with automatic weekly calibration. The first device was provided by IAEA through TC project and the second one was granted to the SNSA by the Republic of Austria. Both have an official verification by the Austrian national metrological institute. Data transmission to the centre at SNSA is via computer lines. Alarms are also sent as SMS to the

officer on duty. A UPS guarantees operation for one hour after a power failure (including the air pump).

The system at Drnovo also includes a gamma dose rate monitor (not included in the automatic ambient dose rate network) and a small meteorological measurement unit (temperature probes at two heights, wind direction, wind speed and precipitation). According to the bilateral agreement the data from this station are automatically transmitted to the Radiation Protection Unit of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management at Vienna as well. For Brinje this is foreseen for the future.

6.2.5. Alarm procedures

After detecting a value above a pre-set level of 250 nSv/h, the gamma dose-rate station sends a warning message to the central server. The monitoring officer on duty is notified and has to immediately check the data. At a level of 300 nSv/h in at least three measuring locations the heads of the emergency expert teams at the SNSA are notified. They check the validity of data, discuss the situation and convene at the headquarters. At an alarm level of 500 nSv/h the full emergency expert teams are notified; they convene at the headquarters and start with their emergency work. In case of an alarm the communication interval for all stations is changed to 5 minutes.

Alarm messages are stored on the main server and distributed through an internet service to GSM phones and local area computer networks to call for duty specialists on a 24h basis. Measurement integration time and interval lengths for data sampling are separately adjustable for each station. Radiological data measured in the environment are used for modelling of dispersion of the radioactivity using appropriate software.

6.3. LABORATORY BASED (OFF-LINE) MONITORING SYSTEMS

6.3.1. General

The responsible organisations (SNSA for environmental media, the Ministry of Health for drinking water and foodstuffs and the Ministry of Agriculture, Forestry and Food for feeding stuffs) outsource environmental sampling and analysis to contractors. Annual calls for tender are published and appropriate organisations are selected for the various tasks. Lately the programme has been taken up by JSI and ZVD in a somewhat alternating manner. These laboratories are also involved in the discharge and environmental radioactivity monitoring of the Krško NPP. At the time of the verification visit this selection process did not necessitate the laboratories being accredited according to ISO 17025.

Maps in Appendix 10 show the locations of the sampling points for various media that are collected within the Slovenian laboratory based network for environmental radioactivity. Details are given in Appendix 3 and in the chapters below.

6.3.2. TLD network

A map of the locations where TLD devices (Panasonic badges type UD-802 with 2 $LiBO_2$ and 2 $CaSO_4$ crystals each) are situated is given in Appendix 9 figure 2. The devices are changed and read semi-annually on a contract basis currently by ZVD (until 2005 by JSI).

6.3.3. Air radioactivity

Airborne radioactivity is sampled in Slovenia at three stations using manual sample change. Filters are sent to the measuring laboratory (currently JSI; until 2005 ZVD). The samplers have been set up by the analysing laboratory and are owned by it.

A map of the air sampler locations is given in Appendix 9 Figure 2. Glass fibre filters are changed weekly (contractor ZVD; old paper filters were changed daily) or monthly (contractor JSI). Monthly composite samples are then analysed for gamma emitters and Sr-90.

6.3.4. Surface water

Radioactivity of surface water is monitored only in inland water. Sampling locations are on the largest rivers of the country. They are shown on the map in Appendix 10, Figure 1.

The contracted laboratory takes water volumes of some 50 litres semi-annually or quarterly by grab sampling. Natural and artificial gamma emitters are analysed as well as Sr-90 and H-3. For the rivers coming from Austria (Drava near Dravograd and Mura near Petanjci) the activity concentration of I-131, which generally originates from medical uses, is determined.

6.3.5. Ground water and drinking water

Monitoring of groundwater is not included into the programme. For drinking water monitoring several sampling locations have been selected. A map showing the sampling sites for drinking water is given in Appendix 10, Figure 3.

The contracted laboratory (JSI) annually takes some 50 litres by grab sampling and performs an analysis of gamma and X-ray emitters as well as of Sr-90 and H-3.

6.3.6. Soil and precipitation

Sampling sites for soil and precipitation are shown in Appendix 10, Figure 2.

Soil samples are taken twice a year by the contracted laboratory in several depth layers (0-5cm, 5-10cm, 10-15cm). The samples are analysed for gamma emitters as well as for Sr-90.

Precipitation is sampled using ombrometers with a collection area of 0.25 m^2 on a monthly basis. The samples are analysed monthly (Ljubljana) or quarterly (other stations) for gamma emitters and Sr-90 by the contractor (currently JSI). In addition, H-3 determination is performed quarterly on monthly samples from Ljubljana by JSI.

6.3.7. Milk

Milk is sampled at dairies in

- Bohinjska Bistrica ('Mlekarna Bohinj')
- Kobarid ('Mlekarna Planika d.o.o. Kobarid')
- Murska Sobota ('Pomurske Mlekarne d.d.'), powdered milk
- Ljubljana ('Ljubljanske mlekarne d.d.')

The methodology and the necessary quantities to be sampled are defined by the contractor. Currently, every day approximately 0.15 l milk is taken and stored. A composite sample from 2 months is dried, ashed and measured. Altogether 24 samples are collected for determination of gamma emitters and Sr-90.

6.3.8. Foodstuffs

A map with the sampling locations is given in Appendix 10, Figure 4.

Foodstuffs collected are:

- *Vegetables (potato, salad, spinach, carrot, cabbage, beans, tomato...):* Vegetables are sampled preferentially in Ljubljana, Novo mesto, Koper, Murska Sobota and Celje. Other samples may be collected also at other places according to seasonal circumstances and availability.

- *Fruit (apples, peaches, cherries, plums, pears, strawberries...)*: Fruits are sampled preferentially in Ljubljana, Novo mesto, Koper, Nova Gorica, Maribor and Celje. Other samples may be collected also at other places according to seasonal circumstances and availability.

- *Cereals, bread (wheat, maize, rye, barley, bread, white flour...):* Cereals and bread are sampled preferentially in Ljubljana, Novo mesto, Koper, Murska Sobota, and Celje. Other samples may be collected also at other places according to the season circumstances and availability of different kinds of samples.

- *Foodstuffs of animal origin (cheese, eggs, pork, beef, fish, poultry, honey, venison...):* Preferential sampling locations are Ljubljana, Novo mesto, Koper, Murska Sobota, Celje and Slovenj Gradec. Meat is sampled preferentially in Ljubljana and Murska Sobota. Samples may be collected also at other places according to seasonal circumstances and availability.

Currently no mixed diet monitoring is carried out.

The methodology and the quantities to be sampled are defined by the approved organisation which carries out the monitoring of foodstuffs. Usually a 3 kg sample is taken, ashed, and measured.

Vegetables and fruit are sampled according to the season, cereals and bread once per year. Meat is sampled twice per year, other foodstuffs of animal origin once.

Nuclide specific analysis of gamma emitters and specific measurements of Sr-90 are performed.

6.3.9. Feeding stuffs

Monitoring of feeding stuffs is managed by the Ministry of Agriculture, Forestry and Food. The programme mainly covers hay, silage and feed concentrates from the main agricultural regions. A map with the sampling locations is given in Appendix 10, Figure 4. Altogether 10 samples are taken for determinations of gamma emitters (including natural radionuclides) and Sr-90.

6.3.10. Products from natural ecosystems

SNSA has funded two short research studies on radioactivity of wild fruit in the forest environment, including also some mushroom samples. These measurements were not seen as a part of the regular national monitoring.

Export or import samples of mushrooms are measured by the IOS or the JSI laboratories, on order of the exporter, the importer or the inspectorate. This is seen as being in compliance with the regulation 737/90/EEC.

7. MONITORING LABORATORIES

7.1. INTRODUCTION

The responsible Slovenian authorities (SNSA and SRPA) as well as the NPP operator use a tendering process for contracting laboratory based monitoring and analysis tasks. The contracts generally are signed for a duration of one year. For environmental media the contract may include sampling (including design, set-up and servicing of any sampling devices), sample transport, sample preparation, measurement and data reporting. Overall reporting on the results of environmental monitoring including evaluation is also outsourced (common call for tender by SNSA and SRPA).

Due to dual ownership of the Krško NPP between Slovenia and Croatia, also the contracts for laboratory measurements are distributed evenly between the two countries. On the Croatian side the Institute for Research and Occupational Health (IMI) and the Ruđer Bošković Institute (RBI) in Zagreb provide the analytical measurement services for the Krško NPP.

7.2. KRŠKO NPP LABORATORIES

7.2.1. General

The operator's Radiation Protection laboratory and Radiochemistry laboratory are not accredited. However, both participate in national/international inter-comparison exercises and proficiency tests.

7.2.2. Radiation protection laboratory (RPL)

Sample registration and preparation procedures

Samples collected by the NPP staff arrive at the laboratory together with filled in sample forms. These forms are signed upon receipt and archived.

Air filter and gas samples which will undergo gamma measurements do not require special sample preparation

Sample measurements

Measurements of particulate filters (paper) and charcoal filters are performed in the RP-laboratory by gamma spectrometry with a GeLi detector.

The laboratory has a sampling line from the stack. Plant vent gas samples are monitored and analysed by gamma spectrometry using a HPGe detector. Also measurement of noble gases is performed. There is an on-line detector also at the stack discharge. Calculations are performed using Genie OS/2 software.

Gross alpha measurements are performed with an Alpha detector Nutronic NT-200.

TLD

The NPP uses thermoluminescent dosimeters for personnel surveillance and environmental monitoring (altogether 6 locations at the fence, serviced by the NPP and JSI). For measurement the laboratory has three Alnor DOSACUS TLD-readers.

Data handling and reporting

Gaseous effluent results are transferred manually into a PC. All records are managed according to the plant record management procedure. Results below detection limits are described as "< MDA" and are maintained only at the level of laboratory analysis.

All results are reported monthly and quarterly to the regulator. In addition, there is a yearly report. Laboratory measurement results and reports are archived.

Data from discharge analysis results are manually transferred to the MIS (plant database). Gamma spectrometry results are stored in the laboratory information systems and also in form of hard copies.

7.2.3. Radiochemistry laboratory (RCL)

The plant radiochemistry laboratory is located within the controlled area. It is equipped with Canberra HPGe detectors of some 30-40% relative efficiency, liquid scintillation counter and alpha/beta counters.

Sample registration procedures

Samples collected by the NPP staff arrive at the laboratory together with duly filled in sample forms. These forms are signed upon receipt and archived. All samples are identified by a code comprising the sample number, number of the sampled tank, name of the sampling person, date and the sampling time.

Sample preparation and measurement

Radiochemical samples are prepared and measured according to the radiochemical procedures of the Plant Chemistry Department. For liquids, tritium sample preparation is performed according to a written procedure. Composite discharge samples are prepared with addition of hydrochloric acid every month and sent to Zagreb for a control measurement.

Sample measurements

The laboratory is equipped with three shielded high purity coaxial germanium detectors with standard configuration and Canberra electronics. Calculations are performed using Genie 2000 software from Canberra.

Gamma spectroscopic measurement of samples is performed directly on the sampling bottle, which is wrapped in a plastic bag to avoid detector contamination.

Calibration of the system is based on Analytics Inc. liquid standards. A detector quality assurance programme includes also regular control of efficiency and peak width (FWHM).

Liquid scintillation counting is performed using a Packard Tri-Carb 1000 system; Eberline alpha/beta counters are available for control purposes.

Data handling and reporting

Data from discharge analysis results are manually transferred to the MIS. Gamma spectrometry results are stored in the laboratory information systems and also in form of hard copies.

All records are managed according to the plant record management procedure. Plant data base system data are archived according to special procedures

Results below detection limits are described as "< MDA" and are maintained only at the level of laboratory analysis. The measurement results are kept on the measurement PC and after approval archived on a central server and in a paper archive.

All results are reported monthly and quarterly to the regulator. In addition, there is a yearly report. Laboratory measurement results and reports are archived.

Sample storage (archiving) requirements

Krško NPP stores charcoal filters for one year for a possible future re-analysis. After this the filters are put in the radioactive waste. Other samples are not archived.

7.2.4. Mobile Measurement and Sampling Unit

The NPP operates a mobile unit for sampling and measurements (in particular for emergency cases). It is based on a Nissan Terrano and is equipped with a Yamaha EF1000 power generator. It also contains a 12 V and a 220 V Staplex mobile air sampler with holders for glass fibre filters and TEDA impregnated charcoal cartridges. The car also serves for holding/operating an Eberline contamination monitor; a Canberra Inspector 2000 system with a HPGe detector (with the possibility of using a small lead shield); a Canberra Inspector 1000 system with a NaI(Tl) detector; a tripod for in-situ measurements; plastic bags and auxiliary tools for sampling. Generally there are two persons in a sampling/measuring team with three teams available. Training is three times per year, with exercises taking place at least 1/year. Forms (with regard to sampling and measurement), procedures, and prepared maps are available in the car. The emergency measurement programme is defined and includes sampling/measuring media and locations, marked on maps; some are marked in the field. The samples are brought to the NPP Radiation Protection laboratory where they are further processed.

7.3. RUĐER BOŠKOVIĆ INSTITUTE (RBI) - ZAGREB

The Ruđer Bošković Institute (RBI) is a Croatian government institute with a total staff of some 900 persons. RBI Laboratory for Radioecology provides analytical measurements for gamma emitters, H-3, Sr-90, Fe-55 and total alpha/beta of the liquid discharge samples from the Krško NPP. In addition the laboratory provides analytical measurements for surface waters, ground water and C-14 samples from the Krško NPP environmental programme.

The institute is, as a whole, quality certified under ISO 1001 by the Croatian national accreditation authority; some of the laboratories are certified under ISO 17025. The radioecology laboratory is still in process of achieving the ISO 17025 certification. The laboratory has participated in several inter-comparison exercises, as required by the Krško NPP and the SNSA.

Sample delivery and registration procedures; sample preparation

Samples from the Krško NPP are delivered along with the corresponding sampling forms and identification codes. The practise is to measure one month composite samples from the NPP. A member of staff signs for the change of custody on receipt and provides the laboratory identification code. Different sample preparation methods are applied for different measurements. The preparation steps are documented on working instructions.

Sample measurements and recording

Gamma spectrometry

The laboratory has four Canberra gamma spectroscopy systems with detector efficiencies ranging form 28 to 35%. The detectors are coupled to analogue measurement electronics systems. Usually only one of the detectors is used for Krško samples, but if needed, the others can be used too. Typically a counting time of 80 000 seconds is used. In order to reduce the radon background the counting chambers inside the shields are kept in a nitrogen atmosphere. The laboratory has also one Canberra Inspector digital system. Genie 2000 software is used for the analysis. All artificial gamma-ray emitters measured above QL (quantification limit) are reported. QL is calculated according to the reference L. A. Currie, Limits of qualitative detection and quantitative determination, Analytical Chemistry (1968) by software GENIE2K.

Liquid Scintillation Counting

RBI has a liquid scintillation counter Packard TriCarb 2770TR/SL. H-3 measurements are typically done in five 10 minute cycles. The LSC system can be used also for Fe-55, Sr-90 and C-14 measurements.

System calibration is performed using commercial activity standards (Analytics Inc. SRS 68372A-508 for Fe-55 and SRS 64920-508 for H-3). Both MS Excel spreadsheet and automatic procedures are used for calculation of results.

Low-level alpha/beta proportional counter

The institute operates a low-level beta proportional counter (Canberra 2400 Alpha/beta/gamma System). Sr-90 is measured in the form of $SrCO_3$ precipitate, on a stainless steel planchette, for 200 min. Total alpha/beta activity is measured for 100 minutes.

Annual calibration of this device for Sr-90 measurements is done using a Sr-90 standard solution obtained from Analytics Inc. (63804-508), for total beta activity using 1 g of K_2SO_4 (Merck). Calibration checks are performed after each measurement. Calculations are done manually using MS Excel sheets.

X-ray counting

An X-ray spectrometer with a Si(Li) detector (Canberra) is used for Fe-55 measurements (measuring time 80 000 seconds). Spectrum acquisition and analysis is done by Canberra Genie 2000 software.

The calculation of results is fully automatic using Genie 2000. It can also be performed using Canberra Axil software.

Annual system calibration is done using commercially available activity standards.

Data handling and reporting tools

Measurement results are recorded electronically in the laboratory database. Additionally, hard copies of documents are stored in filing folder. Radionuclides detected in the sample with activities lower than the quantification limit are reported as the sum of the quantification limit and the uncertainty of the determined activity.

Statutory accounting and reporting obligations

Results of gamma-ray spectrometry analysis and radiochemical analysis (H-3, Sr-90, Fe-55) are reported monthly. Results of total alpha/beta activity measurements are reported quarterly. All reports are delivered to the customer (Krško NPP).

In case of unexpected results reporting to the customer and to the regulatory body has to be performed immediately.

Sample storage (archiving) requirements

Samples are stored for minimum of one year in a storage facility at the nearby high activity laboratory ('hot lab').

Quality assurance

The QA system in the Laboratory for radioecology was established in 1990 on the basis of existing IAEA Safety Guides and later on the basis of ISO/IEC Guide 25:1990 and the Standard EN 45001:1989. In February 2006 a Quality Management System was established in accordance with the new internal quality manual of RBI, made on basis of EN ISO/IEC 17025:2004. LRE is currently in the phase of initial preparation for accreditation according to the HRN EN ISO/IEC 17025 standard at the Croatian Accreditation agency and it participates regularly in inter-comparison exercises.

7.4. INSTITUTE FOR MEDICAL RESEARCH AND OCCUPATIONAL HEALTH (IMI) – ZAGREB

The IMI contract includes measurement of the air sampler filters from the Krško NPP decontamination building ventilation system and filters from the Krško high-volume air sampling stations. The institute contracts also environmental dose measurements with TLDs at locations on the Croatian territory near the border with Slovenia.

The institute has been doing analytical work in radiation protection and radioecology for the Yugoslav/Croatian national measurement programmes for some 45 years. Currently the radiation protection unit of the Institute has a staff of 9 persons, 3 of whom have training in radiochemistry.

Sample delivery and registration procedures; sample preparation

Filters from the NPP Krško decontamination building are collected and delivered by express mail to the IMI Radiation Protection Unit together with the sample forms. On receipt each sample is assigned an individual sample number, which is recorded in a logbook, in a computer log and on the sample envelope. Where required, radiochemical separations are performed using HASL-300 EML methodology.

Sample measurements

IMI performs the measurement of Sr-89/90 using a Danish made low level beta GM multicounter system Risø GM-25-5. System calibration is based on standards of Czech Republic origin. The actual measurement time is 1400 minutes. Five samples can be measured at the same time. Analytical calculations are performed on a Borland Quatro™ spreadsheet programme, but also manual calculations are performed. The procedure for the Sr-89/90 determination is described in the quality manual.

Data handling, recording and archiving

Analysis results are sent to Krško NPP in three month intervals.

Sample storage requirements

Samples are stored after measurement in a small storage room.

Quality assurance

IMI is accredited according to Croatian standards; ISO 17025 accreditation is being accomplished. The laboratory has participated in intercomparison exercises organised by IAEA, WHO and JRC.

7.5. INSTITUTE OF OCCUPATIONAL SAFETY (ZVD) – LJUBLJANA

The Institute of Occupational Health is a private company and deals with all kinds of occupational safety. Overall it employs some 90 staff, among them 6 in the radioactivity measurement unit. More staff could be available and trained for radiological purposes if needed.

With regard to radioactivity monitoring the institute succeeded in a tendering process for food monitoring that had been organised by the Ministry of Health for 2006. (The tender for drinking water monitoring had been won by JSI.) The contract covers sampling, sample transport, sample preparation and measurement, as well as reporting on individual data. Outsourcing of sub-tasks is principally possible. However, the institute uses its own transport capacity with cooling facilities for meat etc.

Sample preparation

Water samples (generally 50 litres) are evaporated in a special stainless steel vacuum device of Slovenian origin that can handle dishes of up to 50x50 cm. Evaporation is to some cm, followed by evaporation to dryness using infrared lamps.

Gamma spectrometry

The unit operates 5 HPGe detectors of different origin in the range 20 to 40% rel. efficiency plus a portable system (Canberra Inspector 2000). NIM electronic devices are from Laben. All units are connected within the laboratory network. For gamma spectrum analysis Canberra Genie 2000 is used (quality control options are extra).

Shields are built up from pre-WWII steel or lead and copper; to avoid contamination aluminium foil wrappers are used. Sample centering is done with plexiglass holders.

Efficiency calibration for the 5 geometries routinely used is performed whenever QC shows results out of range by more than 2 sigma. Energy checks (position and peak shape) are done

every week and every time when energy is shifted. If deviations occur the reason is checked and the system is re-adjusted (using an oscilloscope and amplifier features). When the problem persists Canberra Austria is asked in for servicing.

LN_2 is supplied automatically using a 400 l outdoor container and appropriate low temperature tubing

The room has its own ventilation system to avoid any contamination from outside.

Radiochemistry and beta measurement

The unit employs 2 persons for strontium determinations. All procedures are downloadable from a server and in addition printed versions are available at the workplace (milk, air, soil, food).

As measuring device a Berthold LB770 10 channel low level planchette counter is used together with a Berthold low radioactivity data system LB530 as computer interface. The PC uses an Ortec data system. Counting gas is supplied centrally. Calibration takes place every 2 years using Sr-90.

Sample archives

One room serves for archiving samples from 2005; one contains the samples from 2001 to 2004.

Quality management

The institute has ISO 17025 accreditation for gamma spectrometric analyses and TLD measurements (both personal and environmental). Accreditation for radon determination and Sr-90 analysis is planned for 2007 (procedures are ready but high costs are expected). The radioactivity measurement unit regularly participates in national and international inter-comparison exercises.

Procedures are available on the computer network on the server. Whenever a new version is available, the quality manager sends a respective e-mail to all staff.

7.6. JOŽEF STEFAN INSTITUTE (JSI) – LJUBLJANA

General

JSI is a public research institute with 740 permanent staff, 4 of which are working in the radiation protection unit. In addition, 1 collaborator is working on contract basis in other units but with tasks in radiation protection. Frequently trainees are sent by IAEA to the institute with a view of broadening technical knowledge.

The institute is involved in the NPP gaseous discharge monitoring as well as in the NPP and national environmental monitoring.

Sample receipt, sample handling

Traps of airborne effluents from the NPP stack containing H-3 and C-14 are delivered by NPP Krško to the JSI Tritium-Strontium Laboratory (TSL) together with duly filled in sample forms. These forms are signed by the laboratory staff as confirmation of receipt. The staff gives the code number for the samples.

Aerosol filters from the NPP stack are delivered together with the duly filled in sample form by mail to the JSI Laboratory for Radiation Measuring Systems and Radioactivity Measurements (LMR). These forms are signed by the laboratory staff as confirmation of receipt. After gamma spectrometric measurement at LMR the sample (with the form) is transferred to the Tritium-Strontium Laboratory, where the sample code remains unchanged.

For sample handling (from reception) to archiving a standard operating procedure is in place.

Sample preparation

With regard to stack aerosol filters the contaminated area is cut out and the pieces are inserted between thin (0.01 mm) plastic foils. A composite sample with a diameter of 80 mm is produced. For Sr-90 measurement Sr-carrier solution is added and the oxalate method is applied.

For H-3 analysis in traps desorption, followed by condensation and mixing with scintillator cocktail is performed.

For C-14, adsorbed CO2 in NaOH solution is precipitated as $BaCO_3$ by adding $BaCl_2$ solution. Appropriate mass of $BaCO_3$ (1g) was added to 12 ml scintilator Instagel and shaked by ultrasonic agitation. Then 6ml destilled water was added and finally put in ultrasonic bath at 40^o for some minutes.

Sample measurement

Gamma emitters in composite aerosol samples are measured on a high resolution gamma spectrometer for one day. All artificial gamma-ray emitters measured above the respective quantification limit are reported.

Sr-90 is measured in the form of $SrCO_3$ precipitate, on stainless steel planchettes, with a low-level beta proportional counter (Eberline, FHT 770T-6) for 240 min.

H-3 is measured on a liquid scintillation counter Packard TriCarb 170TR/SL for 10 min, 5 cycles or till measurement uncertainty is below 5%.

C-14 is measured on a liquid scintillation counter Packard TriCarb 170TR/SL for 30 min, 5 cycles or till measurement uncertainty is below 5%.

Gamma spectrometry

The 'high resolution gamma-ray spectrometry group' is under supervision of an internationally recognized expert.

Gamma emitters are measured with 9 high resolution gamma spectrometers, connected to a DEC alpha workstation with Canberra Genie ESP as spectrum acquisition and analysis system.

Detector data are given in the table below.

Manufacturer	Rel. eff. (%)	Type	Geom.	Energy Range (keV)	Shielding
PGT	24	Ge(Li)	Coaxial	40-2700	15 cm Fe
PGT	35	p-type	Coaxial	40-2700	16 cm Pb
Intertechnique	24	p-type	Coaxial	40-2700	12 cm Pb
PGT	~5	p-type	Planar	5-900	12 cm Pb
Canberra	22	n-type	Coaxial	5-2700	10 cm Pb

PGT	36	n-type	Coaxial	15-2700	12 cm Pb
Ortec	40	n-type	Coaxial	5-2700	10 cm Pb
Canberra	50	p-type	Planar	5-2700	12 cm Pb
Ortec	50	n-type	Coaxial	5-2700	10 cm Pb

Calibrations are performed biannually. The procedure is described in the SOP 'Detector calibration'.

Analysis results are checked at basic level under the responsibility of the spectroscopist; relevant results are marked. Comparison with historical results allows for detection of unusual values. Reporting concerns 'all radionuclides' using standardised comments; no selection is applied. The results are then validated by another spectroscopist who was not involved in the analysis procedure. Occasionally statistical tools are used to improve procedures. All operator manipulations are automatically logged in the system (VAX VMS feature).

Beta measurements

H-3 and C-14 are measured by liquid scintillation counting (Packard TriCarb 170TR/SL), while Sr-89/90 is measured with a low-level beta proportional counter (Eberline FHT 770T-6).

The proportional counter is calibrated monthly using standard solutions of Sr-90 prepared as $SrCO_3$. $SrCO_3$ is prepared once per year.

Calibration checks of the LSC are performed routinely monthly using Perkin Elmer IPA software.

Standards used are SR90-ELSC10 (from Areva – Laboratoire Etalons d'Activité) for Sr-90, Perkin Elmer tritiated water SRS 66197-482 for H-3, and from Analytics Inc. for C-14.

Final calculations are performed by hand using MS Excel sheets.

Radiochemistry

Radiochemical preparation of samples, in particular for strontium determinations, is according to written procedures.

Sample archives

With regard to Sr-90 analysis the planchettes are stored for at least one year, the remaining samples of C-14 determinations are stored as well. Samples for H-3 analysis are not stored (samples are collected in the container and sent back to NPP Krško).

Measurement results: recording and archiving

Measurement results for gamma emitters are printed onto the sample form and are automatically transferred to the central database. Minimum detectable activities of radionuclides not detected in the sample are not reported. Radionuclides detected in the sample at activities lower than the quantification limit are reported as the sum of the determined activity and its uncertainty.

Results for H-3, Sr-90 and C-14 are inserted manually in the sample form and into a central database.

Data handling and reporting

Results from gamma spectrometric analysis are stored in a custom made MySQL database on a Linux system; this includes data since 1996). For further applications (e.g. dose calculations) the data in the database can be imported into MS Excel data sheets. For reporting, templates in MS Excel are prepared.

Reporting by the Head of Unit accesses this data base. Reporting leads to result tables which for evaluation are offered to others from inside and outside the unit. The final draft report is then sent to the customer. Comments received are used for improvement of the report. With regard to discharge monitoring (contract from NPP) an overall exposure report is sent to the NPP which forwards it to the Ministry of Health. Activity concentration reports (with all individual data on CD) are sent to the NPP which forwards them to the Ministry of the Environment and Spatial Planning. 'Manual' reports are produced every 3 months to show the 'current status'. The NPP has access to the JSI database for Krško NPP data (contracted tasks) from the current year via internet (via sample code 'K06').

In case of unexpected results of the analysis reporting to the customer and the regulatory body has to be performed immediately.

Quality Management

A quality assurance system for gamma spectrometry in the LMR laboratory was established in 1995. This quality assurance and control system is organized in accordance with the ISO/IEC 17025:2005.

The TSL laboratory is in a final phase of implementation of a quality assurance system according to the ISO/IEC 17025:2005 standard which would cover H-3, C-14 and Sr-90 determinations.

The LMR laboratory is accredited according to the ISO 17025:2002 standard by Slovenska Akreditacija (the Slovenian accreditation body) since March 2003 for measurements of activities of gamma-ray and X-ray emitters in cylindrical homogenous samples with high-resolution gamma spectrometry.

The TSL laboratory is in a final phase of preparation for an application for accreditation according to the ISO 17025 standard.

Both laboratories participate regularly in available inter-comparison schemes.

8. VERIFICATION ACTIVITIES – KRŠKO NUCLEAR POWER PLANT

8.1. INTRODUCTION

With regard to the general set-up of regulatory surveillance, the verification team noted that the SNSA does not have sampling and measurement capabilities of its own or of other governmental institutions. It therefore uses services of contractors selected through a tendering process.

The verification team noted that effluent and environmental monitoring is the responsibility of the NPP operator, partly contracted to research institutions. The regulatory control is based on contracts that may involve the same groups that are contracted by the NPP. Due to the dual ownership of the Krško NPP between Slovenia and Croatia, the contracts for laboratory measurements are distributed evenly between the two countries. On the Croatian side the Institute for research and occupational health (IMI) and the Ruđer Bošković Institute (IRB) in

Zagreb provide the analytical measurement services for the Krško NPP. While at the moment the contractors are willing and able to perform these different tasks in a reasonably independent manner, this arrangement does not fully meet the requirements of independence and transparency.

The verification team recommends setting-up a real independent surveillance system by the regulator both for discharge control and environmental radioactivity monitoring in the surroundings of the Krško NPP.

8.2. DISCHARGE MONITORING

8.2.1. General

Verification team visited the main systems and laboratories associated with the plant discharge monitoring and verified the existence of relevant equipment and procedures. Due to the complexity if the system it was not possible to carry out a detailed verification, but the team was able to get a good overview of the systems and functionalities.

8.2.2. Liquid Discharge Monitoring and Sampling

The routine waste water storage tank sampling procedure involves recirculation of the tank content for 60 minutes. A one litre sample is taken from each tank. Sampling and analysis is performed by the same person and only one sample is handled at the time; therefore no labels on the sampling bottles are used.

In addition to individual tank samples a composite sample is prepared each month and sent to the contracted laboratory for measurement (currently to the Ruđer Bošković Institute, Zagreb).

The verification team verified also the sampling procedure at liquid waste tank 2 (volume 18.9 m^3). The procedure involves recirculation and sampling pipe draining for two minutes before taking the sample. The instruction document was made available to the team.

Verification does not give rise to remarks.

8.2.3. Gas sampling for the containment control system

The verification team verified the system for containment gas sampling. The temperature-controlled system includes on-line noble gas, particulate and iodine monitors and a filter placement for off-line sampling. The off-line sampler has a rolling filter paper with 6 months change interval.

A separate sampling system for post-accident situation is also available, but not used under normal circumstances. In case of an accident, it would be switched on automatically.

Verification does not give rise to remarks.

8.2.4. Decontamination building

The team verified the ventilation sampling system in the decontamination building. The air flow in the system is some 28 000 m^3 per day. The monitoring system samples the particulate and gaseous activity in the air exhaust. There is also an alarm for high activity in the exhaust.

There is no actual monitoring of liquid releases from the decontamination building. The small amounts of active water generated in the building are collected in a sump and transferred to the plant controlled area in drums for treatment at the plant active liquid system.

Verification does not give rise to remarks.

8.2.5. Steam generator blow-down system

The team verified the functionality of the NaI(Tl) detector triggering the discharge automatic shut-down and the primary side liquid sampling system for batch discharges.

Verification does not give rise to remarks.

8.2.6. Atmospheric drain tank

The plant atmospheric drain tank (condensate transfer tank) is sampled on monthly basis before each release. The team verified the sampling location and the related instructions.

Verification does not give rise to remarks.

8.2.7. Turbine ejector

In the turbine ejector there is a high activity monitor, but no automatic shutdown. In addition there is an exhaust sampling system for post-accident situations. The verification team was informed that gas sampling results of the secondary circuit (alpha/beta measurements) have indicated no activity in the secondary side after the steam generators replacement in 2000.

Verification does not give rise to remarks.

8.2.8. Control room

The verification team verified the radiation monitor equipment in the control room.

When performing a liquid release the control room has to make sure the release activity does not exceed the quarterly release activity limit and the concentration in the discharge channel stays below the limit value. In addition the river flow has to be below 1500 m^3/s; i.e. liquid releases are not allowed during river flooding situations.

Verification does not give rise to remarks.

8.2.9. Data management

A spot control on data management was performed on March 2001 discharge data. Data was available on a handwritten book. When comparing the sum of individual sample results measured by the plant laboratory with the composite sample results measured by the JSI certain fairly small inconsistencies could be observed in the activity results. These were apparently due to different methods in reporting activities close to the MDA or different timings used for the decay corrections. It was also indicated that different contractors use different methodology in data management and therefore it is possible that the results between contractors are not fully comparable.

It was also noted that the practise was to report zero activity if the measurement results indicated an activity below the MDA and there appeared to be no SNSA requirement for the MDA in discharge activity measurements.

The verification team suggests defining a common methodology for sample activity measurements for all contractors involved in the work.

The verification team recommends that the SNSA defines a standard for the MDA in all discharge activity measurements.

8.3. NPP ON-SITE ENVIRONMENTAL MONITORING

8.3.1. General

8.3.2. Air sampling

The verification team observed a demonstration of filter change at the air sampling site denominated NPP-L5 – ER900/NC005. The filter is changed with the motor running. Air flow rate is controlled via a flow meter; throughput is registered with a gas counter. Date, time and signature of the sample taker are noted in a book.

The team verified the presence of the automatic outdoor air monitor Bitt AMS02 installed by the SNSA at the plant yard not far from the meteorological tower and that the measurement data are transmitted.

Verification does not give rise to remarks.

8.3.3. Dose and dose rate measurements

The verification team noted the TLD devices at the fence and the GM counters near the meteorological tower. It received a thorough demonstration of the automatic system on the data management and presentation PCs. The team noted that the AMES type detectors are wrapped in thin aluminium foil to avoid contamination of the detector surface

Verification does not give rise to remarks.

8.3.4. Surface water sampling

The verification team noted that procedures are available. The water containers are weekly cleaned of algae in-growth. Twice per month all water is released back to the river during maintenance. If the system freezes during winter a contracted service firm is called. The verification team noted that the NPP liquid discharge point to the river is situated near the Sava river water sampling point.

Verification does not give rise to remarks.

8.3.5. Ground water sampling

The verification team noted that the well was closed and locked. The key seemed not to be locally available, since sampling is done by RBI.

Verification does not give rise to remarks.

8.4. NPP OFF-SITE ENVIRONMENTAL MONITORING

8.4.1. General

For the verification team it proved not always to be easy to distinguish between samplings that are done on behalf of the NPP operator and those done for the regulator. Sometimes tasks are mixed, such as sampling by operator staff and sample transfer as well as sample analysis by the contracted laboratory. An additional source of uncertainty lies in the fact that the contracts are based on an annual schedule and thus information about a site was not always up-to-date.

Verification of both Croatian institutes, RBI and IMI, and their involvement in the NPP off-site environmental monitoring was related only to the sampling points located on the Slovenian territory.

The verification team strongly recommends a clear separation between measuring activities for the NPP and the control measures implemented by the authorities.

8.4.2. Air sampling

The verification team visited the air sampling sites at Vihre and Stara Vas. The devices use 10"x10" glass fibre filters at a flow rate of 13 m^3/h and self prepared TEDA charcoal cartridges at a flow rate of 3 m^3/h. Air volume is determined by gas counters.

Verification does not give rise to remarks.

8.4.3. Dose and dose rate measurements

The verification team visited the ambient dose rate monitoring stations at Vihre and Libna (new AMES type). At Vihre the mounting was satisfactory (open field) whereas at Libna (house Libna 2) the device was mounted on the wall of the building. The former version of the detectors had been set up in an orchard. The station serves as an 'altitude' station and the orography does not allow easy comparison with results from 'ideally located' devices. It is noted that this is not the intention of such siting.

The verification team also visited the TLD devices at Stara Vas and Vihre. Whereas the site at Stara Vas was well selected, the device at Vihre risks being overgrown by plants.

The verification team suggests considering to move the dose rate monitor in Libna 2 to avoid the influence of the house wall. It also suggests reconsidering the siting of the TLD device in Vyhre.

8.4.4. Surface water sampling

The verification team visited the site of the automatic surface water sampling devices at Krško (paper mill) and Brežice (separate container). The team observed sample handling (filtering) by NPP personnel. The samples are collected by JSI.

Brežice

The sampling device at the location at Brežice is maintained by MPO, a construction company from Zagreb, Croatia, based on a service contract. The device uses a peristaltic pump to transport the water (12 m line length, 3.9 m effective height). 3 times per week a small amount is manually transferred to a large container (marked 'Sava', code and tare weight). The water is then filtered; water and filter are monthly collected by JSI. Procedures, schematics etc. were available on site.

The container that houses the pumps and the samples is heated in winter and air conditioned in summer. A hydro-meteorological station is situated in the vicinity, giving river flow data (also available via internet).

Verification does not give rise to remarks.

Krško

The sampling device is located within a building of the Krško paper mill. Maintenance is performed by paper mill staff, on a voluntary basis. Originally the device had used a peristaltic pump. At the time of the visit the pump was electrically disconnected. Water was pumped to the intermediate vessel by other means. This fact seemed not to be commonly known. Daily 1.5 l water is manually transferred to a large container (paper mill staff; procedure available on-site). Filtering is performed by NPP staff. The samples are then collected by JSI.

The verification team recommends clarification and updating of the detailed procedure used.

8.4.5. River sediments

The verification team visited the sediment sampling site at Brežice, situated near the Sava bridge. It was informed that the exact location for sampling generally was chosen on the spot taking into account the accessibility of the site and the water level of River Sava. The site where grab samples of bottom sediments are collected is currently managed by the contractor ZVD. A sketch of the sampling device used by JSI (until 2005) was available: Suspended matter is sinking into two reversed containers with cut-off bottom.

Verification does not give rise to remarks.

8.4.6. Drinking water, wells

The verification team visited the water pumping station at Brežice - Glogov Brod. It received an explanation of the sampling procedure. Personnel from the local waterworks daily takes a sub-sample. The monthly sample is transferred to the laboratory by the contractor (JSI).

Verification does not give rise to remarks.

8.4.7. Food and milk

The verification team visited a farm in Vihre where milk samples and – as available – samples of cereals are taken. Food to the cows is of local origin.

Verification does not give rise to remarks.

8.4.8. Soil and Vegetation

The verification team visited the undisturbed soil and vegetation sampling site 'Amerika' and was shown several pits of former samplings. The sampling procedure with sketches and photos was at hand and gave an impression of the 'monolith' method applied. Four persons of JSI are trained for this task.

Verification does not give rise to remarks.

8.4.9. Precipitation, dry and wet deposition

The verification team saw the sticky plate device at Vihre.

Verification does not give rise to remarks.

9. VERIFICATION ACTIVITIES – NATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING

9.1. INTRODUCTION

The verification team noted that two governmental organisations are involved in national monitoring at the same level of competence, namely SNSA (with regard to general environmental media) and SRPA (with regard to drinking water and food). Collaboration between the two organisations seems to be satisfactory.

9.2. AUTOMATIC NETWORKS

9.2.1. General

The on-line environmental monitoring system in Slovenia is managed in co-operation between SNSA and EARS. The monitoring devices are mostly located in meteorological stations.

9.2.2. Gamma dose rate monitors

The verification team saw the ambient dose rate monitors located at the sites Ljubljana, Brinje, Portorož and Koper. With regard to using the detectors for both early warning and deposition estimation purposes all systems were suitably sited and operational.

Verification does not give rise to remarks.

9.2.3. Air Monitors

The verification team saw the automatic air monitoring station at Brinje, type Bitt ASM02 (without meteorological probes and gamma dose rate detector). The container is situated in a fenced in area belonging to the research reactor site. The device was fully operational.

At Drnovo the verification team could not access the (fenced-in) site of the air monitor, type Bitt AMS01 (with meteorological probes and gamma dose rate detector) because only a wrong key was available. It seems that the lock and key had been changed recently but not all copies of the key had been replaced by the SNSA staff.

The locations of the monitors are well chosen. There were no buildings or high trees are situated near the containers.

The verification team suggests checking also administrative aspects of the monitoring system such as access rights and procedures on a regular basis.

9.2.4. Data Centres

The national monitoring system has two central sites with independent computer systems for enhanced reliability: one at the SNSA and another at the EARS premises. The EARS centre is the main centre for data analysis, public availability (within one hour at a website) and archiving.

SNSA has the responsibility for international data exchange, essentially with the neighbouring countries Austria, Croatia and Hungary, but also to the EURDEP system. Currently the monitoring data from Croatia and Hungary come once daily, so they have no early warning function. There are no data received directly from the Italian monitoring systems.

Technically the monitoring system consist of five subsystems, allowing data to be received from several networks (NPP, regional, etc.). The system receives data also from the Krško NPP from plant monitors located inside the containment and from the liquid discharge line automatic shut-down detector. The network includes also meteorological information (wind speed and direction, rain). A typical communication interval is 30 minutes, but in the event of exceeding alarm thresholds 5 minute intervals will be used. Data back-up servers and electrical power back-up systems are available.

A first alarm is issued to the SNSA duty officer by SMS at the limit of 250 μSv/h on any station, a major alert situation is declared if three stations indicate values above 500 μSv/h.

The verification team received a presentation of the newly developed central data system. The set-up seems to be strongly based on similar up-to-date systems in other countries and uses modern IT technology. Development is still ongoing, based on a flexible contract between SNSA and the supplier (company AMES d.o.o. from Ljubljana). The verification team noted the excellent collaboration between the parties involved in the system development.

Verification does not give rise to remarks. The verification team notes that quicker data transmission from Croatia would be advantageous.

9.3. LABORATORY BASED NETWORK

9.3.1. General

The verification team was informed that laboratory based monitoring is based on contracts by the authorities. Annually, calls for tender are published and suitable laboratories are selected for a one year's programme. This can lead to situations where only by the end of the contract period a laboratory has built up a reliable infrastructure and the necessary connections to efficiently manage the programme, in particular samplings. Such a case could lead to a lack in continuity of applied methods and consequently may cause higher uncertainties of the obtained results.

Currently the authorities are not asking for accreditation of the institution for the tasks contained in the work programme.

The verification team suggests considering contracting for longer periods to allow for more continuity in the work. It also strongly suggests including in the tendering process a request for accreditation according to ISO 17025 for all analysis tasks associated with the work programme.

9.3.2. Monitoring of radioactivity in air

The verification team visited the high volume air samplers located in Predmeja and Brinje ('new' JSI samplers). It received a thorough explanation of the devices used and the reasons for the choice of these sites.

Brinje has been chosen for the flat surroundings, the vicinity to Ljubljana, technical and administrative advantages (it is the nuclear research reactor site). The device is located in the centre of a meadow distant to any constructions that could influence air flow.

Predmeja was selected because it is at the rim of the karst area and thus representative for an important Slovenian region. The device is located at some 800 m a.s.l., relatively close to the mountain side because further out in the field during winter the snow cover would be too high and during times of strong wind (the Bora reaches wind speeds of up to 150 km/h) the risk of damaging the device would be significant. Sample change is monthly by he local owner of the field; the filters and the sample forms filled in locally are sent to JSI by special mail ('hitra pošta'= express delivery mail). Filter change operation was demonstrated to team. The station was first installed in May 2006 and for the time being it had a temporary wooden foundation. The team was informed that a concrete foundation will be constructed in due course.

The 'old' sampler which had been operated until 2005 by ZVD is situated several hundred metres distant and is still running. The verification teams verified the operational status of this device. This station equipped with a charcoal filter; there is no separate fibreglass filter for particulate measurements. The airflow through the cartridge was about 140 litres/minute.

The new JSI devices use differential pressure transmitters for air flow determination. The verification team noted that the length of the air tube before the measuring point does not exceed 10 times the tube diameter which is generally recommended for achieving laminar air flow and thus reliable results. However, in this specific case the manufacturer´s recommendations state that a straight tube with the length twice its diameter at the entrance must be mounted to achieve the declared accuracy.

The verification suggests considering improvement of the air flow measurement when re-designing the new sampler.

9.3.3. Precipitation

The verification team saw the precipitation sampler at Brinje. It is located in a wide meadow apart from any disturbing construction.

Verification does not give rise to remarks.

9.3.4. Surface Water

The verification team saw the location for surface water grab sampling near at the River Sava Brinje. It is located near a bridge and has easy access.

Verification does not give rise to remarks.

9.3.5. Sediment

Verification of this item of the national monitoring system was not included in the verification programme.

9.3.6. Milk

Verification of this item of the national monitoring system was not included in the verification programme.

10. VERIFICATION ACTIVITIES – MONITORING LABORATORIES

10.1. KRŠKO NPP LABORATORIES

10.1.1. General

There are three laboratories at the Krško NPP involved in discharge monitoring. The laboratories are not accredited, but aim to comply with accreditation requirements and occasionally participate in intercomparison exercises.

Verification team supports the intercomparison activity and initiatives towards formal accreditation of the laboratories.

10.1.2. Radiation protection laboratory

The verification team visited the NPP's Radiation Protection Laboratory which is located outside the controlled area. The team verified the functionality of the measurement devices and existence of the related measurement procedures.

The team noted the availability of procedures and documents at location (gamma spectrometry, calibration, sample log; detector data sheets). The team was informed that calibration control measurements are performed, but there is no formalised system for them.

The team verified the procedures for equipment calibration. An Analytics Inc. mixed gamma filter standard is used for calibration of the detector at the laboratory. In addition the laboratory purchases annually one or two single use Xe/Kr gas standards for calibration of the stack detector. Calibration sources are kept in a safe. Source activity certificates were presented to the team.

The verification team suggests putting in place a formalised and documented system for regular control of gamma spectroscopy system stability for energy, efficiency and peak width.

10.1.3. Radiochemistry laboratory

The plant radiochemistry laboratory is located within the controlled area. It is able to perform gamma spectroscopy and liquid scintillation counting on liquid samples.

The team verified the procedure for liquid effluent tank sampling, handling of the sample and the procedure for tank discharge authorisation after the measurement is performed. Gamma spectroscopy measurement of the sample is performed on the sampling bottle, wrapped in a plastic bag to avoid detector contamination. All spectra are archived in a PC and on paper.

Calibration of the system is based on Analytics liquid standards. The laboratory quality assurance programme includes also regular control of efficiency and peak width (FWHM).

For a historical sample from the first quarter of 2001 from the liquid release the measurement chain was verified. The measurement values and the corresponding gamma spectrum were checked to be OK.

Approved measurement instructions were presented to the team. The practise is to report the equipment MDA if the measured activity is below the calculated MDA value.

The team was informed that the individual tank samples are not achieved for a possible need for re-analysis.

The verification team recommends SNSA to consider instructing the NPP laboratory to store the liquid discharge samples for a reasonable time in order to allow for re-analysis.

10.1.4. Mobile Measurement and Sampling Unit

The verification team observed a presentation/demonstration of the equipment and documents.

Verification does not give rise to particular remarks.

10.2. RUĐER BOŠKOVIĆ INSTITUTE (RBI) - ZAGREB

10.2.1. General

The Ruđer Bošković Institute (RBI) is a Croatian government institute with a total staff of some 900 persons. RBI Laboratory for Radioecology provides analytical measurements for gamma emitters, H-3, Sr-90, Fe-55 and total alpha/beta of the monthly composite liquid discharge samples from the Krško NPP. In addition the laboratory provides analytical measurements for surface waters, ground water and C-14 samples from the Krško NPP environmental programme.

The institute is as a whole is quality certified under ISO 1001 by the Croatian national accreditation authority; some of the laboratories are accredited under ISO 17025. The radioecology laboratory is still in process of achieving the ISO 17025 accreditation. The laboratory has participated in several inter-comparison exercises, as required by the Krško NPP and SNSA.

Verification does not give rise to remarks.

10.2.2. Sample receipt

Samples are delivered along with the corresponding sampling forms and identification codes. The practise is to measure one month composite samples from the NPP. A member of staff signs for the change of custody on receipt and provides the laboratory identification code. Different sample preparation methods are applied for different measurements. The preparation steps are documented on work instructions.

Verification does not give rise to remarks.

10.2.3. Gamma spectroscopy

The laboratory has four Canberra gamma spectroscopy systems with detector relative efficiencies ranging form 28 to 35%. The detectors are coupled to analogue measurement electronics

systems. The laboratory has also one Canberra Inspector digital system. Genie 2000 software is used for spectrum analysis.

In order to reduce the radon background the inner detector shieldings are kept in a nitrogen atmosphere.

Usually only one of the detectors is used for Krško samples, but if needed, the others can be used too. Typically a counting time of 80 000 seconds is used.

Analysis is based on commercial calibration standards, which are kept in a safe. Activity standard certificates were presented to the verification team. Stability control (peak energy and width (FWHM)) of the gamma spectroscopy systems is performed occasionally, although it is not specifically required in the quality manual. Background measurements are performed in a few months' intervals.

As a matter of good laboratory practise, the verification team recommends that a gamma spectroscopy system stability control (peak energy, FWHM) be included in the formal quality control programme and results documented in order to detect possible system degradation as early as possible.

10.2.4. Liquid scintillation counting

Tritium measurements are performed using a liquid scintillation counter Packard TriCarb 2770TR/SL, typically for five 10 minute cycles. The LSC system can be used also for Fe-55, Sr-90 and C-14 measurements. System calibration is performed using commercial activity standards. Both MS Excel spreadsheet and automatic procedures are used for calculation of results.

Verification does not give rise to remarks.

10.2.5. Total alpha/beta counting

Total alpha/beta counting is performed with a Canberra 2400 Alpha/beta/gamma counting system. System calibration is performed using commercial activity standards. Excel spreadsheets are used for calculation of results.

Verification does not give rise to remarks.

10.2.6. X-ray counting

An X-ray spectrometer with a Si(Li) detector (Canberra) is used for Fe-55 measurements. System calibration is performed using commercial activity standards. Canberra Axil software is used for calculation of results.

Verification does not give rise to remarks.

10.2.7. Other equipment

Laboratory scales are calibrated annually. Calibration certificates were presented to the verification team.

Verification does not give rise to particular remarks.

10.2.8. Other verification items

The laboratory facilities are very good. The underground counting room is large and controlled for temperature and humidity.

Samples are stored for a minimum of one year in a storage facility at the nearby high activity laboratory ('hot lab'). There was a slight disorganisation in the storage room, so new personnel may have trouble finding correct samples.

Analysis results of gamma spectroscopy and radiochemical analysis are reported to the Krško NPP on a monthly basis. Total alpha/beta results are reported quarterly. Results are archived on laboratory network servers and on paper. There was a slight disorganisation in paper filing, but eventually all requested documents were found.

As a matter of good laboratory practise, the verification recommends the RBI laboratory to make sure the sample storage and filing systems facilitate quick and easy retrieval of archived samples and files.

10.3. INSTITUTE FOR RESEARCH AND OCCUPATIONAL HEALTH (IMI, ZAGREB)

10.3.1. General

The IMI contract with the NPP includes measurement of the air sampler filters from the Krško NPP decontamination building ventilation system and filters from the Krško high-volume air sampling stations.

The institute has been doing analytical work in radiation protection and radioecology for the Yugoslav/Croatian national measurement programmes for some 45 years. IMI is a governmental institute and reports to the ministry of health and to the ministry of science and technology. Currently the radiation protection unit of the Institute has a staff of 9 persons, 3 of whom have training in radiochemistry. IMI is accredited according to Croatian standards; ISO 17025 accreditation is being accomplished. The laboratory has participated in inter-comparison exercises organised by IAEA, WHO and JRC.

Verification does not give rise to remarks.

10.3.2. IMI Radiation protection unit

Filter papers and their corresponding sampling forms are transported to IMI by an express delivery service. On receipt each sample is assigned an individual sample number, which is recorded on a logbook, computer log and the sample envelope.

IMI performs the radiochemical separation and measurement of Sr-89/90 using a low level beta GM multicounter system Risø GM-25-5. System calibration is based on standards of Czech Republic origin. The actual measurement time is 1400 minutes. Five samples can be measured at the same time. Analytical calculations are performed using a Borland Quatro spreadsheet programme, but also manual calculations are performed. The procedure for the Sr-89/90 determination is described in the quality manual.

Analysis results are sent to the Krško NPP in three months intervals. Samples are stored after measurement in a small storage room, but there were no formalised arrangements for sample archiving.

The laboratory operates in very small space, and there is an apparent lack of room for equipment and storage. The measurement equipment is fairly old, but functional. The laboratory has only one beta measurement system, so a technical malfunction could lead to a long backlog in filter measurements.

The verification team verified the presence of the sample logbooks, written instructions for analytical measurements and the reports of selected inter-comparison exercises.

The verification team recommends the IMI, in co-operation with the Krško NPP and the SNSA, to put in place a formalised sample archiving system.

As a matter of good laboratory practise, the team suggests removal of outdated equipment and other stored material from the laboratory facilities.

The verification team points out that the laboratory would benefit from a modern laboratory facility especially constructed for radioactivity measurements.

10.4. INSTITUTE OF OCCUPATIONAL SAFETY - ZVD (LJUBLJANA)

10.4.1. General

ZVD is a private institution having industry, hospitals and the government as clients. The verification team noted that basic staffing of the radiological laboratory consists of 6 persons and more could be available and trained 'when needed'.

The verification team suggests ensuring appropriate training for staff that may be involved in radioactivity measurements well in advance. It also suggests considering an appropriate duty schedule for such persons.

10.4.2. Sample receipt, sample handling

The verification team noted that sample registration is based on a unique code which is given at sampling and kept throughout the analysis path.

Verification does not give rise to particular remarks.

10.4.3. Sample preparation

The verification team noted that the laboratory is well equipped with sample treatment devices. In particular, water evaporation methods seem very efficient.

Verification does not give rise to particular remarks.

10.4.4. Gamma spectrometry

The verification team noted the high level of expertise of the personnel involved in gamma spectrometry.

Verification does not give rise to particular remarks.

10.4.5. Alpha / Beta measurement (in particular for strontium)

At the time of the verification the system was not in operation.

10.4.6. Reporting

The verification team noted that reporting goes to the customer. In case of abnormal values SNSA is informed as well.

Verification does not give rise to particular remarks.

10.4.7. Quality Management

The verification team noted available accreditation for gamma spectrometry and TLD and the planning for accreditation for Sr-90 and radon measurements. It noted that relevant procedures although downloadable from the server were not always locally available in printed form.

The verification team encourages the planned additional accreditations. This should be accomplished well before participation in a respective call for tender. It also suggests keeping printed versions of relevant procedures at all workplaces to avoid problems when the server is down for some reason.

10.5. JOŽEF STEFAN INSTITUTE – JSI (LJUBLJANA)

10.5.1. General

JSI is one of the top institutes in Slovenia that deal with radiation measurement (at the time of the visit it housed trainees from IAEA). Thus, its scientific integrity is not doubted by the verification team.

However, the independence for the various monitoring tasks (for the NPP, the regulator, the national system) was commented to be 'guaranteed by the scientific ethos', by 'own budget', 'strict procedures', 'well protected data bases' and a quality manual 'providing acceptable results' only! A strict 'anonymization' of samples, results, etc. is not foreseen at the moment.

The verification team strongly recommends setting up a system that clearly separates the various contracted tasks by employing administrative and technical measures to ensure transparency and independence.

10.5.2. Sample receipt

Samples arrive by mail, by courier or are taken by the laboratory staff themselves, depending on the sample type. The verification team noted that samples are given unique identifiers upon arrival at the institute.

Verification does not give rise to particular remarks.

10.5.3. Sample preparation

Samples are prepared according to the necessities of the following measurement procedure.

Currently only one person is involved in preparing samples for strontium measurement. The verification team was informed that the load of such determinations is some 250 samples per year.

The verification team noted that the sample planchettes for strontium measurement are not marked. Under certain circumstances this could lead to errors in identification.

The verification team recommends ensuring that enough trained persons are available to be able to manage the workload of strontium determinations, also during times of holidays and any (sick) leaves. Furthermore, it suggests suitable marking of the planchettes (e.g. with scratched-in numbers which in turn refer to the samples) to avoid identification problems.

10.5.4. Gamma spectrometry

The verification team noted that VAX VMS is used as computer system. This system is very reliable but the former producer (Digital Equipment Corporation) since many years is out of business and, thus long term support cannot be guaranteed.

The verification team would support any effort to switch to a Unix or PC based gamma spectrometry system with a view to keep long-term stability of support and updates.

10.5.5. Archives

The verification team tracked a sediment sample from River Sava and an aerosol sample, both from 2004, from sampling to result reporting and found no deviations.

Verification does not give rise to remarks.

10.5.6. Reporting

The verification team noted that the access to NPP data on-line by the NPP is secured by a simple sample coding algorithm only. Taking into account current technical possibilities this does not seem to reliably defend against data base intrusion.

The verification team strongly suggests improving data base security to block as much as possible intrusion from outside.

10.5.7. Quality Management

The verification team noted that procedures are very strict and in place. The laboratory participates regularly in national and international inter-comparison exercises. However, there is not yet accreditation according to ISO 17025 for all areas involved in the contracted services for the NPP and the authorities.

The verification team supports all efforts for widening the area of accreditation according to ISO 17025 to e.g. strontium determination.

11. 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 led 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 with regard to the surveillance of the Slovenian territory are adequate. The Commission could verify the operation and efficiency of these facilities.

(2) A few recommendations are formulated, mainly in relation to general quality assurance and control. These recommendations aim at improving some aspects of the environmental surveillance. These recommendations do not detract from the general conclusion that the Slovenian national monitoring system is in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

(3) A clear separation between measurements performed on behalf of the NPP and any control measurements commissioned by the authorities is recommended to guarantee independence of surveillance.

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

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

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

APPENDIX 1

REFERENCES AND DOCUMENTATION

European Commission

- Verification activities under the terms of Art 35 of the Euratom Treaty: preliminary information questionnaire addressed to the competent authority of Slovenia, 2006.

Ministry of Environment, Spatial Planning and Energy, the Slovenian Nuclear Safety Administration (SNSA)

- First Slovenian Report under the Joint Convention on the Safety of spent Fuel Management and on the Safety of Radioactive Waste Management, 2003
- First Slovenian Report under the Joint Convention on the Safety of spent Fuel Management and on the Safety of Radioactive Waste Management, 2005
- Annual Report 2003 on the Radiation and Nuclear Safety in the Republic of Slovenia
- Annual Report 2004 on the Radiation and Nuclear Safety in the Republic of Slovenia
- National Report on Fulfilment of the Obligations of the Convention on Nuclear Safety - the Second Slovenian Report in Accordance with Article 5, 2001
- National Report on Fulfilment of the Obligations of the Convention on Nuclear Safety - the Second Slovenian Report in Accordance with Article 5, 2004
- Environmental Radioactivity Monitoring in Slovenia, Power Point Presentation

NPP – KRŠKO

- Power Point presentation of the NPP

Jožef Stefan Institute

- Power Point presentation of Activities of the Technical Support Organisations in the radioactivity monitoring of the Krško NPP and the general environmental radioactivity monitoring in Republic of Slovenia

Environmental Agency

- Power Point presentation of Radiation monitoring network

APPENDIX 2

VERIFICATION PROGRAMME

Monday 12/06

1. Arrival at the Krško NPP site - site access formalities.
2. Opening meeting: introductions / presentations / programme of the visit.
3. Verification of the regulatory provision for monitoring/sampling of radioactive discharges of the Krško Reactor (airborne and liquid) and visit of the reactor's operations control room (team 1).
4. Verification of the operator's laboratory for site related environmental samples, its mobile monitoring equipment and the on-site sampling. (team 2).

Tuesday 13/06

5. Continuation. Verification of the operator's laboratory for discharge samples (team 1).
6. Verification of a representative selection of the site-related provisions for environmental monitoring/sampling; verification of a representative selection of the provisions for the national environmental monitoring/sampling programme (team 2).

Wednesday 14/06

7. Verification of the laboratories of the Institute of Occupational Safety and of the Jožef Stefan Institute. (team 2).
8. Verification of monitoring provisions in the surroundings of Ljubljana. (team 2).
9. Verification of the Ruđer Bošković Institute laboratories and of those of the Institute for Research and Occupational Health, Zagreb. (team 1).

Thursday 15/06

10. Verification of the telemetric network management and data centre and of facilities operated by the Environmental Protection Agency, Ljubljana (team 1 and 2).
11. Verification of national monitoring network installations in western Slovenia (team 1 and 2).

Friday 16/06

12. Closing meeting: presentation of preliminary verification findings (Ljubljana airport).

Team 1: C. Gitzinger and V. Tanner

Team 2: A. Godeanu Metz, E. Henrich and M. Betti (as trainee)

APPENDIX 3

REGULAR MONITORING PROGRAMME OF ENVIRONMENTAL RADIOACTIVITY IN SLOVENIA

	Sample type and analysis	Sampling location	Detailed description of sample	Sampling frequ.	Analysis frequ.	Lab.
1.0.	SURFACE WATERS (RIVERS)					
1.1.	Isotope analysis	SAVA (Ljubljana)	unfiltered river water	grab sample, semiannually	½ a	JSI
	HR gamma spectrometry	DRAVA (Maribor)			½ a	JSI
		MURA (Petanjci)			½ a	JSI
		SAVINJA (Celje)			½ a	JSI
1.2.	H-3 specific analysis	SAVA (Ljubljana)		grab sample, semiannually	½ a	JSI
		DRAVA (Maribor)			½ a	JSI
		MURA (Petanjci)			½ a	JSI
		SAVINJA (Celje)			½ a	JSI
1.3.	I-131	DRAVA (Dravograd)		grab sample, quarterly	quarterly	ZVD
		MURA (Petanjci)			quarterly	ZVD
2.0.	AIR					
2.1.	Isotope analysis	Ljubljana	continuous pumping, glass fibre filter [1]	weekly/monthly	monthly	JSI/ZVD [2]
	HR gamma spectrometry	Maribor		weekly/monthly	monthly	JSI/ZVD
		Predmeja		weekly/monthly	monthly	JSI/ZVD

(1) … formerly, paper filters were used that were changed daily
(2) … ZVD until 2005; JSI currently

	Sample type and analysis	Sampling location	Detailed description of sample	Sampling frequ.	Analysis frequ.	Lab.
3.0.	SOIL					
3.1.	Isotope analysis HR gamma spectrometry	Ljubljana Kobarid Murska Sobota	Uncultivated soil depth layers: 0 - 5 cm 5 - 10 cm 10 - 15 cm	½ a ½ a ½ a	½ a ½ a ½ a y	ZVD ZVD ZVD
3.2.	Specific analysis Sr-90	Ljubljana Kobarid Murska Sobota	Uncultivated soil depth layers: 0 - 5 cm 5 - 10 cm 10 - 15 cm	½ a ½ a ½ a	½ a ½ a ½ a	ZVD ZVD ZVD
3.3.	External radiation, gamma dose rate	59 locations, two networks (EARS & SNSA, June 2006)	continuous measurement	Contin.	Contin. hourly Eval.	EARS& SNSA
3.4.	Ambient dose equivalent (TLD)	50 locations (grid of 20 x 20 km)		Contin.	½ a	JSI

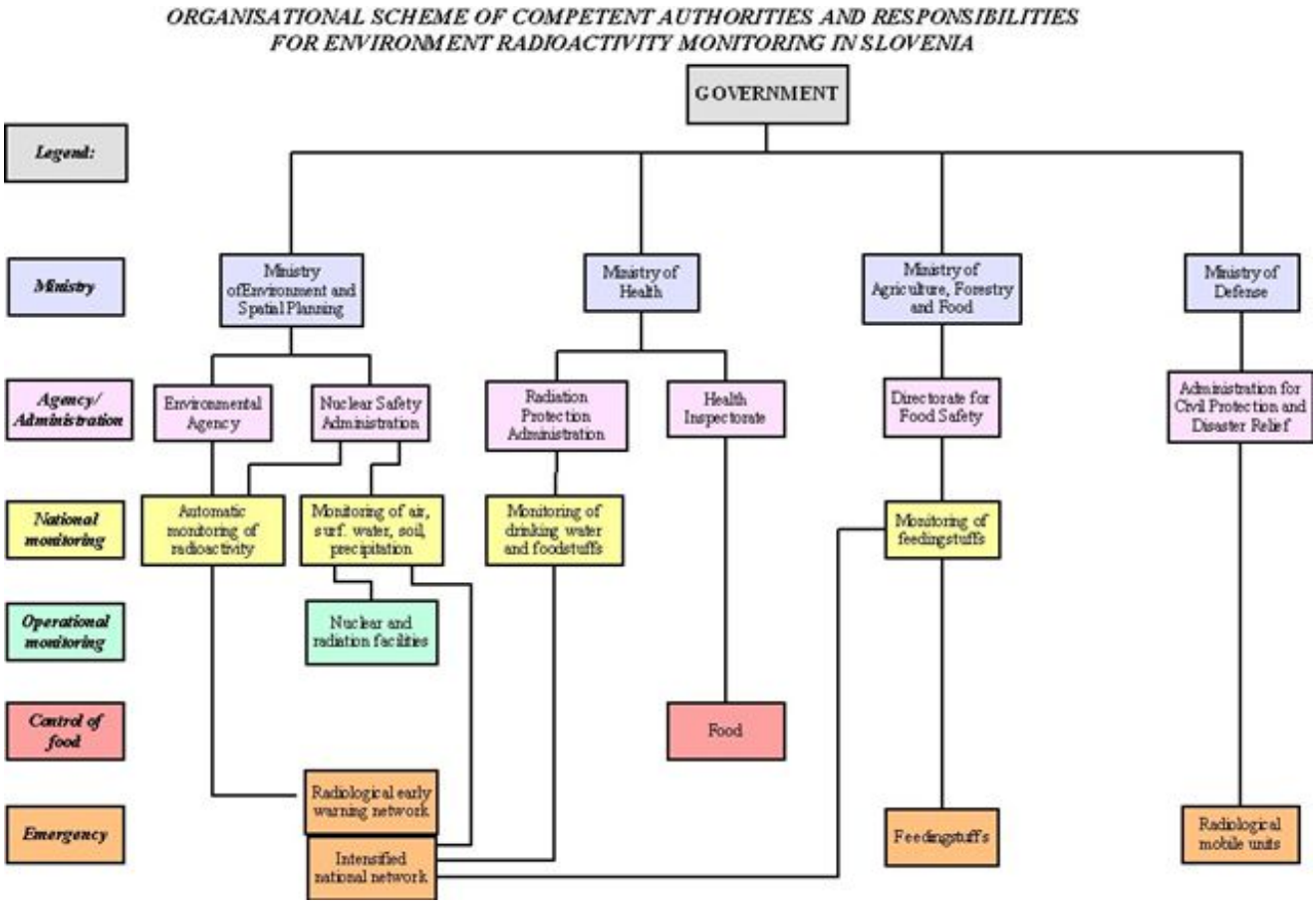
	Sample type and analysis	Sampling location	Detailed description of sample	Sampling frequency	Analysis frequency	Lab.
4.0.	DRY AND WET DEPOSITION					
	Isotope analysis		Monthly			
4.1.		Ljubljana	collected dry and wet	Contin.	monthly	ZVD
	HR gamma spectrometry	Bovec	deposition	monthly	quarterly	ZVD
		Murska Sobota			quarterly	ZVD
		Novo mesto			quarterly	ZVD
			Monthly			
4.2.	Specific analysis Sr-90	Ljubljana	collected dry and wet	Contin.	monthly	ZVD
		Kobarid	deposition	monthly	quarterly	ZVD
		Murska Sobota			quarterly	ZVD
		Novo mesto			quarterly	ZVD
			Monthly			
4.3.	Specific analysis H-3	Ljubljana	collected dry and wet	Contin.	quarterly	JSI
			deposition	monthly		
5.0.	DRINKING WATER					
	Isotope analysis					
			tap water, grab			
5.1.	HR gamma spectrometry	16 towns or bigger	sample	annually	annually	JSI
5.2.	Specific analysis H-3	settlements		annually	annually	JSI
5.3.	Specific analysis Sr-90			annually	annually	JSI

	Sample type and analysis	Sampling location	Detailed description of sample	Sampling frequency	Analysis frequency	Lab.
6.	FOODSTUFFS					
6.1.	Foodstuffs of plant origin					
6.1.1.	Vegetables	Ljubljana	7 most frequently used vegetables: potato, green salad, spinach, carrots, cabbage, beans, tomato	seasonal	annually	ZVD
6.1.1.1.	Isotope analysis HR gamma spectrometry	Novo mesto Koper, Celje Murska Sobota				
6.1.1.2.	Specific analysis Sr-90	Ljubljana Novo mesto Koper Murska Sobota Celje	7 most frequently used vegetables: potato, green salad, spinach, carrots, cabbage, beans, tomato	seasonal	annually	ZVD
6.1.2.	Fruits	Ljubljana	apples, peaches, cherries, plums, pears, strawberries	seasonal	annually	ZVD
6.1.2.1.	Isotope analysis HR gamma spectrometry	Novo mesto Koper, Celje Nova Gorica Maribor				
6.1.2.2.	Specific analysis Sr-90	Ljubljana Novo mesto Koper, Celje Nova Gorica Maribor	apples, peaches, cherries, plums, pears, strawberries	seasonal	annually	ZVD
6.1.3.	Cereals, bread	Ljubljana	wheat, maize, rye barley bread, wheat flour	annually	annually	ZVD
6.1.3.1.	Isotope analysis HR gamma spectrometry	Novo mesto Koper, Celje Murska Sobota		annually	annually	ZVD
6.1.3.2.	Specific analysis Sr-90	Ljubljana Novo mesto Koper, Celje Murska Sobota	wheat, maize, rye barley bread, wheat flour	annually	annually	ZVD
6.2.	Foodstuffs of animal origin					
6.2.1.	Isotope analysis HR gamma spectrometry	Ljubljana	milk	bimonthly	bimonthly	ZVD
		Bohinjska Bistrica	milk			ZVD
		Kobarid	milk			ZVD

	Sample type and analysis	Sampling location	Detailed description of sample	Sampling frequency	Analysis frequency	Lab.
		Murska Sobota	powdered milk			ZVD
6.2.2.	Specific analysis Sr-90	Ljubljana	milk	bimonthly	bimonthly	ZVD
		Bohinjska Bistrica	milk			ZVD
		Kobarid	milk			ZVD
		Murska Sobota	powdered milk			ZVD
6.2.3.	Isotope analysis HR gamma spectrometry	Ljubljana	cheese, eggs,	annually	annually	ZVD
		Novo mesto	beef, pork, poultry,			
		Koper, Celje	honey,			
		Murska Sobota	game, fish			
6.2.4.	Specific analysis Sr-90	Ljubljana	pork, beef	annually	annually	ZVD
		Bohinjska Bistrica	cheese			
		Murska Sobota				
7.	FEEDINGSTUFFS					
7.1.	Isotope analysis HR gamma spectrometry	main agricultural regions	10 samples: hay, silage, concentrates, additives	annually	annually	JSI
7.2.	Specific analysis Sr-90	main agricultural regions	hay, silage, concentrates, additives	annually	annually	JSI

APPENDIX 4

ORGANISATIONAL SCHEME OF COMPETENT AUTHORITIES IN SLOVENIA WITH REGARD TO MONITORING OF ENVIRONMENTAL RADIOACTIVITY



APPENDIX 5

LIST OF LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

General

(1) Act on Ionising Radiation Protection and Nuclear Safety (RPNS), (OJ RS, No. 67/2002, 102//2004)

a. Article 123 - monitoring radioactivity in the environment

b. Article 124- operational monitoring of radioactivity

For nuclear and radiation facilities

(2) RPNS Act, OJ RS, No. 67/2002, 102/2004

a. Article 71 consent to construction licence

b. Article 79 application for operation licence

c. Article 80 operation licence

Various

(3) Regulation, on Methods, Scope and Time Limits for Systematic Examinations of Contamination with Radioactive Materials in the Surroundings of Nuclear Facilities, (OJ SFRY, No. 51/1986)

(4) Decree on designation of institutions complying with conditions for radiation monitoring (OJ SFRY No. 40/86)

(5) Regulations on methods and time limits of reporting to Energy inspectorate of the Republic of Slovenia (OJ RS 12/81-1007)

(6) Constitutional Act on implementation of basic constitutional document art. 4, (OJ RS. 1/91-I), that provides implementation of the former Yugoslav legislation until the new one is in force

(7) Decree on radiation practices (OJ RS, 49/2004)

(8) Decree on dose limits, radioactive contamination and intervention levels (OJ RS 49/2004)

List of legislative acts establishing the responsibilities of the various actors in this domain

(9) Article 123 and 128; RPNS Act, OJ. RS, No. 67/2002, 102/2004

For radiological surveillance of foodstuffs

(10) Act on Ionising Radiation Protection and Nuclear Safety (OJ RS, No.102/04 - official consolidated text), art. 123.

(11) Decree on dose limits, radioactive contamination and intervention levels (OJ RS, No. 49/2004), art. 29 and art. 38 (operative intervention levels for foodstuffs)

(12) Act on Health and Hygiene Safety of Foodstuffs and Products and Materials Coming in Contact with Foodstuffs (OJ RS, No. 52/2000, 42/2002, 47/2004)

(13) Regulations on drinking water (OJ RS, No. 19/2004, 35/2004, 26/2006), appendix I, part C

(14) Regulations on places, methods and time limits for examinations of radioactive contamination - Z1 (OJ SFRY, No. 40/86)

(15) Decree on carrying out Regulations of the Council of the European Union and the European Commission on radioactive contamination of foodstuffs and feedingstuffs (OJ RS No. 52/2006)

(16) Regulations on monitoring of radioactivity (JV 10, draft)

Guidance documents

(17) Main international guidance documents (IAEA, ICRP, EU) upon which the environmental radioactivity monitoring and the radiological surveillance of foodstuffs are based.

Environmental radioactivity (for draft regulations)

(18) Regulations on places, methods and time limits for examinations of radioactive contamination - Z1 (OJ SFRY, No. 40/86)

(19) Environmental and Source Monitoring for Purposes of Radiation Protection Safety Standards Series No. RS-G-1.8

(20) 2004/2/Euratom Commission recommendation of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into environment from nuclear power reactors and reprocessing plants in normal operation

(21) 2000/473/Euratom Commission Recommendation of 8 June 2000 on the application of Article 36 of the EURATOM Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole.

(22) Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment, Safety Reports Series No. 19, IAEA, Vienna, 2001

(23) Guidance on the realistic assessment of radiation doses to members of the public due to operation of nuclear installation under normal conditions, Recommendations of the group of experts set up under the terms of Article 31of the EURATOM Treaty, Radiation protection 127, 2002

(24) Strategies for Monitoring Radionuclides in the Environment, Working Material, Draft Safety Guide DS62, Version 0.3b, October 2002

Radiological surveillance of foodstuffs (for draft regulations)

(25) Council Directive 96/29/EURATOM laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation

(26) Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption

(27) 2000/473/Euratom Commission recommendation of 8 June 2000 on the application of Article 36 of the EURATOM Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole

(28) 2001/928/Euratom Commission recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies

(29) Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment, Radiation Protection 72, European Commission, EUR 15760 EN

(30) Guidance on the realistic assessment of radiation doses to member of the public due to the operation of nuclear installations under normal conditions Radiation Protection 129, European Commission, 2002

(31) IAEA TECDOC–955. Generic assessment procedures for determining protective actions during a reactor accident, 1997

(32) IAEA Safety Reports Series No. 19 Generic Models for Use in Assessing the Impact of Discharge of Radioactive Substances to the Environment, 2001

APPENDIX 6

THE STATUTORY DISCHARGE MONITORING PROGRAMME (AIRBORNE AND LIQUID) AND RELATED INSTRUMENTATION AT THE KRŠKO NPP

Table 1. Radioactive liquid effluent monitoring instrumentation

INSTRUMENT
1. Radioactivity Monitors Providing Alarm and Automatic Termination of Release a. Liquid Radwaste Effluent Line b. Steam Generator Blowdown Effluent Line
2. Radioactivity Monitors Providing Alarm But Not Providing Automatic Termination of Release a. Service Water System Effluent Line b. Component Cooling Water System
3. Continuous Composite Samplers and Sampler Flow Monitor a. Steam Generator Blowdown Effluent Line (alternate to Item 1.b.)
4. Flow Rate Measurement Devices a. Liquid Radwaste Effluent Line b. Steam Generator Blowdown Effluent Line c. Discharge Canal

Table 2. Radioactive liquid waste sampling and analysis program

LIQUID RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (Bq/m^3)
1. Batch Waste Release (2) a. Waste Monitor (WMT) Tank No. 1 b. Waste Monitor (WMT) Tank No. 2 c. Turbine Building Condensate Transfer Tank d. Component Cooling Building Sump	P Each batch	P Each batch	Principal gamma emitters (3) I-131 H-3	$1.9x10^4$ $3.7x10^4$ $3.7x10^5$
	P Each WMT batch	M	Dissolved and entrained gases (gamma emitters)	$3.7x10^5$
	P Each WMT batch	M Composite(4)	H-3 Gross alpha	$3.7x10^5$ $3.7x10^3$
	P Each WMT batch	Q Composite(4)	Sr-89, Sr-90 Fe-55	$1.9x10^3$ $3.7x10^4$
2. Continuous Releases(5) a. Steam Generator Blowdown SystemDischarges (SGBD) b. Essential Service Water (ESW) Discharge	Continuous(6) - of ESW P, S – SGBD Grab sample	W Composite(6) - of ESW W Composite(4) - of SGBD	Principal gamma emitters(3) H-3	$1.9x10^4$ $3.7x10^5$
	P - SGBD Grab Sample	P Composite(4) - of SGBD	Dissolved and entrained gases	$3.7x10^5$
	P, S – SGBD Grab sample	M Composite(4) - of SGBD	H-3 Gross alpha	$3.7x10^5$ $3.7x10^3$
	P, S – SGBD Grab sample	M Composite(4) - of SGBD	Sr-89, Sr-90 Fe-55	$1.9x10^3$ $3.7x10^4$

Note: For 1.c, 1.d and 2.b Principal gamma emitters and H-3 only (for H-3 in ESW Discharges composite samples minimum analysis frequency is M – monthly)

P … each purge/batch; M … monthly; Q … quarterly; S … semi-annually

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TABLE ANNOTATIONS

(1) The Lower Limit of Detection (LLD) is defined, for purposes of these controls, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected

with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.
For a particular measurement system, this may include radiochemical separation:

$$LLD = \frac{(4.66)\cdot(Sb)}{(E)\cdot(V)\cdot(Y)}\cdot e^{(\lambda\cdot t)}$$

Where:

LLD = the "a priori" lower limit of detection (in Bq per unit mass or volume).
S_b = the standard deviation of background counting rate or of the counting rate of a blank sample as appropriate (as count per second).
E = the counting efficiency (as counts per disintegration).
V = the sample size (in units of mass or volume).
Y = the fractional radiochemical yield (when applicable).
λ = the radioactive decay constant for the particular radionuclide (1/s), and
t = the elapsed time between midpoint of sample collection and time of counting (s).

Typical values of E, V, Y and t should be used in the calculation.
It should be recognised that the LLD is defined as an a priori (before the fact) limit representing the capability of a measurement system and not as a posterior (after the fact) limit for a particular measurement.

(2) A batch release is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed by a pump in recirculation mode, to assure representative sampling.

(3) The principal gamma emitters for which the LLD control applies include the following radionuclides: Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, Ce-141. Ce-144 shall also be measured, but with an LLD of 1.85. 10^4 Bq/m^3. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall also be analyzed and reported in Radioactive Effluent Release Report pursuant to Reporting Requirements.

(4) A composite sample is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

(5) A continuous release is the discharge of liquid wastes of a non discrete volume; e.g., from a volume of system that has an input flow during the continuous release.

(6) To be representative of the quantities and concentrations of radioactive materials in liquid effluents, samples shall be collected continuously in proportion to the rate of flow of the effluent stream. Prior to analyses, all samples taken for the composite shall be thoroughly mixed in order for the composite sample to be representative of the effluent release.

NOTE: Grab samples of circulating water (CW) are collected and analyzed once a week for gamma and tritium analysis.

Table 3. Radioactive gaseous effluent monitoring instrumentation

INSTRUMENT
1. Waste Gas Holdup System a. Noble Gas Activity Monitor - Providing Alarm and Automatic Termination of Release b. Iodine Sample c. Particulate Sample d. Flow Control valve e. Sampling Flow
a. Noble Gas Activity Monitor b. Flow Rate Monitor c. Sampler Flow Rate Monitor
3. Vent Header System a. Noble Gas Activity Monitor b. Iodine Samplers c. Particulate Samplers d. Flow Rate Monitor e. Sampler Flow Rate Monitor
4. Containment Purge System a. Noble Gas Activity Monitor – Providing Alarm and Automatic Termination of Release b. Particulate Sampler (c. Flow Rate Monitor d. Sampler Flow Rate Monitor
5. Auxiliary Building Ventilation System a. Noble Gas Activity Monitor b. Iodine Sampler c. Particulates Sampler d. Sampler Flow Rate Monitor
6. Fuel Storage Area Ventilation System a. Noble Gas Activity Monitor b. Iodine Sampler c. Particulates Sampler d. Sampler Flow Rate Monitor
7. Radwaste Area Ventilation System a. Iodine Sampler (Radwaste Area) b. Particulates Sampler (Radwaste Area) c. Sampler Flow Rate Monitor
8. Decontamination Building a. Particulates Monitor Providing Alarm and Automatic Termination of Release b. Particulates and Iodine Sampler c. Flow Rate Monitor d. Sampler Flow Rate Monitor

Table 4. Radioactive gaseous waste sampling and analysis program

GASEOUS RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD [1] (Bq/m^3)
1. Waste Gas Storage Tank (GDT)	P Each tank grab sample	P Each tank	Principal gamma emitters[2]	$3.7x10^6$
2. Containment	P Each PURGE[3][4] and W	P Each PURGE[3] W	Principal gamma emitters[2]	$3.7x10^6$
3.a Plant Vent	W[3][4] Continuous Continuous	W[3] M M	Principal gamma emitters[2] H-3 (oxide) C-14	$3.7x10^6$ $3.7x10^3$ $3.7x10^1$
3.b Fuel Handling Bldg. Vent	M[5]	M	Principal gamma emitters[2]	$3.7x10^6$
3.c Condenser Air Removal	W Grab sample	W	Principal gamma emitters[2]	$3.7x10^6$
4.a Plant Vent 4.b Fuel H. Bldg. 4.c Aux. Bldg. 4.d Radwaste Storage	Continuous[6]	W[7] Charcoal sampling	I-131	0.037
	Continuous[6]	W[7] Particulate sample	Principal gamma emitters[2]	0.37
5.a Plant Vent	Continuous[6]	M Composite particulate sample	Gross alpha	0.37
	Continuous[6]	Q Composite particulate sample	Sr-89, Sr-90	0.37
6.a Containment Air 6.b Plant Vent FHB 6.c AB Vent 6.d Condenser Air Removal	Continuous[6]	Noble gas monitor	Noble gas beta or gamma	$3.7x10^4$
7. Decontamination Building	Continuous[6]	W Particulate sample	Principal gamma emitters[2]	$3.7x10^6$

D … daily; W … weekly; P … each purge/batch; M … monthly

TABLE ANNOTATIONS

(1) The Lower Limit of Detection (LLD) is defined as the smallest specific activity of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal. For a particular measurement system, which may include radiochemical separation:

$$LLD = \frac{(4.66)\cdot(Sb)}{(E)\cdot(V)\cdot(Y)}\cdot e^{(\lambda\cdot t)}$$

Where:

LLD = the "a priori" lower limit of detection in Bq per unit mass or volume.
Sb = the standard deviation of background counting rate or of the counting rate of a blank sample as appropriate (as count per second)
E = the counting efficiency (as counts per disintegration)
V = the sample size (in units of mass or volume)
Y = the fractional radiochemical yield (when applicable)

λ = the radioactive decay constant for the particular radionuclide (1/s), and
t = the elapsed time between midpoint of sample collection and time of counting (s).

Typical values of E, V, Y and t should be used in the calculation.

It should be recognized that the LLD is defined as an a priori (before the fact) limit representing the capability of a measurement system and not as a posterior (after the fact) limit for a particular measurement.

(2) The principal gamma emitters for which the LLD specification applies include the following radionuclides: Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, and Xe-138 in noble gas release and Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, I-131, Cs-134, Cs-137, Ce-141 and Ce-144 in Iodine and particulate releases. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall also be analysed and reported in the Radioactive Effluent Release Report pursuant to the Reporting Requirements.

(3) Sampling and analyses shall also be performed following shutdown, startup, or a THERMAL POWER change exceeding 15 percent of RATED THERMAL POWER within a one hour period.

(4) Tritium grab samples from the Plant Vent shall be taken at least once per 24 hours when the refuelling channel is flooded or during containment purge. (Note that there is a continuous sampler in place)

(5) Tritium grab samples shall be taken at least once per 7 days from the ventilation exhaust from the spent fuel pool area (or from the header), whenever spent fuel is in spent fuel pool. (Note that there is a continuous sampler in place)

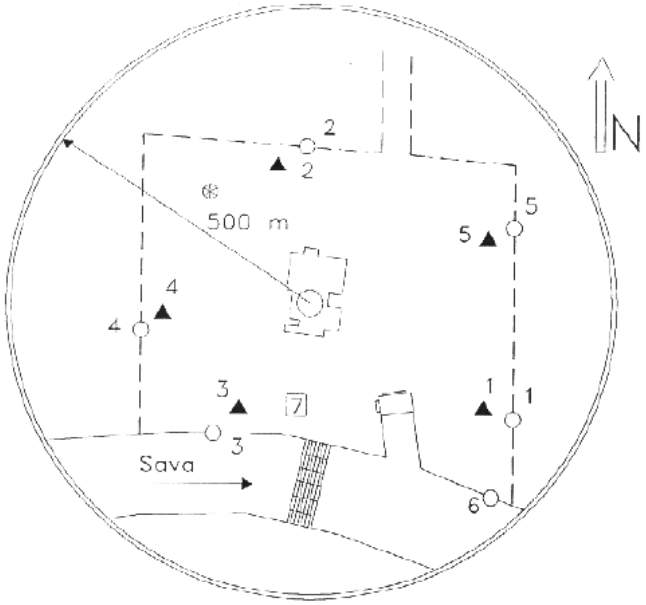
(6) The ratio of the sample flow rate to the sampled stream flow rate shall be known for the time period covered by each dose or dose rate calculation made in accordance with certain procedures.

(7) Samples shall be changed at least once per 7 days and analyses shall be completed within 48 hours after changing, or after removal from sampler. Sampling shall also be performed at least once per 24 hours for at least 7 days following each shutdown, start up, or THERMAL POWER change exceeding 15% of RATED THERMAL POWER in one hour and analyses shall be completed within 48 hours of changing. When samples collected for 24 hours are analyzed, the corresponding LLDs may be increased by a factor of 10. This requirement does not apply if: (1) analysis shows that DOSE EQUIVALENT I-131 concentration in the reactor coolant has not increased more than a factor of 3; and (2) the noble gas monitor shows that effluent activity has not increased more than a factor of 3.

APPENDIX 7

KRŠKO-NPP ON-SITE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

The on-site monitoring covers air, dose (via TLD) and surface water. A map showing the sampling and measuring locations is given below (courtesy SNSA). In addition, precipitation level is measured near the meteorological tower with ombrometer and recorded automatically. There, also dose-rate and air monitoring using automatic devices is performed.



○ TLD(thermoluminiscent dosemeters) (monthly, quarterly and annualy measurements)

▲ Air pumps with charcoal and fiberglass filters

7 Continuous sampling of ESW

⊕ Meteorological tower with continuous dose rate monitor

APPENDIX 8

KRŠKO-NPP OFF-SITE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

Overview map giving the measuring and sampling locations (courtesy SNSA):

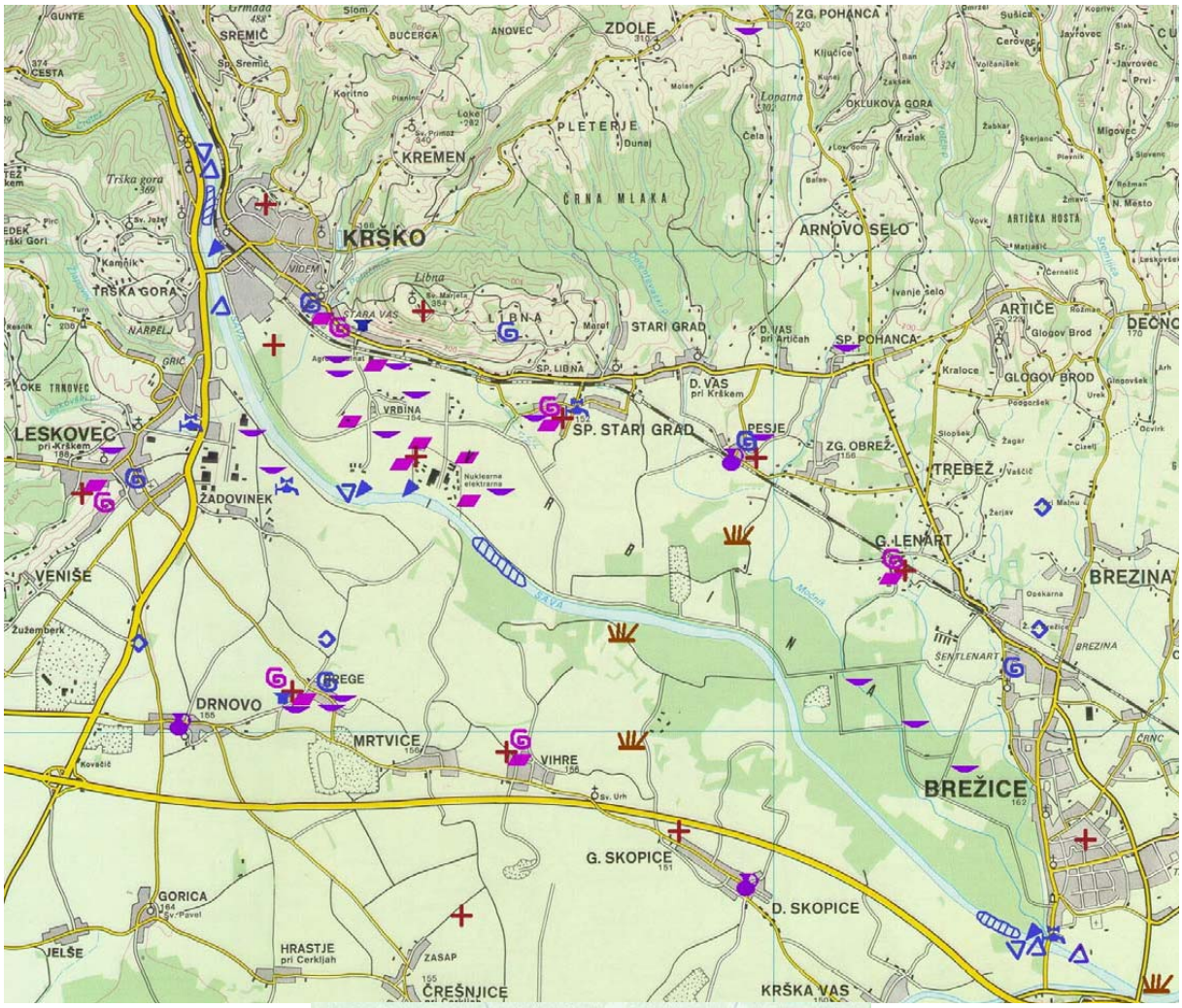


Table 1. Surface water – River Sava

Location	Sample type	Sampling time	Collection frequency	
			Gamma nuclides, Sr-89/Sr-90	Tritium (water)
Krško – 4 km upstream of NPP	Water, suspended matter, filtered matter	1 month	quarterly	monthly
Brežice – 7.8 km downstream of NPP	Water, suspended matter, filtered matter	1 month	monthly *)	monthly
Jesenice na Dolenjskem, 17.5 km downstream of NPP	Water, suspended matter, filtered matter	1 month	monthly *)	monthly

*) … Sr-89 and Sr-90 in filtered matter: quarterly

Table 2. Sediments, water, water biota – River Sava

Location	Sampling type	Collection frequency
Left bank – 0.5 km upstream of NPP	grab	quarterly
Left bank; Brežice – 7.8 km downstream of NPP	grab	quarterly
Right bank; Jesenice na Dolenjskem, 17.5 km downstream of NPP	grab	quarterly
Podsused (Croatia) *)	grab	semi-annually

*) Additional tritium determination in water

Table 3. Drinking water, wells

Gamma emitters, Sr-89/Sr-90 and Tritium

Location	Sampling type	Collection frequency
Krško (water supply)	monthly grab	monthly
Brežice (water supply)	monthly grab	monthly
Orchard at NEK (replaced by on-site well E1)	quarterly grab	quarterly
Water pump station Krško – Beli breg	daily	monthly
Water pump station Krško – Brege	daily	monthly
Water catchment Dolenja vas	daily	monthly
Water pump station Brežice VT1 and 481	daily	monthly
Water well Medsave (Croatia)	daily	monthly
Water well Šibice (Croatia)	daily	monthly

Table 4. Air

Locations	Type *)	Duration of Sampling	Measuring interval
Sp. Stari Grad, Stara vas, Leskovec, Brege, Vihre, Gornji Lenart, Spodnja Libna	B-I	15 days	15 days
Dobova	A-III	quarterly	quarterly
Sp. Libna, Dobova, Stara vas, Leskovec, Vihre, Gornji Lenart, Brege, Spodnji Stari Grad	A-I	monthly	monthly

*) … A – aerosols on glass fibre filters; B – charcoal cartridges;

I – Gamma spectroscopy; II – I-131 and noble gases; III – Sr-89/Sr-90

Table 5. Dose, dose rate

Locations	Type	Sampling/measuring frequency
67 locations in the circular zone 1.5 to 10 km around the NPP; plus 10 locations in Croatia	TLD	semiannually
Krško (2), Brežice, Cerklje, Libna, Sp. Stari Grad, Pesje, Gornji Lenart, Skopice, Vihre, Brege, Leskovec	Ambient gamma dose rate	Continuous, automatic

Table 6. Soil

Layers: 0-5, 5-10, 10-15, 15-30 cm; Grassland or cultivated; Analysis of gamma emitters, Sr-89/Sr-90
Locations: Amerika, Trnje (Kusova Vrbina), Gmajnice (Vihre)

Table 7. Food

Medium	Locations	Analysis *)	Sampling/measuring frequency
Milk	Pesje, Drnovo, Skopice	G, Sr, I	monthly
Fruit	Selected locations in Krško – Brežice area; orchards near NPP; Sremič, Leskovec	G, Sr	yearly
Vegetables, cereals	Selected locations in Krško – Brežice area; Brege, Žadovinek, Vrbina, Sp. Stari Grad, Trnje	G, Sr	monthly
Meat, poultry, eggs	Selected locations in Krško – Brežice area; Žadovinek, Vrbina, Sp. Stari Grad, Pesje	G, Sr	monthly

*) … G: Gamma spectroscopy; Sr: Sr-89/Sr-90; I: I-131 (only during grazing period)

APPENDIX 9

SLOVENIAN DOSE RATE, AIR ACTIVITY AND TLD MONITORING NETWORKS

(Maps courtesy SNSA)

Fig. 1: Automatic ambient gamma dose rate monitoring stations:

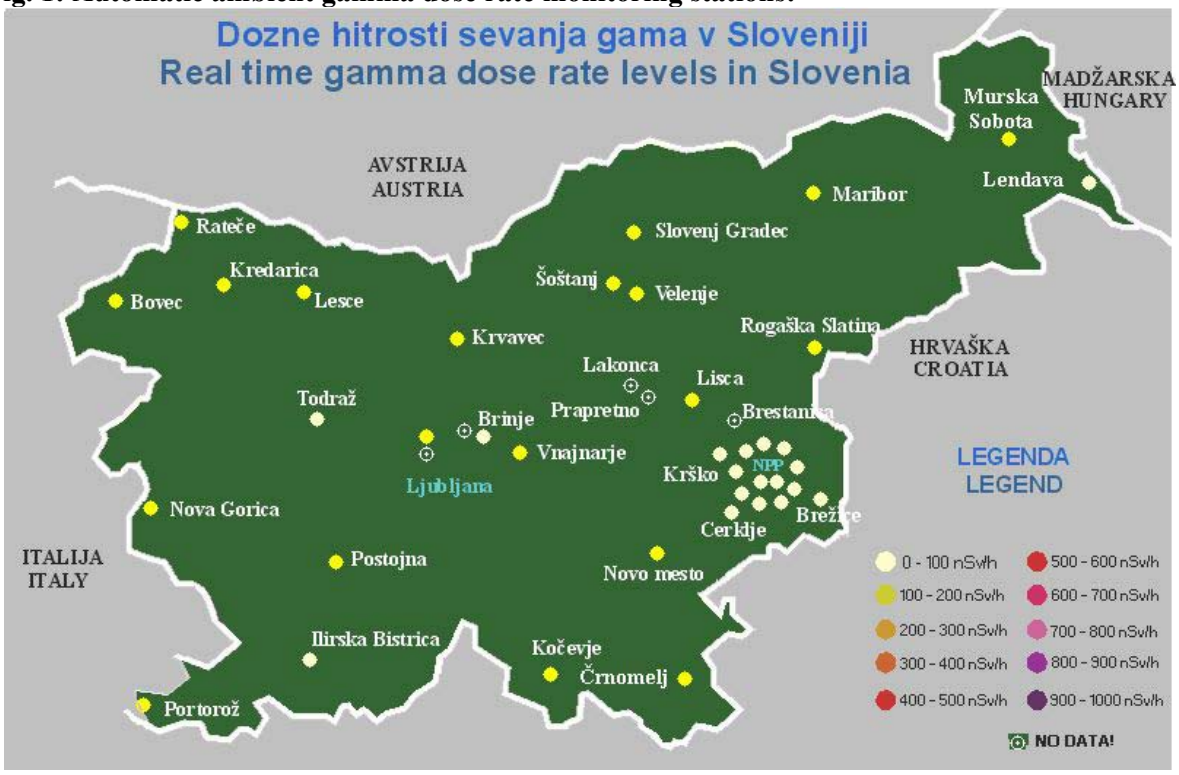
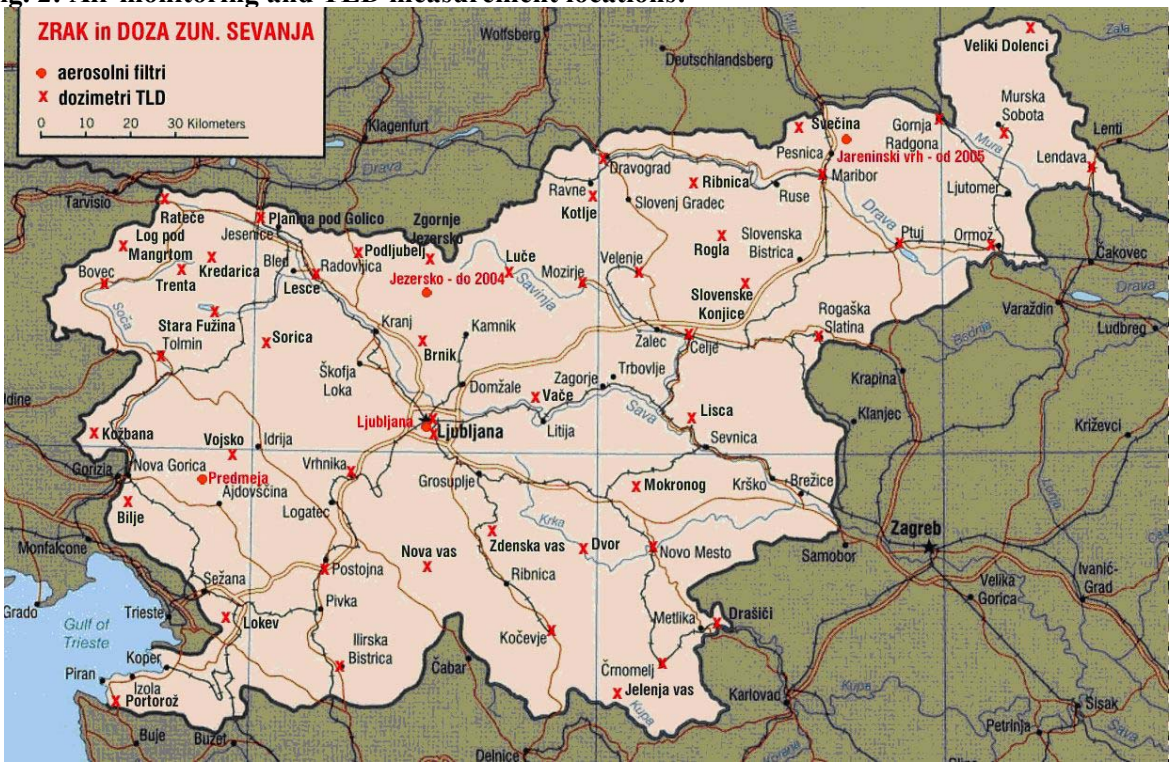


Fig. 2: Air monitoring and TLD measurement locations:

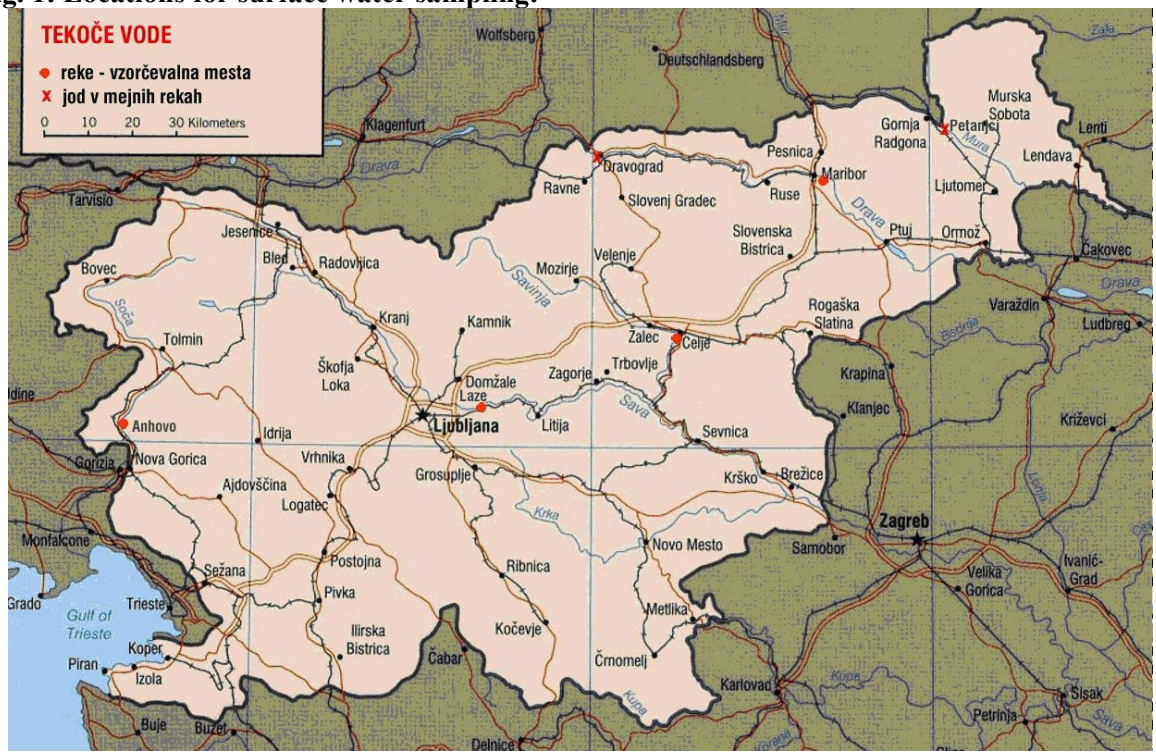


APPENDIX 10

SLOVENIAN LABORATORY BASED ENVIRONMENTAL RADIOACTIVITY MONITORING NETWORK

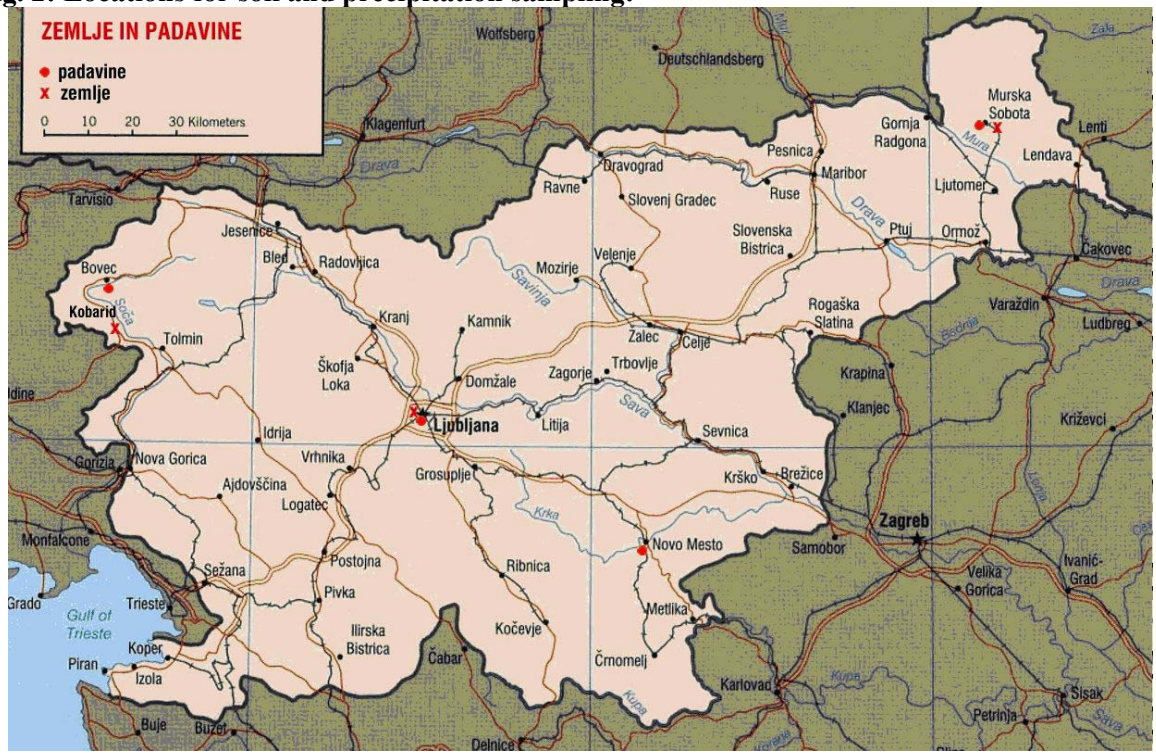
(Maps courtesy SNSA)

Fig. 1: Locations for surface water sampling:



● … rivers downstream large towns x … Iodine measurement at transboundary rivers (from Austria)

Fig. 2: Locations for soil and precipitation sampling:

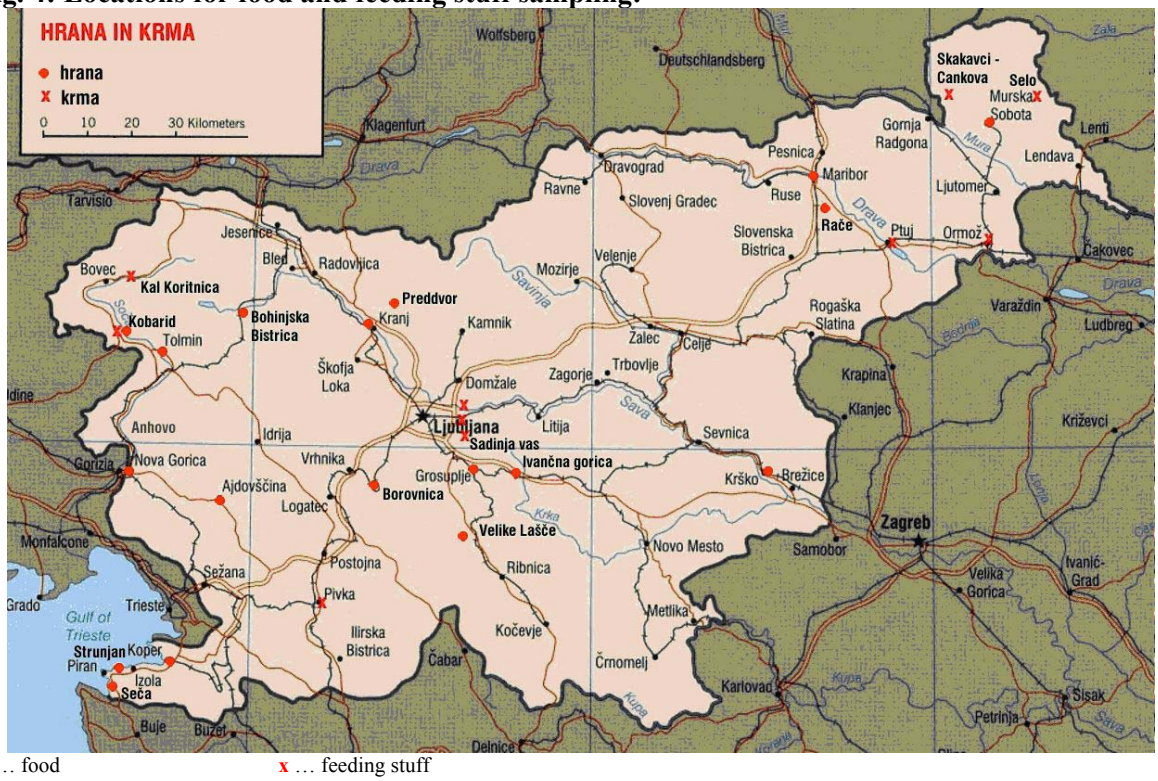


● … precipitation x … soil

Fig. 3: Locations for drinking water sampling:

● … 1st half 2004 x … 2nd half 2004 ■ … 2005 ▲ … 2006

Fig. 4: Locations for food and feeding stuff sampling:



● … food x … feeding stuff