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D.3 - Radiation protection and nuclear safety

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

BELGIUM

**Tihange NPP discharge and environmental monitoring
and
National environmental radioactivity monitoring network in the vicinity
14 – 17 November 2016**

Reference: BE 16-05

**VERIFICATIONS UNDER THE TERMS OF ARTICLE 35
OF THE EURATOM TREATY**

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| FACILITIES | Monitoring of liquid and gaseous discharges at the Tihange Nuclear Power Plant Environmental radiation monitoring in the vicinity of Tihange NPP together with elements of the national environmental radiation monitoring programme |
| LOCATIONS | Tihange, Belgium |
| DATES | 14 to 17 November 2016 |
| REFERENCE | BE 16-05 |
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| SIGNATURES | |

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1 INTRODUCTION

Under Article 35 of the Euratom Treaty, all Member States must establish the facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with basic safety standards¹. Article 35 also gives the European Commission (EC) the right of access to such facilities to verify their operation and efficiency. The radiation protection and nuclear safety unit of the European Commission's Directorate-General for Energy is responsible for undertaking these verifications. The Joint Research Centre Directorate-General provides technical support during the verification visits and in drawing up the reports.

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

- liquid and airborne discharges of radioactivity from a site into the environment;
- levels of environmental radioactivity at the site perimeter and in the marine, terrestrial and aquatic environment around the site, for all relevant pathways;
- levels of environmental radioactivity on the territory of the Member State.

Taking into account previous bilateral protocols, a Commission Communication² describing practical arrangements for Article 35 verification visits in Member States was published in the Official Journal of the European Union on 4 July 2006.

2 PREPARATION AND CONDUCT OF THE VERIFICATION

2.1 PREAMBLE

The Commission notified Belgium of its decision to conduct an Article 35 verification in a letter addressed to the Belgian Permanent Representation to the European Union. The Belgian Government subsequently designated the Federal Agency for Nuclear Control (FANC) to lead the preparations for this visit. This was the second such verification in Tihange; the first verification took place in 1996 [2].

2.2 DOCUMENTS

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

2.3 PROGRAM OF THE VISIT

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

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

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

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

Subsequently Electrabel presented the monitoring of discharges and on-site environmental monitoring at the Tihange NPP.

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

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

AFCN-FANC

| | |
|------------------------|------------------------------------|
| Kamr Eddine OULID DREN | Inspecteur-expert du service IANBI |
| François MENNESON | Expert du service GLTOE (TELERAD) |

IRE Elit

| | |
|-------------------|--|
| Benoit DECONNINCK | Responsable du projet de surveillance radiologique du territoire |
| Damien BRAEKERS | Responsable du laboratoire de mesure de la radioactivité |
| Tony DIEUDONNE | Responsable technique des mesures par spectrométrie gamma |

SCK•CEN

| | |
|----------------|---|
| Liesel SNEYERS | Laboratoire Mesures de Faible Radioactivité |
|----------------|---|

Bel V

| | |
|---------------|----------------------------|
| Etienne MINNE | Contrôleur en Exploitation |
| Pierre BARRAS | Area Manager |

Electrabel Tihange NPP

| | |
|------------------|---|
| Damien CARTON | Chef du service Environnement |
| Thierry HUART | Chef du service Radioprotection |
| Stéphane DEVAHIF | Contremaître Radioprotection Logistique |
| Philippe PETIT | Chef du service Chimie |
| Philippe GILTAIX | Contremaître Chimie T2 |
| Jacques MAQUINAY | Chef du service Déchets |
| Ronan GILSON | Ingénieur Maintenance Instrumentation |
| Christel MILICHE | Nuclear Safety Advisor |

3 RESPONSIBLE ORGANISATIONS

3.1 FEDERAL AGENCY FOR NUCLEAR CONTROL

The Federal Agency for Nuclear Control (FANC) is the public body in Belgium, which is in charge of radiation protection of the population, surveillance of environmental radiation and control of nuclear facilities. It comprises 5 departments and employs some 150 members of staff.

3.2 BEL V

Bel V is a subsidiary of the FANC and has since April 14th 2008 taken over the regulatory controls in nuclear installations formerly carried out by the Authorized Inspection Organization (AVN). FANC relies on the technical expertise of Bel V for carrying out inspections in nuclear power plants and other nuclear installations in Belgium (hospitals, universities and radionuclide production facilities). Bel V acts as an expert for the safety assessments of nuclear projects, participates in meetings and working groups that are organized in the framework of international organizations (EC, OECD, IAEA), exchanges information and experience feedback with Belgian and foreign colleagues and contributes to the emergency plans for nuclear accidents.

3.3 DIRECTION GÉNÉRALE CENTRE DE CRISE

Direction Générale Centre de Crise (DGCCR) is the crisis response organisation of the Belgian government. It maintains stand-by services and analytical capabilities for national emergency situations, including nuclear and radiation emergencies.

4 LEGAL FRAMEWORK FOR ENVIRONMENTAL RADIOACTIVITY MONITORING

4.1 INTRODUCTION

Belgium has a comprehensive legislation on monitoring radioactivity. The national legal provisions for environmental radioactivity monitoring, discharge monitoring, radiation surveillance of foodstuffs and international guidance documents are summarised in the sections below.

4.2 LEGISLATIVE ACTS REGULATING ENVIRONMENTAL RADIOACTIVITY MONITORING

The following legal acts regulate the radiation surveillance of the environment in Belgium:

- *Loi du 15 avril 1994 relative à la protection de la population et de l'environnement contre les dangers résultant des rayonnements ionisants et relative à l'Agence fédérale de Contrôle nucléaire*³, articles 14, 15 and 21, Moniteur Belge 29 July 1994
- *Arrêté Royal du 20 juillet 2001 portant règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants*, articles 70-71, Moniteur Belge 30 August 2001, edition 1 (GRR-2001)

The Royal Decree (GRR-2001) provides the basic nuclear safety and radiation protection regulations. It is amended and updated regularly by the safety authorities in order to take into account scientific and technical developments and the European Union directives. Its Article 20 deals with limitation of doses and Articles 33 to 37 with radioactive waste and discharges

In addition there is an agreement with France of 8 September 1998, which lays down the principles of monitoring the environment around the Chooz NPP, which is located on the border between France and Belgium.

³ Modifiée par les arrêtés royaux du 7 août 1995 et du 22 février 2001 ainsi que par les lois du 12 décembre 1997, du 15 janvier 1999, du 3 mai 1999, du 10 février 2000, du 19 juillet 2001, du 31 janvier 2003, du 1 avril 2003, du 22 décembre 2003, du 20 juillet 2005 et également par celle du 15 mai 2007.

4.3 LEGISLATIVE ACTS REGULATING RADIATION SURVEILLANCE OF FOODSTUFFS

The following legal acts regulate the radiation surveillance of foodstuffs in Belgium:

- *Loi du 15 avril 1994 relative à la protection de la population et de l'environnement contre les dangers résultant des rayonnements ionisants et relative à l'Agence Fédérale de Contrôle Nucléaire*, articles 14, 15 and 21, Moniteur Belge 29 July 1994
- *Arrêté Royal du 20 juillet 2001 portant règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants*, articles 70-71, Moniteur Belge 30 August 2001, edition 1
- *Loi du 4 février 2000 relative à la création de l'Agence Fédérale pour la Sécurité de la Chaîne Alimentaire*, articles 4 and 5, Moniteur Belge, 18 February 2000
- *Convention entre l'Agence Fédérale de Contrôle Nucléaire (AFCN) et l'Agence Fédérale pour la Sécurité de la Chaîne Alimentaire (AFSCA)* of 6 April 2004, revised in 2012

4.4 LEGISLATIVE ACTS REGULATING DISCHARGE MONITORING

The following legal act regulates the radiation surveillance of discharges in Belgium:

- *Arrêté Royal du 20 juillet 2001 portant règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants*, in particular articles 20, 34 and 36.

According to this Decree discharges to the soil are always forbidden. Discharges to surface waters and sewers are forbidden as soon as the concentration in the effluent exceeds one thousandth (at the discharge point) of the limit on the annual ingestion level by adults of the general public. Deviations from these generic limits may be included in the licenses for class I or II facilities, based on performed surveys or studies of radiological impact.

For the Tihange site reactor units in particular, the following legal acts apply:

- *Arrêté royal du 5 septembre 1974 (S.4.216/B)* (Tihange 1)
- *Arrêté royal du 8 juin 1982 (S.5600/B)* (Tihange 2)
- *Arrêté royal du 17 décembre 1984 (S.7766/B)* (Tihange 3)

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 on assumptions) related with a scheme to notify the operators, the Health Physics Department, Bel V and FANC.

Following Article 81.2 of the GRR-2001, the existing authorised discharge limits (gaseous and liquid releases) have been re-evaluated in 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 the annual dose threshold to the public of 1 mSv.

The following legislative acts establish the responsibilities of the various actors in this domain:

- Article 23 of the Royal Decree of 20 July 2001 lays down the requirements and responsibilities for maintaining a register of gaseous and liquids discharges as well as solid radioactive waste at the Tihange NPP
- Administrative note AFCN 010-106-N-F « Déclaration périodique à l'AFCN et Bel V concernant les rejets des effluents radioactifs liquides et gazeux. » of 14 December 2010 requires Tihange NPP to declare monthly liquid and gaseous radioactive discharges to FANC and Bel V.

4.5 INTERNATIONAL LEGISLATION AND GUIDANCE DOCUMENTS

The list below includes the main international legislation and guidance documents issued by the International Atomic Energy Agency, the International Commission on Radiological Protection and the European Union that form the basis for environmental radioactivity monitoring, the radiation surveillance of foodstuffs and the radiation surveillance of radioactive discharges.

- Convention on Nuclear Safety
- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
- OSPAR Convention for the protection of the marine environment of the North-East Atlantic
- Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom
- Council Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption
- Commission Recommendation 2000/473/Euratom of 8 June 2000 on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole
- Council Regulation (EC) No 733/2008 of 15 July 2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station
- Commission Implementing Regulation (EU) No 322/2014 of 28 March 2014 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station
- Clearance of materials resulting from the use of radionuclides in medicine, industry and research, IAEA-TECDOC-1000, IAEA, Vienna, 1998
- Generic models for use in assessing the impact of discharges of radioactive substances to the environment, Safety Reports Series No 19, IAEA, Vienna, 2001
- Handbook of parameter values for the prediction of radionuclide transfer in temperate environments, Technical Reports Series No 364, IAEA, Vienna, 1994
- International basic safety standards for protection against ionizing radiation and for the safety of radiation sources, General Safety Requirements Part 3, No. GSR Part 3, IAEA, Vienna, 2014
- Management of radioactive waste from the use of radionuclides in medicine, IAEA-TECDOC-1183, IAEA, Vienna, 2000
- Regulatory control of radioactive discharges to the environment: Safety Guide, Safety Standards Series No. WS-G-2.3, IAEA, Vienna, 2000
- Sources and effects of ionizing radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report to the General Assembly, Vol. I, United Nations, New York, 2000
- Council Directive 96/23/EC of 29 April 1996 on measures to monitor certain substances and residues thereof in live animals and animal products and repealing Directives 85/358/EEC and 86/469/EEC and Decisions 89/187/EEC and 91/664/EEC
- IAEA Safety Standards, Environmental and Source Monitoring for Purposes of Radiation Protection, Safety Guide No. RS-G-1.8, 2005

5 TIHANGE NPP SITE AND ITS RADIATION SURVEILLANCE PROGRAMME

5.1 INTRODUCTION

The Tihange Nuclear Power Plant (TNPP), also referred to as ‘Centrale Nucléaire de Tihange’ (CNT), is operated by ENGIE Electrabel. TNPP consists of three production units, each with a three loop Pressurized Water Reactor (PWR) (Table I). They are called Tihange 1 (T1), Tihange 2 (T2), and Tihange 3 (T3). Each of the units consists of a similar group of buildings encompassing all of the systems required for independent operation of the unit. The TNPP site covers an area of 75 hectares and is located on the right bank of the Meuse River, downstream, close to the city of Huy (Picture 1).



Picture 1. Tihange NPP

The power output of Tihange 1 was updated in 1994, 1995 and 1997. The power output of Tihange 2 was updated in 1995 and again in 2001; in 2009 the uprating was done for Tihange 3. The fuel cycle lasts 18 months for all three units. The plant uses water from the Meuse River as a coolant in the outer (third) cooling circuit. This cooling water, after passing through the condenser, is fed through a natural draught cooling tower (one for each unit) before being recuperated or discharged back into the Meuse River.

Currently all three units are operational; the operational licences allow an operational lifetime of 40 years. Tihange 1 has been granted extension of 10 years, starting on 1st October 2015.

Tihange NPP environment management system has a general quality accreditation according to ISO 14001 since 1999. Tihange is registered EMAS (Eco-Management and Audit Scheme) following Regulation (EC) No 1221/2009. The plant publishes an annual environmental report⁴.

⁴ <http://corporate.engie-electrabel.be/wp-content/uploads/2016/10/declaration-environnementale-cnt-2016-bd.pdf>

Table I. Tihange NPP technical specifications (PWR 3L - Pressurized water reactor 3 loops, EBL- Electrabel, EDF - Electricité de France)

| | Tihange 1 | Tihange 2 | Tihange 3 |
|-----------------------|------------------|------------------------|------------------------|
| Reactor type | PWR 3L | PWR 3L | PWR 3L |
| Year of commissioning | 1975 | 1983 | 1985 |
| Ownership | EBL/EDF 50/50 | EBL/EDF 89,81/10,19 | EBL/EDF 89,81/10,19 |
| Net electrical power | 962 MWe | 1008 MWe | 1038 MWe |

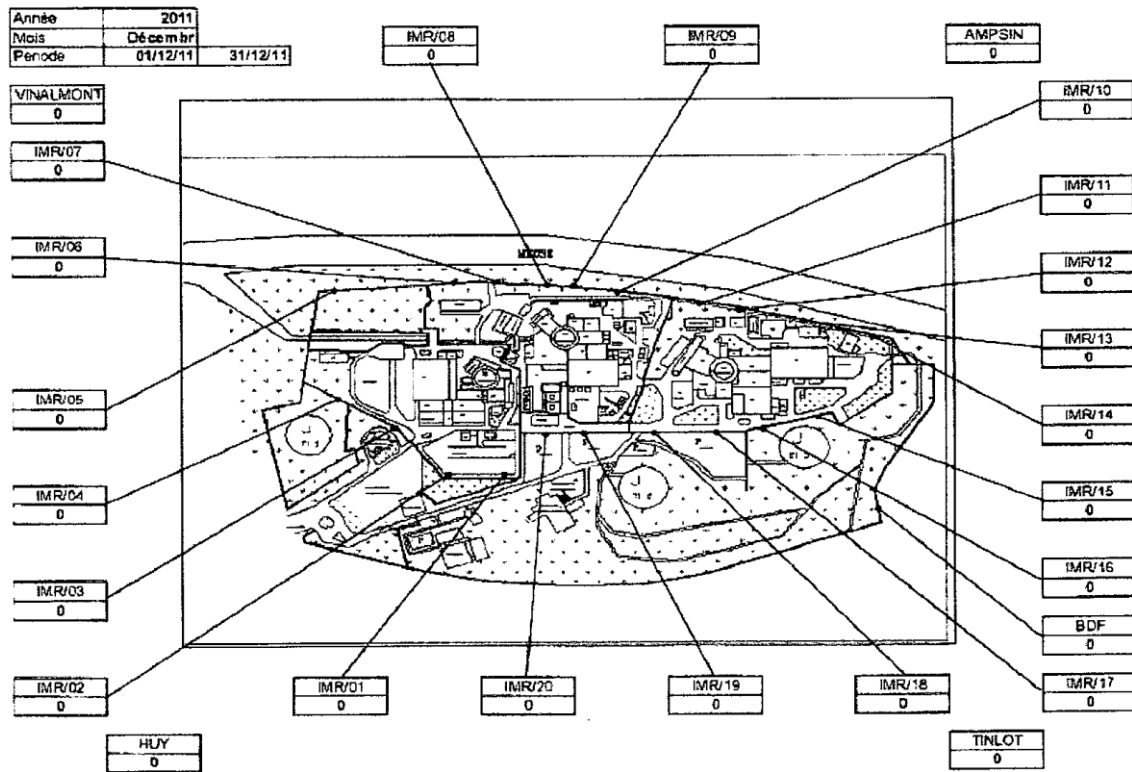
5.2 SITE ENVIRONMENT MONITORING PROGRAMME

5.2.1 Ambient dose rate control

On-site ambient dose rate is monitored with Geiger Muller devices called “GammaTracers”. There are 20 monitoring devices placed at the periphery of the site, close to the TELERAD monitors and about 20 other monitoring devices on the site at particular locations (administrative building access block, gathering points, etc.). As a noticeable exception for the clear distinction between on- and off-site activities, there are also 4 gamma tracers located in the gardens of 4 Electrabel private houses, at Ampsin, Huy, Tinlot and Vinalmont.

The GammaTracers do not report on-line dose rate data to the operators but they have to be read every month. The collected results are plotted on 12 months diagram to check the trend. The peripheral gamma tracers are sometimes used as check for abnormal TELERAD measurements and a systematic comparison with TELERAD data occurs after each monthly reading. The measured dose rates from some of the on-site GammaTracers are furthermore used in order to check that the ambient dose rate at those particular locations does not lead to exposure above the public limit of 1 mSv.

The recording and analysis of the GammaTracers' data are performed by the CARE-SRP logistics service and the results are communicated in the annual report “Rapport Annuel d’Exploitation”, distributed to various stakeholders, amongst which the safety authorities FANC and Bel V. Picture 2 below shows the locations of the 20 peripheral GammaTracers.



Picture 2. Peripheral GammaTracer locations

5.2.2 Contamination control of the site area

Control of on-site radioactive contamination outside the controlled areas is carried out by the following:

- Control at the exits of controlled areas weekly
- Control of the pathways after each revision
- Control of the internal transport means every month

These controls are not focussed on contaminants released by the building stacks, but rather on contaminants that could be locally deposited during on-site transfer of contaminated material. However, those measurements may also serve for the purpose of checking that no radioactive contaminants were deposited following an atmospheric release.

The measurement device for pathway control (Picture 3 below) is motorized and may discriminate between alpha, beta and gamma emitters. In case local contamination is detected, decontamination work will be executed and a sample will be analysed by gamma spectrometry in order to determine the type of contaminant.



Picture 3. Measurement device used for the contamination control of the pathways

5.2.3 Contamination control of the site groundwater

Groundwater measurements were initiated at Tihange NPP after the SOCATRI event in 2008⁵. The process is formalized in the procedure CH 509⁶. This procedure foresees the measurement of one water sample per unit per year, thus in total 3 analyses per year for the whole site. The samples are obtained through the pumping channels of the ground water flowing towards the units dedicated to the preparation of demineralized water. The analysis of the samples includes long time (50 000 s) gamma spectrometry complemented by Tritium activity measurement and alpha spectrometry (one out of three samples) performed by the SCK-CEN.

5.2.4 Contamination control of the site roofs

Contamination control of rain water is carried out in order to detect possible contamination of the roofs of the site buildings. Samples (1 litre) are collected from the rainwater drained from the three machine hall roofs every 6 months and analysed (gamma spectrometry) in the plant laboratory.

⁵ On July 7-8, 2008, an overflow occurred in a tank containing natural uranium at the SOCATRI facility in Tricastin, France. Some of this solution flowed onto the floor of the facility and into the rainwater system.

⁶ CNT procedure «Contrôle radiochimique des nappes phréatiques», SAP 10010180670

6 TIHANGE NPP LIQUID AND AERIAL DISCHARGE MONITORING

6.1 INTRODUCTION

The three reactor units in the Tihange NPP are functionally independent and discharge gaseous radioactive material to the atmosphere via ventilation stacks and liquid radioactive material to the river Meuse via their own coolant discharge channels⁷. Locations of discharge points are presented in Picture 4 below.



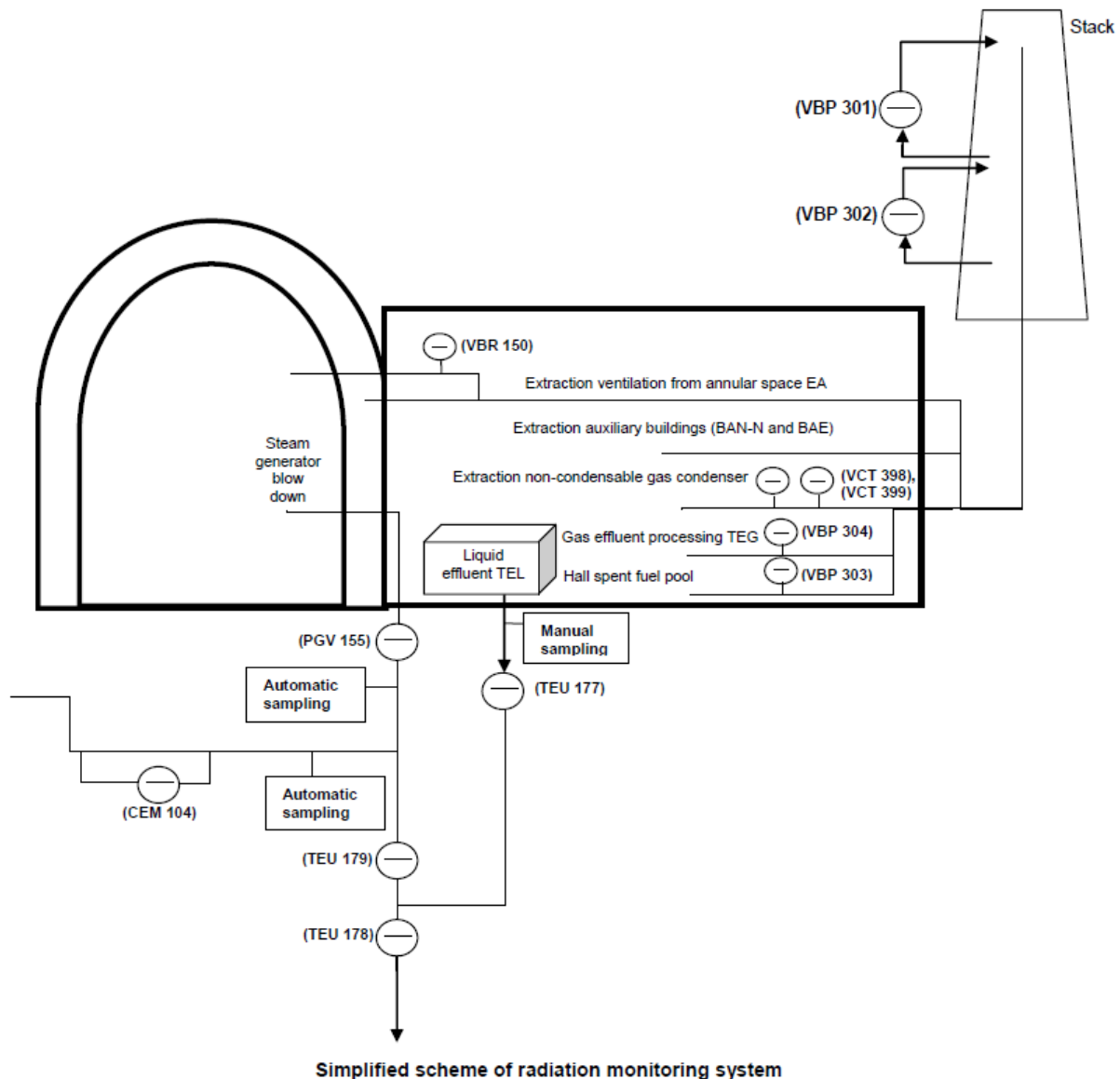
Picture 4. Locations of TNPP liquid and gaseous release points

- 1 - Tihange 1 Reactor coolant outflow channel**
- 2 - Tihange 1 Ventilation stack**
- 3 - Tihange 2 Reactor coolant outflow channel**
- 4 - Tihange 2 Ventilation stack**
- 5 - Tihange 3 Reactor coolant outflow channel**
- 6 - Tihange 3 Ventilation stack**

Each unit is equipped with monitoring systems for continuous radiation surveillance of gaseous and liquid discharges. Picture 5 below presents an overview of the liquid and gaseous monitoring systems at unit 2. Corresponding systems at Tihange 1 and 3 are functionally similar, but different on details (Annexes 3 and 4).

According to the FANC instruction AFCN 010-16 the plant operator is required to make a monthly gaseous and liquid discharge report to the regulatory authority. This information is made available to the public via the FANC website.

⁷ For operational reasons some of the T1 and T3 liquid effluents are treated in the T2 waste water treatment facility, so a part of the T1 and T3 liquid discharge takes place through the T2 discharge point.



Picture 5. Overview of Tihange 2 liquid and gaseous discharge monitoring systems

6.2 DISCHARGE LIMITS

6.2.1 Liquid discharges

Limits for liquid discharges are defined in the Royal Decree of July 20, 2001 (Article 34: Storage, treatment and disposal of liquid waste). The limit is equal to the drinking water activity limit (0.1 MBq/m^3). When the liquid contains a mixture of radionuclides, the principles of Annex III, Point D of the Decree shall apply. Should the exact composition of the mixture not be known, the most conservative value shall be used. This means that the lowest limit for the isotopes present must be used. Of the isotopes potentially present in wastewater, ^{131}I is the one with the lowest limit, i.e.: $1 \cdot 10^5 \text{ Bq/m}^3$ (0.1 MBq/m^3). In addition, the annual limits for discharges by the site are:

- Total isotopes without HTO and dissolved noble gasses $8.88 \cdot 10^5 \text{ MBq}$
- HTO $1.48 \cdot 10^8 \text{ MBq}$

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

6.2.2 Gaseous discharges

Gaseous discharge limits have been defined both in terms of annual release and in terms of maximum stack activity concentration in the Technical Specifications (Tech. Spec. para. 16.3.13.2.3 for T2&3 and 16.4.10-4 for T1). The limits are linked to the dose limit for the population (Royal Decree of July 20, 2001: Art 36). The limits are valid for the totals from the entire site. Bel V must be notified when 1/8 of one of these limits is exceeded during three consecutive months (for each facility) (Tech. Spec. table 4.2.2.3-T.1). Table II below presents the annual and Table III the instantaneous (activity concentration inside the stack) gaseous discharge limits.

Table II. TNNP annual gaseous discharge limits

| | T2 & T3 | T 1 | TNNP total |
|-------------------|--------------------|------------|-------------------|
| Noble Gases (TBq) | 740 | 740 | 2220 |
| Iodine 131 (GBq) | 3.7 | 7.4 | 14.8 |
| Aerosols (GBq) | 37 | 37 | 111 |
| Tritium (TBq) | 18.5 | 18.5 | 55.5 |

Table III. TNNP instantaneous gaseous discharge limits

| | T1 | T2 | T3 |
|--|----------------------|-----------------------|-----------------------|
| Noble gases (MBq/m ³) | 210 | 214.6 | 214.6 |
| Aerosols (MBq/m ³) | 0.03 | 0.0296 | 0.0296 |
| ¹³¹ I (MBq/m ³) | 5.9 10 ⁻⁴ | 5.92 10 ⁻⁴ | 5.92 10 ⁻⁴ |

6.3 MONITORING OF GASEOUS DISCHARGES

Gaseous discharges from each reactor unit are implemented and continuously monitored by the Exploitation Service (OPE) from the panels of the control rooms and from the secondary control rooms. The online instrumentation is periodically checked by the Maintenance Department and the Radioprotection Service (CARE). The samples are analysed by the Chemistry Service (OPC).

Instrumentation

Releases of noble gases, iodine and aerosols through the ventilation stacks are continuously monitored by means of fixed radiation monitoring systems (VBP21 and 301 T1; VBP 301 and 302 T2 and VBP 301, 302, 305 and 306 T3). Releases of noble gases are also measured on a daily basis (VBP 21 and 301 T1, VBP301 and 302 T2, VBP 301, 302, 305 and 306 of T3). Iodine and aerosols are sampled continuously; the filters are changed weekly and concentration determined by gamma spectrometry. ¹⁴C is assessed in a fixed way in accordance with the safety reports and gaseous tritium is assessed by calculation.

Gaseous sampling systems are isokinetic; the sampling lines are heated where necessary. The monitoring instruments in each ventilation stack are listed in Table IV below.

Table IV. Monitoring instruments in the ventilation stacks (1 - Thin plastic PM Beta scintillator, 2 - PM gamma NaI + Am, 3 - Geiger-Muller detector, 4 - Ionisation chamber (2 ranges))

| Parameter | Instrument | Detector type | Range (Bq/m ³) |
|-----------------------|------------------|---------------|----------------------------|
| Tihange 1 | | | |
| Airborne | VBP21 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP 21 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 21 G | 1 | 1E+04 to 1E+10 |
| Airborne | VBP301 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP301 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 301 G | 1+4 | 1E+04 to 1E+16 |
| Condenser gas vent T1 | VCT 34 / 1 and 2 | 1 | 1E+04 to 1E+10 |
| Tihange 2 | | | |
| Airborne | VBP301 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP301 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 301 G | 1+4 | 1E+04 to 1E+16 |
| Airborne | VBP302 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP302 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 302 G | 1+3 | 1E+04 to 1E+13 |
| Condenser gas vent T2 | VCT 398 and 399 | 1 | 8.6E+03 to 8.6 E+08 |
| Tihange 3 | | | |
| Airborne | VBP301 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP301 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 301 G | 1+3 | 1E+04 to 1E+13 |
| Airborne | VBP302 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP302 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 302 G | 1+3 | 1E+04 to 1E+13 |
| Airborne | VBP305 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP305 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 305 G | 1+4 | 1E+04 to 1E+16 |
| Airborne | VBP306 P | 1 | 1E+00 to 1E+07 |
| Iodine | VBP306 I | 2 | 1E+00 to 1E+07 |
| Gas | VBP 306 G | 1+4 | 1E+04 to 1E+16 |
| Condenser gas vent T3 | VCT 398 and 399 | 1 | 1E+04 to 1E+10 |

6.4 MONITORING OF LIQUID DISCHARGES

Liquid discharges are carried out by mixing water from waste water tanks with the plant coolant outflow to the river Meuse. Each unit has its own discharge point. Liquid releases from each reactor unit are implemented and continuously monitored by the Exploitation Service (OPE) from the panel of the control rooms and from the secondary control rooms. The online instrumentation is periodically checked by the Maintenance Department and the Radioprotection Service (CARE). The samples are analysed by the Chemistry Service (OPC). Table V below details the instruments used.

**Table V. Monitoring instruments for liquid discharge monitoring
(3 – Geiger-Müller (GM), 5 - PM gamma (NaI), CF - conversion factor from cpm to Bq/m³)**

| System | Instrument | Detector type | Range (in cpm or in Bq/m ³) |
|---|------------------------|---------------|--|
| TEU discharge T1 | TEL 197 | 5 | 1E+03 to 1E+10 Bq/m ³ |
| TEU discharge T1 | TEL 198 | 5 | 5.2E+03 to 5.2E+08 Bq/m ³ |
| TEU discharge T2 | TEU177-178-179 | 5 | 1E+00 to 1E+06 cpm CF=370 |
| TEU discharge T3 | PGV(TEU) 286, 287, 289 | 5 | 1E+04 to 1E+09 Bq/m ³ |
| PGV blow down T1 | CEN80 | 5 | 1E+03 to 1E+10 Bq/m ³ |
| PGV blow down T1 | PGV15 | 5 | 1 E+00 to 1E+06 cpm CF= 522 |
| PGV Blowdown T2 | CEN 280, 281 and 282 | 5 | 3.7E+03 to 3.7E+08 Bq/m ³ |
| PGV Blowdown T2 | PGV 155 | 5 | 1E+00 to 1E+06 cpm CF= 370 |
| PGV Blowdown T3 | CEN 092, 093 and 280 | 5 | 1E+09 to 1E+14 Bq/m ³ |
| PGV Blowdown T3 | PGV 155 | 5 | 1E+04 to 1E+09 Bq/m ³ |
| PGV Steam T1 | CVP 90a-90b-90c | 3 | 8.2E+09 to 8.2E+14 Bq/m ³ |
| PGV Steam T2 | CVP 401, 402 and 403 | 3 | 1.2E+10 to 1.2E+15 Bq/m ³ |
| PGV Steam T2 | CEN 279 | 3 | 1E+00 to 1E+06 cpm CF= 370 |
| PGV Steam T3 | CVP 101, 102 and 103 | 3 | 1E+09 to 1E+14 Bq/m ³ |
| PGV Steam T3 | CEN 279 | 3 | 1E+04 to 1E+09 Bq/m ³ |
| Liquid discharge from the turbine building T1 | CED 101 | 5 | 1E+00 to 1E+06 cpm CF= 522 |
| Liquid discharge from the turbine building T2 | CEM 104 | 5 | 1E+01 to 1E+06 cpm CF=370 |
| Liquid discharge from the turbine building T3 | CEM 104 | 5 | 1E+04 to 1E+06 Bq/m ³ |
| Waste liquid transfer line T2 | TEP 310 | 5 | 6.2E+03 to 6.2 E+08 Bq/m ³ |
| Waste liquid transfer line T3 | TEP310 | 5 | 1E+04 to 1E+08 Bq/m ³ |

6.5 ALERT AND ALARM THRESHOLDS

The discharge monitoring systems are also used as alarm systems to inform the operators about the level of radioactivity in various processes and at specific plant locations.

Alert levels (S1) and alarm thresholds (S2) have been defined for each system. The alert level S1 is a warning signal that helps operators to detect the abnormal increase of the concentration of radio-nuclides present in the effluents. If the alert for S1 level is triggered, corrective actions are required from the operators. The alarm S2 threshold is a level beyond which an automatic action, for example closing a circuit of an automatic valve and diverting the fluid orientation or interrupting totally the transport of fluid, is generally foreseen. The S2 threshold is prescribed in the Technical Specifications, taking into account the radiological impact to the environment and to the public.

In normal operation, the operators in the control room are warned by an alarm (sound and flashing light) whenever the activity exceeds the S1 alert level. Beyond the S2 alarm level, the discharge line is automatically interrupted.

7 ENVIRONMENTAL RADIOACTIVITY MONITORING IN BELGIUM

7.1 INTRODUCTION

Belgium has a comprehensive programme for monitoring the radiological status of the environment. The radiation monitoring programme in the vicinity of the Tihange NPP is a part of the Belgian national monitoring programme in the Sambre – Meuse basin. It comprises monitoring of radiation dose rate and radioactivity in atmosphere, soil, food and river waters. Table VI below presents an overview of the programme.

Table VI. Radiation monitoring programme for the Sambre – Meuse basin

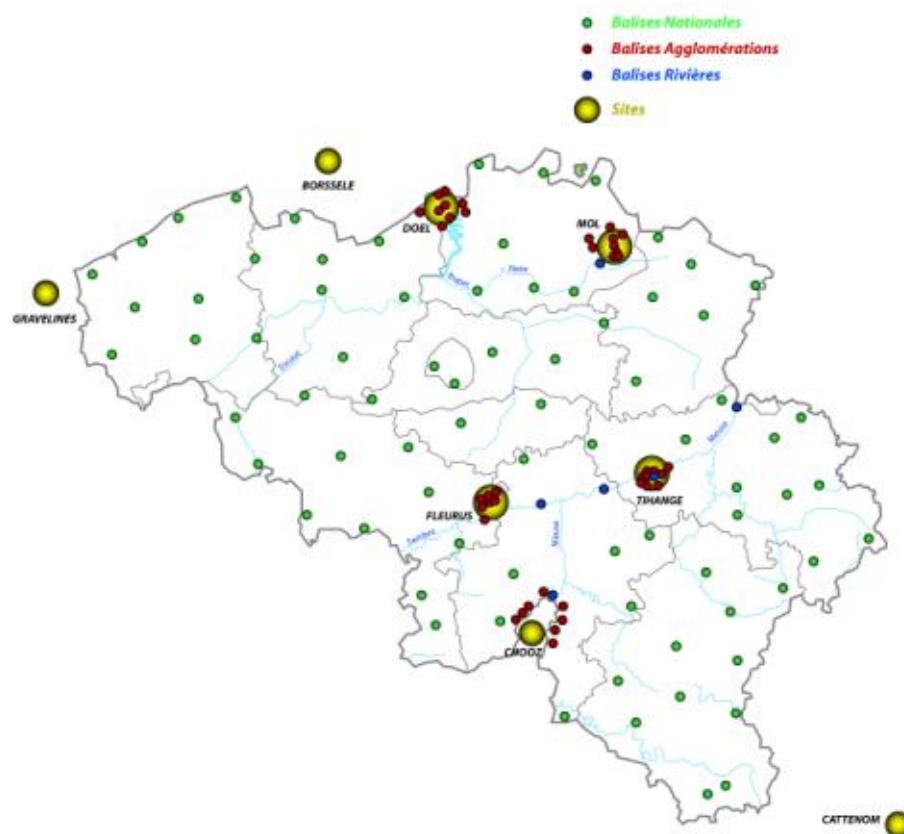
| Zone | | Basin and location of sampling points | | Type of measurement | Frequency of sampling |
|------------|---|---------------------------------------|--|--|----------------------------|
| | | Sambre | Meuse | | |
| Atmosphere | dusts | close to the IRE site (Fleurus) | close to the Tihange site Lixhe | Spectrometry γ : ^7Be , $^{134-137}\text{Cs}$, $^{141-144}\text{Ce}$, $^{103-106}\text{Ru}$, ^{95}Zr , ^{95}Nb , (^{131}I near to the IRE) Spectrometry total β : on paper filters after 5 days decay | every 4 weeks daily |
| | surface deposits (tanks) | close to the IRE site (Fleurus) | Heer-Agimont | Spectrometry γ (untreated water) : ^7Be , $^{134-137}\text{Cs}$, $^{141-144}\text{Ce}$, $^{103-106}\text{Ru}$, ^{95}Zr , ^{95}Nb , ^{131}I | every 4 weeks |
| | | | close to the Tihange site | Spectrometry total β , total α , ^3H , ^{90}Sr (filtered water) | every 4 weeks |
| | | | Lixhe | Spectrometry total β , total α (filter deposits) | every 4 weeks |
| | | | ^{131}I (filtered deposits) close to IRE | every 4 weeks | |
| Soil | permanent meadow (superficial soil – 0.125 m ² on ~ 15 cm depth + short grass cut) | close to the IRE site (Fleurus) | close to the Chooz site close to the Tihange site Lixhe | Spectrometry γ : ^7Be , $^{134-137}\text{Cs}$, $^{(57)-58-60}\text{Co}$, ^{54}Mn , ^{65}Zn , $^{110\text{m}}\text{Ag}$, ^{40}K , $^{226-228}\text{Ra}$, ^{228}Th ^{131}I close to IRE | Annually |
| | agricultural soils | | around the boot of Chooz (24 points) | Spectrometry γ , α , ^{90}Sr , ^{226}Ra | Annually |
| | agricultural plant production | | | Spectrometry γ , ^{90}Sr , ^3H , ^{14}C | |
| River | water | Floriffoux or Mornimont | Heer-Agimont, Andenne, Huy, Ampsin, Monsin, Lixhe | Spectrometry γ : ^7Be , $^{134-137}\text{Cs}$, $^{141-144}\text{Ce}$, $^{103-106}\text{Ru}$, ^{95}Zr , ^{95}Nb , ^{226}Ra Spectrometry β total, total α ^3H , ^{40}K , ^{90}Sr (^{131}I near to the IRE) | every 2 weeks |
| | sediments | Floriffoux | Heer-Agimont, Andenne, Ampsin, Lixhe | Spectrometry γ : ^7Be , $^{134-137}\text{Cs}$, $^{(57)-58-60}\text{Co}$, ^{54}Mn , ^{65}Zn , $^{110\text{m}}\text{Ag}$, ^{40}K , $^{226-228}\text{Ra}$, ^{228}Th , (^{131}I close to IRE) | every 4 weeks |
| | aquatic plants, mosses, bivalves | Floriffoux or Mornimont | Heer-Agimont/ Rivière/Hastière/ Waulsort, Andenne/Gives, Huy, Ampsin/Amay, Lixhe | Spectrometry γ : ^7Be , $^{134-137}\text{Cs}$, $^{(57)-58-60}\text{Co}$, ^{54}Mn , ^{65}Zn , $^{110\text{m}}\text{Ag}$, ^{40}K , $^{226-228}\text{Ra}$, ^{228}Th ^3H organic | quarterly |

7.2 AUTOMATIC MONITORING OF EXTERNAL RADIATION

7.2.1 Introduction

Belgium has a modern automatic radiation monitoring network - TELERAD. Altogether, the network comprises of 237 stations covering the whole Belgian territory (Picture 6). The monitoring frequency is 10 minutes; in the event of elevated radiation values the system sends an automatic alert to FANC.

The system includes GM dose rate monitors, LaBr₃ spectroscopy monitors and water monitoring stations. Data from the system is collected by the PANORAMA software, which is installed at the FANC (Brussels) and the IRE (Fleurus). There is a team of 6 experts in charge of TELERAD operation and maintenance at the FANC.



Picture 6. TELERAD radiation monitoring network

7.2.2 TELERAD external dose rate monitors

The TELERAD dose rate network is made of GM detectors. The IMN and IMA stations have been supplied by the German company ENVINET GmbH. The IMR stations have a spectrometer detector which provides also gamma dose rate values. Each unit is equipped with a rain detector, an 80 Ah battery for 72h independent operation and an internal heating system. Communication between the network centre and the station is via a DSL router and a GPRS modem. There are two alert levels: 200 nSv/h and 400 nSv/h.

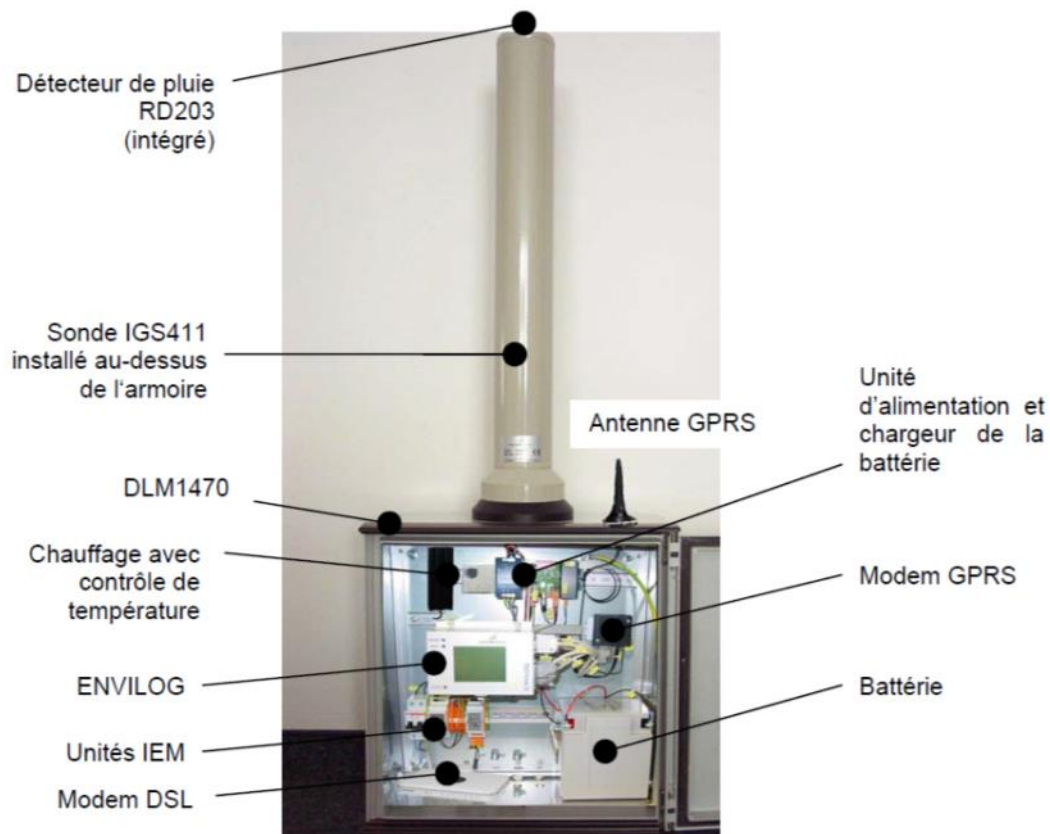


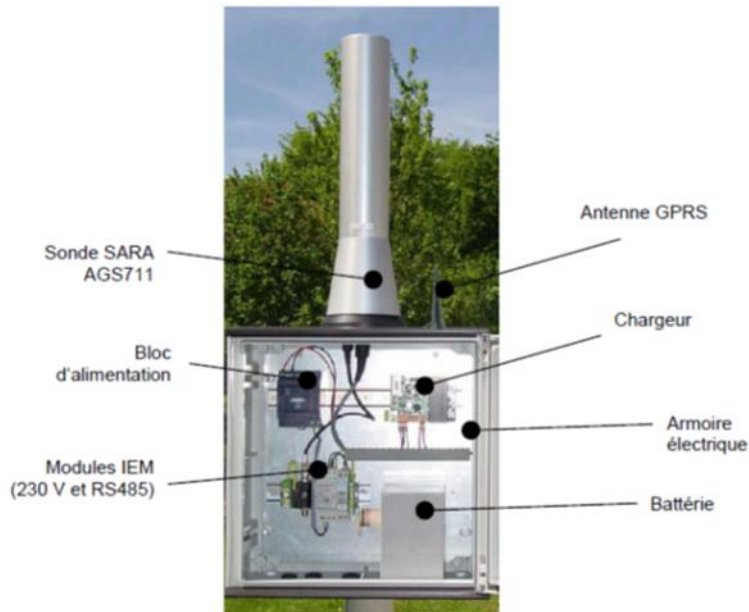
Figure 3-1: Composantes principales de la station de mesure de dose gamma

Picture 7. TELERAD automatic dose rate monitoring station with rain detector

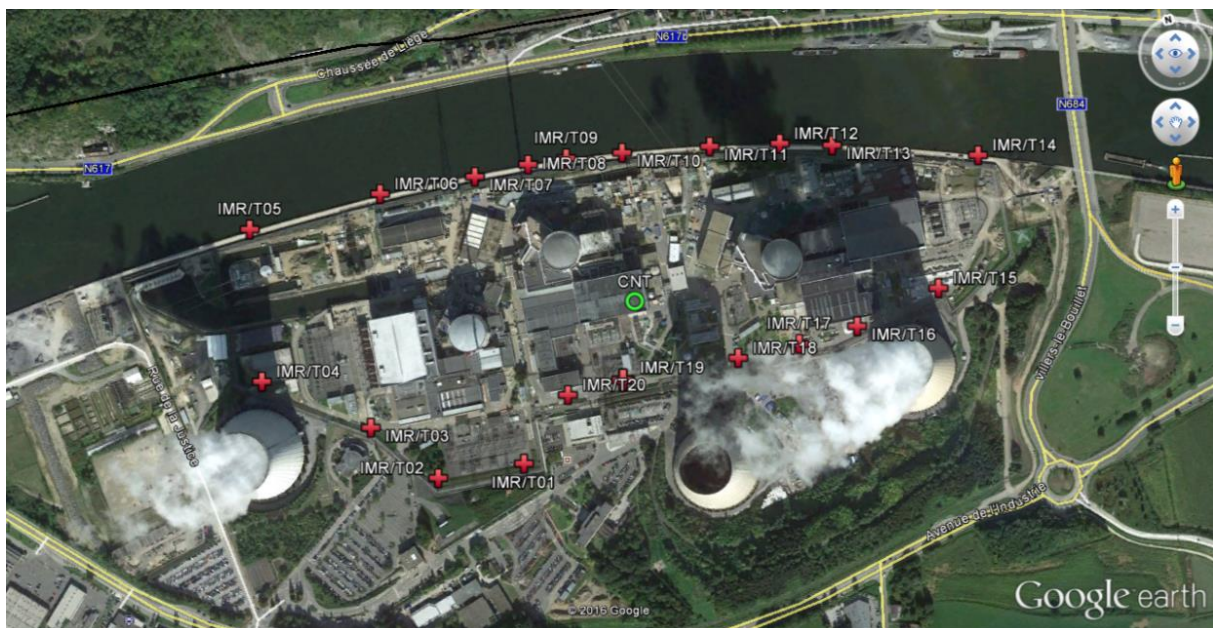
7.2.3 TELERAD spectroscopic radiation monitors

TELERAD spectroscopic radiation monitors (IMR stations) have been supplied by ENVINET GmbH. Such stations have been installed on rings around each nuclear facility (Doel, Tihange, Mol and Fleurus). In Tihange the stations (20 units) are installed on the site fence (Picture 9).

The stations have a SARA gamma spectroscopy system, which uses a 1.5×1.5" NaI detector in normal operation and a GM-tube in high dose rate situations. Each ring has its own electrical back-up (UPS and diesel) for 5 days; in addition each station has battery back-up for 72 hours. Communication between FANC and the ring detectors is either via Internet or GPRS; also satellite communication option is available, but not currently used.



Picture 8. TELERAD automatic spectroscopic dose rate monitoring station



Picture 9. TELERAD ring and water monitoring stations at the Tihange NPP

7.2.4 TELERAD water radioactivity monitors

TELERAD network includes also automatic water monitoring stations. These are located on the main rivers Schelde, Meuse and Sambre, typically both up- and downstream of nuclear facilities (Picture 10). There are two types of water stations; the BCD type, which measures water pumped into a measurement vessel and the BCI type, which has a detector immersed directly in the water outflow of a nuclear facility. Both BCD and BCI type stations have LaBr_3 detectors, so it is possible to receive spectrometric data for nuclide specific analysis. In Tihange, there are three BCI detectors (one in each coolant outflow channel) and one BCD station (downstream about 1 km from the plant) (Pictures 9 and 11).



Picture 10. TELERAD automatic water monitoring stations

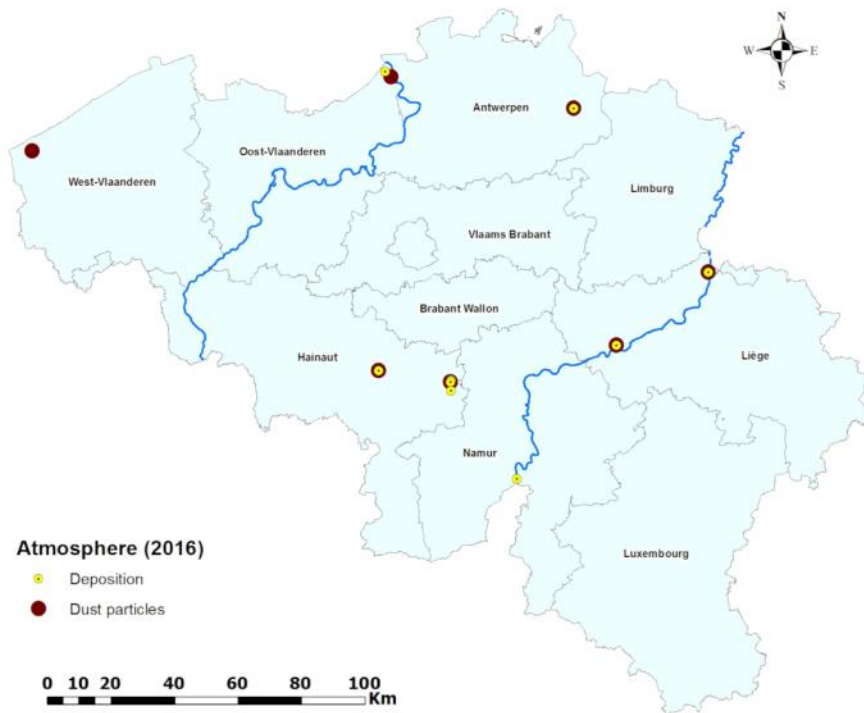


Picture 11. Water monitoring stations in the vicinity of the Tihange NPP

7.3 MONITORING OF RADIOACTIVITY IN AIR

7.3.1 Introduction

Monitoring the atmosphere in the vicinity of the nuclear sites and in the reference zones Brussels Capital, Coxyde (North Sea coast) and Lixhe at the Meuse (nearby the border of the Netherlands) is carried out by means of sampling air dust and surface deposits. The samples are analysed at the IRE-Elit laboratory.



Picture 12. Air and atmospheric deposition sampling locations in Belgium

7.3.2 Particulate material in air

Air dust samples are collected daily using two types of sampling systems:

- In Fleurus, Tihange, Lixhe and Brussels air dusts are collected using an automatic sampling system with a sample changer allowing pumping of about 120 m³ of air, at constant flow rate, from 00:00 to 24:00 for the seven days of the week (Picture 13). Once a week, the seven filters (fibreglass filter of 50 mm diameter) are replaced by new ones. The pumping volume through each filter is downloaded automatically.



Picture 13. Air sampler with a filter for each day of the week

- In 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 (Picture 14). 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, time and the total volume of air pumped through the filter are registered.



Picture 14. Air sampler with a single filter

Filter samples are kept for minimum of 5 days to allow the decay of the natural radionuclides. After 5 days decay time a beta global measurement is done for each filter collected and an alpha global measurement is done for filter collected in Mol. After alpha and/or beta global measurements all filters are stacked, placed into a plastic bag/container to make a 4 weeks composite sample and then sent to the lab for measurement of gamma emitters by gamma spectrometry.

7.3.3 Atmospheric deposition

Sampling of atmospheric deposition is carried out by weekly collection of dry and wet deposition on collector vessels presented in picture 15. The total collection surface is 0.5 m², containing a water film to collect fallout dust. The vessel is protected with a metal grid to prevent birds from contaminating the water and a heating device to prevent the water film from freezing in the winter. In the summer time during longer periods of warm and dry weather the amount of water in the sampling device is kept to a sufficient level to assure proper sampling by adding additional distilled water.

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. The total volume of the sample is measured and the sample is subsequently divided into two equal parts (part A and B). Part A is used to perform gamma spectrometry and part B is used to perform gross alpha/beta and H-3 measurements. Both parts are filtered and acidified to a pH<2 using HCl. Both the filtrates and filters are kept for further processing (a.o. mixing to form 4-week samples). The filters are dried using a drying agent (silicagel).

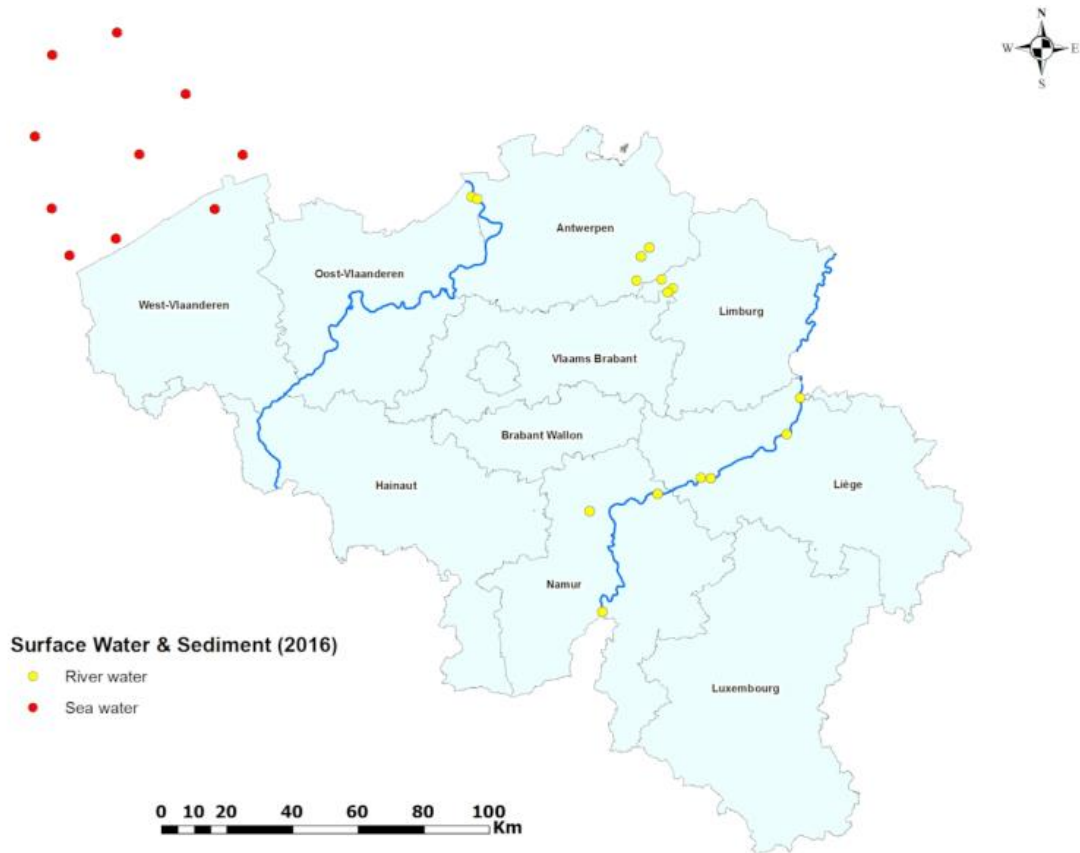
After analysis is complete, the two sets of filters (Part A and Part B) are kept in a dry place for one month after submission of the regular report. The same applies to the metal disc from the gross alpha/beta measurement (Part B). The liquid samples measured by gamma spectrometry are stored in a cool and dark room (< 10°C) for one month after submission of the quarterly report.



Picture 15. Atmospheric deposition sampler

7.4 MONITORING OF RADIOACTIVITY IN SURFACE AND MARINE WATERS

Water radioactivity concentration is monitored by taking samples of water on a regular basis for laboratory analysis. Picture 16 presents the sampling locations of surface water and sediments in the rivers (Sambre, Meuse, Grote Laak, Winterbeek, Grote Nete, Molsse Nete and Scheldt) and in the marine waters (North Sea). Both automatic samplers and manual sampling are used.



Picture 16. Sampling sites for surface and marine water and river sediments

Automatic sampling (continuous sampling over 24h period, collected in separate 1 L or 2.5 L bottles, uniquely identified and stored in a refrigerated compartment) is used for samples at Molsse Nete,

Grote Nete, Grote Laak, Winterbeek, Scheldt and Sambre. The samples are collected every week or every two weeks (depending on storage capacity). Manual sampling is used at Scheldt. Once a week a sample is taken using a bucket attached to a rope. Part of this sample is transferred into a uniquely identified 5 L plastic bottle. Each sample is acidified by concentrated nitric acid to $\text{pH} < 2$. Samples are stored for 24 hours in a cool and dark place before further processing.

A mixed sample is prepared by mixing 250 to 500 ml of 14 consecutive daily samples together. The mixed sample is filtered and the filter is discarded. The rest of the sample is stored in the original bottles in a cool and dark storage room ($< 10\text{ }^{\circ}\text{C}$). 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 ^3H is requested, 100 to 250 mL of the mixed sample is taken and sent to the lab for measurement. If a gamma spectrometry analysis is requested, an aliquot of the mixed sample is transferred into a Marinelli beaker and sent to the lab for measurement. If a measurement of gross alpha/beta is requested, 250 ml to 1 L of the mixed sample is sent to the lab for measurement. For the determination of ^{40}K content, 100 mL of the mixed sample is sent to the lab for measurement. If measurement of actinides is requested (Scheldt and Molve Nete only), 500 mL of the mixed sample is taken and mixed with a similar sample of the previous 2 weeks (i.e. a monthly composite sample is created). This sample is sent to the lab for measurement by alpha spectroscopy.

The residual portions of the mixed sample and the original daily samples are stored. Intermediate samples (prepared by the measurement labs) are discarded after measurement. Samples are stored in a temperature controlled (refrigerated) dark room ($< 5\text{ }^{\circ}\text{C}$). Samples are kept till one month after the submission of the quarterly report.

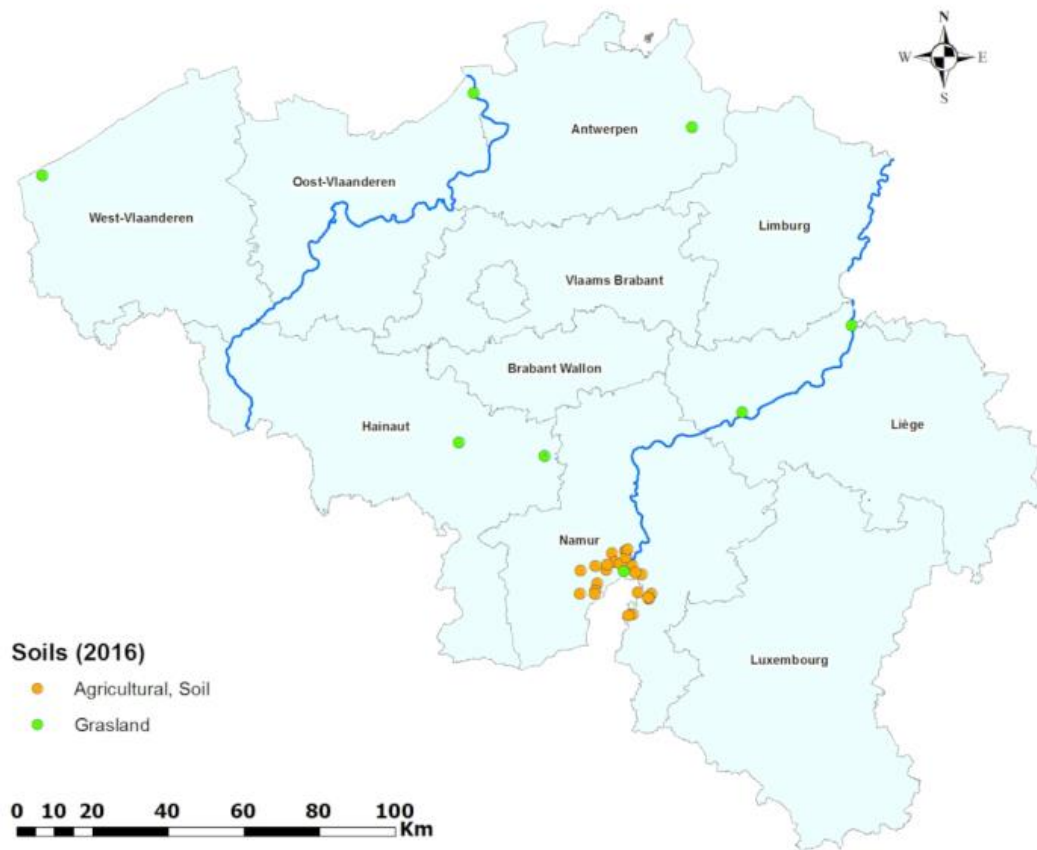
7.5 MONITORING OF RADIOACTIVITY IN SOIL AND SEDIMENTS

7.5.1 Soil

Soil samples are taken in the immediate vicinity of nuclear sites and in certain control regions (sea coast and Brussels Capital region), as well as in the agricultural zone around the booth of Givet (Chooz NPP) (Picture 17). A total surface of 0.125 m^2 to a depth of 0.15 m is collected. The sampling area is carefully selected according the following criteria:

- If a nuclear facility is near (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 should be a flat surface.
- If several samples are taken to achieve the total surface of 0.125 m^2 (using a core sampler), cores must be spaced on a large area to have a 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.



Picture 17. Soil sampling locations in Belgium

7.5.2 Sediments

Sampling of sea sediments (North Sea) is performed by the Belgica, which is an oceanographic research vessel operated by the “Scientific Service Management Unit of the Mathematical Model of the North Sea” (MUMM), which is a branch of the Royal Belgian Institute of Natural Sciences. Three times a year at specific predefined sampling locations, sea sediments are taken. The samples in 10 L plastic containers are stored in a cool and dark place until collection by the SCK•CEN.

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

- Automatic samplers installed in TELERAD cabins (Molse Nete, Sambre and Meuse). The sediment sample is collected every 4 weeks and transferred into a 10 l container.
- Sedimentation bin. At the beginning of the sampling period, a sedimentation bin is placed in the river stream on the bottom, 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 container.

The collected sediment samples (river or sea) are dried between 40-80 °C to a constant weight in an oven or freeze dried (depending on the texture of the sediment). If necessary stones or other larger debris (e.g. sea shells) are manually removed. The sample is then grinded to homogeneity.

From the homogenised sample, depending of the sediment amount, a 20 to 500 ml beaker is filled for gamma spectrometry measurement. Active charcoal is added to trap Rn for the Ra-226 measurement after a period of minimum 3 weeks. 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 (sediments from Molse Nete and Noordzee) and for the measurement of ⁹⁰Sr and ⁹⁹Tc (Molse Nete).

The residual dried sediment sample is kept in a dry place till one month after submission of the quarterly report.

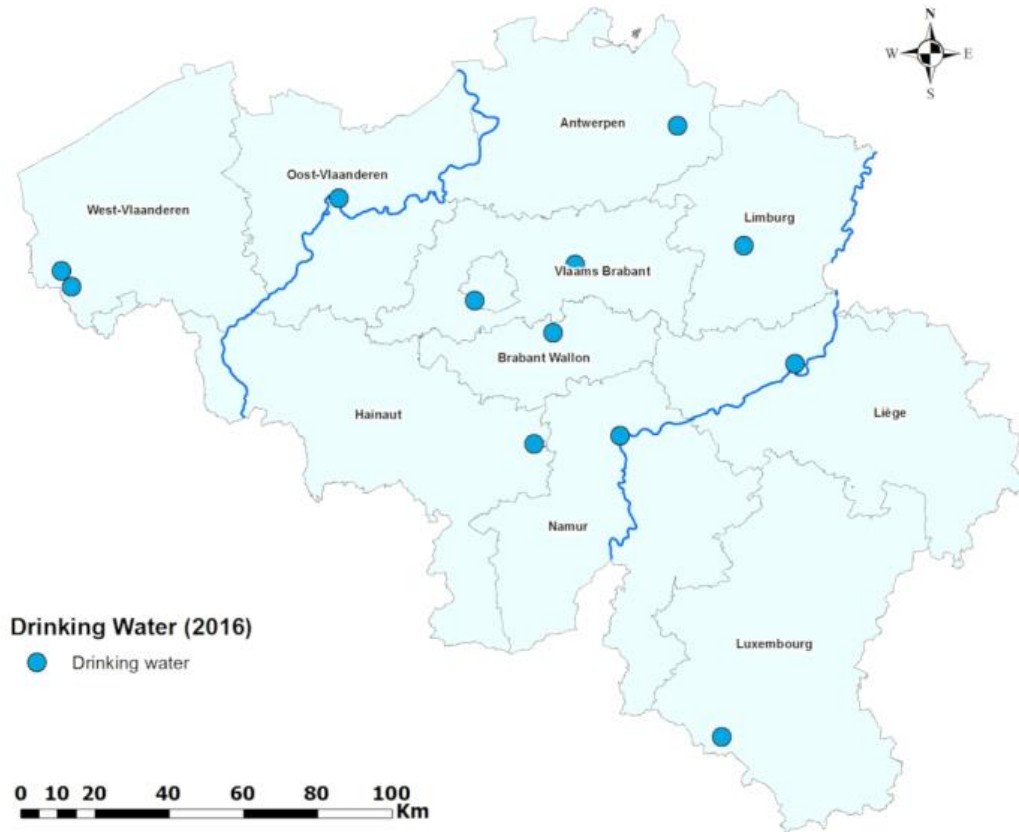
7.6 MONITORING OF RADIOACTIVITY IN FOOD AND DRINKING WATER

7.6.1 Introduction

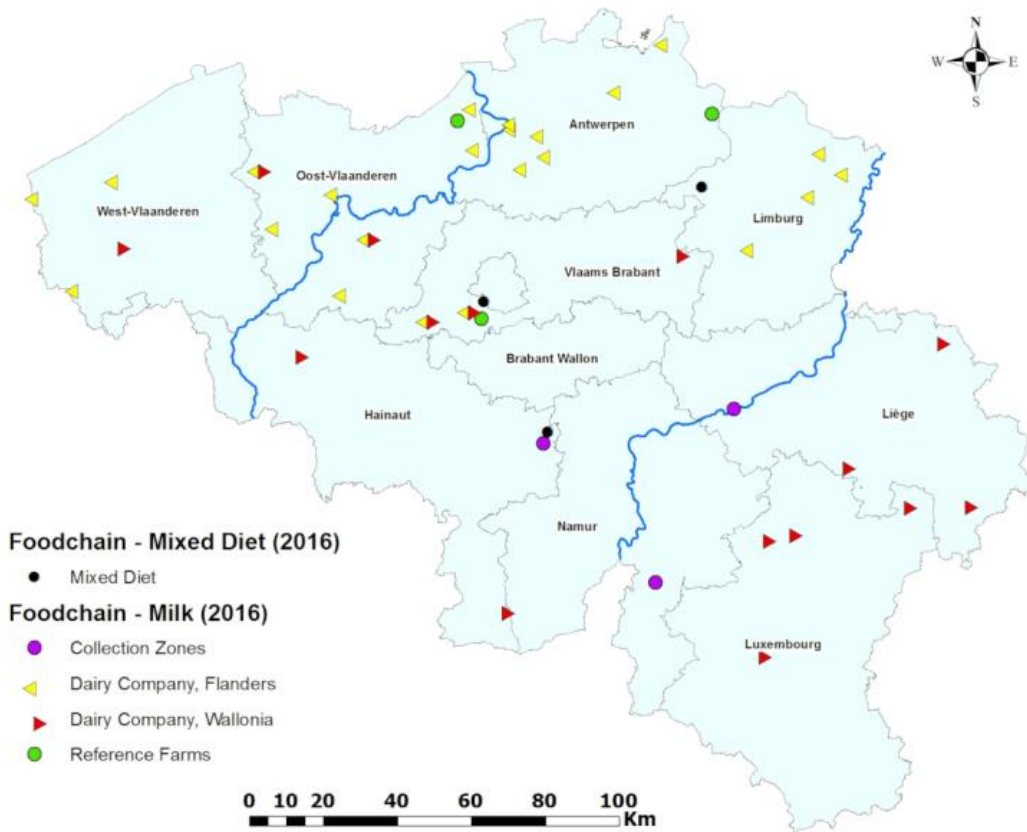
Radioactivity in the food chain is monitored by analysing samples of drinking water, milk, mixed diet and foodstuffs. Table VII below presents the programme summary. Pictures 18 and 19 present the sampling locations.

Table VII. Radiation monitoring programme for the food chain

| | Zone | Location of sampling points | Type of measurement | Frequency of sampling |
|----------------|---|---|---|---|
| Drinking water | mains (tap) | Brussels (Brussels Capital) Wavre (Walloon Brabant) Liege (Liege) Namur (Namur) Fleurus (Hainaut) Florenville (Luxembourg) Ghent (East Flanders) Leuven (Flemish Brabant) Poperinge and Reningelst (West Flanders) Mol (Antwerp) Zepperen (Limburg) | Spectrometry total alpha & total beta, ^3H , ^{40}K Where screening values are exceeded by 0.1 Bq/l in total alpha and 1 Bq/l in total beta, complete spectrometry analyses (alpha, beta, gamma) | quarterly |
| Milk | dairies farms | Brussels region (Brabant) (1 farm) Fleurus region (75 dairies) Tihange region (118 dairies) Doel region (1 dairy) Dessel region (1 dairy) Chooz region (42 dairies) | Spectrometry gamma of which $^{134-137}\text{Cs}$, ^{131}I , ^{40}K ^{90}Sr | weekly every 4 weeks |
| Foodstuffs | vegetables meat fish various (mushroom, flour, etc.) | national territory among small and large scale retailers | Spectrometry gamma of which $^{134-137}\text{Cs}$, ^{40}K ^{90}Sr | 4 samples monthly of meat, fish, vegetables 4 samples annually of meat, fish, vegetables |
| | control meal | company canteens: Mol (SCK•CEN), Fleurus & Brussels (Carrefour) | Spectrometry gamma of which $^{134-137}\text{Cs}$, ^{40}K ^{90}Sr and ^{14}C | monthly quarterly |



Picture 18. Sampling locations of drinking water



Picture 19. Sampling locations for food and mixed diet

7.6.2 Ground water and drinking water

Picture 18 presents the sampling locations of ground water and drinking water. Different sampling methods are applied for sampling for ^{222}Rn measurements and other radionuclides. Sample is transported in such a way the temperature of the sample will not exceed the temperature it had when it was taken (without freezing it), keeping the time between sampling and arrival in the lab for analysis to a minimum (no more than 2 days). In sample preparation, the following procedures are used:

- 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 ^{40}K determination
- 100 ml of the sample is sent to the lab for possible ^{226}Ra measurement by liquid scintillation counting or 500 mL of the sample is brought to the lab for ^{226}Ra measurement using the LUCAS method
- If ^{210}Pb measurement is required, 1.5 L is brought to the lab
- If ^{228}Ra measurement is required, 1.5 L is brought to the lab
- For ^{222}Rn , sample collected is sent to the lab for measurement using the LUCAS method or the liquid scintillation counting

The rest of the sample is acidified in the original bottles using a sufficient amount of concentrate nitric acid to achieve $\text{pH} < 2$. These samples are stored in a dark room ($< 5^\circ\text{C}$) and kept for one month after the submission of the trimestrial report.

7.6.3 Milk

Sampling of milk is carried out in supermarkets and dairies which collect from a large number of farms. Weekly samples of milk are collected as follows:

- For the surrounding area of Fleurus, Tihange and Chooz nuclear sites: 1 litre of milk is collected during each farm's tour around these sites by the carrier and transferred to the office of "Comité du lait" at Battice.
- For the region of Postel, Doel and Brussels: daily samples are taken and collected on a weekly basis. These samples are then pooled and transferred for immediate gamma analysis.

Weekly weighted average samples are prepared by mixing samples collected over one week by region. These samples are transferred into an appropriate beaker and sent to the lab for a gamma spectrometry measurement. For fresh milk samples there is one sample a week for gamma spectrometry and one every four weeks for ^{90}Sr analysis from each sampling location. The frozen week sample is stored at a temperature $< -5^\circ\text{C}$ and the freeze dried samples are stored in a dark and dry place until one month after the submission of the quarterly result report.

7.6.4 Mixed diet

Samples of mixed diet are taken from company canteens on a monthly basis for each region of Belgium (Brussels region, Flanders and Wallonia). Breakfast, lunch and dinner representative for an average person daily meals are collected in a local restaurant or a boarding school.

All the meals (solid and liquid) are grinded to homogeneity and freeze dried or dried at 40°C . From the homogenised sample, an appropriate beaker is filled with the sample for gamma spectrometry measurement. Active charcoal is added to the sample to trap Rn and the sample is kept for a minimum 3 weeks to allow equilibrium and then measured.

Each 3 months, ^{14}C and ^{90}Sr measurements are carried out on the meals. A separate part of the dried sample is used to prepare a trimestrial sample by mixing a portion of the 3 monthly samples. A

portion of dried trimestrial sample is taken for measurement of organic ^{14}C . Another portion of this trimestrial sample is then calcinated at 550°C during 24 hours and transferred to the lab for measurement of ^{90}Sr .

There is one sample a month for each sampling location; this sample is stored for the time needed for the preparation of the trimestrial sample. The residual trimestrial sample is stored in a dry place till one month after the submission of the quarterly results report.

7.6.5 Other foodstuffs

Samples of different foodstuffs are taken on the national territory from retail outlets, supermarkets, markets, abattoirs, fishermen, etc. The programme includes several hundred samples, including samples from border entry points (import from non-European countries), customs agencies, slaughterhouses, farms, warehouses, manufacturers and wholesalers. The following sample types are included:

- Common vegetables (lettuce, leeks, celery, cauliflowers, Brussels sprouts, white cabbages, red cabbages, broccoli, beans, carrots, chicory, asparagus, tomatoes, cucumbers, peppers, salsifies, turnips, eggplant, zucchini, spinach, beets, fennel, pumpkins, onions, rutabagas, potatoes, cultivated mushrooms, wild mushrooms, etc.)
- Common fruits (pears, apples, nectarines, kiwis, plums, mangos, melons, oranges, bananas, wild berries, strawberries, blackberries, grapes, etc.)
- Meat from markets and abattoirs (beef, veal, horse, pork, sheep, goat, rabbit, lamb, poultry, roe and seasonal wild boar)
- Snails and frog legs
- Fish from fisheries (fresh water fish (tilapias, silurids, etc.), deep-sea marine fish (tuna, swordfish, bream, bass, cod, herring, whiting, ray, sea trout, mullet, ocean perch, pollack, salmon, etc.) and fish living on the bottom (plaice, sole, etc.))

7.7 LABORATORIES PARTICIPATING IN THE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAMME

7.7.1 Institut de Radioelements

The National Institute of Radioelements (IRE) is a public organisation carrying out several functions in the nuclear field. IRE laboratory (IRE Elit) performs radioactivity analyses on a wide variety of sample types - drinking water, foodstuffs, NORM samples, biological samples and environmental samples. It has equipment, infrastructures and qualified personnel that enable it to measure low-activity samples. IRE Elit analytical methods are ISO 17025 accredited (the accrediting body is BELAC). There is also a mobile laboratory and equipment for taking the samples.

7.7.2 Centre d'Étude de l'énergie Nucléaire

The Centre d'Étude de l'énergie Nucléaire (SCK•CEN) is a public organisation carrying out several functions in the nuclear field. In total, it employs some 600 people. It holds accreditation by BELAC. In the environmental radiation surveillance, SCK•CEN is the contractor laboratory for FANC.

There are several radiation laboratories within the institute. The ISO 17025 accredited analysis methods are the following:

- Alpha/beta total in environmental samples
- Alpha total
- Uranium concentration in liquids and urine
- Alpha spectroscopy
- ^{226}Ra and ^{222}Rn determination in liquid and solid samples
- ^{131}I in milk
- Liquid scintillation counting
- Gamma spectroscopy of solid and liquid samples

Each SCK•CEN laboratory has a LIMS system, in which all incoming samples and the corresponding measurement results are recorded. After measurements, the environment samples are kept for three months after the regular three-month report to the FANC has been compiled, then discarded. Analysis results are sent to FANC on three month intervals. An annual report of the whole programme results is sent to FANC during the first three months of each year.

7.8 MOBILE MEASUREMENT SYSTEMS

7.8.1 Mobile gamma dose rate monitoring

FANC has 24 GammaTracer XL2 mobile stations (Picture 20) which have been supplied by Saphymo in 2004. They are a part of the emergency preparedness equipment. The Belgian Civil Protection and FANC deploy and/or place these probes; the FANC performs the maintenance.

In routine mode, the probes have a transmission to the server once a day with a measurement cycle of 4 hours. In this configuration, the autonomy is more than 1 year. The probes also have a wake up threshold fixed at 200 nSv/h. Above this dose rate the measurement cycle and transmission cycle is 10 min. In this configuration, the autonomy is reduced to a few weeks. The location of the probes is given by a GPS sensor; coordinates are sent with each transmission.

An alarm test is performed every 3 months and once a year a more profound maintenance is carried out (battery inspection, checking parameters, calibration, etc.).



Picture 20. Mobile automatic gamma dose rate monitor



Picture 21. Portable air sampler

7.8.2 Mobile air sampling

A portable air sampler is available for collecting airborne dust and iodine (Picture 21). Samples are collected using a specially designed, portable air pump with a flow meter and a filter unit mounted on the inlet. This filter unit contains both a paper filter (airborne dust) and an active charcoal cartridge (a.o. iodine). The filter paper and/or charcoal cartridge are replaced once the desired sampling time is reached or the requested sampling volume has passed through the air pump. Every filter/cartridge is sealed in a plastic bag and is transferred to the laboratory for immediate measurement using gamma spectrometry.

8 VERIFICATIONS

8.1 INTRODUCTION

The purpose of this Article 35 verification was to verify the liquid and aerial discharge monitoring arrangements at the Tihange NPP and the environmental monitoring facilities at and around the Tihange NPP.

The verification team verified the installations for discharge monitoring at Tihange NPP unit 2 (T2), the Tihange NPP radiochemical laboratory for analysis of discharge samples and selected installations for on-site and off-site environmental radioactivity monitoring. The verification included both site-specific facilities operated by the plant and facilities belonging to the national radiation monitoring system.

8.2 LIQUID DISCHARGE MONITORING AT THE TIHANGE UNIT 2

Liquid waste water generated at the plant is collected in discharge tanks. Before each discharge from the tank there is a procedure for controlling the radioactivity content of the tank in order to ensure compliance with the plant authorised discharge limits. In addition there are on-line monitors and automated sampling systems for the steam generator blowdown (draining of the steam generator secondary circuit to avoid deposits of sludge and corrosion).

In order to verify the arrangements for liquid discharge monitoring at Tihange 2, the verification team visited the following facilities:

Liquid waste control

The system of waste water tanks (liquid discharge tanks, TEP) is controlled in the TEL control room. The permitted discharge flow is calculated based on the discharge ^3H content and the river Meuse flow rate⁸.

The TEL control room is the place where the operator carries out the discharge of full liquid waste water tanks. Before each discharge a sample is taken in order to determine the amount of discharged activity; results are recorded in a database. There are also safety shutdown monitors in the discharge line of each tank to terminate the discharge in the event of an exceptionally high activity.

Steam generator blowdown monitors

The discharge flow from steam generator blowdown is continuous and large in volume, but normally not radioactive⁹. An on-line monitor is available to provide an alarm in the event of high activity in the blowdown discharge line. In addition, automatic sampling equipment (Bühler-system) is available. There is a two-litre bottle for each day of the week. The sample is taken on 50 ml fractions. Samples are analysed in the plant laboratory.

Liquid waste tank sampling

Waste water is collected in TEP tanks, which have volumes of either 500 or 800 m³. The sampling room has a sampling line connected to each tank. A recirculation pump is available to homogenise the tank content before sampling in order to improve sample representativeness. The sample line is drained before each sampling.

⁸ Water from the River Meuse is also used to produce drinking water intended for human consumption, so the ^3H parametric value of 100 Bq/l needs to be respected.

⁹ All steam generators in Tihange 2 have been replaced in 2001. After that there have been no steam generator tube leaks, i.e. there has been no radioactivity in the steam generator blowdown water.

Monitoring at the liquid discharge channel

Liquid discharges are mixed with the plant cooling water outflow. The detector used for monitoring radioactivity in the T2 coolant outlet channel was presented to the verification team. The detector is located after the point where discharges are mixed in the outgoing coolant water separated from the recirculated coolant water.

Verification does not give rise to recommendations.

8.3 GASEOUS DISCHARGE MONITORING AT THE TIHANGE UNIT 2

Monitoring of gaseous discharges is carried out by on-line monitors and sampling. Monitoring is carried out on outgoing air and on the gas storage tanks, which are typically allowed to decay for 30-50 days before discharge (Xe-decay). In order to verify these arrangements at Tihange 2, the verification team visited the following facilities:

Point source gaseous discharges control

The system of gas storage tanks (TEG) is controlled in the TEG control room. The tanks have either status 'being filled' or 'in decay'. Before the operator can discharge a tank, he needs approval of the shift manager.

Stickers are used to identify tanks, which are 'in decay' or 'being filled'. The verification team noted that these stickers are very small and easily removable (misplaced). There are no interlocking keys to avoid accidental release of a wrong tank (or theoretically all the tanks). The verification team was informed that in T1 there are such keys in use. In T3, there is an administrative locking system.

Gaseous discharge stack

Stack is the sole discharge point for all controlled gaseous radioactive discharges. Total flow measurement in the stack is carried out using pitot-tube flow velocity monitors (Emerson Rosemount) inside the stack. Typically the total flow is in the order of 150 000 m³/h.

On-line gaseous discharge monitoring

Stack discharges are monitored by on-line systems VBP301 and VBP302. These systems monitor an isokinetic bypass gas flow of the outgoing air from the stack. Detection is carried by monitoring beta-activity on a rolling filter paper.

Sampling of radioactive particulates and ¹³¹I

There are two parallel sets of gas filter paper and charcoal cartridges for particulate and iodine monitoring on the same sample line with on-line monitors. In addition there is one such set on the post-accident monitor sample line. These are changed and analysed weekly.

Post-accident monitoring

In the event of a large accident discharge the routine monitoring systems would be saturated; therefore a separate accident monitor BIS 301 for noble gases is available. This system is based on an ionisation chamber and a GM-detector, allowing a very wide measurement range (10⁹-10¹⁵ Bq/m³).

Gas sampling

Gas samples can be taken by passing 500 litres of gas through a sampling system consisting of a filter paper and a charcoal cartridge for ¹³¹I sampling¹⁰. The samples are analysed in the plant laboratory by gas chromatography and gamma spectroscopy.

¹⁰ In addition to discharge gas tank (TEG) sampling also gas samples from the liquid discharge tanks (TEP) can be taken to determine the hydrogen content inside the tank.

Verification team was informed that there is no statutory monitoring of Tritium carried out in Tihange, but an experimental Tritium monitor is being tested at unit T3.

The verification team recommends putting in place a system of interlocks also in T2 to avoid accidental discharge of tanks and suggests improving the clarity of the gas storage tank labelling system.

8.4 TIHANGE 2 LABORATORY FOR ANALYSIS OF DISCHARGE AND ON-SITE ENVIRONMENT SAMPLES

Each unit of the Tihange NPP has its own laboratory. The laboratories are more or less identical. There is a staff of 7 (8 in T2) working in each unit laboratory. The verification team was informed that the main discharge-related analyses in the T2 laboratory are the following:

- Air filter papers: gamma spectroscopy
- Liquid discharge samples: gamma spectroscopy, total gamma/beta counting, beta counting, alpha counting
- Gas sample canisters: gamma spectroscopy

In addition the laboratory carries out analysis on monthly composite water samples, rain water samples (collected from the roof) and - once a year - ground water samples. In order to verify the arrangements for gaseous and liquid discharge monitoring at Tihange 2, the verification team visited the following laboratory facilities:

T2 laboratory (controlled area - 'hot' side)

Discharge samples from the controlled area are received in the 'hot' side of the laboratory and recorded in the LIMS database. Each sample is labelled with its LIMS number.

'Hot' side counting room is equipped with a Canberra 7401 alpha-counter, a Canberra beta-counter, a gamma total counter (NaI detector) and a tri-Carb 2900 TR liquid scintillation counter (³H measurements). The equipment are modern and well maintained.

T2 laboratory (uncontrolled area - 'cold' side)

The 'cold' side of the laboratory is equipped with two Canberra nitrogen-cooled gamma spectroscopy systems (one with N₂-recirculation). These systems are used for measuring discharge and environmental samples on several counting geometries. Efficiency calibrations are carried out using standards prepared in the laboratory, which are based on commercial activity standards. Weekly control of systems includes energy, resolution and efficiency stability controls. Counting results are recorded in the laboratory LIMS-system where the laboratory manager approves them.

Verification team reviewed the recent rain and ground water activity results in the LIMS system.

Verification does not give rise to recommendations.

8.5 ON-SITE ENVIRONMENTAL MONITORING AT THE TIHANGE NPP

8.5.1 Monitoring of radiation dose and dose rate

In order to verify the arrangements for on-site radiation dose rate monitoring at the Tihange NPP, the verification team visited the following facilities:

GammaTracers at the fence

There are 22 GammaTracer stations placed at the site fence. These are operated by the plant personnel. The verification team visited one station on the riverside (4 meters from the floodwall) and one on the other side of the site.

TELERAD stations IMR T18 and T07

There are 22 ENVINET SARA stations placed at the site fence, operated by FANC. The stations belong to the national TELERAD network. The verification team visited one station on the riverside and one on the other side of the site (stations IMR-T18 and IMR-T07).

The number of monitoring stations on the site fence is considerably high. Verification team notes that having so many stations on the site fence provides very quick and accurate alert function in the event of a ground level release from any of the site buildings, but an elevated release from the stack could go undetected by the fence detectors. This type of release can be detected by the TELERAD stations located at a longer distance from the plant.

FANC emergency diesel generator and UPS systems

The emergency diesel generator and associated UPS systems operated by FANC were presented to the team. These systems provide back-up power for the TELERAD stations on the site fence and in the cooling water discharge channels.

Verification does not give rise to recommendations.

8.5.2 Mobile radioactivity monitoring equipment

In order to verify the arrangements for mobile radioactivity monitoring at the Tihange NPP, the verification team visited the following facilities:

Mobile air measurement unit

This Berthold mobile unit can be transported to the monitoring location (indoors) to monitor the radiological quality of air. The system includes a dose rate monitor and particulate activity monitors, connected to a data logger system. There are two such systems available at the Tihange site.

Pathway monitoring vehicle

The Saphymo pathway monitoring vehicle monitors ground contamination (alpha/beta detector; airborne radiation is suppressed) using a gas proportional counter located beneath the vehicle (surface detector of 1800 cm³). The system has no data recording, but the driver hears the detector count rate from headphones, i.e. he can locate possible radiation hot spots on the ground.

Environment monitoring vehicles

There are two mobile radiation monitoring vehicles available at the Tihange NPP. These are Citroen Jumper vans equipped with a NaI detector system for environment sample measurements and environment dose rate monitoring (while the vehicle is moving). There is also a mobile air sampler with filter papers for particulate sampling and a charcoal cartridge for iodine sampling. The system automatically samples 1 m³ of air. In addition the vehicle is equipped with handheld dose rate and contamination monitors. Altogether 6 persons have been trained to use the mobile equipment. Testing of the system is carried out monthly on four test locations.

Verification does not give rise to recommendations.

8.6 OFF-SITE ENVIRONMENTAL MONITORING IN THE VICINITY OF THE TIHANGE NPP

8.6.1 Monitoring of radiation dose rate

TELERAD IMA/T01 and meteorological station

The verification team visited the TELERAD dose rate monitoring station IMA/T01, which is located some 2 kilometres from the NPP on the opposite side of the river Meuse. The station is installed inside a locked gage. The location is very good on an open plain overlooking the Meuse river valley.

On the same site there is also a TELERAD meteorological station. Sensors of this station (wind speed and direction) are installed on 10 meter height.

TELERAD IMA/T05

The verification team visited the TELERAD dose rate monitoring station IMA/T05, which is located about 1 km from plant downstream on the riverbank, next to the river water monitoring container. A demonstration of the station calibration using a radioactive 'calibration ring' around the detector was given to the team.

Verification does not give rise to recommendations.

8.6.2 Monitoring of radioactivity in air

The verification team visited the IRE medium volume air sampler, which is located some 2 kilometres from the NPP on the opposite side of the river Meuse next to the TELERAD station IMA/T01. The location is very good on an open plain overlooking the Meuse river valley.

The sampler has an individual filter for each day of the week; an electronic control system switches the airflow to pass through the correct filter (same as in picture 13). Filters are collected by the IRE on weekly basis, allowing analysis of air radioactivity for each day. Air flow is measured by an air flow meter. The system has a battery back-up for the control system, but not for the air pump, i.e. during a power cut the system does not pump air through the filter, but it maintains the filter control and information on each filter total airflow volume.

Verification does not give rise to recommendations.

8.6.3 Monitoring of radioactive deposition

The verification team visited the dry/wet deposition collector, which is located some 2 kilometres from the NPP on the opposite side of the river Meuse close to the TELERAD station IMA/T01. The collection vessel is heated to avoid freezing. Due to the short electrical cable the system is located only about 0.5 meters from building wall. Proximity of the wall may influence the collection volume in certain wind directions, which may have a small effect on the representativeness of the sample. Sample is collected on weekly basis and analysed for total alpha/beta and nuclide specific gamma.

The verification team recommends a review of the representativeness of the sample.

8.6.4 Monitoring of radioactivity in the river Meuse

The verification team visited the water quality monitoring container about 1 km downstream of the plant after a hydroelectric power plant. The container is heated and equipped with electrical back-up systems. It contains the following instruments:

TELERAD water station IMW/01

This TELERAD water station is a flow-through water circulation vessel where a LaBr₃-detector is immersed in the river water. The system is equipped with a flow meter (yes/no flow info). The nominal water flow through the vessel is about 64 litres/min.

Sediment sampler

This sediment sampler is a container where – during 4 weeks - river water sediment is deposited on the bottom and can be collected to form a sedimentation sample. These 4-weekly samples are analysed at the IRE Elit laboratory.

Automatic water sampler

This sampler automatically takes sample of the river water every 30 minutes. These samples are collected in a sampling bottle for each day. The daily water samples are collected on weekly basis and analysed by the IRE.

Verification does not give rise to recommendations.

9 CONCLUSIONS

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

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

- (1) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the air, water and soil on the territory of Belgium are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.
- (2) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the air, water and soil on and around the Tihange NPP site are adequate. The Commission could verify the operation and efficiency of a representative part of these facilities.
- (3) The verification activities that were performed demonstrated that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the gaseous and liquid discharges at the Tihange NPP site are adequate. The Commission could verify the operation and efficiency of these facilities.
- (4) A few recommendations are formulated; in particular as regards interlock keys at the Tihange 2 gas storage tanks control facility and representativeness of the atmospheric deposition samples. Notwithstanding these recommendations the verified parts of the national monitoring system for environmental radioactivity and the monitoring arrangements in place at the Tihange NPP are in conformity with the provisions laid down under Article 35 of the Euratom Treaty.
- (5) The verification summary is presented in the 'Main Conclusions' document that is addressed to the Belgian competent authority through the Permanent Representative of Belgium to the European Union.
- (6) The Commission services request a report on the implementation of the recommendations by the Belgian authorities and about any significant changes in the set-up of the monitoring systems before the end of 2017. Based on this report the Commission will consider the need for follow-up verification.
- (7) The verification team acknowledges the excellent co-operation it received from all persons involved in the activities it performed.

REFERENCES & DOCUMENTATION

1. Preliminary information questionnaire addressed to the national Competent Authority, received on 28 October 2016
2. Verification effectuees au titre de l'article 35 du traite Euratom, 10-14 Juin 1996, E-96/1 Tihange 1-2-3
3. Centrale nucleaire de Tihange, Declaration environnementale 2015, Electrabel Gdf Suez

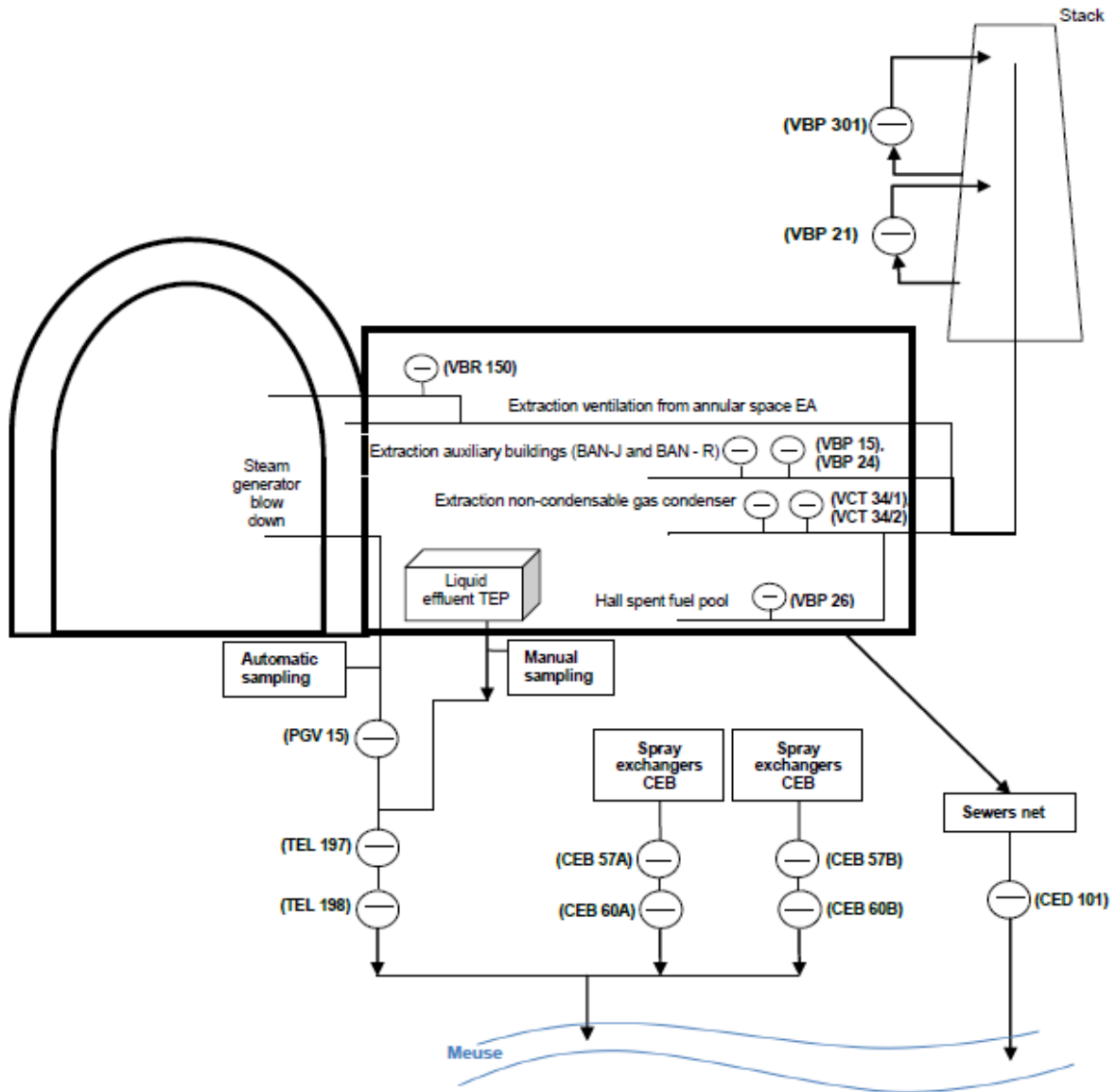
THE VERIFICATION PROGRAMME

Tihange NPP discharge and environmental monitoring and national environmental radioactivity monitoring network in the vicinity

Tihange NPP, Belgium, 14 – 17 November 2016

| Day/date | Time | Verification |
|--------------------------|---------------|---|
| Monday 14 November | 15.00 – 17.00 | Opening meeting with FANC and Tihange NPP representatives |
| Tuesday 15 November | 9.00 – 12.30 | Verification of Tihange 2 gaseous discharge monitoring facilities <ul style="list-style-type: none"> • on-line systems • gaseous sampling arrangements • control room interface |
| | 13.30 – 17.00 | Verification of Tihange 2 liquid discharge monitoring facilities <ul style="list-style-type: none"> • on-line systems • liquid sampling arrangements • control room interface |
| Wednesday 16 November | 9.00 – 12:30 | Visit to laboratories dealing with analysis of Tihange NPP discharge samples |
| | 13:30 – 17:00 | Verification of operator's on-site environmental monitoring <ul style="list-style-type: none"> • periphery gamma monitors • groundwater sampling • rainwater sampling • meteorological station • mobile equipment etc. |
| Thursday 17 November | 9.00 – 15.30 | Verification of regulator's on-site and off-site environmental monitoring and stations of the national monitoring programme in the vicinity <ul style="list-style-type: none"> • BCI/BCD water monitoring stations • TELERAD stations • air samplers • deposition collectors • portable airborne dust/Iodine monitors • river water samplers etc. |
| | 16.00 – 17.00 | Closing meeting with FANC and Tihange NPP representatives |

TIHANGE UNIT 1 GASEOUS AND LIQUID DISCHARGE MONITORING SYSTEMS



TIHANGE UNIT 3 GASEOUS AND LIQUID DISCHARGE MONITORING SYSTEMS

