EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY

DIRECTORATE D - Nuclear Safety and Fuel Cycle
Radiation Protection

TECHNICAL REPORT

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

DOEL NUCLEAR POWER STATION

and the national network of environmental radiological monitoring
Belgium

18 to 22 June 2012

Reference: BE-12/02

VERIFICATIONS UNDER THE TERMS OF ARTICLE 35 OF THE EURATOM TREATY

FACILITIES: Installations for monitoring and controlling radioactive discharges and surveillance of the environment during normal operations of the Doel nuclear power station; facilities of the Belgian national networks for the surveillance of environmental radioactivity.

SITE: Doel, Belgium

DATE: 18 to 22 June 2012

REFERENCE: BE-12/02

INSPECTORS: C. Gitzinger (Head of team)
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DATE OF REPORT: 22 January 2013

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ABBREVIATIONS AND ACRONYMS

ADSL	Asymmetric Digital Subscriber Line (telecommunication)
AFCN	*Agence Fédérale de Contrôle Nucléaire* (*Federaal Agentschap voor Nucleaire Contrôle*, Federal Agency for Nuclear Control)
AFSCA	*Agence Fédérale pour la Sécurité de la Chaîne Alimentaire* (*Federaal Agentschap voor de veiligheid van de voedselketen*; Federal Agency for the Security of the Food Chain)
ALARA	As Low As Reasonably Achievable
Bel V	*Technical support organisation for and subsidiary of FANC*
BELAC	BELgian ACcreditation authority
CELEVAL	*CELlule EVALuation* (evaluation cell) of the CGCCR
CELEMES	*CELlule MESure* (measurement cell) of the CGCCR
CERN	*(Centre) organisation Européenne pour la Recherche Nucléaire* (European Organization for Nuclear Research)
CGCCR	*Centre Gouvernemental de Coordination et de Crise* (Governmental Crisis and Coordination Centre)
CPU	Central Processing Unit
CW	Circulation Water
DG ENER	Directorate-General for Energy (European Commission)
DIS	DIScontinuous (intermittent) discharge
DSL	Digital Subscriber Line (telecommunication)
DT	Floor drains WAB
EC	European Commission
EHS	Environment, Health and Safety (Institute of SCK•CEN)
ELK	*Enliga Lozingen Kanal* (discharge collector channel)
EV	Emergency Vent
FANC	Federal Agency for Nuclear Control *(Federaal Agentschap voor Nucleaire Contrôle; Agence Fédérale de Contrôle Nucléaire AFCN)*
FWHM	Full Width Half Maximum
GLTOE	Department: Health & Environment, Service: Surveillance of the Territory and Natural Radiation
GM	Geiger-Müller (radiation detector)
GNH	(nuclear auxiliary building)
GPRS	General Packet Radio Service (telecommunication)
GPS	Global Positioning System
GSL	(building for secondary discharges)
GW	Gaseous Waste
HPGe	High Purity Germanium (radiation detector)
HV	High Voltage
IANBI	Department: Installations & Waste, Service: Basic Nuclear Installations
IMA	(urban area monitoring station of the TELERAD system)
IMN	(national territory monitoring station of the TELERAD system)
IMR	(ring monitoring station of the TELERAD system)
IMW	(surface water monitoring station of the TELERAD system)
INES	International Nuclear Event Scale

IRE	Institute for RadioElements
IRE-ELiT	Institute for RadioElements - Environment and Lifescience Technology
ISO	International Organization for Standardization
KCD	*Kerncentrale Doel* (Doel NPP)
KON	(continuous discharge)
LIMS	Laboratory Information Management System
LLD	Lower Limit of Detection
LNW	(storage tank)
LOCA	Loss Of Coolant Accident
LRM	Low-level Radioactivity Measurements (expert group at SCK•CEN)
LSC	Liquid Scintillation Counting (radiation measurement)
MCA	Multi-Channel Analyzer
MDA	Minimum Detectable Activity
MV	Main Vent
NaI(Tl)	Sodium iodide, thallium activated (radiation detector)
NORM	Naturally Occurring Radioactive Material
NPP	Nuclear Power Plant
OBT	Organically Bound Tritium
OLL	(instantaneous gaseous discharge limits)
OSPAR	OSlo PARis (Convention)
PIPS	Passivated Implanted Planar Silicon (radiation detector)
PW	Demineralized Water Production
PWR	Pressurized Water Reactor
RGI	Reactor building or annular space
RN	(intermediate cooling)
ROI	Region Of Interest
RV	Reactor Vent
QA/QC	Quality Assurance / Quality Control
SCA	Single Channel Analyzer
SCK•CEN	*StudieCentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire* (Belgian Nuclear Research Centre)
SD	(waste water tank)
SLB	Steam Line Break
SN	Floculation
TELERAD	(continuous on-line radiation measurement system of FANC)
TLD	Thermoluminescence Dosimetry/Dosimeter
TS	Technical Specifications
WAB	*Water en AfvalBehandelingsgebouw* (water and waste treatment building)

1 INTRODUCTION

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

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

For the EC, the Directorate-General for Energy (DG ENER), and in particular its Radiation Protection Unit (currently ENER D.3), is responsible for undertaking these verifications.

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

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

For the purpose of such a review, a verification team from DG ENER visited Doel NPP from 18 to 22 June 2012. The visit to also included meetings with the Belgian competent authority, the Federal Agency for Nuclear Control (FANC; *Federaal Agentschap voor Nucleaire Controle*; *Agence Fédérale de Contrôle Nucléaire*, AFCN), the Belgian Technical Support Organization (Bel V), representatives of the Doel Nuclear Power Plant and of the Belgian Nuclear Research Centre (SCK•CKN, *StudieCentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire*).

Details of the verification programme are given under Section 2.3 below.

The present report contains the results of the verification team's review of relevant aspects of the environmental surveillance at and around the Doel NPP site. The purpose of the review was to provide independent verification of the adequacy of monitoring facilities for:

- Discharges of radioactivity into the environment.
- Levels of environmental radioactivity at the site perimeter and in the terrestrial and aquatic environment around the site, for all relevant exposure pathways.

With due consideration to the scope of the verification 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 operator's monitoring and control facilities for gaseous and liquid discharges of radioactivity into the environment.
- The implementation of the statutory environmental radioactivity monitoring programme as performed by FANC (regulator).
- The operator's effluent laboratories including aspects of quality assurance and control as well as document control.
- The national environmental monitoring programme as established by the competent authority (FANC) in the region of Doel NPP and on the territory of Belgium.
- The present report is also based on information collected from documents referred to in Chapter 2.2 and from discussions with various persons met during the visit, listed in Chapter 2.4 below.

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

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 INTRODUCTION

The Commission's request to conduct an Article 35 verification was notified to the Belgian authorities on 4 January 2012 (letter referenced ENER/D4/CG/es Ares (2012) 6765, addressed to the Permanent Representation of Belgium to the European Union). Subsequently, practical arrangements for the implementation of the verification were made with the persons designated by the Belgian authority.

2.2 DOCUMENTATION

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

2.3 PROGRAMME OF THE VISIT

The EC and the Belgian authority (FANC) discussed and agreed upon a programme of verification activities, with due respect to the Commission Communication[2] setting out the framework and modalities within which Article 35 verifications are to be conducted.

During the opening meeting introductory presentations were given on the following topics:

- Doel Nuclear Power Plant (Doel NPP);
- Environmental Radiological Monitoring Programmes (site related and national);
- the Belgian Technical Support Organisation (Bel V).

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

A summary overview of the programme of verification activities is provided in Appendix 2. The verifications were carried out in accordance with the programme.

2.4 REPRESENTATIVES OF THE COMPETENT AUTHORITIES, THE NPP OPERATOR AND OTHER ORGANISATIONS INVOLVED IN ENVIRONMENTAL RADIOACTIVITY MONITORING

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

FANC/AFCN

Willy De Roovere	Director-General
Patrick Van der Donckt	Director of the Health and Environment department
Yvan Pouleur	Director of the Regulation, International Affairs

2 Commission Communication "Verification of environmental radioactivity monitoring facilities under the terms of Article 35 of the Euratom Treaty — Practical arrangements for the conduct of verification visits in Member States", Official Journal (2006/C 155/02), 4 July 2006

	& Development department
Manfred Schrauben	Director of the Installations and Waste department
An Wertelaers	Head of the Service, Basic Nuclear Installations (IANBI)
Kamr Eddine Oulid Dren	Technical inspector IANBI
Frederik Van Wonterghem	Technical inspector IANBI
Michel Sonck	Head of the Service, Surveillance of the Territory and Natural Radiation (GLTOE)
Jurgen Claes	Environmental Radioactivity Expert GLTOE
Lionel Sombre	Environmental Radioactivity Expert GLTOE

SCK•CEN

Lies Sneyers	Laboratory for Low-level Radioactivity Measurements

Bel V

Etienne Minne	Operations Inspector
Dirk Asselbergh	Operations Inspector Doel NPP
Pierre Barras	Area Manager

Electrabel Doel NPP

Rikkert Wyckmans	Head of Radioprotection Doel
Bram Mayeur	Radioprotection Doel NPP

3 LEGISLATION AND COMPETENT AUTHORITIES

3.1 LEGAL PROVISIONS FOR ENVIRONMENTAL RADIOACTIVITY MONITORING

3.1.1 Legislative acts regulating environmental radioactivity monitoring

3.1.1.1 National level

- Law of 15 April 1994 on the protection of the population and the environment against the dangers resulting from ionising radiation and relating to the Federal Agency for Nuclear Control (amended by the Royal Decrees of 7 August 1995 and 22 February 2001 as well as by the Laws of 12 December 1997, of 15 January 1999, 3 May 1999, 10 February 2000, 19 July 2001, 31 January 2003, 1 April 2003, 22 December 2003, 20 July 2005, and also by the Act of 15 May 2007), Articles 12, 15 and 21, Belgian Official Gazette of 20 July 1994.

- Royal Decree of 20 July concerning the general regulations for the protection of the population, workers and the environment against the dangers of ionising radiation, Articles 70-71, Belgian Official Gazette of 30 August 2001, Volume 1.
- Franco-Belgian Cooperation Agreement relating to the Chooz nuclear power station situated on the Meuse in France close to the border with Belgium. This agreement provides for full monitoring on the Belgian territory of all means of transmitting radiation in the vicinity of the nuclear site as well as for a periodic exchange of results between the countries.

3.1.1.2 International legal framework

3.1.1.2.1 European Commission

Belgium, like every Member State of the European Union, is obliged to meet the requirements of the European Commission (EC) under Article 36 of the Euratom Treaty to communicate data on the monitoring of radioactivity in the environment (radioactivity of the air and airborne dusts, surface and drinking water, milk and foodstuffs).

The latter covers the new provisions on monitoring the food chain resulting from the post-Chernobyl protection measures as well as from Recital (2) of the 2000/473/Euratom Recommendation concerning Article 36 of the Euratom Treaty, which stipulates in point 4 that Member States must communicate to the Commission the data necessary for monitoring radioactivity in the 'mixed regime' in order to obtain overall information on the ingestion of radioactivity by humans through the food chain and, thus, on the doses released.

3.1.1.2.2 OSPAR (Oslo-Paris) Convention

The Convention on the protection of the marine environment of the North-East Atlantic – the 'OSPAR Convention' – was opened for signature at the ministerial meeting of the Oslo Commission (set up in 1972, concerning the dumping of waste at sea) and the Paris Commission (set up in 1974, relating to marine pollution of telluric origin) on 22 September 1992 in Paris.

The Convention was signed and ratified by all the original contracting parties to the Oslo and Paris Conventions (Belgium, the Commission of the European Communities, Denmark, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and Northern Ireland), as well as by Luxembourg and Switzerland). The OSPAR Convention of 1992 is the current instrument governing international co-operation on the protection of the marine environment of the North-East Atlantic.

The OSPAR Convention entered into force on 25 March 1998. Although it replaces the Oslo and Paris Conventions, the decisions, recommendations and all other agreements adopted pursuant to these previous Conventions will remain applicable and retain the same legal effect unless repealed by new measures adopted pursuant to the 1992 OSPAR Convention.

3.1.2 Legislative acts regulating the radiological surveillance of foodstuffs

- Law of 15 April 1994 on the protection of the population and the environment against the dangers resulting from ionising radiation and relating to the Federal Agency for Nuclear Control (amended by the Royal Decrees of 7 August 1995 and 22 February 2001 as well as by the Laws of 12 December 1997, of 15 January 1999, 3 May 1999, 10 February 2000, 19 July 2001, 31 January 2003, 1 April 2003, 22 December 2003, 20 July 2005, and also by the Law of 15 May 2007), Articles 12, 15 and 21, Belgian Official Gazette of 20 July 1994.
- Royal Decree of 20 July concerning the general regulations for the protection of the population, workers and the environment against the dangers of ionising radiation, Articles 70-71, Belgian Official Gazette of 30 August 2001, Volume 1.
- Act of 4 February 2000 on the establishment of the Federal Agency for the Safety of the Food Chain, Articles 4 and 5, Belgian Official Gazette of 18 February 2000.

- Agreement between the Federal Agency for Nuclear Control (FANC) and the Federal Agency for the Safety of the Food Chain (AFSCA) of 6 April 2004, amended in 2012.

3.1.3 Legislative acts regulating discharge monitoring

The main legal radiation protection instrument is the Royal Decree of 20 July 2001 concerning the general regulations for the protection of the population, workers and the environment against the dangers of ionising radiation (GRR-2001), in particular its Articles 20, 34 and 36.

This Royal Decree provides the basic nuclear safety and radiological protection regulations and is amended and updated regularly by the Safety Authorities in order to take account of scientific and technical developments, take into account European directives, etc.

GRR-2001 transposes relevant European Directives into Belgian Law, such as:

- the Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment;
- the Directive 89/618/Euratom on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological emergency;
- the Directive 90/641/Euratom on the operational protection of outside workers exposed to the risk of ionizing radiation during their activities in controlled areas;
- the Directive 1996/29/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.

It also covers the obligations resulting from the Euratom Treaty (e.g. Article 37).

Belgium is a Member State of the European Union and of the European Atomic Energy Community (Euratom), since their foundation in 1957. The Belgian rules and regulations within the field of radiological protection have been developed in implementation of and in accordance with the European Treaties and the relevant directives, as mentioned above.

The legislative texts governing radioactive discharges from the units at the Doel NPP (*Kerncentrale* Doel, KCD) are operating authorisations, in particular:

- Royal Decree of 25 January 1974 (S.3.497/C) for Doel 1/2;
- Royal Decree of 19 March 1982 (S.5599/B) for Doel 3;
- Royal Decree of 21 August 1984 (S.6941/B) for Doel 4.

The restrictions on discharges were established in the framework of Article 37 of the Euratom Treaty in November 1980. The limits thus established are listed in the safety reports of the various units.

The various limits on liquid and gaseous discharges that KCD is obliged to adhere to are listed in the Technical Specifications.

Discharges are defined as authorised and controlled releases into the environment, within limits set by the authority. In addition there are operational release limits (limiting the release on time based assumptions), related with a scheme to notify the operators, the Health Physics Department, Bel V and the FANC.

Following Article 81.2 of the GRR-2001, the existing authorised discharge limits (gaseous and liquid releases) have been re-evaluated since 2002. The evaluation has been formally agreed by the Scientific Council of the FANC in December 2006. The discharge limits, based on this evaluation, respect at least the annual dose to the public of 1 mSv.

3.1.4 Legislative acts establishing the responsibilities of the various actors

Article 23 of the Royal Decree of 20 July 2001 outlines the tasks of the physical inspections department of Doel with respect to the management of discharges. It specifies that physical inspection is responsible for: 'the establishment and keeping of a register in accordance with the modalities established in Article 23.2, for the record of liquid and gaseous discharges as well as for the record of the stored and evacuated solid radioactive waste, including wastes that can be disposed of, recycled or reused pursuant to Article 35.2;'

The Radioprotection Department at Doel is also responsible for reporting the liquid and gaseous discharges from the units at Doel on a monthly basis to the Federal Agency for Nuclear Control (FANC). This reporting obligation results from a notice of FANC 010-106-N-F 'Periodic reporting on the discharge of liquid and gaseous radioactive effluents to FANC and Bel V.' of 14 July 2010.

The obligation to report the discharges is also specified in the Safety Report and in the Technical Specifications.

3.2 BODIES HAVING COMPETENCE IN THE FIELD OF ENVIRONMENTAL RADIOACTIVITY MONITORING.

The following is a concise description of the principal bodies (regional as well as national) having competence in the field of radiation protection and more in particular with respect to:

- Environmental radioactivity monitoring;
- Radiological surveillance of food stuffs.

3.2.1 Ministry of Internal Affairs

The Minister of Internal Affairs coordinates all measures necessary for the application of the nuclear and radiological emergency plan. He is authorised to mobilise and deploy all civil and military means to control or restrain the emergency situation. This ministry also controls imports and exports by means of the customs and excises administration.

3.2.1.1 The Federal Agency for Nuclear Control (under the supervisory authority of the Minister of Internal affairs)

The Federal Agency for Nuclear Control (FANC) is a public body endowed with legal personality, established by the Law of 15 April 1994 on the protection of the population and the environment against the dangers resulting from ionising radiation. This statute grants it broad independence, which is essential for exercising impartially its responsibilities towards society.

The FANC has been fully operational since 1 September 2001. In fact, on this same date, the Royal Decree of 20 July 2001 concerning the general regulations for the protection of the population, workers and the environment against the dangers of ionising radiation (GRR-2001) entered into force. This decree renders the implementation of the Law of 15 April 1994 effective and specifies the conditions and modalities for the execution of the Agency’s duties. It comprises the greater part of the Belgian regulations on the protection of the population and the environment against the dangers of ionising radiation.

Next to the respective operators, who, in line with the international recommendations concerned, bear the primary responsibility for radiation protection in their respective plants, the FANC plays a key role as far as the protection against ionising radiation in Belgium is concerned. The Agency is, among other things, responsible for approving nuclear and radiological plants, for ensuring compliance with the rules and standards in the field of radiation protection and for monitoring the occurrence of radioactivity in the environment. The FANC, endowed with its own Management Board, falls under the supervisory authority of the Minister of Internal Affairs.

From an operational perspective, FANC has five divisions, of which two deal with the present issue: Health & Environment (Department for Monitoring the Territory and Natural Radiation) and Installations & Waste (Department for Basic Nuclear Installations).

In Belgium, the installations and operators in the radiological field are divided into three categories in accordance with the general regulation for the protection against the hazards of ionising radiation (GRR-2001).

Class 1 includes nuclear power plants and the main installations of the fuel cycle, including the management of waste.

Class 2 mainly comprises hospitals and industrial applications that make use of equipment or sources emitting radioactive radiation.

Class 3 comprises individual radiologists, dentists, veterinary surgeons and other parties who make use of equipment or applications emitting lower-level radioactive radiation.

The subdivisions were readjusted under the new organisational structure: the department in charge of 'Basic nuclear installations' deals with class 1 installations and the main class 2 installations, such as cyclotrons and irradiators. The department for 'Medical and industrial installations' deals with other class 2 installations and installations of class 3.

Subject to the responsibility of FANC, the routine checks in the installations have been delegated to approved bodies or directly to the technical service of FANC, namely Bel V. In the Doel power station, these checks are performed by Bel V.

As far as the environment is concerned, the Agency is responsible, especially by virtue of the GRR-2001, for monitoring the radioactivity on the territory and the doses to which the population is exposed as well as for organising the monitoring of the population as a whole.

Note should also be made of the Franco-Belgian Cooperation Agreement relating to the Chooz nuclear power station situated on the Meuse in France close to the border with Belgium. This agreement provides for full monitoring on the Belgian territory of all means of transmitting radiation in the vicinity of the nuclear site as well as for a periodic exchange of results between the countries.

Two articles of the GRR-2001 define the regulatory framework of the 'work activities involving natural radiation sources' (NORM industries). On the basis of these Articles, FANC can require a follow-up on the impacts on the environment in certain sectors of the NORM industries.

One article of GRR-2001 regarding 'interventions in the case of persistent exposure' provides the regulatory framework for sites historically contaminated by radioactive substances. This Article especially imposes on FANC the obligation to ensure the eventual implementation of a system for monitoring exposure.

The sampling and measurement campaigns on the ground are the real cornerstones of radiological monitoring of the territory. They make it possible to refine the radiological profile of the Belgian territory and must enable the levels of natural and artificial radioactivity in the environment to be precisely evaluated, and radiation doses to which the population is subjected to be assessed. They therefore systematically target the main areas of the environment and the principal components of the food chain liable to be contaminated and to which the public may be exposed: the air, atmospheric dusts, rain, rivers, the sea, drinking water, the soil, river and marine sediments, fluvial and marine fauna and flora, milk, meat, fish, vegetables, etc.

Sampling of various foodstuffs is performed on the national territory and focuses on large and small distributors, markets, slaughterhouses, fisheries, etc.

Owing to a co-operation agreement with the Federal Agency for the Security of the Food Chain the monitoring of the foodstuffs is extended to imported products as well as to foodstuffs distributed by wholesalers and large logistics centres.

These analyses measure the alpha, beta or gamma emitting radioelements, either in a general or specific manner. In the latter case, they attempt, in particular, to measure natural radioelements (such as beryllium-7 and potassium-40) which serve as reference points and radioactive elements characteristic of specific human activities (such as radioactive elements linked to the manufacture of fuels powering nuclear reactors, radioactive traces used in nuclear medicine and radium-226, a natural radioactive element found concentrated in the liquid effluents from the production process of phosphate fertilisers). The results obtained are then centralised, analysed and interpreted by the Agency.

3.2.1.2 Governmental Crisis and Coordination Centre (CGCCR); Nuclear and radiological emergency preparedness

The organisation of the nuclear emergency plan falls within the jurisdiction of the Governmental Crisis and Coordination Centre (CGCCR), which is a 24/7 service at the disposal of the Federal Government. It can receive, analyse and disseminate the necessary information to the political and administrative authorities on a permanent basis. Functioning as a watchdog, it enables the Government to respond quickly and to the point if the situation so requires. Furthermore, the Crisis Centre makes its infrastructure and know-how in interdepartmental management and crisis coordination available on a national level.

Its responsibilities are derived from the Royal Decree of 18 April 1988, which defines a crisis as an event that, by reason of its nature or consequences, threatens the vital interests of the country or essential needs of the population, requires urgent decisions and requires the coordination of various departments and organisms. The CGCCR is also responsible for nuclear and radiological emergency plans. In the organisation of the nuclear and radiological emergency plan in Belgium there are two specific consultative cells, in which the FANC bears presidential responsibilities: the evaluation cell (CELEVAL) for the radiological situation in the case of a nuclear emergency and the measurement cell (CELMES) responsible for the deployment of teams on site, for the coordination of measures (also including the data of the automatic radiation monitoring network TELERAD).

The provisions of the Nuclear and Radiological Emergency Plan for the Belgian Territory apply to cases where the population of Belgium is threatened or at risk of being threatened by abnormal radiological exposure (radiological emergency) through different means of exposure resulting from:

- external irradiation due to air contamination and/or deposited radioactive substances (contamination of the Belgian territory);
- internal irradiation by inhalation of contaminated air and/or ingestion of contaminated food or water.

It applies above all in the following specific situations:

- accidental situations occurring in the main Belgian nuclear installations: the nuclear power plants of Doel and Tihange, the Nuclear Research Centre (CEN) at Mol, the Institute for Radioelements (IRE) at Fleurus, Belgoprocess and Belgonucléaire at Dessel;
- accidental situations occurring in foreign nuclear power plants, especially those situated in close proximity to Belgium, in other words, the nuclear power plants of Chooz, Gravelines and Cattenom (France) and the nuclear power plant of Borssele (Netherlands);
- radiological emergency situations concerning space or military equipment or occurring in military installations;
- radiological emergency situations during the transport of nuclear fuel or of radioactive material (including radioactive waste);
- radiological emergency situations in the wake of terrorist acts.

The present plan describes the general organisation. It is supplemented by:

- specific intervention plans on various levels under the authority of the Minister for Internal Affairs or of the Governor of the province concerned;
- specific operational procedures for each cell.

In the case of a radiological emergency situation in a nuclear installation, the operator is and remains the sole party responsible for the conduct of operations on site. Nevertheless, the Emergency Director of the authorities may at any time, in consultation with the Emergency Director of the operator, take measures with the aim to control an emergency situation on the site of the operation if so required to ensure public order or the safety of the population.

Off-site, the authorities are responsible for protecting the population.

3.2.2 Other Federal authorities

3.2.2.1 Public Health

The Minister responsible for public health organises and supervises the proper working of the medical rescue services; furthermore, especially in the field of radiation protection, the Minister is responsible for monitoring the internal contamination of contaminated persons as well as their medical treatment.

In addition, the Federal Agency for the Security of the Food Chain (AFSCA), responsible for matters related to the protection of the food chain and consumers, is represented in various cells and committees within the CGCCR.

3.2.2.2 Employment and Labour

The Minister responsible for occupational safety, occupational hygiene and occupational medicine monitors the safety of the neighbouring 'classical' installations (whether on the affected site or not) and of their workers for whom the emergency situation may present a danger.

3.2.2.3 Agriculture

The Minister in charge of agricultural affairs is responsible for proposing specific measures with respect to agriculture, horticulture and marine fisheries. The Minister participates in the implementation of the practical provisions in the field of agriculture and measures taken by the federal coordinating committee.

3.2.2.4 Foreign Affairs

The Minister of Foreign Affairs participates in the collection of information abroad on radiological emergency situations that have occurred outside Belgium and that may have an impact on the Belgian territory or on Belgian nationals abroad. In such situations, the Minister is obliged to gather and disseminate information on the affected interests and on the situation abroad.

3.2.2.5 Finance

As part of the application of European regulatory provisions on the marketing of contaminated foodstuffs and animal feed, the Minister of Finance monitors this issue.

The samples are taken for the Agency by specialist teams of SCK•CEN (*StudieCentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire*; Belgian Nuclear Research Centre) and IRE-ELiT (Institute for Radioelements - Environment and Lifescience Technology). The frequency of sampling has been defined in such a way as to be in possession of information that is as useful as possible, while taking account of technical and material constraints. The samples are then analysed in the laboratories of these institutions in order to determine the nature and level of radioactivity contained in them in very precise terms.

3.2.3 Cooperation with outside institutions

The following institutions collaborate in various tasks, in particular in environmental and discharge monitoring:

- Institute for RadioElements (IRE), Metrology and Environmental Radioprotection department;
- SCK•CEN (*StudieCentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire*; Belgian Nuclear Research Centre), Low-level radioactivity measurements expert group;
- Food Safety Centre.

4 DOEL NUCLEAR POWER PLANT (DOEL NPP)

4.1 THE SITE

KCD (*Kerncentral*e Doel; Doel Nuclear Power Plant; Doel NPP) is located in the port of Antwerp, on the Scheldt River, a few kilometres from the border between Belgium and the Netherlands. The site covers a surface area of 80 hectares. The power plant has two 170 meter high cooling towers which form a landmark in the area. Figure 1 gives an overview over the site.

Figure 1: Doel Nuclear Power Plant (4 units; WAB … water and waste treatment facility).

4.1.1 Construction and history of the NPP

Doel NPP consists of four PWR reactors with a combined net installed power of 2839 MW_{el} (end 2007).

At the time of the verification Unit 3 was on outage. Thus, besides on-site environmental monitoring and general discharge monitoring, the visit covered unit specific discharge monitoring aspects only at Units 1, 2 and 4.

4.1.1.1 Doel 1 and 2 (D1, D2)

Doel 1 and 2 are twin units. Both reactors have a common control room and various common safety and emergency systems.

- Architect/Engineer: Tractionel (Tractebel) and Electrabel
- Type of reactor: PWR
- Start of construction: 1969
- Commissioning: 1974
- Commercial generation: 1975
- License: Westinghouse
- Owner: 100% Electrabel
- Net electrical power Doel 1: 392.5 MW_{el}
- Net electrical power Doel 2: 432.5 MW_{el}
- Major upgrades:
  - Construction of a common bunker with emergency systems in 1990.
  - Replacement of steam generators in Doel 2 in 2004 (+ 40 MW)
  - Replacement of steam generators in Doel 1 in November and December of 2009 (+ 40 MW). The net electrical power for Doel 1 is 432.5 MW_{el} after the replacement of the steam generators. Startup was in mid-January 2010.

4.1.1.2 Doel 3 (D3)

- Architect/Engineer: Tractionel (Tractebel) and Electrabel
- Type of reactor: PWR
- Start of construction: 1974
- Commissioning: 1982
- Commercial generation: 1982
- License: Framatome
- Owner:
  - 89.81% Electrabel
  - 10.19% SPE-Luminus
- Net electrical power Doel 3: 1008 MW_{el}
- Major Upgrades:
  - Replacement of steam generators in 1993 (+ 70 MW_{el})
  - Replacement of low-pressure rotors of steam turbine in 1996 (+ 36 MW_{el})

4.1.1.3 Doel 4 (D4)

- Architect/Engineer: Tractionel (Tractebel) and Electrabel
- Type of reactor: PWR
- Start of construction: 1977
- Commissioning: 1984
- Commercial generation: 1985
- License: Westinghouse
- Owner:
  - 89.81% Electrabel
  - 10.19% SPE-Luminus
- Net electrical power Doel 4: 1006 MW_{el}
- Major Upgrades:
  - Replacement of steam generators in 1996 (+ 0 MW_{el})
  - Replacement of low-pressure steam turbine rotors in 2009 (+ 35 MW_{el})

4.1.2 General information

Altogether there is more than 1000 staff, 53 persons of whom work in Radiation Protection (for all 4 reactors). Before starting work there are three training weeks at SCK•CEN in Mol for theoretical subjects; then there is on the job training with an exam after one year. Specific issue training is supplied if changes in a process occur. Every 5 years a four-day 'recycle training' has to be performed at Mol. In addition to these 'generally' formed staff members a few persons with more specific and longer training and experience (three per functional post) are available. Radiation Protection is organised in six teams: Doel 1+2; Doel 3; Doel 4; waste treatment; an expert team; an instruments team. For outages specialised staff is available.

4.1.3 Discharge monitoring - reporting to regulator

The monitoring of the liquid and gaseous radioactive discharges is performed by the operator. The regulator has issued a notice on the routine reporting of radioactive discharges, pursuant to which the operator is required to report each month the balance of the liquid and gaseous radioactive discharges emitted by its installation.

All data that have to be reported are put together in one report which is based on the information stored in the LIMS (e.g. for gamma spectrometry the printout from the Canberra Genie analysis software is interfaced to LIMS).

A technical administrator scrupulously checks the data from all units and forwards them to FANC.

Data are kept for a long time (as decided by FANC; however, no time limit is demanded); The verification team was told that currently there is a two months delay in reporting due to the amount of paper work.

A file on the routine discharge of liquid and gaseous discharges as well as on the impact of such doses of discharges is made publicly available on the website of FANC.

4.1.4 (Potential) radioactive liquid discharge monitoring – description and verification

4.1.4.1 Liquid discharge limits

The valid limit for liquid discharges is the drinking water limit: 0.1 MBq drinking w.eq/m^3 (drinking water equivalent).

This limit comes from the Royal Decree of July 20, 2001: Art 34: Storage, treatment and disposal of liquid waste. Art 34.2 stipulates that "*The discharge of radioactive liquid effluent in surface water or in the drainage system is forbidden when the radionuclide concentration (expressed in Bq/l) exceeds by one thousandth the annual limit for ingestion by an adult member of the general public*". When the liquid contains a mixture of radionuclides, certain summation rules apply. Should the exact composition of the mixture not be known, the most conservative value for the summation quotient has to be used. This means that the lowest limit for the isotopes present must be used.

Of the isotopes potentially present in waste water, I-131 is the one with the lowest volumetric discharge limit, i.e.: 1.10^5 Bq/m³ (0.1 MBq/m³).

In addition, the annual limits for discharges by the site are:
- Total isotopes without HTO and dissolved noble gases: 1.48 10^6 MBq;
- HTO: 1.04 10^8 MBq.

Bel V must be notified when half of one of these limits is exceeded during three consecutive months.

The pipes that carry potentially contaminated effluent from the technical installations of the reactor units to the Building for Secondary Discharges do not run through underground connection galleries, but lie directly in the soil. As a result, there is a risk that these effluents may leak into the soil if there are leaks in the pipes. The verification team was told that in future, the activity of effluents transferred through such non-channelled pipes will be limited to 0.075 MBq Cs-137eq/m³ and thus modifications in the liquid discharge monitoring system will be installed.

4.1.4.2 Origin and types of potential radioactive liquid discharges

4.1.4.2.1 Non-industrial waste water

Non-industrial waste water (rainwater, overflow from septic tank, cold sanitary waste water) is non-radioactive and is ultimately released into the Scheldt via drains, bio-rotors, etc. This waste water will not be discussed here, as in this case radiation protection does not apply. However, such discharges must comply with environmental standards.

4.1.4.2.2 Industrial waste water (SEK and GZ)

Industrial waste water is subject to radiological inspections, and will therefore be discussed in detail. This group comprises two types of potential radioactive discharges: SEK (secondary waste water) and GZ (waste water from the controlled areas).

Secondary waste water (SEK):

This water comes from the secondary circuit in the nuclear units (water-steam cycle) and the water treatment facilities. This water can be contaminated by possible radioactivity in the water from the unit's secondary circuit. It comprises:

- Blowdown drains steam generators
- Regeneration effluent

Potentially non-active effluent:

- Overflows in the machine room

Waste water from the controlled area (GZ):

This kind of waste water comes from radioactive systems in the controlled areas. GZ water from the entire site is released or treated via the treatment facilities in the WAB building. The discharge pipe is fed from inspection tanks. There are one or more tanks per type of major water category:

- Primary waste water: distillate from boric acid recovery and leaked water
- Chemical waste water from decontamination and laboratories
- Water from the controlled area floor (distillate)
- Laundry and shower water
- Water from the machine room floor if via WAB
- Regeneration effluent if via WAB

All discharges of this type are batch discharges.

4.1.4.2.3 Cooling water (CC)

Cooling water (CC) discharges come from leaks in the heat exchanger between the intermediate cooling circuit and the circuit which cools it. Since this is not industrial waste water, no other waste water may be added to it. (At D1/2, leaks may occur between these circuits

All waste water is ultimately discharged into the Scheldt River after having received specific treatment and inspection.

4.1.4.3 Management of liquid (radioactive) discharges

With regard to management of discharges a distinction is made between **controlling** which pertains only to checking the admissibility of a discharge and **logging** which is an ad post action that pertains to the quantitative and qualitative determination of discharged radioactivity (e.g. by sampling and sample analysis in a laboratory).

In addition, there is also **preliminary controlling**, which must precede permission to discharge, if required, and therefore precedes discharge itself, as well as **controlling during discharge**.

Preliminary controlling is only required (and feasible) for (discontinuous) discharges from controlled areas (GZ), i.e. from inspection tanks. Controlling during discharge is always required for all types of discharges, but the form differs depending on the type; it can be fully automatic.

Discharge parameters are observed and the appropriate evidence (e.g. samples for subsequent analysis for logging) is secured during the inspection.

Administratively, inspection data are entered in “technical witness supporting documents” by filling in information sheets for radioactive discharge and inputting data into the NPPs (*UNILAB*) LIMS application, depending on the type of discharge.

As an example, the procedure for controlling a GZ (batch) discharge is:

1. Request to discharge: must be sent to the department responsible for controlling.
2. Tank homogenisation: Recirculate the volume of water in the tank at least once. No water may be added during this process.
3. Check that the required discharge instrumentation is in good operating condition:
    a. Radiation Protection checks whether the requirements set out in the Technical Specifications are fulfilled.
    b. Source test carried out on the discharge measuring chains to be used, and comparison with reference values (max. 20% deviation).
4. Sampling and first controlling measurement: samples taken of at least 3 litres, of which 1 litre will be used for a γ total measurement and control sample, and the other 2 litres for aliquots.
5. First decision:
    a. If γ total < 1.85 MBqCs-137eq/m³: permission to discharge.
    b. If γ total > 1.85 MBqCs-137eq/m³: see second decision.
6. Second decision:
    a. Carry out isotopic analysis and complement it with estimations of present isotopes (tritium and α-ß emitters).
    b. Check that the Technical Specifications threshold: 0.1 MBq drinking w.eq/m³ in the CW channel are not exceeded.
7. Authorisation to discharge: If first or second decision is positive, the effluent may be discharged.

All the above data and parameter readings must be entered on the GZ discharge card (before, during and after discharge), and can be found in the LIMS.

Table 1 gives an overview over tasks involved in logging discharges.

Table 1: Logging tasks for the various liquid discharge types.

Type	**Aliquot**			**Original samples**
	Weekly	***Monthly***	***Quarterly***	
GZ	Gamma emitters	Beta emitters and tritium	Alpha emitters	Of each discharge
SEK	Gamma emitters	Beta emitters and tritium	Alpha emitters	Weekly aliquot
CC	X	Gamma emitters, Beta emitters and tritium (1)	Alpha emitters	Monthly sample

(1) Not an aliquot, but a monthly sample (if leaked activity is not < 3.7 MBqCs-137eq every day)

4.1.4.4 Schematic description for units D1 and D2

Waste water from the machine hall of units 1 and 2 is piped to the discharge collector (*Enliga Lozingen Kanal*, ELK) via the building for secondary discharges (GSL), supervised by the measuring device 0RM36. If the GSL is out of commission, the waste water from the machine room can be discharged directly into the ELK; in that case an additional measurement is performed via the monitor 0RM37.

The measuring chain R0RM36 continually measures the activity of the floor waters of the machine hall, before being pumped to a collection tank (volume of $1200m^3$) located in GSL. If the net activity is greater than 0.185 MBq/m^3 this discharge route will be automatically closed and the discharge will be routed via the ELK. The measuring chain comprises the following components:

- 2"x2" NaI(Tl) detector (*Hartmann & Braun*)
- A measurement probe, installed in the pipe to be sampled (14") in which the detector is located. Part of the pipe is shielded with lead.
- A remote-controlled test source (37 kBq Cs-137 in 1982) to check the correct operation of the measuring chain. It is operated on the measuring chain in the auxiliary control room.
- Measuring electronics in the auxiliary control room.

The sensitivity of the measuring chain R0RM36 is 3.43 E-4 cps per Bq/m^3; the measuring range is 2.92 E+2 to 1.46 E+9 Bq/m^3. If a certain level is exceeded, this measuring chain launches a series of actions, including opening and closing of various valves and stopping of pumps.

The R0RM37 measuring chain measures and limits the activity of the collected discharge water from the SD tanks and regeneration effluents before being pumped to the ELK. If the net activity exceeds 1.85 MBq/m^3, the water is sent to the SD tanks. The chain comprises the following components:

- 2"x2" NaI(I) detector (*Hartmann & Braun*)
- A measurement probe, installed in the pipe to be sampled (14") in which the detector is located. Part of the pipe is shielded with lead.
- A remote-controlled test source (37 kBq Cs-137 in 1982) to check the correct operation of the measuring chain. It is operated on the measuring chain in the auxiliary control room.
- Measuring electronics in the auxiliary control room.

The sensitivity of the measuring chain and the measuring range are the same as for R0RM36.

If a certain alarm level is exceeded, this measuring chain launches a set of actions, including opening and closing of several valves and stopping of pumps.

Waste water from the waste water tanks SD0R2A and B is discharged via the water and waste treatment facility (WAB). This water can be recirculated until the activity is low enough for discharge (measurement using the monitor 0RM05).

The measuring chain R0RM5 comprises the following components:

- A shielded measuring tank (with a 1.25"x1" NaI(Tl) crystal), through which flows a fraction of the discharge to be inspected. This fraction is branched off from the discharge pipe via a diaphragm in the pipe.
- The location is selected so that the concentration of the water in the tanks SD0R02A and B can be measured both during the recirculation phase (preparation for discharge) and during the discharge phase.
- The detection unit is fitted with a Cs-137 source for source testing, controlled from the control room.
- Local processing unit for the system (including spectrum and event buffer, self-tests, energy checks using an Am-241 source built-in in the detection system)

- Measuring electronics in the auxiliary control room.

If an alarm level is exceeded, the effluent is pumped back to the WAB.

The sensitivity of the measuring chain is 2.348 E-5 c/s per Bq/m³ Cs-137 equivalent. The measuring range of the measuring chain is 1 E+3 to 1 E+10 Bq/m³.

Readings of all measuring chains are once during shift; the systems are routinely tested and calibrated.

Discharges from controlled areas (GZ discharges) are pumped to WAB for further treatment and discharge.

4.1.4.5 Schematic description for unit D3

The DT circuit collects the floor water from the various buildings via drains, overflows and pumps. The floor water from the controlled area is routed to waste processing. The floor water from the non-nuclear buildings is sent to the LNW (storage tank). The regeneration effluent and the drains of the steam generators can be directly discharged if their radioactivity so allows.

Three measuring chains are installed.

Chain DT-L-1 (DT1607-R) monitors the radioactivity of the floor water from the machine hall, from the full demineralisation building and from the bunker. If the activity is too high, the measuring chain causes an automatic closure of the valve that forms the connection with the collector that routes the waste water to the LNW (storage tank).

Chain DT-L-2 (DT 1606-R) monitors the radioactivity of the regeneration effluent from the full demineralisation, before it is routed to the discharge collector. The effluent from the PW circuit is also monitored by this measuring chain.

The fluids checked by measuring chain DT-L-2 are then re-checked by measuring chain DT-L-3 (DT 1608-R). If the activity is too high, the measuring chain causes an automatic closure of the valve that forms the connection with the discharge collector (ELK) and with the Doel 3 RN (intermediate cooling) pipe.

All the measuring systems have the same structure. They are designed as in-line systems with a view to avoid problems that could arise with off-line systems in highly contaminated water, such as clogging due to using a pump, a measuring tank, etc.. They consist of:

- a detector installed in a section of pipe that is part of the DT circuit, protected by a measurement probe. The size of the measurement volume provides good shielding from background radiation. This shielding is further improved by an externally applied lead castle.
- a valve system which enables the insulation and bypassing of that part of the pipe in which the detector is installed. The aim is to make it possible to clean the detector and a part of the pipe.
- the electronics needed to boost the signal from the detector and transfer it to devices installed in the control room, where the signal is indicated, recorded and monitored;
- a test source (100 µCi i.e 3.7 MBq Cs-137), operated remotely, which, in a test position, causes an increase in radiation intensity of at least two orders of magnitude above the lower limit of detection.

In the event of high radioactivity (a certain threshold value being exceeded), the DT-L-1 chain causes closure of the valve that forms the connection with the collector to the LNW (storage tank).

In the event of high radioactivity, the DT-L-3 chain causes closure of the valve that forms the connection with discharge collector (ELK) and of the valve that forms the connections with the Doel 3 RN line.

Each chain has a 2"x2" NaI(Tl) detector, working at ambient temperatures of 0 to 50°C and at ambient pressures of 0.7 to 1.2 bar. Every eight hours control measurements are performed; source tests, functional tests and calibrations are routinely performed.

4.1.4.6 Schematic description for unit D4

The description for D4 is analogous to the one for D3 above.

4.1.4.7 Schematic description for the waste and water treatment facility WAB

The contents of an inspection tank (in WAB) may only be discharged after the contents have been sampled and analysed in accordance with the procedure, to check whether the activity concentration is low enough to allow such discharge. The threshold value is 1.85 MBq Cs-137 eq./m³. This sample must be saved for one year.

A measurement of the discharge line is performed with a 2"x2" NaI(Tl) detector (without shielding); The discharge is interrupted if the discharge limits are exceeded.

4.1.4.8 Schematic diagram for the discharge collector line (ELK)

The activity of the water to be discharged (i.e. the water in the ELK line) is measured in the measuring chain LN 1543–R before being mixed with river Scheldt water (CW water; pumped to the discharge building) in the discharge building. The action level of this measuring chain is set to 18.5 MBq Cs-137eq./m³. (This is ten times higher than DT-L-3.) In such a case a valve closes, ELK is set out of service and the water can be pumped back to the water and waste treatment facility (WAB).

Flow measurements for ELK and CW water allow observing the minimal requested dilution.

Before being discharged into the Scheldt River the mixed water (ELK + CW) is measured for activity by the measuring chain RM 1548–R. The action level of this measuring chain is set to 0.1 MBq drinking w.eq/m³. This chain gives an alarm in the WAB control room. However, since the whole set-up (with measurements at the ELK line and the minimal dilution) is structured in such a way that the drinking water limit cannot be exceeded without the ELK closing, no other action is foreseen.

Both measuring chains use 2"x2" NaI(Tl) detectors.

For control, water samples from the Scheldt River are taken near the discharge location.

4.1.4.9 Verification

The verification team visited the sites of the measuring devices, the regulating valves and the necessary pumps, in particular with regard to the WAB, at the ELK line and at the building where the discharge to the Scheldt River is monitored.

<u>Discharge building (Doel code LKL), ELK line</u>

The team verified the measuring device (Doel code RRIAS1543) in the controlled zone, which is monitoring waters in the ELK. The high activity alarm automatically closes an isolation valve (Doel code LN188), located some three metres apart; in addition, a manually operated valve is available. In case of failure a signal is sent and all discharge pumps are stopped. If pressure becomes too high an additional valve opens and the liquids are released to the sump and from there back to WAB.

A sampling pipe (Doel code LN1553-A) allows automatic sampling of ELK water.

<u>Discharge pavilion (Doel code LZP), to Scheldt River</u>

Waters collected from the various units are firstly measured at the utilities and then lead through the ELK (*Enliga Lozingen Kanal*) line to the discharge pavilion. The team specifically verified the online measuring point labelled '1548' (measuring chain RM 1548–R; ELK and river water mixed; last measurement before discharge). A gross gamma measurement is performed in a submarine shaped lead shield, with a calibration source holder on top. A filter is mounted before the measuring device. The electronics rack (*Hartmann & Braun*) showed the reading in impulses per second, and in volts. The single channel analyser was set at 100 keV (lower value). Three alarm channels are set, the lowest one being for tests; data are transmitted to the control room of WAB.

For tests (calibration setting to 'on') the Cs-137 source moves into the measuring chamber. Such tests are performed once per month. Once every eighteen months a secondary calibration is performed.

In the same building a tank (Doel code RM-RR-03) is installed for weekly sample, the tank generally being full in that time. Before sampling the content is stirred for 20 minutes; then the sampling pump is started, the sampling valve opened and a one litre sample is taken (sampling point Doel code DT/RM-VV0116).

Water and waste treatment facility (WAB) control room

The team visited the WAB control room which is now fully computerized; the former large display board has been removed.

For the SN/ELK circuits the team received a presentation of various functions, e.g. the display showing a scheme with various measurement values, status information, etc.. For example red icons show open and green icons closed valves. For measurements the respective values are directly displayed on the main window of the screen. Another window showed trending in real time.

The system has been produced by *Tractebel Engineering / Fabricom GdF Suez / Cegelec.* All data are stored in a secured database, printouts are kept in archives.

The team verified calibration information for measuring chain RM1548 (logs with data, formula, values incl. decay factor, signature of validator, initials of measuring staff).

The team also verified a functional test log with check list, initials, data; ca. 50 items have to be checked including SCA, HV and alarm settings.

For the measuring chain RM 1543 a calibration log similar to the one for RM1548 was verified; this one included the conversion factor MBq.h/m^3 per impulse per second and includes the background value.

With regard to the valves at WAB (Doel codes LN357 and LN326; double for redundancy) the team verified that both were closed. For discharge both are open, after discharge both are closed; in case of high value at the WAB discharge measuring chain (Doel code RRIAS1512) both valves close and thus block discharge to the discharge (ELK) line.

The team was informed that for samples from the water and waste treatment facility (WAB) all measurements are done in the laboratory of the Radiation Protection Department, whereas samples for the reactor units are analysed in the Chemistry Department, which also manages QA tasks (e.g. calibration, servicing) for the other laboratory.

The verification does not give rise to specific remarks.

4.1.5 (Potential) radioactive gaseous discharge monitoring – description and verification

4.1.5.1 Gaseous discharge limits

The following limits apply for total activity discharged in 12 consecutive months:

- Aerosols: 148 GBq
- I-131: 14800 MBq

- Noble gases: 2960 TBq.Xe-133.eq
- HTO: 88800 GBq

These limits are set out in the Technical Specifications and are valid for the entire site. The distribution between the discharges of the (potential) sources WAB, D1, D2, D3 and D4 is calculated for each entity: D1 + D2: ½ of WAB; D3: ¼ of WAB; D4: ¼ of WAB. Bel V must be notified when 1/8 of one of these limits is exceeded during three consecutive months (per facility).

The instantaneous discharge limits for the (potential) sources are given in table 2. These limits are the maximum concentration in the stack on average per consecutive hour.

Table 2: Instantaneous gaseous discharge limits (OLL) for WAB and the reactor units.

TYPE	WAB	D1, D2	D3, D4	
			MV*)	RV*)
Noble gases (MBq/m³)	148	148	111	185
Aerosols (MBq/m³)	$1{,}48.10^{-2}$	$7{,}4.10^{-3}$	$1{,}11.10^{-1}$	$2{,}22.10^{-1}$
I-131 (MBq/m³)	$2{,}59.10^{-6}$	$2{,}59.10^{-6}$	$1{,}85.10^{-4}$	$3{,}70.10^{-4}$

*) … MV … Main vent; RV … Reactor Vent

Unlike the activity limits for 12 consecutive months, these limits are based on the dose limits for the general population (Royal Decree of July 20, 2001: Art 36). They are also set out in the Technical Specifications. Bel V must be notified if the concentration is greater than 10 times the OLL **and** the activity is greater than 1% of the annual limit.

4.1.5.2 Origin and types of potential gaseous radioactive discharges

Various radioactive gaseous discharge types are monitored, e.g.:

- Gaseous waste (GW) - Discharges from the decay tanks of the waste-gas processing system.

- Reactor building or annular space (RGI) - Discharge of the gas initially transferred by an air-cleaning system from a reactor building or annular space (transferred to KON).

- Intermittent discharge (DIS) - Intermittent, mainly involuntary or forced discharge not bookable ahead of time that takes place via a nuclear ventilation outlet. However, some voluntary discharges (which cannot be listed under GW or RGI, such as test discharges) can be listed here. The normal (nearly exclusive) use of this category is for peaks above continuous discharges whose origin is difficult or impossible to identify.

- Continuous discharge (KON) - Continuous discharge from various non-checkable sources that takes place via nuclear ventilation outlets which are active over longer periods.

- Iodine testing (I test) - Discharges of I-131 during iodine tests. Periodic tests are carried out on all carbon filters using radioactive I-131. For stacks MV (Main Vent), RV (Reactor Vent) and EV (Emergency Vent) logging is done via the normal collection filters (KON type). For some ventilation outlets the measurement results from the authorised inspection agency are included in the discharge totals. For iodine testing at these locations no monitoring via real-time monitoring chains is possible (only sampling lines with laboratory analysis).

The real-time monitoring systems installed for the stacks (for particulate matter, iodine and noble gases) have alarm levels that allow immediate reaction. Some are set to considerably lower levels than foreseen in the Technical Specifications. This guarantees that even under very unfavourable conditions gaseous discharges (particulate matter and iodine) would not lead to significant soil contamination.

4.1.5.3 Management of (potential) gaseous radioactive discharges

In a similar way as for liquid discharges at Doel NPP a distinction is made between **controlling**, **logging** and **preliminary controlling**.

Preliminary controlling is only required (and feasible) for voluntary (batch) discharges from decay tanks (GW) and reactor buildings (RGI), and for special cases such as test discharges, which must always be considered separately with respect to the possibility of exceeding Technical Specification limits, and for which no generally applicable procedure can be devised.

Controlling during discharge is always required for all types of discharge, but the form will differ depending on the type; it can be fully automatic.

Discharge parameters are observed and the appropriate evidence (e.g. samples for subsequent analysis for logging) is secured during the inspection.

Administratively, controlling data are entered in "technical supporting documents" by filling in information sheets for radioactive discharge and inputting data into the LIMS application.

As examples for controlling the following analyses are performed:

- GW discharges: γ spectrum prior to discharge (noble gases and Kr-85);
- RGI discharges: γ spectrum prior to discharge (noble gases and Kr-85);tritium prior to discharge;
- Weekly (all discharges): γ spectrum on dust filter and carbon pipe;
- Monthly (all discharges): tritium determination; γ spectrum (noble gases and Kr-85 via gas tank); external analyses (by SCK•CEN Mol) for α emitters and β emitters (Sr-89, Sr-90).

For logging, depending on the source (GW, RGI, DIS, KON, etc.) e.g. sampling frequencies are defined (every discharge, weekly and/or monthly).

4.1.5.4 Schematic description of gaseous effluent monitoring

Gaseous effluent monitoring at Doel 1 and 2, respectively at Doel 3 and 4, is done with equipment from *Hartmann & Braun*.

4.1.5.4.1 Doel 1/2

Doel units 1 and 2 each have their proper stack and a common one.

Doel 1/2 GNH (Nuclear Auxiliary Building)

For Doel 1/2 GNH (Nuclear Auxiliary Building) gaseous effluent monitoring covers 'normal' situation monitoring, accident measurements, logging tasks and HTO determination, using different flow rates, all with manual flow control. For the effluents, a common cylindrical stack with a height of 21 m and an internal diameter of 1.5 m is used, housing isokinetic sampling lines.

The detection unit for normal situations consists of three specific measuring chains and a common part (including a pump):

- The measuring chain for particulates comprises a PIPS detector mounted in a lead castle with a paper filter box mounted on the detector (filter change every 168 hours); and an electronic pressure gauge, which measures the drop in pressure over the filter paper and in case of too high drop, leads to a filter change. The measuring range is 1 to 1 E7 Bq/m³; the detection limit is 0.5 Bq/m³.

- The measuring chain for iodine comprises a NaI(Tl) detector mounted in a lead castle with a box with active carbon to absorb the iodine mounted on top. The measuring range is 1 to 1 E7 Bq/m³; the detection limit is 1.85 Bq/m³.
- The noble gas measuring chain (that serves for logging purposes) comprises a PIPS detector mounted in a measuring chamber in a lead castle. The measuring range is 1 E4 to 1 E10 Bq/m³; the detection limit is 3.7E4 Bq/m³.
- All measuring devices contain Cs-137 sources for the source tests controlled from the control room.
- The common part consists of the sampling pump, an electronic flow meter and auxiliary devices. Local units process the information from the NaI(Tl) and the PIPS detectors.

If the action level 'HL2' value is exceeded in one of the measuring chains, the absolute filters and active carbon filters in the GNH ventilation are deployed by opening and closing appropriate valves.

The measured values are read at each shift. For testing a fixed schedule (monthly or annual) has been set up; for example, source tests are made monthly, electronic and secondary calibrations are performed annually.

Another measuring arrangement consists of a measuring chain for high noble gas concentrations in accident conditions in series with the logging filter for particles and iodine (replaced weekly for laboratory analysis).

The measuring chain detection unit comprises a measuring tank made of stainless steel with a volume of 0.385 litres, surrounded by lead shielding, a 15 µm Ti window ionisation chamber with a built-in 37 MBq Sr-90 test source (operated from the control room) and filled with xenon at a pressure of 5.5 bar, measuring mainly beta radiation and weak photons; and auxiliary devices.

The sampling device consists of a filter housing with a simple handle mechanism making it possible to quickly change the logging box (which consists of a particulate and an active carbon filter); the necessary valves; a heating system to reduce the humidity in the logging box; a differential pressure gauge with a low and high alarm, transferred to the control room, to check the pressure difference across the filter; and a flow meter sending its metering information to the control room.

The devices use a common pump with a flow rate of 1 m^3/h (adjustable).

If the action level 'HL2' value is exceeded in the measuring chain, the absolute filters and active carbon filters in the GNH ventilation are deployed by closing and opening the appropriate valves. Depending on the relative humidity, air heaters are also deployed. Any GW discharge in progress is stopped by the closing of the appropriate valves.

The measuring range of the chain is 1 E-13 A to 1 E-5 A (with a sensitivity of 1.69 E-21 A/Bq for Xe isotopes.

The measured values are read once per shift; source tests are performed monthly, functional tests quarterly and (electronic) calibrations annually.

A third measuring line is in place to measure both the aerosol (Cs-137 'window' set at 612 to 712 keV) and the iodine concentration (I-131 'window' set at 314 to 414 keV) in the high measuring range (accident measurements).

The detection unit comprises a 1.25"x1" NaI(Tl) crystal mounted in a lead castle (with an active carbon pipe and a paper filter mounted on the crystal to allow simultaneous detection of I-131 and Cs-137 by using two separate energy 'windows'); a sampling pump (rated flow of 1 l/min); a Cs-137 source which can be controlled from the control room, for the source tests; electronics and auxiliary devices.

The measuring range for the Cs-137 determination is 1 E4 to 1 E10 Bq/m³ (with a detection limit of 65 Bq/m³), the measuring range for the I-131 determination is 1 E4 to 1 E9 Bq/m³ (with a detection limit of 126 Bq/m³).

The measuring chain does not perform any automatic actions.

The measured values are read once per shift; source tests are performed monthly, functional tests quarterly and calibrations (electronic and secondary) annually. Filters are replaced monthly.

A separate chain measures the noble gas concentration in the discharges of the GW (waste-gas processing system) circuit, located in the discharge line of the GW tanks. The purpose of the tanks is to have the discharge gases collected in these tanks decay as much as possible and only then to discharge them via the GW discharge line. These gases only contain Kr-85 after decay.

The detection unit comprises a measuring tank made of stainless steel with a volume of 0.385 litres; 10 µm Ti window ionisation chamber with a built-in test source of 37 MBq Sr-90 (operated from the control room). The ionisation chamber is filled with argon and is at a pressure of 5.5 bar. The detector measures mainly beta radiation and weak photons. The detector is mounted as a cover on the measuring tank.

Under normal circumstances, to prevent the measurement signal from being too low a small Cs-137 source (1.5 MBq) is placed underneath the detector. For secondary calibration, the detector must be removed from the measuring tank and a Sr-90 source (in the form of a cover) must be placed on the detector window.

If the concentration in the discharge line exceeds the limit of 6.12 E+11 Bq/m³ discharge is stopped automatically by closing appropriate isolation valves. This prevents the activity of noble gases in the GNH stack from exceeding the limit of 1.48 E+8 Bq/m³.

The measuring chain has been set up in such a way that the sensitivities to Kr-85 and Xe-133 do not differ much from each other, with an average sensitivity of 3.16 E-21 A/Bq/m³. The measuring range is from 1 E-13 A to 1 E-6 A; the detection limit is 9.27 E5 Bq/m³.

The measured values are read once per shift; source tests are performed monthly, functional tests quarterly, electronic calibrations annually, and secondary calibrations bi-annually.

In order to be able to determine the quantity of discharged tritium in the form of HTO the water vapour in the air discharged is filtered out using vials (using a bubbler). This sample is first distilled to counteract contamination in the sample. The sample is then mixed with a scintillation liquid and measured in a liquid scintillator counter. The sampling system uses three vials. The first vial is empty and is used to collect the condensate from the pipes. Vials 2 and 3 contain 'normal' water and are used to collect the water vapour containing the tritium. The flow bubbling through vials 2 and 3 is adjusted so that the maximum tritium is washed in vial 2 (vial 3 may show only 20% of the concentration in vial 2).

Doel 1/2 RGB (Reactor Building)

Doel 1/2 RGB gaseous effluent monitoring covers monitoring the atmosphere of the two reactor buildings and the annular space and the stack of the reactor buildings. Each unit has its own cylindrical stack with a height of 21 m and an inner diameter of 1.5 m, housing isokinetic sampling lines. Two devices for each reactor unit check aerosol, iodine and noble gas activity during normal operation of the power station and during incidents or after an accident (one chain measures aerosol and iodine activity, the other noble gases).

Air sampling for the monitoring task can be performed in various ways during normal operation of the power station or while the power station is shut down, using a selector switch which will open one of a set of solenoids and thus routing different air flows to the measuring devices. The options are: 'RG' (sampling air from the reactor building); 'SCH' (sampling air from the ventilation stack in the reactor building); 'SPUI' (sampling calibration air for background recording; 'TUR' (sampling from the annular space); and two reserves.

The air is first routed across the measuring chain handling aerosol and iodine measurement. This chain consists of two sets located in room 'GNH910' (Doel 1) and in room 'GNH917' (Doel 2). The systems consist of a permanent lead-shielded measurement unit with a stainless steel filter box (equipped with filter paper and active carbon); a pure germanium detector (HPGe, 23% relative efficiency, electrically cooled), which at the same time measures aerosol and iodine activity; electronics; a remote-controlled source; a remote-controlled lead screen in order to be able to set a higher measuring range (attenuator); and the necessary switches, pumps, valves, etc.. For aerosol measurements 50 mm dimeter paper filters are used; for iodine measurements impregnated active carbon (one main cartridge, one auxiliary or control cartridge) is used. The entire filter box and detector is surrounded by a lead castle (min. 10 cm) in order to reduce background. Between the box and the detector a lead attenuator can be deployed from the control room in order to increase the measuring range. A 18.5 MBq Ba-133 remote-controlled source can be deployed for source tests. To this end, a hole is drilled in the lead castle to make it possible for the detector to detect the source. At the same level, an opening was drilled in which is located a permanent rod-shaped calibration source (150 Bq Am-241) in order to enable continual energy calibration via software.

Next, the air is routed across the chain measuring noble gas activity. The measuring chain, apart from the necessary switches, pumps, valves, etc., comprises: a measuring chamber surrounded by a lead sheath (total volume: 18 litres; measuring geometry: $4\,\pi$) with three measuring volumes that can be adjusted from within the control room, each having a different level of sensitivity (in order to achieve a larger measuring range); a pure germanium detector (HPGe, 10% relative efficiency, electrically cooled); electronics; and a remote-controlled source. Under normal circumstances, the air is routed to the inlet of the normal measuring volume (V3). This volume is a tank of around 18 litres made of stainless steel, fitted along its axis with a brace in order to mount the detector. The tank is placed at the top of the detector (comparable to a Marinelli arrangement). Inside the tank the inlet pipe is extended via a tube, in which numerous small openings are drilled to distribute the air in all directions, all the way down to the bottom of the tank. Measuring volume “medium” (V2) comprises a stainless steel piece of pipe, with a useful measuring volume of around 550 cm³. Measuring volume “accident (V1)” comprises a pipe with a useful measuring volume of around 12.4 cm³. The entire tank detector is surrounded by a lead castle (min. 10 cm) in order to reduce background. A 1.85 MBq Cs-137 source can be be inserted by remote-control from the control room for tests. In the tank itself there are two sources (135 kBq Am-241 and 500 Bq Cs-137) fitted to enable energy calibration by software.

In the 'normal' measuring range (i.e. the most sensitive one) triggering the 'HL2' alarm leads to shutting certain valves and to starting the evacuation alarm of the corresponding reactor building. Appropriate settings prevent unintential tripping.

The measured values are read once per shift; source tests are performed monthly, functional tests minimum quarterly, electronic and energy calibrations annually. Aerosol filters are changed weekly.

For tritium (HTO) sampling the setup is the same as at the GNH (Nuclear Auxiliary Building).

4.1.5.4.2 Doel 3/4 MV (Main Vent)

Doel units 3 and 4 each have their own stack. The stacks are made from 3 carbon steel ducts of 3.15, 2.7, and 2.7 m diameter. The Doel 3 vent stack has a height of 36.55 m, the Doel 4 stack is some 34.96 m high. For all the stack parts (MV, Main Vent; outer segment, ca. 2/3 of stack cross sectional area; RV, Reactor Vent; outer segment, ca. 1/3 of stack cross sectional area and EV, Emergency Vent; core part, central cylinder of stack) sampling is isokinetic.

Two measuring chains monitor the radioactivity of particulates ('P'), iodine ('I') and the noble gases ('G') present in the gases that leave the power plant via the main stack of the respective unit. These gases come mainly from the ventilation and air conditioning circuits of the nuclear auxiliary building (GNH) and the standby power generator (SPG), as well as from the GW (gaseous waste) circuit in case of discharge. One of the chains ('MV-PIG-1') serves for monitoring in normal situations, the other one ('MV-PIG-2') in accident circumstances. The measuring ranges of the two chains are different and overlap partially.

The sampling pipes consist of armoured Teflon, the aim being to keep iodine losses to a minimum and to eliminate electrostatic charges. The chains are set up in such a way that the feed pipes are as short as possible, in order to prevent deposition in the measuring pipes.

In addition to the usual arrangement, the accident measuring chain MV-PIG-2 has an additional branch, i.e. the ‘normal logging chain’, that enables a simple summation of the released aerosol and iodine activities, as well as an accurate laboratory investigation of their isotopic composition; periodic analysis of the carbon filter generally makes investigation of the carbon filter cartridge of the normal measuring chain redundant, insofar as this remains below the lowest alarm threshold (which is usually the case). It also allows taking into account aerosol bound iodine. The components in this measuring branch are a filter house with a simple handle mechanism to enable the logging box (aerosol filter and active carbon material) to be changed quickly; connections for a sampling bottle; a pressure gauge with low alarm connected to the control room in order to monitor underpressure in the logging branch; and a flow meter/regulator that controls the flow through the logging branch and the actual MV-PIG-2 measuring chain and keeps it at a constant value or else proportionate to the flow through the stack by acting on a three-way valve fitted over the pump. The filter set (paper filter and active carbon filter) is in commission for a certain period of time. At the end of the period, the filter package is manually removed and replaced; the filters are measured in the counting chamber.

The systems are manufactured by *Hartmann & Braun*.

In measuring chain MV-PIG-1 the detection of radioactivity in aerosols is based on a 2"x2" NaI(Tl) detector, mounted in a shield made of 'old' lead (to reduce background with a view to reach the needed lower limit of detection) and a simple mechanism for manually replacing the paper filter cartridges. A radioactive source (3.84 MBq Cs-137) can be remotely put in test position. A differential pressure gauge sets off an alarm if the pressure difference is too high (filter clogging) or too low (filter break).

The measuring device for determining iodine radioactivity is also based on a 2"x2" NaI(Tl) detector and uses an 'old lead' shield for background reduction. A simple mechanism is in place for manually replacing the active carbon filter. A 1.85 MBq Ba-133 source can be remotely put in test position. Two temperature control devices allow to control the heating of the sampling air to prevent condensation and to heat the carbon filter in order to limit the absorption of noble gases.

Determination of noble gas activity in MV-PIG-1 is based on a plastic scintillator ß, γ detector in a stainless steel, 8-litre measuring tank, surrounded by a lead shield which is thick enough to be able to reach the required detection limit. The sampling air is cooled to prevent damage to the detector. A 0.37 kBq Sr-90 source can be remotely put in test position.

General devices include a pump with manual or automatic flow control, a flow measuring device with high and low alarm in the control room which controls the flow through the measuring chain and keeps it at a constant value and a pressure gauge with low alarm in the control room. The pressure gauge is fitted before the pump with a view to detect a drop in pressure compared with the intake point. The aim of this is to determine a correction factor by which the noble gas radioactivity measurement reading has to be adjusted.

For investigating the tritium content of the air in the measuring chain devices similar to the ones at Doel 1/2, (see chapter 4.1.4.4.1) are set up.

Measuring chain MV-PIG-2 is constructed in the same way as measuring chain MV-PIG-1 with differences only in some of the components used. For aerosol monitoring a 10 µm Ti window ionisation chamber (Ar or Xe as counting gas, 6 bar) and a 7.4 MBq Sr-90 test source are used. The same is valid for the noble gas monitor; in addition, this device has no cooler. At the iodine monitor, it is possible to place a lead plate in front of the detector in order to reduce the sensitivity and thus achieve a higher measuring range.

In case of exceeding certain limit values, actions such as insertion of active carbon filters and absolute filters in the GNH and SPG air outlet pipes, closing of the GW discharge pipe, by appropriate closing valves, are automatically initiated.

Control measurement values are read every eight hours; source tests are performed monthly, functional tests quarterly and calibrations every 1 ½ years.

Filters are replaced weekly for analysis.

4.1.5.4.3 Doel 3/4 RV/EV (Reactor Vent/Emergency Vent)

Radioactivity of the aerosols (P), iodine (I) and noble gases (G) in the reactor building stack (RV) and in the emergency ventilation outlet (EV) in normal circumstances is monitored by measuring chain 'RV-PIG-1'. In accident circumstances, monitoring is done by 'RV-PIG-2'. The set-up of the devices and their specifications are very similar to the ones for the main stack (MV, see chapter 4.1.4.4.2 above).

The function of these measuring chains is to monitor the radioactivity of the air in the reactor building stack (RV) or in the emergency stack (EV), including in the event of abnormal pressure and temperature. Consequently, the demands placed on the materials used are very high.

The current state of the art can meet these demands without compromising the specifications of a normal measuring chain (e.g. in terms of response time, etc.).

Similar to the setup at the main vent, in addition to the usual arrangement, the accident measuring chain RV-PIG-2 has another branch, the ‘normal logging chain’, set-up in an analogous way and performing analogous functions.

The switchover of measuring chains RV-PIG-1/2 from the reactor building stack to the emergency stack occurs in the event of the following incidents:

- steam pressure too low in one of the loops;
- temperature too low in one of the loops;
- containment pressure too high;
- pressuriser pressure too low.

One of these events is sufficient to trigger the start signal ('signal T') for the switchover and other automatic actions.

The measuring chains monitor the air in the stack of the reactor building, including in the event of abnormal pressure and temperature. The measuring chains can operate at a pressure of 4 bar and a temperature of 100°C. This means that, if necessary, a measurement can be performed one hour after an accident (LOCA or steam line break - SLB).

To prevent problems resulting from condensation, the damp air from the reactor building is transported in pipes surrounded by a heat-insulating material. There is also an automatic heating system to heat the air to a temperature that it would have in the event of an incident (around 100°C) with a view to avoid transitional situations.

A valve system, commanded by the start signal for the emergency stack, enables the measuring chains to start monitoring the emergency stack instantaneously.

The reactor building stack (RV) and the emergency stack (EV) never operate together, so that the measuring chains can monitor both and thus there is no need for separate measuring chains to monitor the RV and EV.

It is possible to switch off one measuring chain manually to enable a brief sampling in the other chain. An ‘interlock’ stops the valve system from closing until the emergency stack is open, to prevent a temporary obstruction in the measuring chains.

During normal operation of the reactor the two measuring chains are connected to the reactor building stack RV.

During flushing of the reactor building (“OPEN VENTILATION”) the two measuring chains are connected to the reactor building stack and perform full monitoring of the three types of contamination (P, I and G). The summation of the aerosol and iodine activity is done, where possible, via the filters of the 'normal logging chain' in RV-PIG-2.

In the case of a defect in a measuring chain, an assessment will be made and the necessary actions then taken. In some cases, a replacement measuring device will need to be provided during the repair period. The measuring chains are specially equipped for this purpose.

As for the equipment at the main vent, control measurement values are read every eight hours; source tests are performed monthly, functional tests quarterly and calibrations every 1 ½ years; and filters are being replaced weekly for analysis.

4.1.5.4.4 WAB (waste and water treatment facility)

The waste and water treatment facility (WAB) has its own stack, where gaseous discharges are monitored with regard to aerosols, iodine and noble gases ('RM-PIG-1'). The taking of samples for laboratory analysis is included in the 'normal logging chain' ('RM-PIG-2'). Sampling is isokinetic.

The chain RM-PIG-1 consists of:

- a device for measuring aerosol activity in the air, using paper filters and a gamma detector unit housed in a shield of 'old' lead (in order to reach the required detection limit); including a Cs-137 test source;

- a device for measuring iodine activity, consisting of an active carbon filter and a NaI(Tl) detector with a single channel analyser set at the energy of I-131 (364 keV), housed in a shield of 'old' lead; including a Ba-133 test source;

- a stainless-steel measuring tank for measuring gas activity, using a scintillation detector for beta measurement, surrounded by a shield of 'old' lead; including a Sr-90 test source;

- a local flow meter with high and low flow alarm, located after the pump and as close as possible to the discharge point in the stack;

- auxiliary equipment.

Sampling and stack flow rates are continuously recorded on a two-channel recording device.

There are three radioactivity alarms (low, high and very high level).

The 'normal logging chain' RM-PIG 2 comprises a double filter (aerosol and iodine) intended for periodic analysis in the counting chambers; a by-pass is provided. An air sampling bottle can also be included in the circuit. This chain serves for detailed logging of dust and iodine discharges and also for determining the isotopic composition of a sample of discharged noble gases through measurement in the counting chamber. The analysis of the filters is weekly. If the logging chain is not working correctly, the normal range chain can be used as an emergency solution for logging iodine and aerosol activity.

4.1.5.5 Verifications

The team verified the facilities installed for monitoring and sampling aerial discharges at Doel 4. The team observed the two monitoring sets (1 set RV+EV, particulates, iodine, gas; 1 set MV) and received a plan showing the details of isokinetic sampling at this stack (which is rather complex due to the stack design).

With regard to the paper filter on top of the charcoal device the team verified the presence of two sets (currently set 1 in use, set 2 on site, will be changed Sunday midnight).It noted that all monitoring devices are from *Hartmann & Braun AG*, Germany; all tubing is insulated.

With regards to calibration of the monitors three sources (high, medium, low activity) are used. The calibration sheet contains date, factors, computer printout, etc., no signature; however, the official document has the signatures of the person performing the calibration and the responsible; calibrations are done every 12 or 18 months, depending on the system (18 months also being the reactor cycle). All technical specifications are stored and available in the company's business software system (*SAP*); there is an early warning, if a specification is not met and the monitoring chain concerned becomes unavailable. Such an event would lead to corrective action plus an according INES rating.

It was explained that for the main vent MV the normal operation chain is calibrated with the low and medium activity sources, the accident chain is calibrated with the high and medium activity sources. The calibration data are kept in the work management system (frequency, date, time, all info), however, there are no labels on the devices showing such data.

The team also visited the Doel 4 control room containing computerized displays (*Honeywell Minitrend*) that replaced the old system using paper writers. Measurement data are given in Sv/h, ips, m^3/h; the parameter ratios are marked on paper labels: $MBq.h/m^3$ / ips.

Checks of the electronic connection between a monitor and the control room display are done every month during tests by staff from the instrumentation team.. Checks on the monitors using a check source are performed by staff from the radiation protection unit (every month).

All warnings and alarms are presented locally, at the operator's desk, and on the control panel.

For reporting measurement values daily logs are produced by each shift (there are three shifts per day) containing information such as hour, time lap, reading volume, volume difference, brut cps, detection limit if applicable (value given as minimum detectable activity (MDA) divided by 4, which is seen as easy procedure, the value being on the 'safe' side), released activity, paraph. Weekly logs are set up in a similar way

The team was told that for reporting the measured value (if above the detection limit) is used; for results below the limit of detection since some time the decision limit = ½ detection limit at 95% or ¼ of MDA is used; an automatic calculation is in place. Formerly, if a measurement result was below the detection limit a value of 0 was taken; thus, now artificially 'increased' release values are reported. For bookkeeping a similar procedure is in place.

If the 'normal' monitor, which has a low LLD, is out of order the 'accident' monitor, which has a higher (i.e. worse) LLD, is used. In such a case this higher LLD is taken as a basis for the reported 'value', which means that 'higher' releases are reported, although the factual releases may be zero.

Currently, for Doel 3 and 4 plans exist for replacing the air monitoring equipment, including electronics and racks in the control room.

> *The verification team suggests signing the calibration sheets by the person performing such calibrations. It also suggests placing labels on the monitoring equipment with calibration information such as date of the last calibration or foreseen date of the next calibration, with a view to facilitate quality control tasks.*

4.1.6 Doel on-site environmental monitoring – description and verification

4.1.6.1 Environmental monitoring with TLD system

Radiological environmental monitoring at Doel Nuclear Power Plant takes place in accordance with the Technical Specifications.

The monitoring program is based on a network of TL dosimeters at 18 different locations around the site's perimeter fence. The reference point for the set-up is the stack of the GNH (nuclear auxiliary building) of Doel 1 and 2 (18 sectors of 20° each). There are two dosimeters at each point, which are collected and read on a quarterly basis by SCK•CEN. Detector change is laid down in a maintenance plan in *SAP*.

The dosimeters enable the estimation of the integrated dose around the Doel site, and thus the noble gas concentration in the air above (since the contribution of aerosols and iodine is negligible).

Thus, the dosimeters are called 'testimony-dosimeters' since the reading of the TLD's with a view to estimating the possible dose received around Doel due to an emergency, is only possible after the emergency situations.

The verification team verified the device at point 5 (63°). It was informed that the data as supplied by SCK•CEN are contained in the monthly Safety Report, which is communicated to FANC and Bel V.

Verification does not give rise to specific remarks.

4.1.6.2 Site contamination measurements

Radiological surveys on the site's roads with a view to detect any contamination are carried out annually if possible (i.e. when the weather conditions allow such work), The total surface area to be surveyed measures approximately 20 000 m² and comprises asphalt and concrete roadways (including some parking areas).

According to a maintenance plan put down in *SA,* measurements are also performed at the gates, using handheld contamination monitors.

Recently, Doel NPP bought and equipped a completely new emergency van ('ITW1'), to perform measurements in the surroundings in case of an emergency. This van is also being equipped to perform routine site contamination measurements with higher efficiency and accuracy; it will be fully operational in the course of 2012.

The verification team received a thorough explanation of the set-up of the new mobile equipment. It is based upon a *Peugeot* van with pneumatic stabilisation, 4x4 drive, and rear camera; total weight is ca. 2.5 tons. A specific battery set is available to power measuring devices and auxiliary equipment; it is continuously loaded when not in use. Above 1500 rpm electric current for the 'lab' devices is supplied by the car.

A direct radio connection to the emergency room is available which also serves for data transmission.

The following measuring devices are built into the van:

- A *Berthold LB 2045* gamma spectrometer, based on a NaI(Tl) detector and using two ROI's (for Cs-137 and I-131), with a laptop for data handling;

- A *Berthold BAI 9128* air monitor (step filter band type; alpha and beta measurement with calculation of artificial beta activity), with iodine monitor (NaI(Tl) detector, calibration with a Ba-133 source); laptop computer for data handling; calibration is 1/year, functional tests once every three months. The equipment is usually operating all the time (24/7); shortly before the time of the visit the equipment had to be restarted due to a power problem.

- Gamma dose rate detector on the roof of the van (*Automess AD5*; calibration 1/a).

The van holds various sampling and auxiliary devices (according to a 'standard' list of devices that are accepted as minimum for mobile units; e.g. four *Staplex* air samplers, spiral drill for soil, …). The samples are brought back to the NPP and then distributed to the labs.

A GPS is built in; however, a display of measuring data combined with GPS info (e.g. with route specific geographical information) is not possible in the van.

Low activity radioactive sources for functional tests are available in the van.

Service contracts have been signed with *Canberra*, *Berthold* and *RADOS* for the respective equipment.

The team could also verify the multi-detector device that is used for road surface contamination measurements (mountable in front of the van). The device is based on 4 large *Berthold 6386* alpha-beta gas flow detectors (Argon Methane supplied by *Messer*), and 4 small 1.5" NaI(Tl) detectors for gamma detection (as 'background' information). The device can be operated at up to 1 km/h in 'push mode' (giving an LLD of 1 kBq per detector site). Measuring data are transferred to a laptop in the car and to one held by the accompanying person (on foot). When needed (in case of dubious results) the procedure is stopped and the van moves back. Before each measuring campaign the detector probes are purged for 24 hours and a calibration is performed; before each individual measurement a functional test takes place.

The team was also shown the predecessor of the new van ('ITW2'), which is similarly equipped as 'ITW1' (except for the air monitor) and will serve as backup. An old van ('KCD') is out of operation.

The team was also shown a trailer containing boxes with protective gear / decontamination devices; it noted that the handling description was only given in Dutch.

Due to international experience, Doel also started to develop a broader measurement program to detect contamination outside the controlled area. Contamination controls of the secondary systems are already performed since the start-up of the power plant, and contamination measurements of the road and at the gates are already standard since several years. But until recently, no contamination measurements were periodically performed on the roofs of the buildings surrounding the ventilation stacks. A yearly control of all roofs is being implemented for every power plant on the Doel site and will be effective soon.

The verification encourages the expansion of the monitoring programme.

4.1.6.3 Ground water activity measurements

Sampling is made at the more than 100 existing sampling points at the Doel site used to determine classic soil contamination. A 5-year programme has been defined in order to include the most representative sampling points at least once every 5 years.

Water is pumped with a sampling pump after controlling that the water is not stationary (thus certainly ground water). For each sampling point, a new clean hose and recipient is used.

All samples are measured:

- γ-global (200 s);
- γ-spectrometry (40 000 s) if the result of the γ-global measurement is > 0.020 MBq/m³;
- tritium analysis.

The team was informed that altogether 150 ground water points exist on the site, including the ones in an area that was planned for a 5th unit, with depths of 4 to 7 m. Sampling sites are selected beforehand for several years.

The team visited the location coded PKD_DS/MM_PR0032 (part of the 'old' system), 'locked' by a plastic fixing strip, and a 'new' groundwater sampling point (near the diesel tanks). The latter is made of stainless steel, 10 cm diameter; inside a 5 cm diameter pipe and a 8 mm diameter Teflon pipe allow connection to a pump; since the device had been newly set up the appropriate label was not yet in place.

Sample volume for ground water is1 l.

Verification does not give rise to specific remarks.

4.1.6.4 Rain water activity measurements

Besides the direct measurements performed on the roofs of several buildings, possible contamination can also be measured through analysis of the rain water after collection in the water reservoirs. A sample of every reservoir is analysed periodically to determine the activity.

Biological sewage purification installations serve for rainwater sampling: Discharges of rainwater from streets, building roofs etc. and sanitary water from 'outside' (i.e. not technical areas) is collected at five such locations. Water and sediment samples are taken twice per year.

The verification team inspected location no. 2; all drainage pits linked to the site were well labelled.

The possibility of further measurement programs is still being considered.

Verification does not give rise to specific remarks.

4.1.6.5 Doel meteorological station

The installation of the Doel nuclear power plant meteorological station consists of:

- Two anemometers and two measureing devices for wind direction. Two dynamic calculation modules use the signals from these measurements.
- A temperature measurement;
- Two pluviometers.

The two anemometers are mounted on a 380 kV high voltage pole near the plant (height 72 m), at sufficient distance from any buildings or cooling towers which may cause interference to the measurement. The power for the equipment can be supplied by the emergency room diesel generators..

The measurements are displayed in the control room, emergency room and in the on-site technical support centre, where they are also registered.

The meteorological measurements at Doel NPP provide the necessary data to perform dispersion calculations in case of emergency and major radiological releases. Doel operates both, a manual as well as a computer based dispersion model, which both need the meteorological information.

Due to its use for emergency purposes the measurement equipment has a high availability (above 90%). For this reason ultrasonic wind speed and wind direction measurement devices are installed. The sensors are completely encased and have built in heaters for operation in case of freezing or snowfall. The sensors are replaced and inspected every five years.

The meteorological measurements are included in the reporting of the radiological releases of the site, because:

- Concerning meteorology, the Doel site has been initially completely characterized according to a weather model based on the measurements results over a period of three years.

- The release limits are determined in such a way that no restriction has to be taken into account due to unfavourable meteorological circumstances.
- The analysis of the dose to the public is performed using conservative meteorological coefficients.

5 LABORATORIES PARTICIPATING IN THE (DISCHARGES AND ENVIRONMENTAL) SURVEILLANCE OF THE NPP SITE

5.1 THE OPERATOR'S LABORATORY/IES FOR DISCHARGE SAMPLES

At the Doel site the operator only performs measurements of discharge samples. Analysis of all environmental monitoring samples is outsourced to SCK•CEN.

5.1.1 Sample reception: sample identification and registration procedures

Liquids:

All samples are marked with a sticker containing information on date of sampling, sample type, entity, year as well as a frequency indication (day, week, month, quarterly) and the number of the respective period.

5.1.2 Sample preparation

Liquids:

Daily aliquots: normally the samples are collected in an automatic way (manual sampling is also possible).

ELK: for every 5 tons of water 200 ml is collected with an automatic sampling system.

GSL: for every 5 tons of water 270 ml is collected with an automatic sampling system.

Every 24 hours the collected liquid (in a 25 litre container) is homogenized and transferred to a 5 litre container for transport to the laboratory. 2 l of the liquid is spiked with 20 ml HNO_3 and afterwards stored for preparing the weekly-aliquot.

For ELK (and if applicable GSL) 1 l is temporarily stored for 1 day, the reason being to have an additional sample in case of the water containing oil or a high amount of suspended particles.

Weekly Aliquot: Out of the daily samples of the past week a representative mixture is prepared. From this sample a 1 l sub-sample is stored as witness sample, 1 l is used to prepare the monthly aliquot and 250 ml is sent to the Radiation Protection (RP) unit.

Monthly Aliquot: Out of the weekly samples a representative mixture is prepared. Out of this sample 1 l is stored to prepare the quarterly aliquot, 250 ml is used for isotopic analysis and gross gamma measurement, 250 ml is stored for tritium analysis, and 250 ml is sent to RP.

Quarterly Aliquot: Out of the monthly samples a representative mixture is prepared. One litre of this sample is sent to RP.

Gases

'D12': Before discharging a tank of gaseous waste, a sample is taken and analysed (gamma-spectrometry). At least 21 days of decaying are foreseen before discharging.

'D34': Before discharging a tank of gaseous waste a sample is taken (discontinuous process).

5.1.3 Sample measurement

Liquids:

For daily aliquots (only applicable for ELK samples) pH and gross gamma are measured.

For weekly aliquots 2500 ml is analysed (gross gamma as Cs-137 eq/m³ and isotopical analysis).

For monthly aliquots 250 ml are analysed (isotopical analysis, gross gamma as Cs-137 eq/m³, tritium).

For the quarterly aliquots (250 ml) gross gamma is measured as Cs-137 equivalent/m³.

Gases:

'D12': Gamma spectrometry (counting time 20000 s) is performed, however no gross gamma measurement.

'D34': A 2 litre sample of the gaseous waste tank is analysed by spectrometry for noble gases or gross gamma measurement as Xe-133 eq/m³ and by spectrometry for noble gases for accounting (gamma-spectrometry with a counting time of 4000 s).

For gamma spectrometric measurements at each entity two HPGe-coaxial detectors (one of them well type), manufactured by *Canberra*, are available. All results are calculated using *Canberra Genie* software. Maintenance takes place under a service contract with *Canberra*.

For tritium determination at each entity a *Packard* (now *Perkin-Elmer*) *Tricarb 1000 TR* LSC is available. Results are calculated with Perkin Elmer software. Sample preparation is with PicoFluor15 scintillation cocktail (to be replaced by *Biofluor+*). For the LSC devices there is no maintenance contract.

5.1.4 Recording ,archiving, data handling and reporting

For measurement results below the detection limit, the detection limit divided by 4 is used as the 'value'.

All data are collected and stored within the laboratory information tool (LIMS).

Within 60 days after the end of each month, KCD has to report the results of the accounting of the gaseous and liquid discharges of that month.

The report has to contain following information:

- Specification of the installation;
- Accounting period;
- The discharged volumes;
- Information in the radionuclides:
    - detection limits;
    - discharge limits;
    - discharged activity;
    - fraction of the discharge limits;
    - cumulated activity for the calendar year;
    - further specific information.

At the latest on May 1, a yearly report has to be transmitted to Bel V and FANC, which contains the following information:

- a summary of the radiological releases
  - a follow-up of the release limits;
  - a short description of the methods and techniques to determine the released activity;
  - the results of the radiological surveillance program;
  - the calculation of the dose to the public due to the declared releases;
- an evaluation of the long-term development and measures taken from an ALARA viewpoint.

5.1.5 Quality assurance and control procedures

For every sample LIMS has an automatic control of the value compared to the limit for the type of sample. If the limit is exceeded, an indication comes up and the chief of the laboratory has to validate the result manually. The procedures to be applied are described in internal quality control documentation.

The Doel operator's laboratories do not have ISO accreditation. However, for non-radionuclide analyses the laboratories do participate in international inter-comparison exercises (IQS, Barcelona, Spain; and R-concept, Laupheim, Germany).

For radionuclides (only gamma-spectrometry), there is an internal comparison programme between the different laboratories at Doel.

Gross alpha measurements are outsourced and performed by SCK•CEN.

The verification team inspected the site's Chemistry Department.

Shift personnel from the Chemistry Department takes the filters each Sunday night (aerosol filter and active carbon cartridges).

Samples are registered in a log book before measurement (manual input).

The team verified the measuring equipment (three *Canberra* HPGe detectors with NIM electronics for gamma spectrometry; one *Canberra* alpha chamber with vacuum pump - not in operation; a *Packard TriCarb 1000TR* LSC device with a *Canberra* NIM frame housing a *Canberra 3002D* high voltage unit, a single channel analyzer and a dual counter/timer; and a *Berthold LB20460* alpha-beta monitor). Calibration labels were placed on all equipment ('*geeijkt op … doer …*').

For gamma spectrometry background checks are performed weekly. Also weekly efficiency controls are done using a radioactive source; if the difference to the last test is larger than 10% the analysis quality is seen as not sufficient and a new background spectrum respectively a new efficiency calibration spectrum is taken. Altogether, 15 geometries are calibrated (cylindrical, Marinelli); there is no Monte Carlo method (e.g. *Canberra LABSOCS®*) based calibration. For spectrum management and analysis *Canberra Genie* software is used; as calibration source a mixed radionuclide source (MRNS) from *Canberra* (certified material by *CERCA*, France) is available. LN_2 filling for detector cooling is twice per week (Mondays and Wednesdays) with nitrogen supplied by *Messer Cryoservice*. There are also LN_2 tanks on site that are filled by *Air Liquide*.

For LSC background checks are weekly; two labels were on the device (one with regard to tritium analyses, a 2nd one regarding general quality control).

The team was informed that the LIMS is a *SIMATIC®* (*IT Unilab*). Results of gamma spectrum analysis are transferred to the LIMS by an interface, without manual input. Checks of the results are firstly done by the Chemistry Lab, then by Radiation Protect5ion. For reporting to FANC a centralised procedure is in place.

For result tracing the team selected an air filter from 17 May 2012 (one week sampling) from Doel 1+2, with measurement on 21 May 2012. The middle of the sampling week was taken as reference date for the analysis.

The team noted that for the chosen sample for the carbon cartridge the *Genie* analysis printout showed a certain level of Cs-137; the value in the LIMS system for Cs-137 however, was < LLD. The reason for showing different values could be explained (LIMS automatically takes the Cs-137 value from the aerosol filter). The values for I-131 showed perfect agreement between the *Genie* printout and LIMS, which for I-131 uses the carbon cartridge analysis.

With regard to the 'contamination' of the charcoal cartridge with Cs-137 checks (measurements in the night following the findings) revealed that there seemed to be a real Cs-137 contamination on the carbon in the cartridge. Older measurements using cartridges of different production dates did not show such behaviour. The laboratory team confirmed they would continue to search for the reason of this effect.

> *The verification team would like to be informed about the details of the tests concerning the Cs-137 content of the charcoal cartridge. Otherwise the, verification does not give rise to specific remarks.*

5.2 THE REGULATOR'S LABORATORY FOR DISCHARGE SAMPLES

The Belgian Nuclear Research Centre (*StudieCentrum voor Kernenergie - Centre d'Etude de l'Energie Nucléaire*; SCK•CEN) performs most of the analyses of control samples on behalf of the regulator. The centre was verified in in 2009; detailed results can be found in the Technical Report reference BE-09/01.

SCK•CEN is a Foundation of Public Utility (FPU) with a legal status according to private law, set up according to the law on 'non-profit associations' on 9 April 1952, and converted into an Establishment of Public Utility (EPU) on 29 May 1957, approved by Royal Decree of 23 July 1957.

The legal status of SCK•CEN, with some modifications, was confirmed in a Royal Decree of 16 October 1991 (Belgian State Gazette 22 November 1991). By virtue of the Law of 5 May 2002 (Belgian State Gazette 11 December 2002), SCK•CEN is governed by a Board of Governors. The articles and memorandum of association were approved by the King and published in the annexes of the Belgian State Gazette of 27 March 2006.

In accordance with its articles of foundation, SCK•CEN is the owner of its assets, built up by its activities or acquired by funding from the public authorities. SCK•CEN has no shareholders. The operational means comprise an annual grant for operations and investments provided from the federal budget and income resulting from contract research and services.

SCK•CEN is governed by an independent Board of Governors, appointed upon proposal of the Minister of Energy in consultation with the Federal Government. The Minister of Energy has a right of veto on any decisions of the Board of Governors.

Presently, the global SCK•CEN workforce amounts to about 600 employees, including about 150 researchers. SCK•CEN is accredited in accordance with ISO 17025 by the Belgian Accreditation Authority BELAC for all analyses made by the institute. It is not accredited for samplings.

Currently (2012) the LRM laboratory is busy extending the accreditation for all matters relating to sampling, sample preparation and sample management. The accreditation is envisaged for the second half-year of 2013. All methodologies (with the exception of the sampling methods) are accredited by BELAC (ISO 17025). All of these data are available via the Intranet.

By virtue of an agreement with FANC, it is the EHS Institute (Environment, Health and Safety), which is responsible at SCK•CEN for ensuring the safety of people and environmental protection as part of the use of radioactivity and of applications involving the emission of ionising radiation such as research into and protection against ionising rays.

The statutory mission of SCK•CEN accords priority to the research on aspects of safety, radioactive waste management, protection of people and the environment, the management of combustibles and other strategic materials and societal implications as part of sustainable development. These aspects also define the mission of the EHS Institute.

Its activities are supported by several approved laboratories that carry out analyses, apply measurement techniques and take radioprotection measurements, all of them specifically linked to radiation.

Low-level radioactivity measurements are carried out by specialist technicians in various laboratories assigned to this purpose. These measures concern the monitoring of the radioactivity in the environment around nuclear facilities and the health of the workers of such facilities. Every year, several thousands of biological (urine, faeces, etc.) and environmental samples (airborne dust, rainwater, surface water, sediments, soil, vegetation and foodstuffs) are collected and analysed.

The laboratories in question offer services to SCK•CEN as well as to external clients such as IRE. They are accredited for routine radio-biological analyses on environmental and biological samples. Accreditation was granted by BELAC, first in compliance with the European standard EN45001 (since 1998), and later on, since 2001, in compliance with the international standard ISO-17025.

The methods covered by the accreditation are:

- global alpha activity and global beta activity in aqueous samples;
- global alpha activity in nose blow samples;
- uranium concentration (by mass) in aqueous and urine samples;
- alpha spectroscopy to determine the isotope-specific activity in aqueous samples (including urine) and solid samples;
- Ra-226/Rn-222 activity measurement (Lucas method) in aqueous and solid samples;
- Sr-90 activity measurement in aqueous and solid samples;
- I-131 determination in milk samples;
- liquid scintillation counting of aqueous samples and combustible solid samples;
- gamma Spectrometry in aqueous and solid sample.

SCK•CEN was not part of the verification in 2012; verification details are given in the Technical Report of the verification of 2009 (reference BE-09/01) that mainly focussed on the monitoring of the Fleurus isotope production site.

6 THE NATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME (DESCRIPTION AND VERIFICATION)

With regard to national environmental monitoring the verification concentrated on the vicinity of the Doel site. However, in the following, a general description of the systems applied is given. Some details can also be found in the Technical Report of the verification visit performed in 2009 (reference BE-09/01).

6.1 INTRODUCTION

The radiological monitoring of the territory comprises two complementary parts:

- *Global monitoring of the territory* outside the zones where significant nuclear activity is carried out. It indicates, in particular, the level of radioactivity to which the population is naturally subjected. It particularly covers zones far away from nuclear sites such as the coastal region as well as 'reference' zones such as the Brussels conurbation, which is the largest urban area in Belgium with 10% of the population;

- *Close monitoring around sites* where an activity liable to have a radiological impact on the environment is carried out. This essentially concerns the following sites:

  1. the sites of the Doel and Tihange nuclear power stations;
  2. the surroundings, on Belgian territory, of the French nuclear power station at Chooz;
  3. the site of the Belgian Nuclear Research Centre (SCK•CEN), at Mol,
  4. the sites of *Belgoprocess*, *Belgonucléaire* and *Franco-Belge de Fabrication de Combustibles International* (FBFC International), at Mol and Dessel;
  5. the sites of the National Institute of Radioelements (IRE), *MDS-Nordion*, *Sterigenics and Ion Beam Applications S.A.* (*IBA*) at Fleurus (industrial zone).

  The monitoring around these installations and nuclear sites has a number of objectives:

  1. ensuring that the legal and regulatory provisions concerning environmental contamination are respected,
  2. checking through the control of discharges into the environment that these comply with the standards and authorised limits,
  3. if necessary, assessing the potential doses received by particular sections of the population,
  4. informing the public in an objective manner.

  Close monitoring also applies to installations where radioelements are used, such as hospitals, universities or particular industries, such as the industry producing feed phosphates in the Tessenderlo region. The process of this non-nuclear industrial activity notably concentrates a natural nuclide, radium 226, in the liquid effluents it discharges.

In practice, the radiological monitoring of the territory, which deals with the level of both artificial and natural radioactivity, is conducted in two ways:

- In a *continuous* way, by the automatic TELERAD network for measuring local ambient radioactivity;
- In an *intermittent* way, via periodic sample taking and analysis.

In order to monitor the environment correctly, FANC has developed its territorial monitoring programme along several lines:

- Responding to the primary duty of monitoring and protecting the environment and the population by taking account of the nuclear sites in Belgium and neighbouring countries;
- Responding to the requirements of international organisations to which Belgium adheres: the EC and the OSPAR Convention.

In practical terms, the libraries of radioactive elements to be measured have been adapted to respond optimally to these duties and requirements. Depending on the type of facilities at the nuclear sites, the type of practices and the more specific nature of some such practices, a number of radioactive elements have been systematically added to the lists of radionuclides to be sought, e.g.:

- In the surroundings of IRE: iodine (I-131) because it may be produced by this site and may have been discharged;
- In the waters of the Sambre, Meuse and Scheldt: iodine (I-131) due to their receiving waste water from the hospitals in the major urban areas adjacent to them;
- In the Molse Nete: U-234, U-235, U-238 and transuranic elements — Pu-238, Pu-239+240 and Am-241 —, in addition to the usual array of gamma emitters (fission and activation products including radio-caesium) because this watercourse receives liquid discharges from the nuclear installations of the Mol-Dessel site via the liquid waste treatment installations of Belgoprocess 2;
- In the Nete basin: Ra-226 because this stream is draining the waters of the Grote Laak and Winterbeek where the Tessenderlo facility producing feed phosphates (NORM industry) discharges its process water enriched with radium;

- In milk and drinking water: Sr-90 (fission product originating in nuclear reactors and nuclear fuel reprocessing plants) to meet the recommendation pertaining to Article 36 of the Euratom Treaty;
- In control meals: C-14 (as e.g. produced in nuclear reactors) is always verified in the context of reporting to the EC of data under Article 36 of the Euratom Treaty;
- In samples of marine fauna and flora (shrimps, mussels, seaweed): U-234, U-235, U-238 and transuranic elements — Pu-238, Pu-239+240 and Am-241 — in addition to the usual array of gamma emitters (including radiocaesium), Sr-90, Tc-99 and organic H-3 (OBT) as indicators of activities of the nuclear power industry – nuclear power and reprocessing plants – spent nuclear fuel reprocessing plants at La Hague (France) and Sellafield (United Kingdom);
- Natural 'control' radionuclides such as Be-7, cosmogenic, primarily detected in air and precipitation; and K-40, primordial origin, present 'everywhere' in the environment and in the human body (at a level of around 60 to 70 Bq/kg).

6.2 AUTOMATIC NETWORKS

The TELERAD network is the automatic remote radioactivity measuring network in Belgium. It comprises 219 radioactivity measuring stations, which constantly measure the radioactivity of the air and river waters (IMW).

The measuring stations are distributed throughout the entire country (IMN), around the nuclear facilities of Tihange (IMR), Doel, Mol and Fleurus, as well as in the urban areas (IMA) close to these installations and in those around the Chooz nuclear installations. These measuring stations are linked to a centralised system which they alert automatically if they detect any abnormal rise in radioactivity levels.

The TELERAD network is a measuring and early warning network and, as such, pursues the following two major objectives:

- The continuous recording of measurements (integration of 10 min) to provide all necessary statistical information on the level of radiation found in the country;
- The setting off without delay, of an alarm to signal exceeding a warning threshold.

TELERAD is thus an alarm network that enables the real-time detection of any abnormal situation, which may lead at its highest level of severity to the launching of the Emergency Plan for Nuclear Risks.

Figure 2 shows the locations of the various measuring stations.

In the event of a nuclear accident, TELERAD will play an important role in decision making,, optimising interventions and countermeasures implemented by the relevant authorities as well as keeping the country's citizens informed on a continuous basis.

FACN is in charge of operating the system. Visualization for the systems is achieved using the *PANORAMA* software. Public access to the results is possible via the internet (http://telerad.fgov.be/).

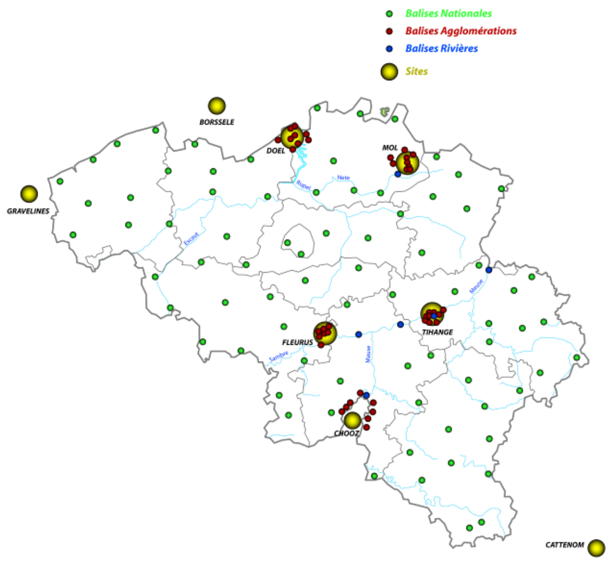

Figure 2: Map indicating the monitoring locations of the network stations.
(Balises nationales … national beacons; Balises agglomerations … urban area beacons
Balises rivières … river beacons; Sites … (nuclear) sites)

6.2.1 Ambient gamma dose rate monitoring system

The national (IMN) and urban areas (IMA) measuring stations for ambient gamma dose rate monitoring contain the following elements:

− An *IGS411* gamma dose probe with

- a low dose rate GM detector;
- a high dose rate GM detector;
- a rain sensor;

− and an inox case with

- *ENVILOG* — a computer system based on an embedded *Linux* controller used for recording data and as controller unit, including local display on a touchscreen monitor;
- adapter / GPRS modem including a standard antenna;
- DSL router;
- electric power units;
- battery power units (72 hours holding time except for heating);
- auxiliary units.

The case has a shield ensuring that the station can operate without ventilation and in varying environmental conditions.

The GM detectors for low dose and high dose rates have different sensitivities in order to cover a measuring range for the dose rate equivalent to the ambient dose H*(10) of 10 nSv/h to 10 Sv/h.

The central processing unit (CPU) manages the measuring intervals and calculates the measurement values. Average values are created at intervals of one minute, of ten minutes, of one hour and of 24 hours. They are saved in the memory buffer of the probe and are transmitted to the control unit with a time-stamp and the status of the information upon request.

The calibrated energy range is 38 keV to 1.3 MeV (upper limit of the calibration range at 1.3 MeV, due to absence of available reference sources for higher level energies). The upper radiation detection limit is in excess of 3 MeV. Given the fact that the detectors are not compensated for these high-level energies, a slight overestimation of higher-level energies is to be expected.

The accuracy of the detection is ± 10% for low doses and ± 15% for high doses. It is defined by means of a reference source (Cs-137) and is valid within a temperature range from -40°C to +60°C.

The *IGS411* probe uses a *70031A* GM detector for the low dose rate range with the following features:

- Sensitivity: 10 nSv/h ... 2 mSv/h
- Efficiency: 823 cpm/µSv/h
- Background noise of the detector: 38 cpm (this value is automatically subtracted from the measured value)
- Rate counted at point of overload: 300 000 cpm

For the high dose rate range *70018A* GM detector the features are:

- Sensitivity: 100 µSv/h ... 10 Sv/h
- Efficiency: 1.03 cpm/µSv/h
- Rate counted at point of overload: 3,000 000 cpm

The *IGS411* device is equipped with a certain number of self-tests to check the proper functioning of the GM detectors. The results of the automatic verification of the quality as well as of the status of the measurement (normal / reference test) are saved in a status of the measured valued and attributed to each value / set of data. The evaluation of the thresholds that will trigger an alarm can be activated separately for each group of data.

The rain detector was conceived as an extension for radiation monitoring stations in areas requiring a low rate of energy consumption and maintenance-free operation. It is directly installed on the top of the probe and is capable of detecting small quantities of rain or snow. The output of the rain detector is an indication of the presence of precipitations (yes / no), which is necessary to analyse the effect of wash-out and for the distinction between natural and artificial origin of the detected radiation. The result is saved with every reading in the status of the measurement value.

A controller unit comprises all resources necessary to manage the redundant communication (DSL and GPRS) with the surveillance centre (*PANORAMA*), to read out the measurement value and the technical status of the *IGS* probe, store the data locally, transmit the data and the status information upon request or spontaneously to the centre and to manage the power supply to the station, including the emergency power supply (battery).

The *ENVILOG* data recorder (consisting of a processor, a memory, interfaces including a touch screen human interface) serves for storing the measured values.

The capacity is such that up to a total of 170 000 values per ensemble can be recorded temporarily (1-minute values more than 3 months; 10-minute values more than 3 years; 1-hour values: around 20 years).

For the transmission of the data and of the status information, *ENVILOG* uses two communication devices, a DSL router connected via Ethernet; and a backup communication by GPRS modem.

Both methods provide access to the internet. Hence, all stations are at all times accessible online. Under 'normal' circumstances, the values and status information are regularly queried by the *PANORAMA* application at the main control station of FANC or by the secondary control stations by means of ADSL or by GPRS. If a radiological threshold is exceeded , or if the activation of a technical alarm is detected by a control unit, the monitoring station transmits the relevant information without delay ('spontaneous message') to the operating station and also redundantly (centre backup) by DSL or GPRS.

With regard to maintenance, annual checks are scheduled, comprising an accuracy test measurement with a Eu-152 test source.

6.2.2 Gamma spectrometric measuring stations (IMR)

Each measuring station of the 'ring' (IMR) installed around the four nuclear facilities consists of the following elements:

− an *AGS711F* gamma spectrometer using a *SARA* probe with:
  - a 1.5 "x 1.5" NaI (Tl) detector;
  - a GM detector for high gamma dose rates;
  - an integrated GPRS modem and a GPRS antenna;
  - an electric supply unit;
  - a battery for emergency supply (72 hour capacity);
  - a rain detector (optional);
  - auxiliary components.

− a concentrator installed in the local FANC stations, consisting of the following functional components:
  - *ENVILOG*-embedded *LINUX* system *INUX* used as a system for acquiring data and as a control unit;
  - an electric supply unit;
  - connection devices (for DSL and satellite; the satellite connection is not yet operational);
  - auxiliary equipment.

The case containing the measuring device is protected in order to allow operation without heating or ventilation. It is hermetically sealed (completely waterproof) and filled with gaseous nitrogen. An internal humidity sensor serves to detect leaks in the case.

Each of the four nuclear facilities at Doel, Tihange, Mol and Fleurus has a monitoring ring consisting of a maximum of 2x10 spectroscopy monitoring stations and a data concentrator.

Data transmission between the devices and to the data centre at FANC is set up in a complex, redundant way, to give a high reliability, including direct GPRS communication links from the stations to the data centre as backup.

The alarms for the radiological thresholds or the default techniques are transmitted to the concentrator by means of a 'station to station' transfer mode. If a radiological threshold is exceeded , or if a technical alarm activation is detected and received by the concentrator, the data concentrator will transmit the relevant information without delay ('spontaneous message') to the operation centre Brussels or the backup at Fleurus (redundant) using DSL, satellite or GPRS.

The NaI(TI) detector of the *SARA* probe has an energy resolution of < 6.6% FWHM for Cs-137 and an energy range of 30 keV to 2 MeV. The spectrum currently uses 2048 channels. A rough calibration is done at the factory, the on-site calibration (automatic) uses K-40. Dose rate is determined as H*(10). Radionuclide identification is adjustable with an internal library. Report files that include the dose rate value and the results of the spectral analysis are transmitted to the data centre.

A self-test system compares the results of the scintillator measurement with the ones of the high dose rate GM detector and thus enhances the reliability of the system.

6.2.3 Automatic surface water measuring stations (IMW)

The automatic surface water measuring stations (IMW) use medium resolution $LaBr_3$ gamma detectors, produced by *Saphymo*. The MCA is set at 1024 channels. The system contains all analysis instrumentation, communication units, electric supply, backup battery, and auxiliary devices.

The use of a $LaBr_3$ crystal enables the generation of higher resolution spectra, compared to a NaI(Tl) crystal of similar size. With $LaBr_3$, a resolution of 2.4% (FWHM) for 662 keV is currently achieved. The energy range of the system as installed is 30 keV to 2 MeV, the range of operating temperatures is -20°C to +55°C.

System stabilization is based on the intrinsic background noise of the crystal due to the radioactivity of La-138 (0.08% occurrence in the natural composition of lanthanum): Two gamma peaks can be used, one at 1473 keV, the other at 37 keV.

Analysis of the measured spectra takes into account the relevant background noise spectrum, calculated for the same conditions. Radionuclide analysis is performed on the individual acquisition spectrum as well as on a cumulated spectrum of several successive individual spectra, among them the last spectrum.

The efficiency curve is calculated by a Monte Carlo simulation (software distributed by CERN). It is valid for a LaBr3 crystal of 1.5" x1.5" located in the centre of a water basin with at least 70 cm of water in all directions around the centre of the crystal and more specifically, for energies ranging from 30 keV to 2 MeV.

An alarm is triggered if the reading exceeds one of three thresholds defined in advance specifically for the radionuclide concerned.

Maintenance is done once per year; in addition, checks are carried out once every three months.

6.3 LABORATORY BASED MONITORING NETWORK

6.3.1 Air and deposition

The sampling locations for the monitoring of the atmosphere in the vicinity of the nuclear sites, in the reference zone, at Coxyde (close to the coastal areas of the North Sea in West Flanders) and at Lixhe on the Meuse (close to the border with the Netherlands) by means of aerosol sampling and sampling of surface deposits (dry and/or wet precipitation) are shown in figure 3.

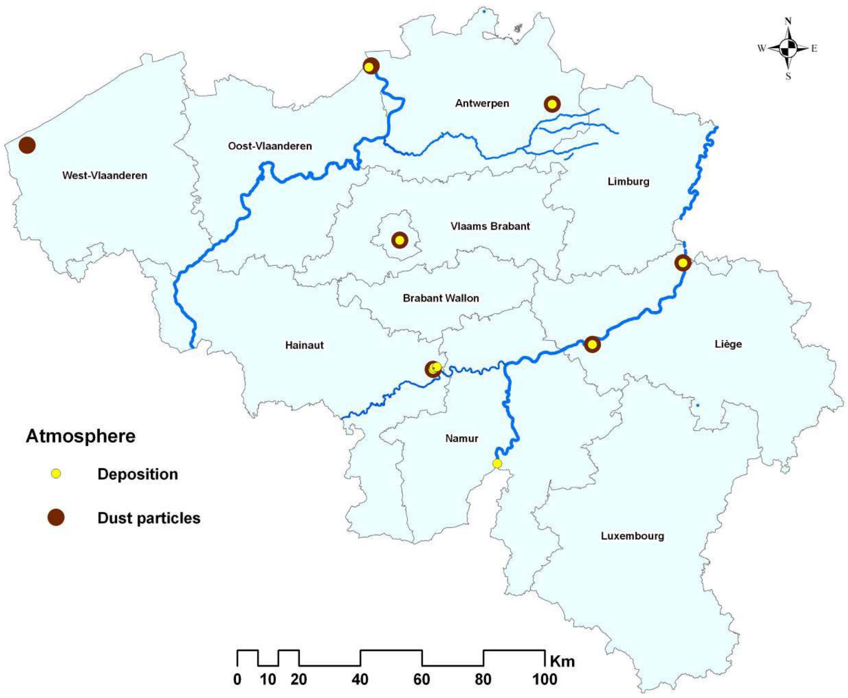

Figure 3: Sampling points for aerosols (brown) and precipitation (yellow)

6.3.1.1 Aerosols – fixed system

At fixed monitoring stations aerosol samples are collected daily using two types of sampling systems:

For Fleurus, Ampsin, Lixhe and Brussels, air dusts are collected using an automatic sampling system (OASIS - Outdoor Aerosol Sampling Intelligent System, developed by IRE-Elit) with a sample changer allowing the pumping of about 120 m³ of air, at constant flow rate, from 00:00 to 24:00 for the seven days of the week. Once a week, the seven filters (fibreglass filter of 50 mm diameter) are removed and replaced by new ones. Each filter is previously labelled (location code, number, date). The air volume sampled for each filter is automatically downloaded by communication means.

For Mol, Doel and Koksijde, daily samples are collected using a specially designed installation consisting of a filter holder, a paper (cellulose) filter with a diameter of 115 mm and an air pump which continuously pumps air through the filter paper. The total volume of the air pumped through the filter is measured by an integrating flow meter (approximately 300 m3 per 24 hours). The filter paper is replaced every 24 hours. Collection date and time and total volume of air pumped through the filter are registered.

Filters are stored for a minimum of 5 days to allow the decay of the natural radionuclides. After that decay time, gross beta activity is measured for each filter collected; for filters collected at Mol, a gross alpha measurement is done.

After gross alpha and/or beta measurement, all filters are stacked to produce a 4 weeks' sample, which is then sent to the laboratory for gamma spectrometry. These samples are stored for one month after submission of the respective quarterly result report.

6.3.1.2 Air – portable system

For mobile air sampling specially designed, portable air pumps with flow meter and a filter unit mounted on the inlet are available within the monitoring network. The filter unit contains both, a paper filter (for aerosols) and an active charcoal cartridge (e.g. for elemental and organic iodine).

The filter paper and/or charcoal cartridge are replaced once the desired sampling time is reached or the requested sampling volume has been reached.

After sampling, each filter/cartridge is sealed in a plastic bag and transferred to the laboratory for immediate measurement using gamma spectrometry.

For archiving, the filters/cartridges are kept according to specific requirements.

6.3.1.3 Precipitation

Weekly precipitation samples are collected using a quadratic stainless steel bin with a total surface of 0.5 m², containing a water film to also collect dry deposition.

The bin is protected with a metal grid to prevent birds from contaminating the water.

The sampling device has a heating device to prevent the water film from freezing in winter.

In summer time, during longer periods of warm and dry weather, the amount of water in the sampling device is kept to a level sufficient to assure proper sampling (by adding additional distilled water if necessary).

Each week, the content of the bin is transferred into a large plastic bottle after thoroughly stirring the content to resuspend any deposition. The bin is then rinsed with distilled water; this water is also collected in the same bottle. Finally, 10-15 L of distilled water is poured into the bin for the next sampling period.

The total volume of the sample collected is determined and the sample is subsequently divided into two equal parts, part A and part B. Part A is used to perform gamma spectrometry, part B is used to perform gross alpha/beta and H-3 measurements.

Both parts (A and B) are filtered. Both, the filtrates and filters are kept for further processing (a.o. mixing to form 4-week samples). The filters are dried.

Part A (gamma spectrometry): 4-week ('monthly') samples are prepared by mixing four consecutive filtered weekly samples (Part A) or four consecutive filters (Part A).

The four filters are placed on top of each other and measured by gamma spectrometry.

The mixed 4-week sample (filtrates Part A) is evaporated to 2.5 L. By adjusting the pH to above 7 losses of iodine are prevented. The final sample is transferred into a Marinelli beaker for measurement.

Part B (gross alpha/beta and H-3 measurement): The four filters (Part B) are measured individually for gross alpha and gross beta content.

From each weekly sample (filtrate Part B), 100 mL is taken and mixed to form a 4-week ('monthly') sample for the measurement of tritium.

The residual amounts of the weekly samples (filtrates Part B) are mixed to form a 4-week ('monthly') sample. This mixture evaporated to dryness onto a metal disc for measurement of gross alpha and gross beta activity.

For short-term storage, the two sets of filters (Part A and Part B) are kept in a dry place for one month after submission of the quarterly report. The metal disc for the gross alpha/beta measurement (Part B) is also kept in a dry place for one month after submission of the quarterly report. Since all of the filtrate is used in the process of sample preparation and measurement, no liquid samples are kept in storage. No long-term sample archiving is performed.

6.3.2 Water sampling programme

6.3.2.1 Surface waters

Figure 4 shows the sampling locations for river water and river sediments (Sambre, Meuse, Grote Laak, Winterbeek, Net Molse, Ruppel and Scheldt) and for the seaside environment (North Sea).

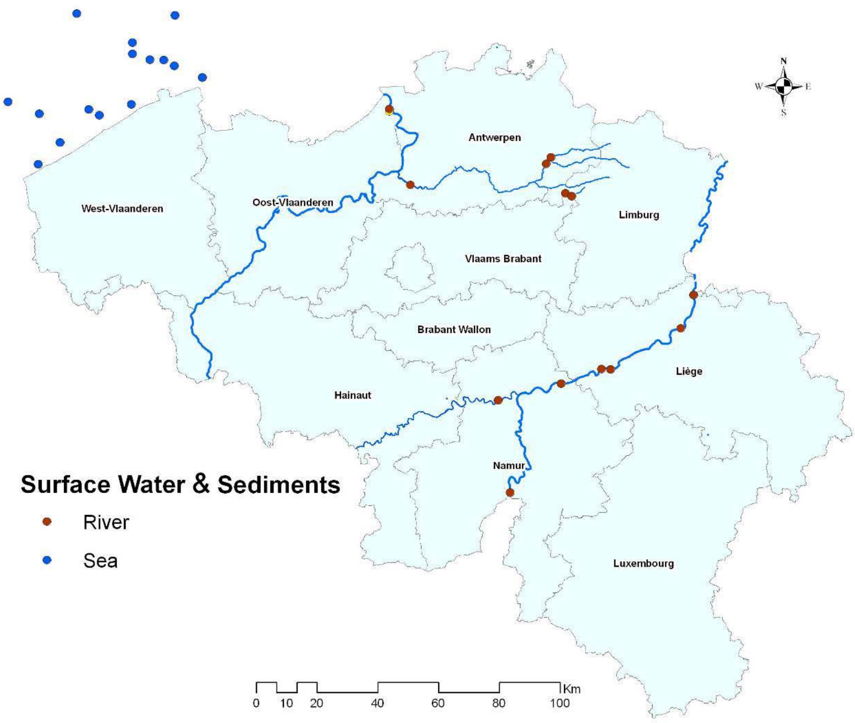

Figure 4: Sampling locations for surface water (rivers and sea) and for river sediment

For river waters both, an automatic method and manual collection, are applied.

Automatic sampling uses *PPMOS* samplers that allow continuous sampling over a 24 hr period, collected in separate 1 L or 2.5 L bottles. The bottles are uniquely identified and stored in a refrigerated compartment. Depending on the storage capacity of the *PPMOS* device the samples are transported to the measuring laboratory every week or every two weeks.

The automatic method is applied at Molse Nete, Grote Nete, Grote Laak and Winterbeek.

The manual method consists in taking once a week a 'weekly' grab sample using a bucket attached to a rope. Part of this sample is transferred into a uniquely identified 5 L plastic bottle.

The manual method is used for the samples from Rupel and Scheldt (taking into account the tides: sampling is done at low tide to avoid high salt concentrations).

Of each daily sample, 350 to 500 mL are mixed and filtered. The filter is discarded.

Of each weekly sample, 2.5 L is taken and filtered. The filtrates of two weeks are combined. The filter is discarded.

The rest of the samples is acidified and stored in the original bottles in a cool and dark storage room (< 10 C). These samples are kept for one month after the submission of the quarterly report.

The mixed sample is divided into sub-samples, according to the requested analyses:

- If an analysis of H-3 is requested, 100 mL of the mixed sample is taken and sent to the lab for measurement.
- If a gamma spectrometric analysis is requested, an aliquot of the mixed sample is transferred to a Marinelli beaker and sent to the lab for measurement.
- If a measurement of gross alfa/beta is requested, 1 L of the mixed sample is sent to the lab for measurement
- For the determination of the K-40 content, 100 mL of the mixed sample is sent to the lab for measurement.
- If measurement of actinides is requested (Scheldt and Molse Nete only), 500 mL of the mixed sample is taken and mixed with a similar sample of the previous two weeks (i.e. a monthly mixed sample is created). To the total volume of 1 L, 55 mL of concentrated nitric acid is added. This sample is sent to the lab for measurement by alpha spectroscopy.

No long-term sample archiving is performed. Only the residual portions of the original samples are stored. Intermediate samples (prepared by the measurement labs or the mixed samples) are discarded after measurement). Samples are always acidified for storage (to prevent loss for example of. actinides by adsorption to the vessel wall) using a sufficient amount of concentrated nitric acid to achieve about 1M in concentration. Storage is in a temperature controlled room (< 10°C) and in absence of light. The samples are kept till one month after the submission of the quarterly report.

6.3.2.2 Drinking water

Tap water

Figure 5 shows a map with the sampling locations for drinking water.

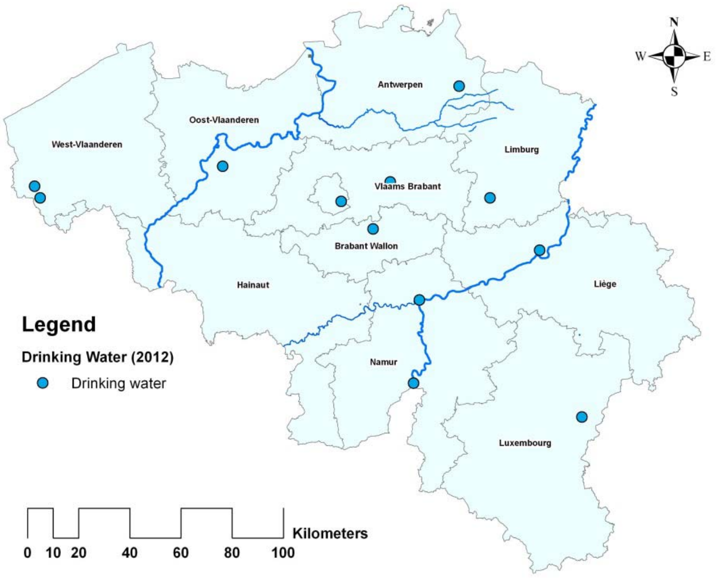

Figure 5: Sampling locations for drinking water (national monitoring system)

Within the national monitoring system drinking water samples are taken directly at the tap and transferred into plastic bottles (minimum 2 L).

The sample is divided into sub-samples, according to the requested analyses:

- 100 to 300 mL of the sample is taken and sent to the lab for tritium measurement.
- 300 mL to 1 L of the sample is taken and sent to the lab for gross alpha and gross beta measurements.
- an aliquot of the sample is taken and sent to the lab for K-40 determination.
- 10 mL of the sample is mixed with 10 mL of scintillation cocktail (*Perkin Elmer UltimaGold F*) in a *Teflon*® coated polyethylene vial, ready for any Ra-226 measurement or equivalent.

No long-term sample archiving is performed; the rest of the sample is acidified in the original bottles using a sufficient amount of concentrated nitric acid to achieve about 1M in concentration. These samples are stored in a dark room (< 10°C) and kept for one month after the submission of the quarterly report.

Spring water ('water harvesting')

Samples are taken as close as possible to the spring and transferred into plastic bottles (at least 2 L).

In the case of Rn-222 measurement, 10 mL of water is collected with a hypodermic syringe and mixed with 10 mL scintillation cocktail (*Perkin Elmer UltimaGold F*) in a *Teflon*® coated polyethylene vial or an equivalent method.

The sample is divided into sub-samples, according to the requested analyses:

- 100 to 300 mL of the sample is taken and sent to the lab for tritium measurement.
- 300 mL to of the sample is taken and sent to the lab for gross alpha and gross beta measurements.
- An aliquot of the sample is taken and sent to the lab for K-40 determination.

- 10 mL of the sample is degassed and mixed with 10 mL scintillation cocktail (*Perkin Elmer UltimaGold F*) in a *Teflon*® coated polyethylene vial, awaiting any Ra-226 measurement, or an equivalent method may be used.

No long-term sample archiving is performed; the rest of the sample is acidified in the original bottles using a sufficient amount of concentrate nitric acid to achieve about 1M in concentration. These samples are stored in a dark room (< 10°C) and kept for one month after the submission of the quarterly report.

6.3.3 Soil and vegetation related sampling programme

6.3.3.1 Soil

Figure 6 shows the soil sampling locations in the immediate vicinity of nuclear sites and in certain reference regions (seaside, Brussels Capital Region).

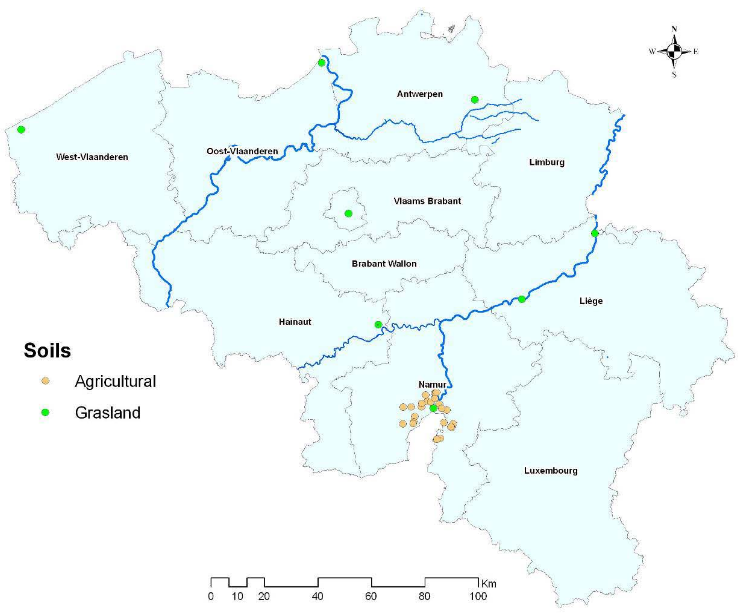

Figure 6: Sampling locations for soil

Yearly soil samples are collected using a tool designed for this purpose. A total surface of 0.125 m² is collected to a depth of 0.15 m. The sampling area is selected according the following criteria:

- If a nuclear facility is nearby (e.g. Doel, Mol, Fleurus, Tihange) the area is selected downwind of the facility (prevailing wind direction).
- The area is selected in an open space (not close to trees, roads, buildings, …). If possible the area to be sampled has a flat surface.
- When using a core sampler, if several samples are taken to achieve the total surface of 0.125 m², core locations must cover an area of 1 m² or more to have better soil homogeneity.

Any vegetation present (such as grass) is removed by cutting as close to the surface as possible and discarded.

Once the surface is cleared, the soil is removed up to a depth of 15 cm and collected in an appropriate container.

Sample preparation for measurement, consists in drying at 70 C to constant weight, manual removal of stones and roots, and grinding for homogeneity.

From the homogenised sample, a Marinelli beaker is filled for gamma spectrometric measurement. For Ra-226 measurement, some active charcoal is added to the sample to trap Rn-222 and the beaker is tightly sealed. For measurement of actinides (soil from Mol only) by alpha spectroscopy, an appropriate amount (50 - 100 g) is taken for calcination (destruction of organic material present in the dried sample) at 550°C during one day.

No long-term sample archiving is performed; the residual dried soil sample is kept in a dry place for one month after submission of the quarterly report.

6.3.3.2 Soils and crops in agricultural ecosystems

For each sampling point a representative soil sample is formed with a minimum of 15 individual samples per parcel collected with a soil corer. Sampling depth is 0-10 cm in the case of permanent pastures, and 0-20 cm in other cases.

Edible parts of crops for animals/human beings are sampled at the locations corresponding to soil samples or at the farms where they have been stored.

The samples are placed in paper bags, weighed and oven dried (60 to 70°C) until constant weight.

In the case of soil, stones are removed, samples are weighed, crushed and sieved.

The fraction < 2 mm is placed in a Marinelli beaker or a suitable beaker for smaller volumes and transferred to the lab for gamma spectrometric measurement. For Ra-226 determination, some active charcoal is added to the sample to trap Rn-222 and the beaker is tightly sealed and measured after a minimum of 3 weeks.

After measurement, appropriate amounts of sample are taken from the Marinelli beaker, for alpha spectrometric measurement (for soil only), for organic H-3/C-14 determination (for crops) and for Sr-90 analysis (for soil and crops).

No long-term sample archiving is performed; samples are kept one month after the annual result report.

6.3.3.3 Sediment (river and sea)

Sampling of sea sediment (North Sea) is performed by the ship *Belgica*, quarterly at specific, predefined sampling locations. The samples taken are frozen in 10 L recipients for collection by the SCK•CEN labs.

For the sampling of river sediments, two different systems are used:

Automatic samplers are installed in TELERAD cabins (Molse Nete, Sambre and Meuse). The sediment sample is collected every 4 weeks and transferred into a 10 L recipient.

At the other locations sedimentation bins are used. At the beginning of the sampling period, a sedimentation bin is placed in the river stream, attached to a fixed point on the river bank. After 4 weeks, the bin is retrieved and all collected sediment is transferred into a 10 L recipient.

Sediment sample (river or sea) preparation is by drying at 70°C to constant weight. If necessary stones or other larger debris (e.g. sea shells, …) are manually removed. The sample is then ground for homogeneity.

From the homogenised sample, a Marinelli beaker is filled for gamma spectrometric measurement. Active charcoal is added to trap Rn. In case of insufficient sample material, instead of a Marinelli beaker, a smaller plastic bottle is used.

From the homogenised sample, an appropriate amount (50-100 g) is taken for calcination (destruction of organic material present in the dried sample) at 550°C during one day. This sample is sent to the lab for measurement of actinides by alpha spectroscopy (sediment Molse, Nete and North Sea only) and for the measurement of Sr-90 and Tc-99 (Molse and Nete only).

No long-term sample archiving is performed; the residual dried sediment sample is kept in a dry place for one month after submission of the quarterly report.

6.3.4 Terrestrial and aquatic fauna and flora

Figure 7 shows the sampling locations for the monitoring programme of the living environment with a view of radioactivity in fresh water and salt water aquatic fauna and flora (bioindicators for the presence of radioactivity).

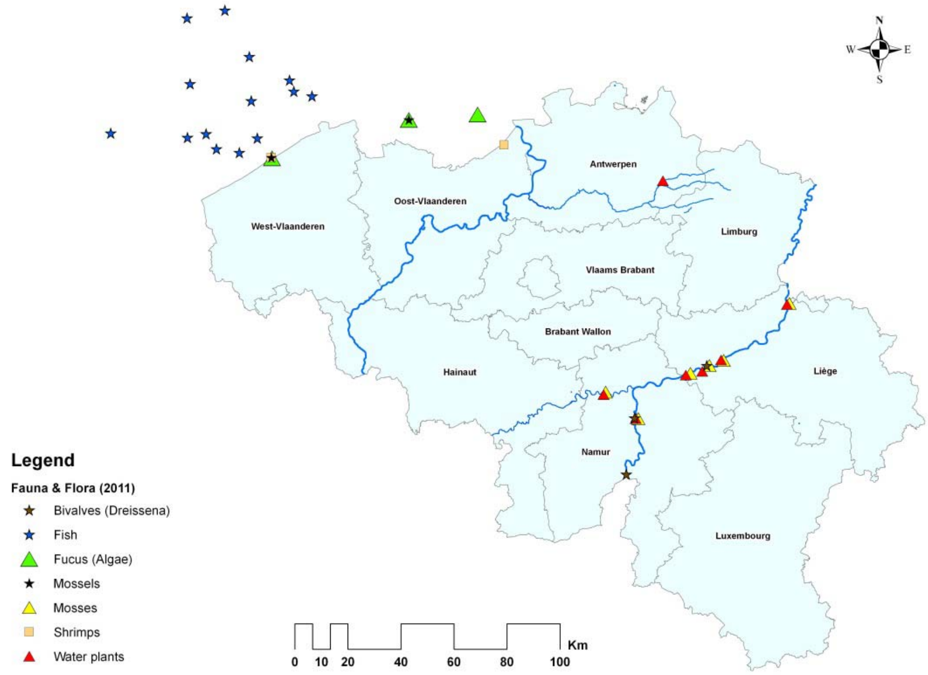

Figure 7: Sampling locations for aquatic bioindicators

6.3.4.1 Fauna and flora of fresh water (river)

Four times a year, aquatic flora samples are collected along river banks. The samples are collected directly by cutting.

Twice a year, samples of mussels (Dressena) are recovered using a special tool which allows scraping the banks at a depth of a few meters.

All samples (fauna and flora) are dried at 70 to 105°C for a minimum of 3 days; then crushed and transferred to an appropriate beaker for gamma spectrometry. A part (5 to 30 g) of the sample is processed for organic H-3 (OBT) analysis.

No long-term sample archiving is performed; samples are kept in a dry place for one month after the submission of the quarterly result report.

6.3.4.2 Fauna and Flora (estuary and marine environment)

For flora samples (fucus) a sufficient amount of plant material is collected in areas that are flooded by high tide but are accessible for harvesting at low tide. The sample is stored in a plastic bag.

For fauna samples (shrimps) a sufficient amount (about 3 kg) is bought from a local fisherman. For shell fish a sufficient amount is collected during low tide and stored in plastic boxes.

Fucus samples are rinsed with tap water, cut into pieces, dried in an oven at 70°C and ground.

Shrimps samples are dried in an oven at 70°C and ground.

Shellfish samples are rinsed with tap water and then steamed until they open. The meat is removed from the shell. The shells are discarded, the meat is dried in an oven at 70°C and ground.

For all samples a part is transferred into a plastic bottle for measurement by gamma spectrometry. One part (ca. 50 g) is transferred to the liquid scintillation laboratory for measurement of organically bound tritium (OBT). Another part of the sample (ca. 50 g) is calcinated at 550°C; the residue is dissolved in nitric acid for measurement of Sr-90 and actinides.

If a measurement of Tc-99 is requested part of the dried sample is transferred to the laboratory. About 100-300 mg of the sample is treated in a microwave oven (total dissolution); the resulting solution is measured by liquid scintillation for its Tc-99 content.

No long-term sample archiving is performed; the residual dried samples are kept in a dry environment for one month after submission of the quarterly report.

6.3.5 Foodstuff monitoring programme

Monitoring of foodstuffs is based on sample collection from markets and the retail trade, representing the typical meal of an average Belgian. Milk is collected at supermarkets and dairies that collect from a large number of farms — several thousands in Flanders and in Wallonia.

6.3.5.1 Milk

Weekly, a set of milk samples is collected for each region:

In the neighbourhood of Fleurus, Tihange and Chooz the following procedure applies: Every 6 to 8 weeks, a set of 1 litre beakers is brought to the office of the "Comité du Lait" at Battice. The beakers have been previously filled with a coloured chemical conservative prepared by dissolving 100 ± 0.5 g of sodium azide in 1000 g of demineralized water and adding 2 ± 0.1 g of blue Bromophenol. The office of the "Comité du Lait" transfers these beakers to the dairies of Recogne and Chéoux, then the samples are collected by the milk transporters, and are brought back to Battice. Every week such samples are recovered at the office of the "Comité du Lait" at Battice.

For the regions of Postel, Doel and Brussels daily samples are taken and combined on a weekly basis. These samples are then pooled and transferred for immediate gamma analysis.

The samples are pooled region by region; a portion of the sample is transferred into a Marinelli beaker and sent to the lab for a gamma spectrometric measurement.

The rest of the pooled samples is kept in a fridge at ≤ 10°C in order to allow preparation of 4-week average samples. These 4-week samples are calcinated and transferred to the lab for measurement of Sr-90.

There is one sample a week/month for each sampling location; this sample is kept the time needed for the preparation of the quarterly sample. No long-term sample archiving is performed; the residual quarterly sample is kept in a dry place for one month after the submission of the quarterly result report.

6.3.5.2 Mixed diet

'Reference' meals are collected on a monthly basis for each region (Brussels Capital Region, the Flemish Region and the Wallon Region) from company restaurants. Figure 8 shows the locations of sampling.

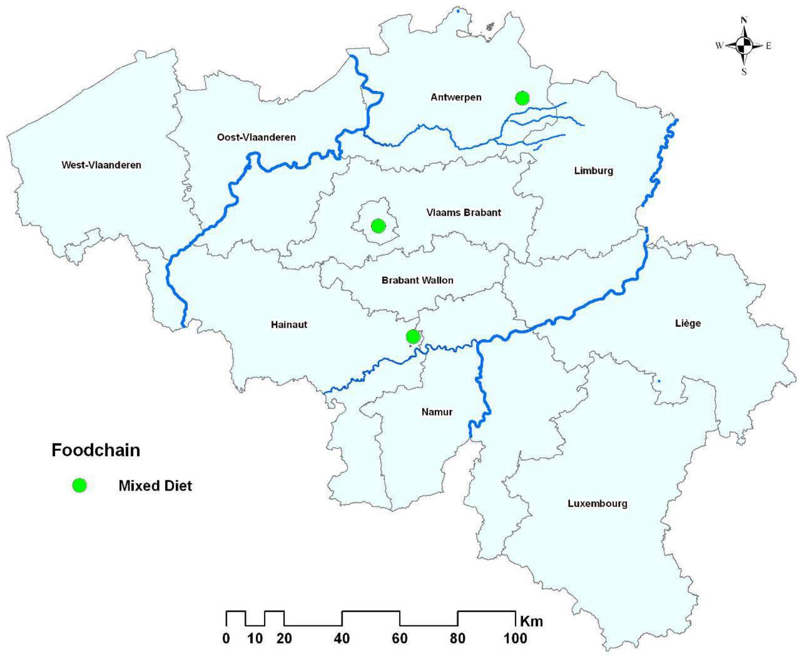

Figure 8: Sampling locations for mixed diet ('reference' meals)

6.3.5.3 Various foodstuffs (including wild foodstuffs)

The sampling of various foodstuffs is performed on the national territory and targets small and large distributors, markets, abattoirs, fisheries, etc.

The following vegetables are collected (depending on market availability): salads, leeks, celery, cauliflower, Brussels sprouts, white cabbage, red cabbage, broccoli, beans, carrots, chicory, asparagus, tomatoes, cucumbers, bell pepper, oyster plants, turnips, eggplants, courgettes, spinach, beetroot, fennel, pumpkin, onions, swede, potatoes, button mushrooms, wild mushrooms, etc.

Also fruit are collected as available at the market: pears, apples, nectarines, kiwis, plums, mangos, melons, oranges, bananas, berries, strawberries, blackberries, grapes, etc.

Meat from markets and abattoirs is also analysed: beef, veal, horse, pork, mutton, goat, rabbit, lamb, poultry (including chicken, turkey, pheasants, ducks, geese, ostriches, etc.), venison, wild boar in season. Snails and frog legs are checked as well. Varying concentrations of radionuclides may occur in the organs of one animal due to the metabolic processes by which radioactive elements penetrate and eventually settle in an organism. For example, caesium is mainly deposited in the muscles, strontium behaves similar to calcium and thus is built into the bone structure. Physiological concentration factors, differences in the fat and water contents of the organs may also have an impact on the concentration mechanism of the radionuclides. As the edible part of animals mostly consists of muscles it is seen as sufficient to determine the radiocaesium content of the muscles (meat) to obtain a general opinion on the quantity of radioactivity that may be transferred to people.

Fish from the fishing industry and fishmongers are also taken into account: fresh water fish (tilapia, catfish, etc.) and fish from the open waters (tuna, swordfish, bream, bass, sea perch, cod, herring, whiting, skate, sea trout, red mullet, ocean perch, coal fish, salmon, etc.) and groundfish (flounder, sole, etc.).

For Mol, Antwerp and Brussels, sampling of food chain products is done once every month by buying seasonal products at the local markets (four meat samples, four fish samples and four vegetable and/or fruit samples).

For Fleurus, sampling for the food chain is done once a week (one meat sample, one fish sample and one vegetable or fruit sample).

In preparation for measurement, each sample is sliced into smaller pieces and dried (fish and vegetables) at 70 to 80°C or freeze dried (meat). The weight before and after drying is registered. Each (freeze) dried sample is ground for homogeneity. From the homogenized sample, a Marinelli or a smaller plastic beaker is filled for gamma spectrometric measurement. If a statistically significant result for Ra-226 is found, active charcoal is added to trap Rn, and the sample is kept for three weeks to allow equilibrium and then measured again.

For each of the three different types (meat, fish and vegetable) a mixed quarterly sample is prepared by taking and mixing portions of the monthly samples. These quarterly samples are calcinated at 550°C and transferred to the lab for measurement of Sr-90.

No long-term sample archiving is performed; the residual dried samples are kept in a dry place for one month after submission of the quarterly report.

6.4 NATIONAL MONITORING SYSTEM – VERIFICATION ACTIVITIES

Parts of the national monitoring system were also touched by the verification in 2009 (see Technical Report ref. BE-09/01). Thus, the verification team concentrated on monitoring installations in the vicinity of the Doel NPP.

6.4.1 National monitoring installations on the NPP site perimeter

The verification team observed several FANC stations that are installed within the premises of the Doel NPP (a few metres inside the site fence). In particular, it could verify the operation of the device IMR/D16; *SARA Envinet* type *IGI711-B*; Ser.Nr. 0194.

6.4.2 National monitoring installations off-site the NPP site perimeter

The verification team visited the FANC station located off site just after the NPP fence. The ground belongs to the NPP, however it is separately fenced in, with a locked gate.

The team received several presentations, in particular on the renewed automatic systems, and could verify several sets of devices, some of them kept as spares at that location.

With regard to data management and data presentation it received an on-line presentation of the web based *PANORAMA* system.

The team was informed that maintenance of all stations is by FANC. At the time of the visit, one TELERAD station showed power failure; responsible FANC staff have three days to go to the station and check the device. (The information on the screen includes the initials of the technician responsible/on duty.)

With regard to data presentation the team saw that data are also presented in Bq/m^2, calculated as a rough deposition estimate, based on the surface the detector 'sees'; FANC staff is aware that the value is not correct, but can be compared with 'normal' values and thus, offers valuable information in emergencies.

The team was shown a set of new and old mobile probes and noted that the new ones are much smaller and easier to handle.

All data communication equipment for the station (including a *CISCO 800 series* router etc.) is contained in a large 19" rack.

The team was also shown spare $LaBr_3$ detectors that are used for testing the new water measurement system in the Scheldt River.

The large area around the station building houses a 30 m meteorological mast, with a Telerad (gamma dose rate monitoring) device mounted.

Furthermore, there is an ultrasonic wind detector which is no longer in operation as it did not work properly, and a precipitation measuring device.

The visit to other nearby sites was cancelled; it was deemed unreasonable because the automatic devices will be moved to another place; at the current location there were problems with the tide. Currently, sampling of water and sediments is done manually.

> *Verification does not give rise to specific remarks. The verification team would like to be informed about the results of testing $LaBr_3$ detectors.*

7 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 conclusions:

(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 around the site of Doel NPP as well as on the territory of Belgium in the vicinity of the site are adequate. The Commission could verify the operation and efficacy of a representative part of these facilities.

(2) A few topical recommendations and suggestions are formulated. These aim at improving some aspects of discharge monitoring from, and environmental surveillance around the Doel NPP site and the national monitoring system. They do not discredit the fact that environmental monitoring around the NPP site as well as the verified parts of the national monitoring system for environmental radioactivity are in conformity with the provisions laid down under Article 35 of the Euratom Treaty.

(3) The verification findings and ensuing recommendations are compiled in the 'Main Conclusions' document that is addressed to the Belgian competent authority through the Belgian Permanent Representative to the European Union.

(4) The competent Commission services would ask to be informed by the Belgian authorities about any significant changes in the set-up of the monitoring systems and – in particular – about experiences with using advanced monitoring equipment such as $LaBr_3$ detectors.

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

(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

Overview-questionnaire - Background Issues Discharge and Environmental Monitoring DOEL - NUCLEAR POWER PLANT - Discharges and on site environmental monitoring, Belgium

FANC

- http://www.fanc.fgov.be/page/homepage-federaal-agentschap-voor-nucleaire-controle-fanc/1.aspx
- The Radiological Surveillance Programme around DOEL (ppt presentation)
- Regulatory Body in Belgium, Federal Agency for Nuclear Control and Bel V (ppt presentation)
- The Radiological Surveillance in Belgium (ppt presentation)
- Department of Nuclear Facilities (IANBI) (ppt presentation)
- The New TELERAD Network - *The Radiation early warning automatic network in Belgium* (ppt presentation)
- The Radiological Surveillance Programme around DOEL (ppt presentation)

Bel V

- http://www.belv.be/index.php?lang=english
- Regulatory Inspections in Belgium (ppt presentation)

Doel NPP

- Doel NPP Discharges and on site environmental monitoring (ppt presentation)

APPENDIX 2

THE VERIFICATION PROGRAMME – SUMMARY

Monday 18/6

EC team travels to Brussels

Opening meeting at FANC/Brussels

Tuesday 19/6

EC team travels to Doel

Verification activities with regard to discharge monitoring by the NPP operator (aerial)

Wednesday 20/6

Verification activities with regard to discharge monitoring by the NPP operator (liquid)

Verification activities with regard to the NPP operator's laboratories for discharge and environmental monitoring

Thursday 21/6

Verification activities with regard to on-site environmental radioactivity monitoring by the NPP operator

Verification activities with regard to environmental radioactivity monitoring by the authority in the surroundings of the Doel NPP

EC team travels to Brussels

Friday 22/6

Closing meeting at FANC/Brussels

Return of EC team to Luxembourg

EC team: Constant Gitzinger, Eberhardt Henrich, István Turai ('trainee')

Team leader: Constant Gitzinger