OSPAR COMMISSION

Protecting and conserving the
North-East Atlantic and its resources

Sixth Implementation Report: Report in accordance with PARCOM Recommendation 91/4 on radioactive discharges

Belgium

Radioactive Substances Series

2015

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union européenne.

This report has been prepared by Sombré Lionel, PhD. & Claes Jurgen, ir. (FANC).

Contents

GENERAL INFORMATION

At its 2010 meeting in Stockholm, Sweden, the OSPAR Radioactive Substances Committee established, on a trial basis, revised "Guidelines for the submission of information on the assessment of the application of Best Available Technology (BAT) in nuclear facilities". In this report the requested information for Belgian nuclear installations is given. The report covers the four (five)-year period 2010-2013 (2014) inclusive.

Implementation of BAT/BET in terms of the OSPAR Convention in Belgian legislation and regulation

The first law concerning protection of the population from ionising radiation dated from March 29th, 1958. The legislation with respect to radiological protection was based on the Royal Decree of February the 28th 1963. After some modifications by the Royal Decrees of May 17th 1966, May 22nd 1967, December 23rd 1970, May 23rd 1972, May 24th 1977, March 12th 1984, August 21st 1985 the legislation was thoroughly adapted by the Royal Decrees of January 16th and February 11th 1987 when the ICRP-26 and 30 (regarding the methodology for calculation internal radiation dose) were taken into account. Other modifications were made by the Royal Decrees of February 12th and September 6th 1991, June 17th 1992, September 7th 1993, October 2nd 1997 and May 3rd 1999.

The Federal Agency for Nuclear Control (FANC) was established by law of April 15th 1994 and according to its position it has a great independency, necessary to take up his responsibility to the society in an impartial way. It is lead by a board of directors and the daily management is observed by a General-Director.

A new legislation was created by the Royal Decree of July 20th 2001 *(General Regulations for the Protection of the population, workers and the environment against the dangers of Ionising Radiation - GRPIR*), which was necessary to harmonise the Belgian legislation with the European Directives (that take into account some recommendations of the ICRP-60). This Royal Decree attributes to the FANC the objectives of "protection of the population, workers and the environment against the dangers of ionising radiation" that consist to:

- propose, apply and improve law and regulations;
- control human (and non-human) activities responsible for exposure of man to radioactivity;
- ensure the surveillance of radioactivity on the territory (telerad automatic network - Radiological Surveillance Monitoring programme);
- co-operation to nuclear emergency plans;
- distribute neutral and objective information.

Law of August 5th, 2006 that gives right to the public in accessing information with regard to the environment, which transposes the EU directive 2003/4/CE of the European Parliament and council of January 28th, 2003 regarding the public access to information related to the environment, led to the diffusion of a note from the Belgian Safety Authority that regulates the periodical reporting of radioactive releases from nuclear installations (see §2.9).

Basis for national legislation/regulation:

The Belgian policy is based on EC Directives, on international conventions and on recommendations of appropriate international bodies like the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). The major principles in these regulations are:

- justification of exposure: exposure to radiation is only allowed if the advantage is larger than the possible risk and damage of the exposure;

- optimisation: known as the alara-principle (As Low As Reasonably Achievable), exposure has to be as low as possible, taking social and economic factors into account;
- dose limits: exposure of individuals as result of the combination of different exposures, has to be subject to limits to prevent unacceptable risks.

Dose constraints/limits for nuclear installations

The limits, which are given by the Belgian regulation *General Regulations for the Protection of the population, workers and the environment against the dangers of Ionising Radiation* (GRPIR), are the following.

Dose	Public art. 20.1.4	Workers art. 20.1.3	apprentices and students ≥ 18 years art. 20.1.5	 16≤ <18 years art. 20.1.5
Effective (whole body)	1 mSv/a	20 mSv/a *	20 mSv/a *	6 mSv/a
Equivalent for any individual organ or tissue	-	500 mSv/a *	500 mSv/a *	-
Equivalent for lens of the eye	15 mSv/a	150 mSv/a *	150 mSv/a *	50 mSv/a
Equivalent for skin **	50 mSv/a	500 mSv/a *	500 mSv/a *	150 mSv/a
Equivalent for hands, arms, feet and ankles	-	500 mSv/a *	500 mSv/a *	150 mSv/a

* for 12 consecutive months.

** average dose for each area of 1 cm² of skin

Remark: the above limits do not take into account medical exposure

Nuclear installations apply for their workers a dose constraint of 10 mSv/a.

Discharge limits

The annual limits for discharges and emissions are specified for a nuclear facility in such a way that the resulting doses to the population shall not exceed 1 mSv per year for all pathways combined (art. 20 of the Royal Decree of July 20th 2001).

The Royal Decree introduces also a notion of dose constraint (optimisation principle-ALARA): the discharge limits have to be based on a fraction of the public annual limit of 1 mSv. Dose constraints have been discussed with the FANC: the following table shows the dose constraint used by the nuclear sites.

	Dose constraint (mSv/a)			Evaluation of real committed dose (average over the last 10 years) (mSv/a)			Reduction Yes / No
	Atmospheric discharge	Liquid discharges	Total	Atmospheric discharge	Liquid discharges	Total**	
Belgoprocess (Site of Mol)	0.3	0.25	0.55	$60\ 10^{-6}$	$625\ 10^{-6}$	$685\ 10^{-6}$	Y
NPP Tihange	0.19	0.08	0.21	$47\ 10^{-3}$	$2.5\ 10^{-3}$	$49\ 10^{-3}$	N
NPP Doel	0.18	0.23*	0.37	$18\ 10^{-3}$	$2.3\ 10^{-3}$	$19\ 10^{-3}$	N

* take into account a specific critical group

** maximum dose does not necessary correspond to the sum of doses due to atmospheric or liquid releases: the critical individual, even localised at the same place, is not always in the same age category

The model used to estimate the radiation exposure for a critical group caused by radioactive effluents of nuclear power plants was based on the NUclear REgulatory Guide (NUREG) 1.109 rev. 1, USNRC. Some conservative adaptations have been made by taking into account:

- Dose conversion factors (RD of July 20th 2001) based on the icrp 72;
- 6 classes of age (RD of July 20th 2001) : ≤ 1y, 1-2y, 2-7y, 7-12y, 12-17y and > 17y;
- Eventual adaptation of some parameters (e.g. consumption habit,…).

The dose is calculated at the most unfavourable receiving points, taking into account the relevant exposure pathways and living habits, e.g. the consumption rates of different foodstuffs. On the basis of these assumptions and parameters used in the models, the radiation exposure to individuals cannot be underestimated.

Monitoring programmes of discharges and environmental concentrations of radionuclides

Under the Royal Decree, the Federal Agency for Nuclear Control (FANC) is charged in particular with *monitoring the radioactivity of the territory and the doses received by the population* (Article 70) as well as organising the *monitoring of the population as a whole* (Article 71). It should also be noted that the Franco-Belgian co-operation agreement of September 8th 1998, relates to the Chooz nuclear power station situated on the Meuse in France close to the border with Belgium. This agreement ensures the full monitoring on Belgian territory of all radioactivity transfers around the nuclear site as well as the periodic exchange of results between states.

Between 2002 and 2004, the Agency reviewed its entire sampling and measurement programme in order to completely harmonise it with international requirements. The former 1998 European Directive on drinking water and the new Council Directive 2013/51/EURATOM had imposed:

- stronger controls, with new requirements in terms of control;
- the reporting of radiological surveillance data to the European Commission resulting from the application of Article 36 of the euratom treaty.

Finally, the OSPAR Convention (OSlo-PARis Convention, 1998 – ratified by Belgium) on the protection of the marine environment of the North Sea and North-East Atlantic makes the development of monitoring and research programmes concerning the impact of radioactive discharges on the marine environment mandatory.

The programme for the radiological monitoring of the territory currently (2009-2010) relies on about 5,300 samples annually, which are subjected to almost 32,000 alpha, beta and gamma radioactivity analyses. This radiological monitoring programme includes radioactivity measurements carried out in:

- the Meuse and Sambre basins;
- the Scheldt and Nete basins;
- the marine zone;
- a reference zone (Brussels Capital region).

for the major parts of the biosphere (air, soil, water and biocenosis) as well as in the main constituents of the food chain, supplemented by the follow-up of the atmospheric and liquid discharges of the main nuclear sites and through dose rate measurements around these facilities.

Wastes releases from hospital will be also controlled in sewage purification plants by using submersible automatic gamma spectrometry probes. The goal is to qualify and quantify if possible the radioactivity that enters the environment at the outlet of the sewage plants. The in situ controls of the hospital practices conducted by nuclear inspectors will be also linked with the obtained results. The final aim being to minimize the radioactivity levels of the hospital releases.

The discharges and environmental impact of some NORM and legacy sites are also monitored. This monitoring occurs either periodically or in the framework of a specific measurements campaign. These NORM sites belong to the phosphate and to the titanium dioxide production sectors. An environmental follow up of a legacy site related to a former radium extraction facility is also performed.

Environmental norms and standards

The art. 34 of the RD of July 20th 2001 defines that liquid discharges in surface waters or sewer canalisations are forbidden when concentration in radionuclides, expressed in Bq/litre, exceeds one thousandth of the annual limit of intake by ingestion for an adult (annexe III D of the RD).

National authority responsible for supervision of discharges

All licensing and supervision activities concerning construction and operation of nuclear facilities is carried out by the regulatory authority of the federal state (FANC) with the co-operation of authorized inspection and controlling bodies (Bel V, Controlatom, …). This is also the case for authorisation of radioactive discharges to the environment. FANC is under the authority of the Ministry of Interior.

Nature of inspection and surveillance programmes

The nuclear installations are inspected several times each year by the federal authorities (FANC and authorised inspection and controlling bodies). The environmental monitoring programme is undertaken by special authorised laboratories under the co-ordination and the responsibility of the federal authority (FANC). Laboratories undertake analyses in accordance with internal Quality Control procedures also involving regular calibration of detectors and yearly comparison exercises. Therefore, the quality of environmental and discharge sample measurements, and the assessment of impact of discharges and emissions on members of the general public, is based on an independent national system of governmental bodies and experts.

The TELERAD network - automatic remote radioactivity measuring network in Belgium - has been modernised in during 2010. The network now comprises 218 stations, which constantly measure the radioactivity of the ambient air, river waters. The stations are distributed throughout the entire country for nationwide monitoring, in rings around the nuclear sites at Tihange, Doel, Mol, Fleurus and Chooz to monitor the installations, as well as in the urban areas close to these installations.

In addition, in selected sewage purification plants the radioactivity of waters are controlled in situ with automatic (submerged) gamma spectrometry probes (see also 2.6).

The modernisation in 2010 comprised the replacement of all stations by stations of a new generation and with modern data communication links. To improve the nuclear sites surveillance, the ring stations (situated around the sites on the fence) have been equipped with a gamma spectrometry to make a quick identification of nuclides present in the ambient air of these stations. In addition, existing river stations are also modified and are now equipped with a gamma spectrometry with identification of present nuclides. Finally, new automatic gamma spectrometry probes are implemented upstream and downstream of the Doel NPP on the Scheldt river. The surveillance of the aquatic releases from NPPs are now directly done by automatic gamma spectrometry probes placed at the outlet of the release channels of the NPPs (Tihange and Doel).

All stations are linked to a centralised system that is automatically alerted when detecting any abnormal rise in radioactivity levels or a nuclide is detected above a preset threshold on the ring stations. The central systems has a full redundant set-up at a disaster recovery site.

Reporting

The results of discharge measurements performed by operators are reported monthly to the federal authority (FANC) and are also available through annual reports. Moreover, a new note from the FANC concerning the periodical reporting of radioactive releases (gas and liquid) is applicable since January 2011. the note transposes the requirements of the EU recommendation 2004/2/Euratom.

Belgium reports annually on the FANC website all the results obtained from the radiological surveillance programme of the territory (including TELERAD, foodchain, nuclear sites discharges, NORM and legacy sites…).

Belgium reports discharge data from nuclear installations annually to EURATOM (art. 35&36 of the treaty) and to the OSPAR secretariat.

Belgium also reports hourly the dose rate data from the TELERAD network to the European Commission (EURDEP).

SITE -SPECIFIC INFORMATION

Nuclear Power Plants (NPP) general information

Nuclear power currently accounts for about 61.7 % of Belgian's electric energy production (45.1 % of the capacity) in 2013[1]. The nuclear power stations are located near Doel and Tihange. There are 7 operational pressurised water power reactors (3 at Tihange and 4 at Doel).Discharge data are given for reactor sites. The activity concentrations of radionuclides in non-human biota of river water are so low that it is generally not possible to detect them.

Information to be submitted in accordance with the BAT Guidelines is given in Annex 1 referring to nuclear power plants for the period between (1998) 2010 and 2013.

For each installation, the information as defined in BAT Guidelines is given in tabular form:

- Name of facility;
- Type of facility;
- Date commissioned;
- Location;
- Installed electrical generation capacity;
- Electricity generation;
- Shut-down year;
- Annual emissions and discharges, absolute and normalised according to actual output as compared to the UNSCEAR ranges;
- Individual dose as compared to the national dose limits;
- Waste treatment.

The determination of individual dose covers all radionuclides discharged to the environment.

Other nuclear sites general information

There are two other nuclear sites in Belgium: the Fleurus site (IRE-National Institute of Radioelements and MDS-Nordion) in Wallonia and the Mol-Dessel site (the Nuclear Research Centre SCK●CEN / Belgoprocess sites 1&2 (BP) / Belgonucléaire (stopped in August 2006, dismantling started in 2009 and to be completed in 2014) / FBFC International - Franco-Belge de Fabrication de Combustibles International / IRMM – Institute for Reference Materials and Measurements) in Flanders. The facilities at these sites carry out scientific, technical and commercial programmes in the nuclear field.

For the Fleurus site there are no liquid discharges: all liquid wastes are sent to the Belgoprocess site 1 for treatment. After treatment, eventual liquid discharges are released by the Belgoprocess site 2. All the liquid discharges produced by the Mol-Dessel site are also managed by the Belgoprocess facilities.

For **Belgoprocess site 2** the information, as defined in BAT Guidelines, is given in tabular form (annex 2):

- Name of facility;
- Type of facility;
- Location;

[1] ELECTRABEL FAITS & CHIFFRES 2013, Electrabel GDF SUEZ, 36 pages, mai 2014

- Annual emissions and discharges;
- Individual dose as compared to the national dose limits;
- Waste treatment.

The determination of individual doses covers all radionuclides discharged to the environment.

1. SITE CHARACTERISTICS

1.1 Tihange Nuclear Power Plant

1.1.1 Tihange

1.1.2 Type of facility (see Annex 1)

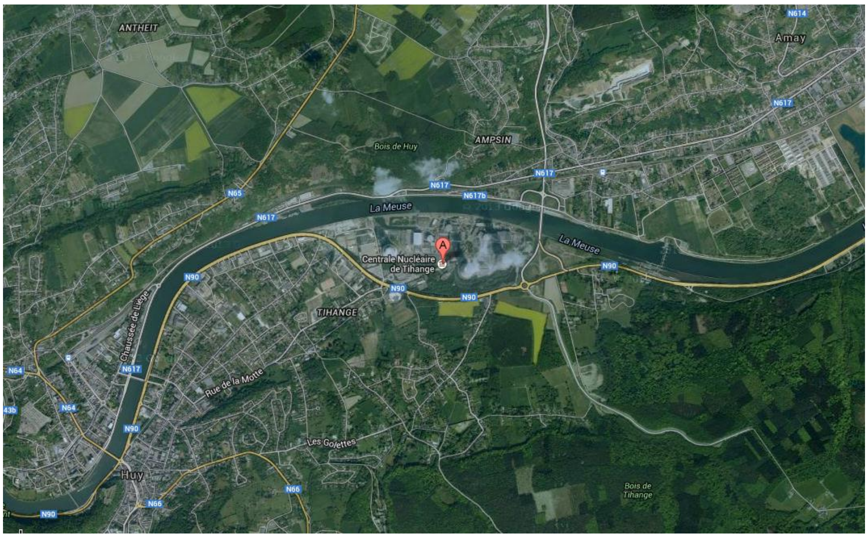
Three PWR.

1.1.3 Year for commissioning/licensing/decommissioning

- Tihange 1 : 1975/2015 => 2025;
- Tihange 2 : 1982/2022;
- Tihange 3 : 1985/2025.

1.1.4 Location

The site is situated on the right Meuse river side near of Huy and Tihange cities.



1.1.5 Receiving waters and catchment area, including, where relevant, information on water flow of receiving rivers

Meuse river.

1.1.6 Production

See "Tihange" tables in the annex 1.

1.2 Doel Nuclear Power Plant

1.2.1 Doel

1.2.2 Type of facility (see Annex 1)

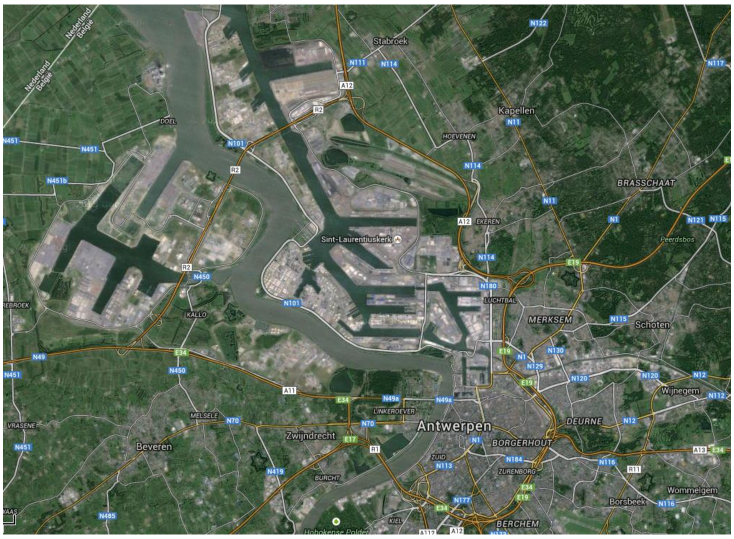
Four PWR.

1.2.3 Year for commissioning/licensing/decommissioning

- Doel 1 : 1975/2015=>2025 ? [2];
- Doel 2 : 1975/2015=>2025 ? [3];
- Doel 3 : 1982/2022;
- Doel 4 : 1985/2025.

1.2.4 Location

The site is situated on the left Scheldt river side near Antwerpen city.



1.2.5 Receiving waters and catchment

[2] Governmental decision, now in negociation between the Department of Energy and Tractebel.
[3] Governmental decision, now in negociation between the Department of Energy and Tractebel.

area, including, where relevant, information on water flow of receiving rivers

Scheldt river.

1.2.6 Production

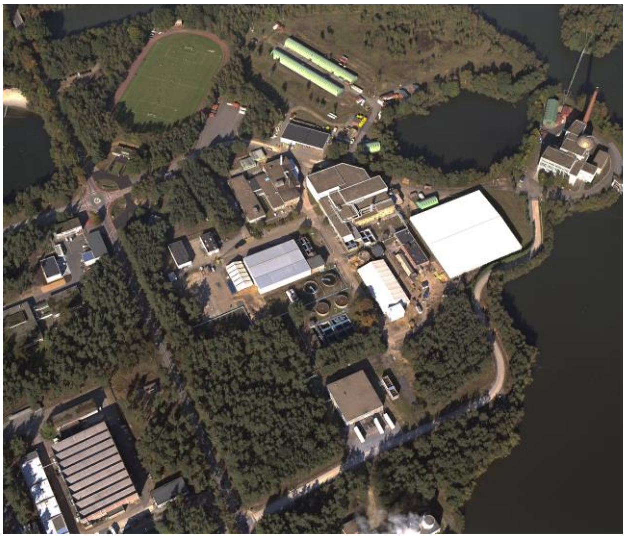
See "Doel" tables in the annex 1.

1.3 Other Nuclear Sites

1.3.1 Belgoprocess (BP)

Belgoprocess site 1

Belgoprocess site 2 (liquid waste treatment and releases)



1.3.2 Type of facility (see Annex 1)

Waste treatment and storage facility.

1.3.3 Year for commissioning/licensing/decommissioning

1984/-

1.3.4 Location

The site is situated in the Mol-Dessel region and liquid releases are discharged in the Molse Nete river by an underground pipe of 10 km long.

1.3.5 Receiving waters and catchment area, including, where relevant, information on water flow of receiving rivers

Molse Nete river.

1.3.6 Production

NA.

2. DISCHARGES

2.1 Tihange NPP

The radionuclides to be monitored are stipulated in the "licence to operate" of the NPP reactors under the responsibility of the federal authority (FANC).

2.1.1 System(s) in place to reduce, prevent or eliminate discharges of radioactive substances

Origin: there are 3 reactors and for each reactor building there are 2 main categories of liquid wastes: recyclable waste waters (primary waters or hydrogenous waters) and non-recyclable waste waters (floor, laundry, lavatory, chemical such as labs decontamination component cooling systems, "demineralisation effluents" from steam generators, regeneration effluents from machinery, …).

Treatment: ion-exchange procedures, filtration and evaporation of waste waters (in evaporators, Tritium from the distillate is condensed and released as a liquid fraction). The concentrate phase is conditioned in the NPP itself as solid concrete waste.

Waste management: recyclable effluents are collected in their respective units (Tihange 1, 2 or 3) and then pumped to unit 2 where they are filtered (1 or 5 µm filters), demineralised (anionic, cationic and mixed bed resins), degassed (fission gas) and evaporated. The distillate (bore) is recovered, the filtrate (containing tritium) is sent to the RAR tank (storage tank before release to river) of the originating unit. The residue (containing residual non recovered bore) is eliminated as solid waste (cementation).

Non-recyclable effluents are identically collected in their respective units and are also pumped to unit 2. If the radioactivity is low, treatment will be conducted by filtration. If the radioactivity is higher, most of the effluents will be treated by evaporation or through filters and ion exchange resins. The distillate (evaporation) and/or filtrate (filtration) are treated as a low level activity effluents, analysed and repumped to the RAR tank (storage tank before release to river) of the originating unit. In either case, solid residues are treated as solid waste according ONDRAF[4] procedures.

All effluents from the RAR, after second analyses, are pumped to their own end collector. There, they are mixed with and diluted by waters from raw water cooling system before being released to the Meuse river.

In 2009, CNT decided to lower the limit for treatment of liquid effluents at ~1 MBq/m³ (gross gamma counting).

2.1.2 Systems abatement efficiency

Abatement systems and management (according to 2.1.1 and 2.1.2).

[4] National Agency for Radioactive Waste and enriched Fissile Material.

Abatement system/ Management	**Into operation (Year)**		**Efficiency of abatement system**		**Comments**
	Existing	**Planned**	**Decontamination Factor**	**Other measure of efficiency**	
Discharges:					
delay tank(s**)** **Liquid** : storage tanks prior to release in the river Meuse) 2tanks /reactor **Gas** : on each unit , several gas tanks of different capacities and design pressures	**Liquid** **Ti 1**: 1986 **Ti 2**:1982 **Ti 3:** 1985 **Gas**: **Ti 1** 1975 (part of original design) and ca.1980 (two additional tanks) **Ti2 and Ti3:** part of original design of the plants		**Liquid** :See Ion exchange for typical figure **Gas** : delay policy is used on a regular basis in order to avoid short lived gas species releases (Xe-133) . gas release are mandatory filtered on PRE, HEPA and Active carbon filters		**Ti 1** : the 2 release tanks for liquid were added during the first 10 -years outage. **Ti 2 and Ti 3** : part of the basic design Discrepancies in storage capacities exist according to different ages and design
chemical precipitation	In operation in the late years 1980		Typical figures were poor (FD = about 20 but needed multi-step precipitation)	Gross gamma counting	One floculator (30 m^3) in CNT2 Given up according to poor DF
centrifuging	NO	NO			
hydrocyclone	NO	NO			
cross-flow filtration					
ion exchange (with pre and post filtrations, coupled with thermal degazifier and evaporator) for primary (recyclable) liquids , boric acid liquors are recycled , tritiated distillate are stored prior to release Evaporator alone : for non-recyclable liquids	Classical Filter/Ion exchange/ Filter /degazifier/ evaporator process or evaporator only		Typical figures are … > 95 … 99 % for the whole treatment process of the primary effluents	Efficiencies of the ion exchange resins are checked by gross gamma counting / spec gamma, Efficiency of the single evaporation is measured by checking the distillate gross gamma activity	

osmosis	One semi-industrial unit in operation in TI3 in the mid-1990		DF measured by IN and OUT effluents activities	Gross gamma and spectro gamma counting's	Fused for Boraflex issue only , given up after the removal and the replacement of the Boraflex
ultrafiltration	NO	NO			
Emissions:					
electrostatic precipitation	NO	NO			
cyclone scrubbing	NO	NO			
chemical adsorption	NO	NO			
HEPA filtration	YES, part of the basic design of the 3 units		> 99 % (measured according to the technical specifications for classified filters or on a voluntary basis for the unclassified ones)		Discrepancies exist because the 3 unite are of different ages and designs
cryogenics	NO	NO			
Active carbon filter	See HEPA		> 95 % classified filter > 90 % for un-classified items		See HEPA

2.1.3 Annual liquid discharges

For tritium, the range for normalised liquid discharges since 2000 is 11.1 to 20.0 TBq/GWa with an average value of 15.4 TBq/GWa. No clear trend is discernible.

For beta/gamma emitters excluding tritium, the range since 2000 is 2.6 - 20.7 GBq/GWa, 2.6 - 7.3 during the period 2009 to 2013 with a mean value of 13.3 GBq/GWa. Up to 2004, a clear decreasing tendency is noted.

Comparisons with UNSCEAR ranges show that:

- Tritium discharges are near the lower end limit of the range;
- Non-tritium discharges into water are always below the level of the range up to 2006;
- Liquid releases in Tihange NPP have decreased.

See annex 1 part 2 and trends graphs.

2.1.4 Emissions to air of concern for the marine environment

See annex 1 part 3 and trends graphs.

Note that Tihange NPP air emissions doesn't concern the marine environment, the data are mentioned for information only. Tihange NPP has reach lowest values for releases of iodine and noble gas.

Origin: 1) space between the reactor building itself and the second containment ("inter-space"), fuel building (spent-fuel pool), nuclear auxiliaries building (ventilation, machinery rooms, laundry building, demineralisation building, decontamination building, …); 2) Gaseous effluents from hydrogenous circuits (primary circuit, chemical and volumetric conditioning circuits); 3) atmosphere of each reactor building itself (70,000 m^3).

Treatment: all gas releases from 1) are continuously monitored, can be filtered and released (at a rate of 150,000 to 250,000 m^3/h). Gas releases from 2) are sent to storage / decay tanks. Venting of the atmosphere of the reactor building is done after monitoring and filtered if necessary.

Waste management: releases from 2) for each reactor (Tihange 1, Tihange 2 & Tihange 3) are sent to primary storage tanks. Once the radioactivity of a full storage tank has sufficiently decreased, effluents are released through the chimney at a maximum rate of 75 m^3/h (presence of filters and continuous monitoring). All gas from 1) is continuously released and monitored. When "action" levels are exceeded, gas releases are by-passed through HEPA filters (High Efficiency Particulate Air filters) and active carbon filters. Filters and active carbon cartridges - trapping iodine (excepted for laundry and decontamination buildings) - are analysed weekly (determination of iodine concentration and gamma spectrometry). Using monthly aliquots, beta and alpha measurements are conducted on filters; ^{85}Kr is determined on gas; tritium is determined by calculation taking into account flow rate and concentration.

2.1.5 Quality assurance

Tihange NPP AQ system is based on the IAEA Safety Standards for protecting people and environment (DS338, Draft 10, 1st December 2005). AQ system also integrate recommendations of the international standards ISO-14001 (environment), EMAS, OHSAS-18001 (safety) and WANO. System for quality assurance is defined in two internal QA procedures : SUR/00/040, SUR/00/041.

All liquid waste management and treatments are audited according to EMAS (Eco-Management and Audit Scheme) and ISO 14001 certifications.

2.1.6 Site specific target values

Liquid releases

- Beta –gamma emitters : 14,5 GBq (authorized limit : 888 GBq).

Gas releases

- Noble gas : 8,88 TBq (authorized limit : 2220 TBq);
- Aerosols : 500 MBq (authorized limit : 111 GBq);
- Iodine : 14,8 MBq (authorized limit : 14.8 GBq).

2.1.7 Any other relevant information

See 2.3.

2.1.8 Explanations for lack of data or failure to meet BAT/BEP indicators

Tritium gas releases are actually calculated, they will be in a next future measured.

Change records are underway to determine tritium measurements in the chimney of each unit.

The carbon-14 gas emissions, actually calculated and conservative, will also be measured in the 3 units in the future. To do that, modifications are underway in order to dispose of these C-14 measurements in each unit chimney.

2.1.9 Summary evaluation

Total releases in Tihange NPP is equivalent to average release between 2004 and 2013.

During 2013, we notice that:

- Tihange NPP has reach lowest values for releases of iodine and noble gas;
- Liquid releases in Tihange NPP have decreased.

2.2 Doel NPP

The radionuclides to be monitored are stipulated in the "licence to operate" of the NPP reactors under the responsibility of the federal authority (FANC).

2.2.1 System(s) in place to reduce, prevent or eliminate discharges of radioactive substances

Origin: there are 4 reactors and in each reactor building there are 3 kinds of liquid wastes: recyclable waste waters (leakages from primary circuit) from the controlled areas called "primary waters", non-recyclable waste waters (floor, laundry, lavatory, chemical, "demineralisation effluents" from steam generators) from the controlled areas and non-recyclable waste waters (floor, regeneration effluents from machinery, …) coming from other non-controlled areas.

Treatment: ion-exchange procedures, filtration and evaporation of waste waters (in evaporators, Tritium from the distillate is condensed and released as a liquid fraction). The concentrate phase is conditioned in the NPP itself as solid concrete waste.

Waste management: primary waters as non-recyclable waters coming from controlled areas are sent to the WAB (water and waste treatment building). Waters coming from other non-controlled areas are directly sent to the GSL (building of secondary discharges) then to the ELK (unique release collector to the Scheldt river after dilution) after control of the radioactivity concentration. In WAB, effluents are kept in a tank. After treatment, effluents are sent to a management building (L building) where they are diluted by secondary waters at a flow rate of 150 m^3/h. Diluted waters are then sent to the ELK building. There is a late dilution with tertiary cooling waters (at a flow rate of 150,000 m^3/h). Then waters are released to the Scheldt river if the radioactivity is below 0.1 MBq/m^3. After treatment, the effluent through local L, where an activity measurement may interrupt the discharge, and through the discharge pavilion is sent to the Scheldt. In the discharge pavilion effluent is diluted by adding tertiary water, and moreover it is checked whether the Scheldt contains an activity less than 0.1 MBq / m^3 drink water equivalent.

2.2.2 Systems abatement efficiency

All liquid waste management and treatments are audited according to EMAS (Eco-Management and Audit Scheme) and ISO 14001 certifications.

For the 2001-2014 period, following factors have influenced the reduction of radioactive liquid releases:

- more liquid wastes are evaporated to solid wastes instead of being released in the Scheldt river;
- replacement of the steam generators of reactor 2 (2004) allows to recover the "blow-down" waters which induced a significant decrease of liquid releases;
- Steam Generators and power uprate of reactor 1: by the replacement of the steam generators (2009) the risk of leaks form the primary to the secondary circuit has decreased. Due to the power increase, the inventory of radioactive products present in the reactor core as in the primary circuit can raise to reach a possible maximum level proportional to the power increase factor. This doesn't necessary mean that releases towards the environment will rise and this is due to the dependence of plenty of other factors such as for example pH and mainly of the degree of leak tightness of all different barriers between the source of activity and its surroundings. Nevertheless, after the implementation, control and surveillance showed that the actual discharge limits - according to the Technical Specifications which remained the same as

before – are still well respected and likewise amply meets the appropriate dose limits for the population.

Abatement systems and management (according to 2.2.1 and 2.2.2).

Abatement system/ Management	**Into operation (Year)**		**Efficiency of abatement system**		**Comments**
	Existing	**Planned**	**Decontamination Factor**	**Other measure of efficiency**	
Discharges:					
Delay tank(s): ▪ Liquid: o the primary waters & the non-recyclable waters coming from the controlled areas of the 4 reactor units are stored in 2 storage tanks in the WAB prior to release in the river Scheldt o non-recyclable waste waters are stored in the GSL prior to release in the river Scheldt ▪ Gas: on each unit, several gas tanks of different capacities and design pressures	Liquid: 1982 Gas: D12: 3 tanks are part of original design, 2 additional tanks in placed since end '80's D3, D4: part of original design of the plants		Gas: delay policy is used to avoid short lived gas species releases.		WAB = water and waste treatment building D12: prior to the startup of the WAB in 1982, liquid releases were handled by D12. Since 1982 all liquid releases from controlled areas are handled by the WAB.
chemical precipitation	NO				
centrifuging	NO				
hydrocyclone	NO				
cross-flow filtration	NO				

ion exchange: with pre and post filtrations, coupled with thermal degazifier and evaporator) for primary (recyclable) liquids , boric acid liquors are recycled, tritiated distillates are stored prior to release. Evaporator alone: for non-recyclable liquids.				Efficiency of the ion exchange resins is checked by gross gamma counting / spec gamma. Efficiency of the single evaporation is measured by checking the distillate gross gamma activity.	
osmosis	NO				
ultrafiltration	NO				
Bandfilter for the laundry water		2015			
Emissions:					
electrostatic precipitation	NO				
cyclone scrubbing	NO				
chemical adsorption	NO				
HEPA filtration	Yes, part of the basic design of the units.			>99,95%	
cryogenics	NO				
Active carbon filtration	Yes, part of the basic design of the units.			Efficiency according to the Technical Specifications	
Bag filtration on the shredder	Beginning of 90’s				

2.2.3 Annual liquid discharges

For tritium, the range for normalised liquid discharges for the whole period is 9.9 to 19.0 TBq/GWa with an average value of 15.3 TBq/GWa. No clear trend is discernible.

For beta/gamma emitters excluding tritium, the range since 2000 is 0.9 - 10.2 GBq/GWa, 2.2 - 5.2 during the period 2009 to 2013 with a mean value of 3.9 GBq/GWa. Up to 2004, normalized discharges are very low.

Comparisons with UNSCEAR ranges show that:

- Tritium discharges are **near the lower end limit** of the range;
- Non-tritium discharges into water are always **below** the level of the range up to 2000.

See annex 1 part 2 and trends graphs.

2.2.4 Emissions to air of concern for the marine environment

See annex 1 part 3 and trends graphs.

Origin: reactor building, space between the reactor building itself and the second containment, fuel building, nuclear auxiliaries building.

Treatment: all gas releases from hydrogenous circuits of the four reactors (primary circuit, …) or the WAB (water and waste treatment building) are sent to storage tanks. All gas from other sources (leak, ventilation of the buildings, non-condensable gas, machinery rooms, demineralisation building, other WAB building areas, …) are continuously released and monitored.

Waste management: Once the radioactivity of a full storage tank has sufficiently decreased, effluents are released through the chimney (continuous monitoring). All gas from other sources (leak, ventilation of the buildings, non-condensable gas, machinery rooms, demineralisation building, other WAB building areas, …) are continuously released and monitored. When “action” levels are exceeded, gas releases are by-passed through HEPA filters (High Efficiency Particulate Air filters). Filters and active carbon cartridges - trapping iodine - are analysed weekly (determination of iodine concentration and gamma spectrometry). Using monthly aliquots, beta and alpha measurements are conducted on filters; ^{85}Kr is determined on gas; tritium is determined on condensed gas, gamma spectrometry on noble gases.

2.2.5 Quality assurance

The Nuclear Power Plants of Electrabel have an integrated management system, which includes policies for the Care Systems. These concern Nuclear Safety, Health & Safety, Environment, Assets Security and Fire Protection. The management system is in accordance with general safety requirements published by the IAEA GS-R-3 (Nuclear Safety) and with international standards ISO-14001 (environment), OHSAS-18001 (safety).

The management system contains an internal code for Nuclear Safety and a Reference for Operational Nuclear Safety (RONS).

Nuclear safety performance is monitored by several internal monitoring mechanisms:

- Supervision within each team (Quality Control 1);
- Independent controls by the Care Department (Quality Control 2);
- Independent nuclear safety monitoring by the Electrabel Corporate Nuclear Safety Department (Quality Control 3) and;
- internal audits by the Quality Assurance section from the PPM Department.

All our processes are documented and activities are supported by operational procedures, instructions, support documents and witness documents. Document & Data management is one of these processes.

The operational procedure PREV/55 describes the management of radiological water discharge and atmospheric emissions.

All liquid waste management and treatments are audited according to EMAS (Eco-Management and Audit Scheme) and ISO 14001 certifications.

2.2.6 Site specific target values

NA.

2.2.7 Any other relevant information

See 2.3.

2.2.8 Explanations for lack of data or failure to meet BAT/BEP indicators

Tritium gas releases are actually calculated, they will be in a next future measured.

Change records are underway to determine tritium measurements in the chimney of each unit.

The carbon-14 gas emissions, actually calculated and conservative, will also be measured in the units in the future. To do that, modifications are underway in order to dispose of these C-14 measurements in each unit chimney.

2.2.9 Summary evaluation

Total releases in Doel NPP is equivalent to average release between 2004 and 2013. We notice that liquid releases remain very low since 2004.

2.3 Other relevant information concerning the Belgian nuclear sites (Tihange and Doel NPP)

2.3.1 Flaw indications in the reactor pressure vessels of Doel 3 and Tihange 2: technical information note (2013.02.01)

Context

Doel 3 and Tihange 2 are two of the seven Belgian nuclear reactors operated by Electrabel, a GDF-SUEZ Group company.

In June 2012, during a new type of in-service inspection conducted for the first time in Belgium, several thousands of flaw indications were detected in the base metal of the Doel 3 reactor pressure vessel, located mainly in the upper and lower core shells. As a precaution, similar inspections were conducted in September 2012 on the Tihange 2 unit, whose reactor pressure vessel is of identical design and construction. Flaw indications were detected as well, but to a lesser extent.

The pressure vessel is a key-component in a reactor unit, and its failure is not covered by safety studies. As a result, the licensee decided to keep both units in cold shutdown state, core unloaded, at least until in-depth analyses have been achieved and submitted to the Federal Agency for Nuclear Control (FANC) in view of a possible restart of the operation.

With the support of internal and external experts, the licensee started an investigation of the precise nature and origin of these indications in the summer of 2012, and built its own analysis to determine whether or not the reactor units in question could safely resume operation in spite of the detected flaws. The demonstration of the licensee was recorded in two safety case reports and backed by a number of technical documents, leading the licensee to conclude that both Doel 3 and Tihange 2 reactor units were eligible for immediate restart. In parallel, the licensee also proposed several additional measures designed to further increase the safe operation of the units, to monitor the pressure vessels state along time or to extend its initial material testing program.

Meanwhile, the FANC built up a dedicated organisation and commissioned several national and international expert groups to seek scientific and technical advice in order to elaborate an independent, founded and balanced judgement about the issue.

Along the assessment process, the expert groups raised a number of questions that were discussed with the licensee and its technical supports. From those discussions, a number of open issues were raised about the manufacturing of the reactor pressure vessels, the suitability of the in-service inspection technique, the possible evolution of the flaws during future operation, the characterization of the material properties, and the structural integrity of the reactor pressure vessels under penalizing loadings.

FANC Findings

Based on the data provided by the licensee and the conclusions released by Bel V, AIB-Vinçotte and the national and international experts groups about the flaws of the Doel 3 and Tihange 2 reactor pressure vessels, the Federal Agency for Nuclear Control draws the following global conclusions for each topic:

Regarding the manufacturing of the reactor pressure vessels:

Based on the sole manufacturing files, the presence of flaw indications since the manufacturing stage cannot be confirmed as the indications which were detectable at this stage were not reported in the final inspection reports of the manufacturing of the reactor pressure vessels.

Regarding the in-service inspections:

Some uncertainty still exists regarding the capability of the in-service inspection techniques to properly detect and characterize all present flaws in the reactor pressure vessels.

Regarding the metallurgical origin and evolution of the indications:

The most likely origin of the indications identified in the Doel 3 and Tihange 2 reactor pressure vessels is hydrogen flaking due to the manufacturing process. Significant evolution over time of hydrogen flakes due to the operation of the reactor units is unlikely.

Regarding the material properties:

More experimental data on tensile and toughness properties of the materials are needed to validate the approach followed in the structural integrity assessment.

Regarding the structural integrity of the reactor pressure vessels:

The approach adopted by the licensee to justify the structural integrity of the reactor pressure vessels still needs to be completed or validated for some topics. The probabilistic assessment approach provided by the licensee is used only for information.

Regarding the additional measures and actions proposed by the licensee:

The additional operational measures proposed by the licensee are relevant.

The in-service inspection program proposed by the licensee should focus particular attention on the most adverse flaws.

Some uncertainties still remain in the structural integrity assessment and call for additional experimental verification.

In the current state of knowledge and given the available data, the open issues identified along the assessment process do not represent conditions that require a definitive shutdown of the Doel 3 and Tihange 2 reactor units.

However, these open issues lead to some uncertainties that might reduce the conservatism of the licensee's safety demonstration and hence impair the level of confidence in the safe operability of the reactor units in question.

As a consequence, the Federal Agency for Nuclear Control considers that, in the current state, the Doel 3 and Tihange 2 reactor units may only restart after the requirements listed in the next paragraph § 3 hereafter are fulfilled by the licensee.

The licensee shall elaborate an action plan to meet those requirements, including a methodology and associated acceptance criteria where applicable. This action plan shall be approved by the Belgian nuclear safety authority.

Once the licensee has implemented its action plan, the FANC, together with Bel V and AIB-Vinçotte, will evaluate whether all the safety concerns at the origin of the requirements are solved and whether the related reservations can be lifted. On this basis, the FANC will motivate its decision about the possible restart of the Doel 3 and Tihange 2 reactor units in a final evaluation report.

This position applies only to the Doel 3 and Tihange 2 reactor units and does not extend to other nuclear reactors potentially concerned elsewhere in the world. The evaluation of their safety remains within the jurisdiction of the competent national authorities.

FANC requirements

The suggestions, observations and conclusions of these different organisations and working groups were evaluated by the Federal Agency for Nuclear Control. Wherever appropriate and relevant, the FANC decided to use this input in the formulation of the specific requirements for the licensee.

The FANC issues the following requirements for each topic.

Regarding the manufacturing of the reactor pressure vessels:

Given that the whole documentation currently available was exploited and no additional finding can be derived from that material, the FANC issues no further requirement on this topic.

Regarding the in-service inspections

As a prerequisite to the restart of both reactor units, the short-term requirements on inspections mentioned in the AIB-Vinçotte assessment shall be fulfilled by the licensee:

- The licensee shall re-analyse the EAR acquisition data for Tihange 2 in the depth range from 0 to 15 mm in the zones with hydrogen flakes to confirm whether or not some of these technological cladding defects have to be considered as hydrogen flakes;
- The licensee shall demonstrate that no critical hydrogen flake type defects are expected in the non-inspectable areas;
- The licensee shall demonstrate that the applied ultrasonic testing procedure allows the detection of the higher tilt defects in the Doel 3/Tihange 2 data (2012 inspections) with a high level of confidence;
- The licensee shall present the detailed report of all macrographical examinations including the sample with the 45°T reflections and shall also analyse and report additional samples with 45°T reflectivity;
- The licensee shall include a set of defects partially hidden by other defects for macrographic examination, to confirm whether the sizing method continues to function well;
- The licensee shall re-analyse the tilts of the defects in the VB-395/1 block with the same method as applied on-site.

As soon as possible after the restart of both reactor units:

- The licensee shall achieve a full qualification program to demonstrate the suitability of the in-service inspection technique for the present case. The qualification shall give sufficient confidence in the accuracy of the results with respect to the number and features (location, size, orientation...) of the flaw indications. Where appropriate, the process shall be substantiated by appropriate experimental data using representative specimens. The full qualification program shall be achieved before the next planned outage for refuelling.

Regarding the metallurgical origin and evolution of the indications:

After the restart of both reactor units:

- The licensee shall perform follow-up in-service inspections during the next planned outage for refuelling to ensure that no evolution of the flaw indications has occurred during operation.

Regarding the material properties:

As a prerequisite to the restart of both reactor units:

- The licensee shall complete the material testing program using samples with macro-segregations containing hydrogen flakes. This experimental program shall include:
  - small-scale specimen tests:
    - local toughness tests at hydrogen flake crack tip;
    - local tensile tests on ligament material near the flakes;
  - large-scale (tensile) specimen tests.
- The licensee shall perform additional measurements of the current residual hydrogen content in specimens with hydrogen flakes, in order to confirm the results of the limited number of tests achieved so far. For example, the licensee has estimated an upper bound on the amount of residual hydrogen that might still be present in the flaws. The licensee shall demonstrate that the chosen material properties are still valid, even if the upper bound quantity of hydrogen would still be present in critical flaws.

As soon as possible after the restart of both reactor units:

- A further experimental program to study the material properties of irradiated specimens containing hydrogen flakes shall be elaborated by the licensee;
- The licensee shall further investigate experimentally the local (micro-scale) material properties of specimens with macro-segregations, ghost lines and hydrogen flakes (for example local chemical composition). Depending on these results, the effect of the composition on the local mechanical properties (i.e. fracture toughness) shall be quantified;
- The licensee shall further evaluate the effect of thermal ageing of the zone with macro-segregation.

Regarding the structural integrity of the reactor pressure vessels:

As a prerequisite to the restart of both reactor units:

- Taking into account the results of the actions related to the previous requirement on the detection of the higher tilt defects during in-service-inspections, the licensee shall evaluate the impact of the possible non-reporting of flaws with higher tilts on the results of the structural integrity assessment;
- The licensee shall complete the on-going material testing program by testing larger specimens containing hydrogen flakes, with the following 2 objectives:
  - Objective 1 : Tensile tests on samples with (inclined) multiple hydrogen flake defects, which shall in particular demonstrate that the material has sufficient ductility and load bearing capacity, and that there is no premature brittle fracture;
  - Objective 2 : An experimental confirmation of the suitability and conservatism of the 3D finite elements analysis.

Regarding the action plan proposed by the licensee:

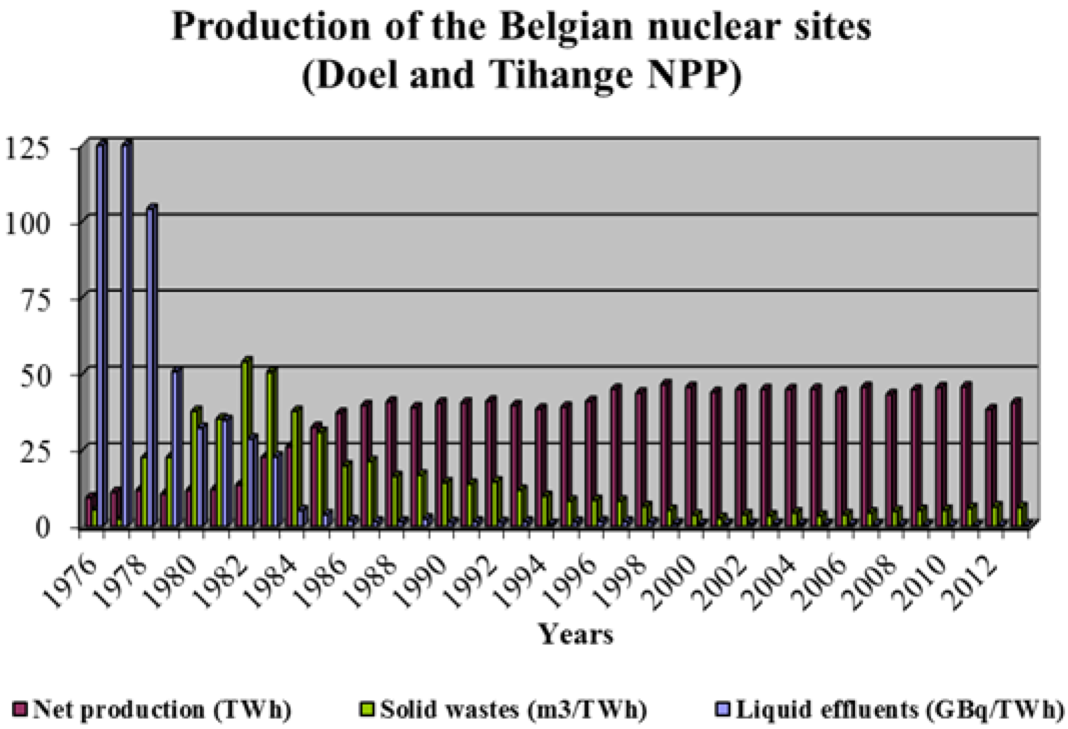
As a prerequisite to the restart of both reactor units:

- In addition to the actions proposed by the licensee and the additional requirements specified by the FANC in the previous sections, the licensee shall perform a load test of both reactor pressure vessels;
- The objective of the test is not to validate the analytical demonstration on the reactor pressure vessel itself but to demonstrate that no unexpected condition is present in the reactor pressure vessels. The methodology and associated tests (acoustic emission and ultrasonic testing...) will

be defined by the licensee and submitted to the nuclear safety authority for approval. The acceptance criterion will be that no crack initiation and no crack propagation are recorded under the pressure loading.

2.3.2 Quantity of liquid and solid waste generated by nuclear power stations (chart below).

While the total production of electricity has remained more or less constant in recent years at around 45 TWh with a decrease to about 40 TWh in 2012 and 2013 due to shutdown of some reactors, the quantity of radioactivity discharged in the liquid effluents has sharply declined: from around 42 GBq in 2003 and 2004, it decreased progressively to about 17 GBq in 2010 to reach about 15.7 GBq in 2012 (0.408 GBq/TWh) and 17,8 GBq in 2013 (being 0,438 GBq/TWh).



This observation is even more amplified when the volume of solid waste generated per TWh produced and removed for treatment and storage by the National Organisation for Radioactive Waste and Enriched Fissile Materials (ONDRAF - NIRAS) is considered: from 1985 a clear decreasing trend is observed up to the years 2001 (~ 3 m^3/TWh). From then on, volumes have increased slowly up to a value of 5.4 m^3/TWh in 2009. Current volumes are stable around 6 to 6.4 m^3/TWh since three years. This slight increase of solid waste is related to the decrease of the produced liquid waste during that same period. That means that BAT are applied to reduce liquid discharges (more concentration/solidification).

This shows also the efforts made by Belgian NPP's to reconcile the objectives of optimising industrial operations, notably in reducing the volumes of waste produced and the related costs while, on the other hand, "reducing" the discharge of effluents as far as possible. These elements of assessment clearly demonstrate the application of the BAT concept with regard to liquid and solid waste.

2.4 Belgoprocess nuclear site

The radioactive liquid effluents are generated by the waste treatment unit of Belgoprocess 2. Liquid discharges are operated in the Molse Nete river with a limit set at 25 GBq/month and a maximum of 150 GBq/year according to the following weighting formulae:

2,5 [α total] + 0.4 [^{90}Sr-^{90}Y] + 2.5 10^{-5} [^{3}H] + [^{60}Co] + 1.5 [^{134}Cs] + 1.5 [^{137}Cs] + 0.1 [β] $\leq$ 25 GBq/month (150 GBq/year maximum with a concentration limit of 15 MBq/m³) in the river Molse Nete.

with [β] = [β total] – ([^{90}Sr-^{90}Y] + [^{60}Co] + [^{134}Cs] + [^{137}Cs])

The discharges from the site into the Molse Nete adequately comply with the limit set, even though they are not negligible. The principal radionuclides arising in liquid waste are tritium and, to a much lesser degree, activation and fission products. See Annex 2.

2.4.1 System(s) in place to reduce, prevent or eliminate discharges of radioactive substances

Origin: liquid wastes treated by BP are mainly produced by SCK•CEN and Belgoprocess installations. Besides that, there are also effluents coming from Doel and Tihange NPPs, Belgonuclaire, FBFC International, IRE, IRMM (production of calibrated/reference sources, cyclotron) sites and finally hospitals and research centres (universities, …).

Kind of effluents:

Relatively low activity effluents:

- *suspicious* effluents where activity is < 400 kBq/m^{3} for beta/gamma emitters and < 40 kBq/m^{3} for alpha emitters;
- *contaminated* effluents where activity is < 400 MBq/m^{3} for beta/gamma emitters and < 800 kBq/m^{3} for alpha emitters;
- *higher radioactive* effluents where activity is < 40 GBq/m^{3} for beta/gamma emitters and < 80 MBq/m^{3} for alpha emitters.

Medium activity effluents:

- with activity < 40 TBq/m^{3} for beta/gamma emitters (i.e. liquid wastes of medium activity from the IRE site).

Treatment: effluents are treated by sedimentation in decantation tank, the particulate phase is sent to a storage tank where other sedimentation/decantation processes occur. Depending on the radioactivity levels, the liquid phase is evaporated by BP.

Waste management: residues or solid phases are conditioned by BP cementation before storage (since 2005 bitumisation is not applied). Up to 1992, high solid wastes - coming from the former Eurochemic plant (dismantled now) - were vitrified and stored. Now these processes are stopped. Before liquid effluents are released into the Molse Nete river, the following limits have to be respected: concentration < 15 MBq/m^{3} and < 25 GBq/month or 150 GBq/a according to the weighting formulae described in 2.4.

The radionuclides to be monitored are stipulated in the licences of the nuclear sites under the responsibility of the FANC federal authority.

2.4.2 Systems abatement efficiency

Abatement systems and management (according to 2.3.1 and 2.3.2).

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	Planned	Decontamination Factor	Other measure of efficiency	
Discharges:					
delay tank(s)	**Liquid** : <		**Liquid** : see	Gamma	Ventilation air to

Liquid : storage tanks prior to release in the river Molse Nete) 5 tanks (3 with volume of 350m³ and 2 with volume 250 m³. **Ventilation Air and process gases** : Emissions consist of ventilation air, each installation is equipped with a discharge point with stack release after filtration.	1960 **Ventilated Air** : <1970 part of the original design since 1960. Also for recent installations		precipitation and ultra-filtration **Ventilated air and process gases**: release are mandatory filtered on PRE, HEPA filters See HEPA	spectroscopy and alpha/ beta counting	keep installations in under pressure. Process gases mainly coming from the extraction of the incinerator and extraction of the tank ventilations.
chemical precipitation	In operation in the late years 1960		Typical figures 95% Flocculation for both radiological and chemical contaminants and sedimentation	Gross alpha, beta counting and gamma spectroscopy	4 reception tanks of 100 m³ each, 2 decanters of 100 m³ 'Cold' LW is treated in online system. LLW is treated batchwise
centrifuging	NO	NO			
hydrocyclone	NO	NO			
cross-flow filtration	NO	NO			
osmosis		NO			

Ultrafiltration: of the chemical components in the discharge liquid	Installation in operation since 2014		Removal of chemical parameters Hg, Ag, Co, U and Be to meet discharge norms	ICP analyses	
Evaporation: Liquid with higher activity contents, medium -level aqueous waste water is concentrated by evaporation	Installation in operation since < 1970		Distillates are further treated by flocculation. Concentrates are stored.	Gamma spectroscopy and alpha/ beta counting	Treatment of MLW
Emissions:					
electrostatic precipitation	NO	NO			
cyclone scrubbing: extracted ventilation air from process installations passes a wet scrubber cyclone filter	Part of the original design		Washing and neutralization of acid gases before they reach the HEPA filtration. 90%		Neutralization of acid
chemical adsorption	NO	NO			
HEPA filtration	part of the basic design of each installation		> 99 % (measured according to the technical specifications for classified filters)		Intervention area's with high alpha contamination are equipped with double HEPA filters
cryogenics	NO	NO			
Active carbon filter	NO	NO			

2.4.3 Annual liquid discharges

The installations have been operating more or less steadily throughout this period, so liquid discharges have been fairly constant.

For tritium, since 2000, releases are more or less constant around 2-3 TBq per year. These releases are almost entirely due to the operation of the BR2 research reactor (PWR) situated on the SCK●CEN site. Observed fluctuations are linked to the number of working days during a considered year. Since the power of this reactor is small (125 MWth), produced quantities of tritium are also limited.

For beta emitters excluding tritium, releases decrease exponentially from 2000 to 2013 (2.4 GBq to less than 0.13 GBq). For alpha emitters, releases have increased to a maximum of 98.7 MBq in 2001 and then remain low with fluctuations: between 45 MBq in 2012 and 5.4 MBq in 2013.

See annex 1 part 2 and trends graphs.

2.4.4 Emissions to air of concern for the marine environment

Origin: at Belgoprocess, gaseous wastes can be produced by burning solid and liquid wastes, by the gaseous and liquid waste treatments, by building ventilations, … The other nuclear installations also produce atmospheric wastes but will not be further discussed in this report.

Treatment: filtration by HEPA filters before releases in the chimneys.

Waste management: after filtration, releases are continuously monitored and sampled.

See annex 1 part 3 and trends graphs.

Note that Belgoprocess air emissions doesn't concern the marine environment, the data are mentioned for information only.

2.4.5 Quality assurance

Belgoprocess has a quality, safety and environmental policy. In order to implement this policy Belgoprocess has an integrated management system in accordance with the international standards ISO-9001 (quality), ISO-14001 (environment), OHSAS-18001 (safety) and ISO-17025 (lab). All the processes and activities are written down in process descriptions, instructions, forms and other matters.

Instruction-522 describes the control of discharge of waste water.

The monitoring and measurement of the atmospheric emissions are written down in instruction-751.

Data management occurs in order with these instructions and with the ISO-standards (records and records management is one of the requirements of the ISO–standards).

2.4.6 Site specific target values

Belgoprocess’ s aim is to perform all her activities with full consideration for the environment and the safety of its employees and of the population by reducing the effects of its operations to as low as reasonably achievable (ALARA). The discharge of radioactive effluents in the water (Nete at Mol) and emissions to the air are reduced and minimised by implementing the ALARA-policy. All the activities are carried out in accordance with the legislation and licenses and within its own requirements.

Specific target for radioactive liquid discharge:

Belgoprocess total discharged weighted radioactivity for 2013 was 0,139 GBq or just 0,1% of the permitted value (150 GBq/year). The specific site target is to emit not more than 2% (= 0,50 GBq/month) of the maximum month limit (25 GBq/month).

Specific target for radioactive atmospheric discharge:

The chimneys of the nuclear installations are continuously monitored and sampled after filtration (preliminary filters and high efficiency particulate air filters) so that a total overview is obtained of global alpha- and beta-emissions. The various chimneys on Belgoprocess sites 1 and 2 only emitted in 2013 a minimal fraction (maximum 0,5%) of the relevant authorised limits (N4).

The radon emissions from the waste stored at the Solarium are not included (emitted via the chimney 280X). The specific site target is to emit not more than 10% of the authorised limit (N4) or N3 (= N4/10) by each chimney.

Relevance of target and closeness to target value

Closeness to target value for radioactive liquid discharge:

The specific site target is to emit not more than 2% (= 0,50 GBq/month) of the maximum month limit (25 GBq/month).

The liquid discharge results for 2013 show that only a minimal fraction (maximum 6%) of the specific site target (= 0,50 GBq/month) is emitted in 2013.

Closeness to target value for radioactive atmospheric discharge:

The specific site target is to emit not more than 10% of the year limit (N4) or N3 (N4/10).

The atmospheric discharge results for 2013 for all chimneys show that only a minimal fraction (maximum 5%) of the specific site target (N3) is emitted in 2013 (except for radon chimney 280X).

2.4.7 Any other relevant information

NA.

2.4.8 Explanations for lack of data or failure to meet BAT/BEP indicators

NA.

2.4.9 Summary evaluation

Liquid and atmospheric releases remain very low since 2004.

3. ENVIRONMENTAL IMPACT

3.1 Concentrations of radionuclides of concern in representative samples of water, sediment and fish

The environmental surveillance programme in the vicinity of nuclear power stations is performed by the FANC radiological monitoring programme. The analyses of environmental samples (sediment & water in rivers and north-sea, fauna & flora in freshwater and marine water, soil, air, rain, milk, foodchain, drinking water) show that there are no detectable α- and β-activity concentrations (excluding tritium) referring to radioactive discharges from NPP. Tritium discharges from pressurised water reactors can increase the tritium concentrations in surface water of rivers by 10 to 30 Bq/l (e.g. river Meuse).

In 2013 (as previously) several sampling points have been chosen off the Belgian coast where sampling of sea water, sediments and fish living on the bottom is organised 4 times a year by the oceanographic vessel, the "Belgica" (photo on the right taken from the site of the North Sea Mathematical Model Management Unit). Sixteen samplings are carried out in a belt of 5 to 25 km offshore from the towns of Coxyde, Newport, Ostend and Blankenberge (one point is located 37 km directly below Wenduine near Blankenberge). The measurements taken relate to monitoring the levels of alpha, beta and gamma emitting radioactive nuclides, as well as ^{40}K as far as natural radioactivity is concerned.

On the coast, because of their accumulation and concentration capacity, samples are essentially taken of seaweed, fish, molluscs and crustaceans to measure the main fission and activation products as well as Th, Pu and U.

The compartments monitored are:

- Atmosphere compartment: dust samples from the air (filters) near Coxyde;
- Land compartment: taking of soil samples (meadows) near Coxyde;
- Marine compartment: water sediments and samples of fauna (crustaceans, bivalves, fish) and flora (seaweed).

Generally: The results obtained clearly show that the radiological situation of the maritime area does not give rise to any particular comments and does not require any action. Indeed, only natural radioactivity is measured (^{40}K). Although traces of artificial radioactivity (^{137}Cs and transuraniums in fish) are sometimes detected (at the level of the detection limits of the measuring equipment), they remain entirely negligible.

Sixteen sampling points are visited quarterly by the oceanographic vessel, the "Belgica". They are situated in a band of 5 to 25 km off the towns of Coxyde, Newport, Ostend and Blankenberge (one point is situated 37 km offshore from Wenduine near Blankenberge). Samples of algae (Fucus vesiculosus) are taken on a pier in Ostend, shrimps (*Crangon sp.*) and mussels (*Mytilus edulis*) are also sampled.

The measurements taken relate to monitoring the levels of alpha, beta and gamma emitting radioactive nuclides, as well as ^{40}K as far as natural radioactivity is concerned.

Samples of sea water are taken with the help of "Niskin" bottles.

The sediments are brought to the surface using a "Van Veen" scoop (photo on the left), a sort of grapnel with an open jaw lowered to the sea bottom at the end of a steel cable.

As soon as the jaws touch the bottom, the spring which keeps the jaws open is released. Before returning to the surface, the jaws close and trap a quantity of sand or sediment from the sea bed.

Samples of the fauna (fish) are collected for subsequent radioactivity analyses using a trawl net (photos to the right).

The results obtained confirm the absence of any problem concerning the radiological state of the marine environment. The following table summarises the results obtained.

In greater detail:

- The results obtained show that the presence of natural radioactivity (^{40}K) is detected on a regular basis;
- Traces of artificial radioactivity (^{137}Cs) are revealed in the marine sediments and the fish (barely significant);
- No artificial radioactivity is demonstrated in fish.

Radioactivity measurements for the marine environment: waters and sediments

	Waters (Bq/l)		Sediments (Bq/kg dry)	
	measurement	DL	measurement	DL
γ	NM	~ 0.1 to 0.3	NM	0.7 to 1.0
^{137}Cs	NM	0.19	1 to 4	~ 0.8
^{60}Co	NM	0.19	traces	~ 0.9
total β	10 to 14			
^{40}K	9 to 11		180 to 300	
α total	traces	~ 0.35		
$^{226,228}Ra$	NM	0.4 to 0.7	6 to 18	
$^{238,(239+240)}Pu$	NM	~ 0.1 10^{-3}	NM	~ 0.4

NM: non-measurable, measurement less than or equal to the detection limits (DL)

Radioactivity measurements for the marine environment: flora and fauna

	Flora (seaweeds) (Bq/kg dry)		Fauna (mussels and shrimps) (Bq/kg dry)		Fauna (flat fish) (Bq/kg dry)	
	measurement	DL	measurement	DL	measurement	DL
γ	NM	< 0.3	NM	< 0.5	NM	0.3 to 0.6
^{137}Cs	NM	~ 0.2	NM	~ 0.4	NM	~ 0.4
^{60}Co	NM	~ 0.3	NM	~ 0.4	NM	~ 0.4
^{131}I	traces	~ 4.4	NM	4 to 7	NM	~ 30
^{90}Sr	NM	~ 0.8	NM	~ 0.9	NM	~ 1.2
^{40}K	160 to 250		35 to 70		90 to 110	
^{3}H	NM	~ 2.2	NM	2 to 4	NM	~ 2.9
^{99}Tc	traces	~ 5			traces	~ 2.5
$^{226,228}Ra$	traces	0.5 to 2.0	NM	0.7 to 2.0	NM	0.8 to 1.7
$^{238,(239+240)}Pu$	NM	~ 0.027	NM	~ 0.01	NM	~ 0.01
^{241}Am	NM	~ 0.024	NM	~ 0.04	NM	~ 0.01

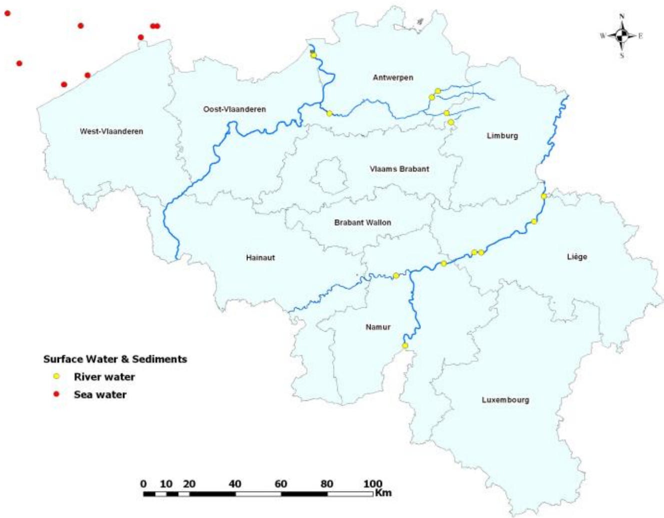
NM: non-measurable, measurement less than or equal to the detection limits (DL)

Summary:

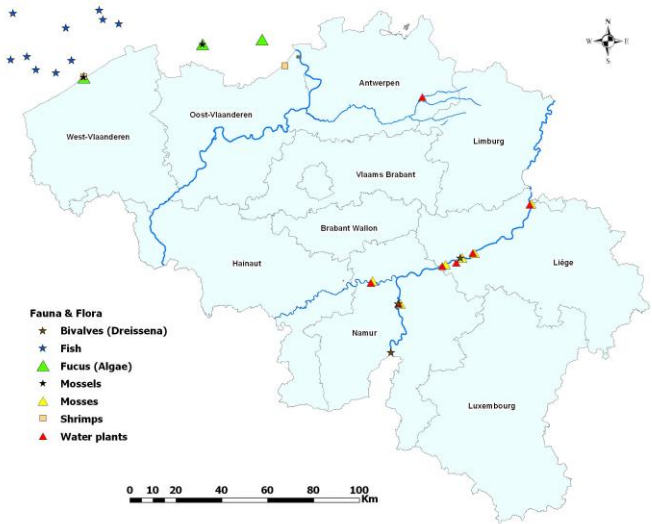
- Natural radioactivity (^{40}K) is mainly responsible for the radioactivity of the different sections of the marine environment;
- ^{137}Cs, $^{238,(239+240)}Pu$ and ^{241}Am, transuranic nuclides of artificial origin (produced and discharged by the nuclear power plants and discharged by the reprocessing industry of used fuel – reprocessing plants of the Hague in France and Sellafield in the United Kingdom) are not detectable: all the levels are of the order of the detection limits.

3.2 Environmental monitoring programme, frequency of sampling, organisms and or other types of environmental samples considered

Monitoring surface water and sediments in fresh – rivers (Sambre, Meuse, Grote Laak, Winterbeek, Grote Nete, Molse Nete and Scheldt) and marine water – North Sea;



Monitoring the living environment by searching for radioactivity in fauna in fresh and salt water (molluscs from fresh and salt water, shrimps and fishes) and in flora in fresh water (aquatic plants and mosses) and seawater (algae) who are bio-indicators of the presence of radioactivity;



Radiological monitoring programme for the maritime zone (North Sea and Scheldt estuary)

Zone		Location of sampling points	Type of measurement	Frequency of sampling
North Sea	water	off the coast (Belgica campaign), 16 locations	Spectrometry γ: $^{134\text{-}137}Cs$, $^{57\text{-}58\text{-}60}Co$, ^{54}Mn ^{40}K Spectrometry β total & α total Spectrometry α: $^{238\text{-}(239+240)}Pu$	quarterly
	sediments	off the coast (Belgica campaign), 16 locations	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th Spectrometry α: $^{238\text{-}(239+240)}Pu$	quarterly
	seaweeds	Ostende – Belgian coast	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th ^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic, ^{99}Tc	quarterly
	mussels & shrimps	Ostende – Belgian coast	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th ^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic	quarterly
	fish	off the coast (Belgica campaign), 16 locations	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th ^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic, ^{99}Tc	quarterly
Scheldt	shrimps bivalves, seaweeds	estuary downstream from Doel (Kieldrecht) estuary/North Sea (Hoofdplaat & Kloosterzande)	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{(57)\text{-}58\text{-}60}Co$, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226\text{-}228}Ra$, ^{228}Th ^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic, (^{99}Tc for seaweed)	quarterly

3.3 Systems for quality assurance of environmental monitoring

ISO 5667: Water quality - Sampling - Preservation and handling of water samples

ISO 18589: Measurement of radioactivity in the environment - Soil - Sampling strategy, sampling and pre-treatment of samples.

3.4 Any other relevant information

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. The measuring stations are distributed throughout the entire country, around the Tihange, Doel, Mol and Fleurus, as well as in the urban areas 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 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 the exceeding of 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.

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

The measuring stations used in the TELERAD network for measuring radioactivity in the air are of four types:

The **dosimetry stations** (Geiger Müller detector type) for measuring the ambient gamma radioactivity, of which there are 128 on the territory (including those around the boot of Givet for monitoring the Chooz nuclear site).

Each measuring station is equipped with a rain detector which provides information about the presence and duration of rainy periods. Following photographs show a station in the environment with a view on its electronics.

The **gamma spectrometry stations** (NaI detector) for measuring the ambient gamma radioactivity and the gamma radioactivity of some radionuclides, of which there are 64 localized on the fences around nuclear sites of SCK•CEN, nuclear power stations of Tihange and Doel as IRE. Photographs show a station in its environment.

The **aerosol stations** (ZnS detector), of which there are 7 for measuring the radioactivity of dusts suspended in the air (aerosols and fine particles), which determine the total alpha and total beta radioactivity.

The photograph on the left shows the alpha/beta measuring unit with a view of the unreeling filter tape which collects the dusts and particles impacted when the air is pumped.

These stations are supplemented by a unit measuring radioactive iodine on the aerosols and the air particles when a pre-determined threshold of beta radioactivity is exceeded (7 units in total coupled with alpha/beta measurement). The photograph on the right shows the detector in its casing (cylinder) and the parallelepipedal tube containing the active charcoal cartridges (on the right).

If the warning thresholds are exceeded, active carbon cartridges, intended to trap the radioactive iodine, are automatically measured after pumping the outside air in order to determine the level of radioactivity.

TELERAD also has 8 **river stations** which continuously measure the gamma radioactivity of river waters. These stations are of two types:

Retrofit : this type of station (6) is installed close to the three rivers receiving discharges from nuclear sites and waste water from major urban centres (combining research centres, universities and hospitals): the Meuse, the Sambre and the Nete.

These stations are large containers from which two inlet and outlet pipes allow river water to be pumped to the detector and returned after radioactivity has been measured – photograph on the right.

On the far left of the photograph, a programmable automatic sampler (Buhler type PP MOS) enables water to be pumped into flasks for gamma, alpha and beta spectrometry (for the programme for the radiological monitoring of the territory).

Inside is the gamma spectrometry unit ($LaBr_3$ crystal coupled to multi-channel analyser) housed in its own tank, surrounded by a strong lead screen protected by a stainless steel casing in which the water pumped from the river enters and leaves – photograph on the left. Ten radionuclides are defined in the recognition software.

The photograph here below shows the inside of the PP MOS with the pumping instruments in its upper section and all the 2.9-litre flasks (12 in all) at the bottom base.

This fully programmable unit enables pre-determined volumes of water to be collected over a fixed time period and frequency.

Above the PP MOS are the counting unit and the high voltage supply of the river station detector.

To the left of the gamma spectrometry unit is a large volume water sampler (SwedMeter type) which enables a sample of the water in the pipe to be taken automatically as soon as an alarm level is exceeded. This water is stored in a 25-litre flask for the purpose of subsequent gamma (and beta) spectrometry analyses in the laboratory.

BCI : these stations have their probe directly immersed in river water. They are two in number located in the Scheldt downstream and upstream of the Doel nuclear power plant.

these stations also have a $LaBr_3$ detector which is coupled to a multichannel detector. Ten radionuclides are defined in the recognition software.

3.5 Explanations for lack of data or failure to meet BAT/BEP indicators

NA.

3.6 Summary evaluation

The revision of the entire radiological surveillance programme of the territory, the redrafted version of which was implemented from 2003 to 2004, was based on an effort to harmonise the libraries of radionuclides measured for the entire territory and taking account of the latest requirements of the relevant international bodies (European Commission, OSPAR in respect of the Sintra agreements under the policy to protect the North Sea and the Atlantic).

This new programme – with more than 4,900 samples giving rise to almost 26,200 radioactivity measurements – enables better monitoring of the different regions of the country while taking account of their specific nature. Comparisons between sections of each region and between regions themselves have been made easier.

The radiological situation is generally excellent:

The radiological monitoring of the territory, which makes it possible to obtain an accurate picture of environmental radioactivity in Belgium and the risks to the population, does not reveal any major problems. Most of the time, the radioactivity of artificial origin is considerably lower than radioactivity of natural origin, if it can be measured at all in the samples taken.

The radiological monitoring of the territory also clearly shows that the dose rate (ambient radioactivity) particularly depends on the nature of the soil: the rocky soil in the south of the country emits more radon (natural radioactive gas) than that in the north of the country (sandy soil). It is for this reason, for example, that the dose rate measured in Wallonia is greater than that measured in the vicinity of the Doel nuclear power station, which itself has a negligible impact on the environment.

Nuclear power stations, in particular, have a negligible or even undetectable radiological impact on the environment. Of course, any anomaly detected by the agency or brought to its attention is examined and dealt with in the appropriate manner.

Particular attention is required:

The radiological situation of the Belgian territory is perfectly satisfactory; however, one basin, i.e. the entire Laak-Winterbeek-Nete-Scheldt hydrographic network, still arouses attention on account of its abnormally high charge of both artificial and natural radioactivity (226Ra). This concerns the entire Laak-Winterbeek-Nete-Scheldt hydrographic network.

Certain nuclear facilities in the Mol-Dessel region have a measurable, though small, radiological impact on the environment. The same applies to the non-nuclear industry producing feed phosphates in the region of Tessenderlo, with a discharge of 226Ra. On the other hand, the – measurable – radiological impact of these installations in the north-east of the country has declined sharply in recent years.

4. RADIATION DOSES TO THE PUBLIC

4.1 Nuclear Power Stations : Tihange and Doel

4.1.1 Average annual effective dose to individuals within the critical group(s) via the marine exposure pathway(s), and caused by current discharges

For both nuclear power stations, calculations made for liquid and atmospheric discharges under conservative assumptions show that the maximum effective doses to the population in the vicinity of the NPP's are well below the national limits of 1 mSv/a (maximum limit including all atmospheric and liquid contributions).

See annex 1 part 4 and annex 3: trend line figures.

4.1.2 Total exposures (i.e. including those from emissions and historic discharges/emissions)

The total dose due to releases in 2013 for the most critical person[5] (children 1-2 years) is 0.049 mSv, far below the legal limit of 1 mSv/a. It is always the C-14 and to a lesser extent Tritium which are major contributors to the dose to the individual person.

Liquid discharges: for Tihange for the period 2009 to 2013, the total exposures represents between 0.14 to 0.19% of the annual dose limit (1 mSv/a) and for Doel for the same period between 0.08 to 0.16% of the total dose limit. If we take into account the dose constraint (see page 4 - Discharge limits), calculations show that effective doses represent: from 1.8% to 2.4% for Tihange and from 0.33 to 0.68% for Doel of the dose constraint (0.08 and 0.23 mSv/a for Tihange and Doel respectively).

Atmospheric discharges: for Tihange around 2.27% of the annual maximum dose limit of 1 mSv/a for the period 2009 - 2013 and between 0.9 and 1.0% in the same period for Doel. If we take into account the dose constraint (see page 4 - Discharge limits), calculations show that effective doses represent: ~ 12% for Tihange and from 4.94 to 5.52% for Doel (0.19 and 0.18 mSv/a for Tihange and Doel respectively).

See annex 1 part 4 and annex 3: trend line figures.

4.1.3 The definition of the critical group(s), including information on age distribution, size and other relevant information, and on whether the critical group is real (identified) or hypothetical

Since the calculation of the radiological consequences in the EURATOM Article 37 Dossier, the principle of the "most vulnerable person" is implemented for all calculations; this most vulnerable person is part of different critical groups (by age category) in order to determine which individual in a specific age category is the most vulnerable. It means a person located at the place with the highest radionuclides concentration resulting from the dispersion of the releases in the air. Similar conservative assumptions are considered for the liquid releases. Information on nearby population was gathered for the Article 37 dossier, however as mentioned, the critical group is hypothetical, chosen in order to be conservative in terms of resulting dose.

The assumption of the most exposed person is conservative as regards exposure to releases (= exposed continuously at the point of maximum exposure). Critical person is an extremely pessimistic situation: it is a person living permanently near the nuclear power plant, feeding exclusively produced food around the plant, swimming and practicing water sports in the Meuse. Different age classes are taking into account : baby, child (1-2 years, 2-7 years, 7-12 years, teenager, adult).

Local meteorological conditions are taken into account in the meteorological model (Art. 37 §3.4.1) that was developed in the years 1968-1971 for the plant licensing studies.

---

[5] The critical Person is an extremely pessimistic situation: it is a Person living permanently near the nuclear power plant, feeding exclusively produced food around the plant, swiming and practicing water sports in the Meuse.

Local habits were taken into account by age category (as defined in NUREG 1.109 and applicable ICRP publications) in the definition of the exposure pathways that are locally significant. Conservative assumptions are taken into account (such as no dilution of the liquid releases in the Schelde, use of underground water coming from undiluted water from the Schelde with a transfer period of 82 days…).

This approach is consistent with the US 10CFR50 which is an important regulatory basis for the Belgian NPPs.

4.1.4 Information on exposure pathway(s) considered, and whether these are treated individually or collectively

Total dose to the most vulnerable person is calculated for atmospheric and liquid pathways.

Dose from atmospheric releases:

- direct exposure to the noble gas cloud;
- contamination due to iodine releases, aerosols, gaseous tritium and C-14:
  - air inhalation;
  - body exposure to deposition on the surface/ground;
  - contamination by ingestion of contaminated food (milk, meat, vegetables, fresh vegetables).

Dose due to liquid effluent discharges:

- By ingestion:
  - drinking water;
  - fish;
  - aquatic food other than fish;
  - milk and meat from contaminated domestic animals by water watering;
  - Food contaminated by irrigation water.
- external irradiation:
  - swimming;
  - water sports;
  - professional navigation;
  - stay on the banks;
  - stay on dredging sludge/mud.

4.1.5 Basis for methodology to estimate doses (models, actual measurements, and verification of data, as appropriate)

The calculation method is identical to the one used during the design of the units, the hypotheses are similar. This method is described in §3 and §4 of the Euratom Article 37 notification file for the Doel nuclear site. The calculation method is based on NUREG 1.109. The calculation method used, was drafted in the framework of the Euratom Article 37 notification file.

In 2002, a re-evaluation of the dose calculation was made, taking into account new parameters (e.g. new dose conversion factors, respiration rate, etc.) by the applicable ICRP publications. This document takes into account 6 age categories (instead of the 4 age categories used in NUREG 1.109). For nuclear power plant: adult, calculated by NUREG 1.109, DCF ICRP-72[6]. The re-evaluation of the dose calculation was made in the framework of Council Directive 96/29/Euratom of the European Commission.

In the framework of the PSR, an actualisation of the impact study for radiological consequences will be made.

4.1.6 Site-specific factors for significant nuclides, used to estimate the dose to critical group members from discharge values

The C-14 discharge is not measured. The activity is determined conservatively, based on scientific literature and the Safety Analysis Reports of the units.

4.1.7 Site specific target annual effective dose

The legal effective dose limit is 1 mSv/year.

The estimated effective dose limit taking into account the discharge limits for the different nuclides, as defined in the Technical Specifications of the Safety Analysis Report, is 354 µSv.

The legal limit is determined in Article 20.1.4 of the Royal Decree of 2001: “General regulations for the protection of the public, workers and the environment against the dangers of ionizing radiation”.

The effective dose is calculated each year. The average effective dose for the years 2004 – 2013 was less than 2 % of the legal limit and less than about 5 % of the TechSpec limit, despite being calculated in a conservative manner.

Tihange Nuclear Power Plant doesn’t defined a site specific target for annual effective dose. Objectives are fixed only on gaseous and liquid releases (see 2.1.6).

Effective dose constraint is fixed to 0.21 mSv/a for Tihange NPPs and to 0.37 for Doel NPPs by technical specifications (FANC).

4.1.8 Systems for quality assurance of processes involved in dose estimates

Quality Assurance is made of several steps:

- At the time of dose estimation, the applicable referential is assessed, meaning that up-to-date reference documents (regulatory, standards and guides) are used; a regulatory watch is conducted on legislative texts, regulations, standards and guides and their impact on the dose assessment process is checked regularly;
- Dose estimates are made by use of internationally approved methods (US Regulatory Guides, ICRP publications…) from which calculation results are made then compared for consistency with expert judgement and results on similar contexts;
- Use of a Quality Management System based on ISO-9001 for the overall process.

Dose estimates are produced every year for the actual routine releases and averaged on the last 10 years period. This is based among others on the NUREG 1.109 and applicable ICRP publications.

In the framework of the Periodic Safety Review, an actualisation of the dose estimation for routine releases is underway. It intends to use state of the art modelling tools together with recent meteorological data and actualised local habits.

Similarly, dose estimates are reviewed at the light of recent knowledge in accident conditions. This process is driven by both the Corporate Nuclear Safety Department of the operator and the Safety Authorities.

---

[6] Calculation of annual doses to man from routine releases of reactor effluents for the purpose of evaluating compliance with 10 CFR part 50, Appendix I, Regulatory Guide 1.109 rev.1, USNRC-October 1977.

4.1.9 Any relevant information not covered by the requirements specified above

NA.

4.1.10 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities

On-going activities: in the framework of the Periodic Safety Review, an actualisation of the dose estimation for routine releases is being made.

4.1.11 Summary evaluation

The method for estimating the dose to the public caused by routine discharges, being based on requirements of Article 37 of the Euratom Treaty, is relevant and reliable. The calculations are performed in a conservative manner. The calculation method is kept up to date, e.g. in the framework of new directives, decennial revision, etc.

Total releases in Tihange and Doel Nuclear Power Plant are equivalent to average release between 2004 and 2013.

In 2013, total doses to the most critical person due to those releases (1-2 years children) is 0.049 mSv for Tihange and 0.020 mSv for Doel NPPs . This value is largely below the legal limit (1 mSv/a) and the value given in the technical specifications (0.21 mSv/a for Tihange and 0.37 mSv/a for Doel).

4.2 Belgoprocess nuclear site

4.2.1 Average annual effective dose to individuals within the critical group(s) via the marine exposure pathway(s), and caused by current discharges

See annex 1 part 4, annex 2 part 3 and annex 3: trend line figures.

4.2.2 Total exposures (i.e. including those from emissions and historic discharges/emissions)

Liquid discharges: for the period 2009 to 2013, the total exposures represents between 0.0037 to 0.0052% of the dose limit (1 mSv/a). If we take into account the dose constraint (see page 4 - Discharge limits), calculations show that effective doses represent from 0.015% to 0.021% of the dose constraint (0.25 mSv/a).

Atmospheric discharges: for the period 2009 - 2013, the total exposures represents between 0.75 to 1.0% of the dose limit (1 mSv/a). If we take into account the dose constraint (see page 4 - Discharge limits), calculations show that effective doses represent from 2.5 to 3.2% of the dose constraint (0.3 mSv/a).

See annex 2 part 3 and annex 3: trend line figures.

4.2.3 The definition of the critical group(s), including information on age distribution, size and other relevant information, and on whether the critical group is real (identified) or hypothetical

Dose impact of liquid waste discharge

Two categories of potentially exposed people are considered in the assessment. Both categories consists of local people, that is, people living sufficiently close to the river that they could be potentially exposed either directly to radionuclides in the river or indirectly. A second group is defined as people who are more intensive exposed due to special activities like fishing, swimming, farming,… Within the two categories of people two age groups are considered, 20 year old adults and 10 year old children, they cover the range of exposures.

Dose impact atmospheric

The calculation method bases on the IFDM model uses 6 age groups of exposed people with age distribution from baby to adults. Reference is the NUREG NG1.109.

Dose conversion factors and the 6 age groups are included in the national legislation "*General regulations for the protection of the population, workers and the environment against the dangers of ionising radiation (GRPIR)*".

4.2.4 Information on exposure pathway(s) considered, and whether these are treated individually or collectively

Exposure pathway liquid discharge

The calculated dose is based on a calculation model from NRPB for the representative local people near the river Molse Nete.

It consists of 22 exposure pathways from which 19 have to do with internal contamination due to inhalation of contaminated dust particles and the ingestion of food that possibly could have come in contact with water from the river the other 3 pathways comprise the direct external radiation from the waste water and the sediment of the river. It is assumed the mean exposed group near the river spend 50 h/ year near the riverside, swims 10 h in the river and spend 300 h/ year on area that contains sediment from the river. It is also assumed that the local habitat consumes 10% of the vegetables that has grown nearby the river.

Exposure pathway atmospheric discharge

Exposure pathways are inhalation, ingestion and external exposure.

The most critical person is an adult who stays permanently near the fence of the site border. Additionally this person consumes vegetables, meat and milk from cows near the site border.

4.2.5 Basis for methodology to estimate doses (models, actual measurements, and verification of data, as appropriate)

For Belgoprocess nuclear site: adult, water pathway calculated by NRPB-231 (1990) and air pathway calculated by NUREG 1.109, DCF ICRP-72 (from 2002).

Model liquid discharge

Based on a mathematical model developed by NRPB. The doses calculated are the sum of the effective dose equivalent due to external radiation received in a year and the committed effective dose equivalent due to intakes of radionuclides in the same year.

Model atmospheric discharge

Calculation with the mathematical model IFDM (Immission Frequenty Distribution Model). Model developed by SCK•CEN and is an calculation of the dispersion of a pollution with a bi Gaussius dispersion model based on the NUREG 1.109.

4.2.6 Site-specific factors for significant nuclides, used to estimate the dose to critical group members from discharge values

NA.

4.2.7 Site specific target annual effective dose

Site constraint dose of 300 µSv per year due to atmospheric discharges and of 250 µSv per year due to liquid discharges.

The effective doses to the representative persons are assessed every year.

4.2.8 Systems for quality assurance of processes involved in dose estimates

The processes involved in dose assessment comply with the ISO 9001 quality standards and as part of the integrated certification management system ISO 14001, ISO 9001, OHSAS 18001 and ISO 17025 (lab). That is to say that they are traceable and subject to verifications conducted by independent Q&A organisms.

4.2.9 Any relevant information not covered by the requirements specified above

NA.

4.2.10 Explanations for lack of data or failure to meet BAT/BEP indicators, as well as, when appropriate, a description of on-going or planned activities

NA.

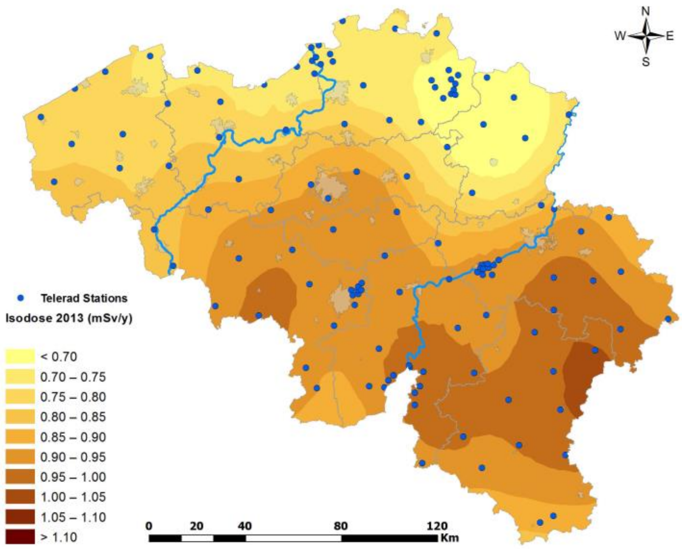
4.2.11 Summary evaluation

It can also be concluded that based on the evaluation of the BAT/BEP indicators for discharges from the Belgoprocess site that relevant and reliable management and technical systems are in place. Discharges are constant or in a downward trend.

The methods for estimating the doses are relevant for the assessment of the exposure of the population and to check the compliance with dose limits and constraints.

It can be concluded that based on the BAT/BEP indicators for discharge, environmental impact and radiation doses to the public that the BAT have been applied at Belgoprocess site during the time period covered by this report.

4.3 TELERAD: instrument for calculating the external exposure dose rate

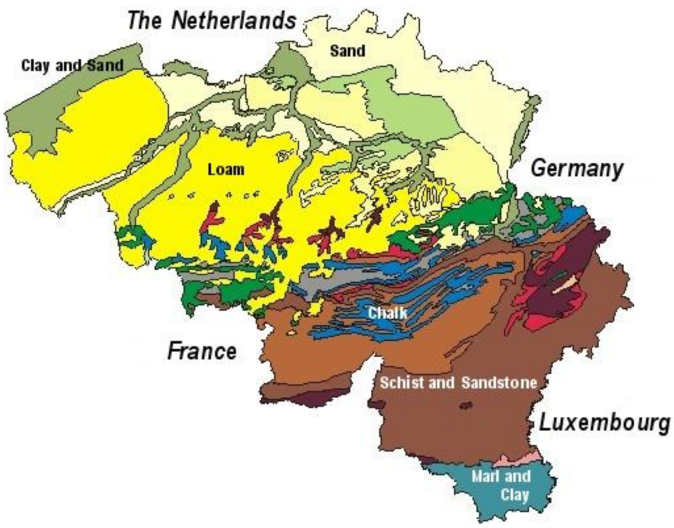


Since the TELERAD network measures a dose rate (µSv/h) continuously, it is possible to calculate the annual gamma exposure dose on a station-by-station basis. A group of values – only slightly different in value - can be brought together under the same colour by aid of a mathematical interpolation, enabling zones or surfaces where measurements are in a same value range to be represented on a map.

The map on the left shows the outcome of such processing which results in the construction of an illustrative map (because build up on basis of relatively limited detectors) of the natural background radiation due to gamma radioactivity. This background noise represents the annual exposure expressed in mSv (external gamma exposure dose) to which the territory is subjected.

An analysis of the exposure map shows that the average gamma exposure dose in Belgium is 1 mSv/year; it increases from 0.7 mSv/year in the north to about 0.8 - 0.9 mSv/year overall in Flanders until 1.1 mSv/year in Wallonia and, more particularly, in the Ardennes.

The exposure varies according to the nature of the soil. The doses are, indeed, generally higher in old terrains made up of rock such as chalkstone, schist, psammite and mixed sands with chalk etc. which is the case for Belgium in the Ardennes and Condroz area – see the geological map opposite. In Flanders, where the soil is predominantly made up of sedimentary terrains (sand, alluvium and clay), the doses are lower. It is noted that, in the south of the country, i.e. a marly, clayey region with sandy-silty layers over a chalk sub-stratum, the dose declines to reach values comparable to those in the north of the country.



The limit for the dose of ionizing radiation in the population, set at 1 mSv/year, does not take account of the natural radiation linked to cosmic radiation or the radiation of the soil and subsoil or the radiations used for medical purposes. Consequently, it does not apply in this case (natural ambient background noise).

ANNEX 1

NPPs

1. Site Characteristics

By: Claes Jurgen
Sombre Lionel

Name of facility	NPP Tihange
Type of facility	PWR
Date commissioned	1975-1982-1985
date of shut-down	2015-2022-2025
Location	Belgium (Tihange)
Receiving water	Meuse

Installed capacity	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
MW[e]	2973	2973	2973	2973	2985	2985	2985	2985	2985	2985	2985	3011	3022	3016	3016	3016

Electricity generation (net)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GWh		~23000			23186	23141	23495	23183	22597	23097	22740	23674	23656	23086	20068	19912

2. Discharge and emission data
annual liquid discharges, Bq/a

Radionuclide (TBq/a)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Co-58	8.46E-03	6.21E-03	8.34E-03	2.06E-02	1.46E-02	1.37E-02	1.07E-02	8.40E-03	7.63E-03	4.55E-03	6.78E-03	9.10E-04	6.07E-04	1.45E-03	1.09E-03	1.70E-04
Co-60	4.60E-03	3.84E-03	3.78E-03	5.30E-03	5.32E-03	5.07E-03	8.33E-03	5.22E-03	1.02E-02	6.10E-03	6.90E-03	3.48E-03	2.39E-03	4.29E-03	4.62E-03	3.13E-03
Zn-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-05	1.80E-05	0.00E+00	0.00E+00	0.00E+00	8.50E-05	5.98E-05
Sr-90	2.10E-05	5.75E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-05	1.46E-05
Zr/Nb-95	1.59E-04	2.20E-04	2.35E-04	1.02E-03	6.93E-05	3.00E-04	5.28E-04	2.62E-04	2.00E-04	7.15E-04	6.74E-04	7.00E-05	7.56E-05	1.51E-04	3.39E-04	8.23E-05
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-04	2.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.85E-05	3.48E-04	1.43E-04
Ag-110m	1.87E-03	3.59E-04	8.40E-04	3.57E-04	8.27E-04	1.48E-03	1.44E-03	7.16E-04	7.85E-04	4.32E-04	7.33E-04	2.57E-04	1.23E-03	6.99E-04	3.74E-04	4.52E-04
Sb-125	1.58E-03	4.02E-04	2.70E-04	4.47E-04	1.02E-03	8.48E-04	1.95E-03	8.43E-04	6.71E-04	1.26E-04	6.75E-05	4.19E-06	4.49E-05	3.09E-04	1.83E-04	1.36E-04
Cs-134	2.47E-04	9.05E-05	5.10E-05	9.62E-05	2.99E-04	1.17E-03	2.08E-03	7.89E-04	1.05E-03	4.51E-04	1.97E-04	1.06E-04	1.56E-04	1.18E-04	2.28E-04	8.90E-05
Cs-137	1.05E-03	2.88E-04	3.50E-04	4.22E-04	5.36E-04	1.15E-03	2.10E-03	1.27E-03	2.02E-03	1.01E-03	4.83E-04	3.09E-04	3.20E-04	5.90E-04	8.69E-04	7.32E-04
Ce-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-06	9.00E-06	2.91E-05	4.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-04	6.09E-05
Total-Beta*	2.00E-02	1.27E-02	1.57E-02	3.32E-02	2.66E-02	2.66E-02	3.13E-02	1.90E-02	2.41E-02	1.66E-02	1.77E-02	5.53E-03	5.10E-03	8.26E-03	1.36E-02	6.58E-03
Total activity excluding H-3	3.80E-02	2.41E-02	2.96E-02	6.15E-02	4.93E-02	5.03E-02	5.84E-02	3.66E-02	4.67E-02	3.00E-02	3.36E-02	1.07E-02	9.93E-03	1.59E-02	2.19E-02	1.16E-02
H-3	3.29E+01	6.66E+01	3.31E+01	4.10E+01	5.96E+01	4.35E+01	4.55E+01	4.60E+01	4.41E+01	5.71E+01	3.37E+01	5.34E+01	5.50E+01	3.93E+01	5.26E+01	4.24E+01
Total-Alpha	9.00E-07	9.00E-07	7.10E-07	1.20E-07	0.00E+00	9.10E-10	5.13E-09	2.11E-09	1.73E-09	2.52E-09	1.36E-09	1.27E-09	1.09E-09	8.70E-10	2.66E-06	2.02E-06

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total activity excluding H-3 (TBq/a)	3.80E-02	2.41E-02	2.96E-02	6.15E-02	4.93E-02	5.03E-02	5.84E-02	3.66E-02	4.67E-02	3.00E-02	3.36E-02	1.07E-02	9.93E-03	1.59E-02	2.19E-02	1.16E-02
Annual limit (TBq/a)	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01	8.88E-01
% of annual limit	4.3	2.7	3.3	6.9	5.5	5.7	6.6	4.1	5.3	3.4	3.8	1.2	1.1	1.8	2.5	1.3
Normalised to capacity (GBq/GWa)	12.8	8.1	9.9	20.7	16.5	16.9	19.6	12.3	15.6	10.1	11.2	3.5	3.3	5.3	7.3	3.9
UNSCEAR ranges (GBq/GWa)									14 - 140							
H-3 (TBq/a)	3.29E+01	6.66E+01	3.31E+01	4.10E+01	5.96E+01	4.35E+01	4.55E+01	4.60E+01	4.41E+01	5.71E+01	3.37E+01	5.34E+01	5.50E+01	3.93E+01	5.26E+01	4.24E+01
Annual limit (TBq/a)	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02	1.48E+02
% of annual limit	22.3	45.1	22.4	27.8	40.4	29.5	30.8	31.2	29.9	38.7	22.8	36.2	37.3	26.6	35.6	28.8
Normalised to capacity (TBq/GWa)	11.1	22.4	11.1	13.8	20.0	14.6	15.2	15.4	14.8	19.1	11.3	17.7	18.2	13.0	17.4	14.1
UNSCEAR ranges (TBq/GWa)									7,9 - 80							

3. Annual aerial emissions (Bq/a)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
H-3 (TBq/a)	6.35	7.32	7.56	5.65	5.26	5.66	6.75	6.51	5.66	6.26	6.68	7.49	7.35	6.84	7.05	7.06
H-3 Normalised to capacity (TBq/GWa)	2.14	2.46	2.54	1.90	1.76	1.90	2.26	2.18	1.90	2.10	2.24	2.49	2.43	2.27	2.34	2.34
Total B-G (TBq/a)	2.87E-05	1.38E-05	4.03E-06	2.66E-05	7.81E-05	6.00E-05	4.75E-07	3.22E-05	1.53E-05	1.05E-05	8.47E-06	1.22E-06	0.00E+00	2.74E-06	2.66E-04	2.25E-04
Total B-G Norm. To capacity (TBq/GWa)	9.65E-06	4.64E-06	1.36E-06	8.95E-06	2.62E-05	2.01E-05	1.59E-07	1.08E-05	5.13E-06	3.52E-06	2.84E-06	4.05E-07	0.00E+00	9.09E-07	8.82E-05	7.46E-05
Iodine (TBq/a)	4.61E-06	5.87E-06	6.35E-07	7.72E-06	7.60E-07	4.47E-04	6.94E-05	5.33E-05	6.70E-05	1.29E-04	2.75E-05	3.00E-05	1.05E-05	6.62E-06	3.29E-05	5.91E-06
Iodine (Norm. To capacity TBq/Gwa)	1.55E-06	1.97E-06	2.14E-07	2.6E-06	2.55E-07	0.00015	2.32E-05	1.79E-05	2.24E-05	4.32E-05	9.21E-06	9.97E-06	3.47E-06	2.2E-06	1.09E-05	1.96E-06
Noble Gases (TBq/a)	8.04E+00	4.32E+00	3.52E+00	4.65E+00	8.46E+00	3.24E+01	1.84E+01	1.40E+01	1.81E+01	3.35E+01	2.88E+01	1.25E+01	5.01E+00	6.67E+00	8.15E+00	4.91E+00
Noble Gases (Norm. to capacity TBq/GWa)	2.70E+00	1.45E+00	1.18E+00	1.56E+00	2.83E+00	1.09E+01	6.16E+00	4.69E+00	6.06E+00	1.12E+01	9.65E+00	4.15E+00	1.66E+00	2.21E+00	2.70E+00	1.63E+00

C-14 is not measured and estimated to 5,55E+02 GBq/a (according to literature** that mentions 5 Ci/a (18.5 GBq/a) for 1000 MWe installed)

4. Radiation doses to the public

Effective Dose (mSv/a)***	1992 to 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Water pathway	0.0024	0.0024	0.0024	0.0025	0.00226	0.00295	0.00213	0.0028	0.00237	0.00182	0.00165	0.00159	0.00153	0.00192	0.00145
% of dose limit (1 mSv/a)	0.24	0.24	0.24	0.25	0.226	0.295	0.213	0.28	0.237	0.182	0.165	0.159	0.153	0.192	0.145
Air pathway	0.0225	0.0225	0.0225	0.0224	0.0228	0.0227	0.0226	0.0226	0.0238	0.023	0.0227	0.0226	0.0228	0.0228	0.0227
% of dose limit (1 mSv/a)	2.25	2.25	2.25	2.24	2.28	2.27	2.26	2.26	2.38	2.3	2.27	2.26	2.28	2.28	2.27

* Value of "other radionuclides" (= total Beta-Gamma) reported as mentioned in the 'instructions for the reporting format for liquid discharges of radioactive substances from nuclear installations' (point 8)

** Investigations into the emission of C-14 compounds from nuclear facilities,
J. Schwibach, H. Riedel und J. Bretschneider, november 1978, Commission of the European Communities

*** given for an adult. Calculated by NUREG 1.109, DCF ICRP-72

1. Site Characteristics

By: Claes Jurgen
Sombre Lionel

Name of facility	NPP Doel
Type of facility	PWR
Date commissioned	1975-1975-1982-1985
date of shut-down	2015-2015-2022-2025
Location	Belgium (Doel)
Receiving water	Scheldt

Installed capacity	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
MW[e]	2776	2776	2776	2776	2776	2776	2817	2817	2840	2840	2840	2845	2911	2911	2911	2911

Electricity generation (net)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GWh	21800				21801	21780	21404	21886	21627	22669	20500	21167	21890	22741	18123	20720

2. Discharge and emission data
annual liquid discharges, Bq/a

Radionuclide (TBq/a)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Co-58	2,91E-03	9,32E-03	5,15E-03	8,43E-04	2,29E-03	5,09E-04	3,85E-04	0,00E+00	0,00E+00	7,24E-04	3,92E-04	5,69E-04	7,33E-04	1,36E-03	4,65E-04	1,11E-04
Co-60	5,30E-04	2,43E-03	1,37E-03	9,50E-04	1,21E-03	1,05E-04	2,17E-04	3,09E-04	2,84E-04	3,82E-04	5,54E-04	8,63E-04	7,31E-04	1,68E-03	7,56E-04	2,88E-04
Zn-65	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,20E-06	3,00E-07	3,00E-07	4,60E-06	1,20E-06	6,88E-05	4,11E-05	2,84E-05
Sr-90	2,20E-05	2,13E-04	1,33E-04	2,31E-05	9,20E-06	1,00E-06	0,00E+00	3,70E-06	6,60E-06	0,00E+00	0,00E+00	0,00E+00	7,00E-08	4,27E-06	3,50E-06	2,10E-06
Zr/Nb-95	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,59E-05	4,19E-05	3,33E-05	1,11E-04	9,89E-05	3,94E-05	2,82E-04	1,50E-04	6,74E-05
Ru-106	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,57E-05	2,29E-05	1,20E-04	3,22E-05	1,99E-05	2,80E-04	2,10E-04	1,23E-04
Ag-110m	1,80E-04	4,30E-05	5,18E-04	6,32E-05	3,68E-05	5,23E-04	1,31E-03	2,76E-04	1,78E-04	3,31E-04	6,56E-04	4,95E-04	3,66E-04	5,93E-04	4,11E-04	1,03E-04
Sb-125	1,94E-03	2,25E-03	2,13E-03	2,11E-03	1,98E-03	2,54E-03	1,14E-03	2,16E-03	4,19E-04	4,56E-04	4,11E-04	4,04E-04	1,44E-03	1,58E-03	6,70E-04	4,05E-04
Cs-134	3,08E-03	3,54E-03	6,57E-04	0,00E+00	2,50E-04	6,00E-05	5,80E-05	3,67E-05	8,60E-06	9,80E-06	1,74E-05	2,10E-06	2,40E-06	3,80E-05	9,47E-05	3,63E-05
Cs-137	6,67E-03	9,42E-03	3,49E-03	2,73E-03	3,62E-03	3,49E-03	1,40E-03	5,81E-04	1,01E-06	2,62E-04	2,64E-04	3,59E-04	1,28E-04	2,88E-04	8,83E-04	1,46E-03
Ce-144	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,00E-07	1,74E-04	1,19E-04	8,22E-05
Total-Beta*	1,60E-02	2,78E-02	1,50E-02	6,70E-03	1,17E-02	8,41E-03	5,22E-03	4,52E-03	1,71E-03	2,54E-03	3,10E-03	3,53E-03	3,94E-03	8,67E-03	5,12E-03	3,23E-03
Total activity excluding H-3	3,13E-02	5,50E-02	2,84E-02	1,34E-02	2,11E-02	1,56E-02	9,73E-03	7,92E-03	2,69E-03	4,76E-03	5,63E-03	6,36E-03	7,40E-03	1,50E-02	8,92E-03	5,94E-03
H-3	4,71E+01	4,84E+01	3,09E+01	3,80E+01	2,75E+01	3,43E+01	4,21E+01	3,99E+01	4,61E+01	5,37E+01	4,17E+01	5,31E+01	5,18E+01	5,52E+01	4,76E+01	3,66E+01
Total-Alpha	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,20E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,90E-06	1,41E-05	6,50E-06

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total activity excluding H-3	3,13E-02	5,50E-02	2,84E-02	1,34E-02	2,11E-02	1,56E-02	9,73E-03	7,92E-03	2,69E-03	4,76E-03	5,63E-03	6,36E-03	7,40E-03	1,50E-02	8,92E-03	5,94E-03
Annual limit (TBq/a)	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00	1,50E+00
% of annual limit	2,1	3,7	1,9	0,9	1,4	1,0	0,6	0,5	0,2	0,3	0,4	0,4	0,5	1,0	0,6	0,4
Normalised to capacity (GBq/GWa)	11,3	19,8	10,2	4,8	7,6	5,6	3,5	2,8	0,9	1,7	2,0	2,2	2,5	5,2	3,1	2,0
UNSCEAR ranges (GBq/GWa)	14 - 140															
H-3	4,71E+01	4,84E+01	3,09E+01	3,80E+01	2,75E+01	3,43E+01	4,21E+01	3,99E+01	4,61E+01	5,37E+01	4,17E+01	5,31E+01	5,18E+01	5,52E+01	4,76E+01	3,66E+01
Annual limit (TBq/a)	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02	1,04E+02
% of annual limit	45,5	46,7	29,8	36,7	26,5	33,1	40,6	38,5	44,5	51,8	40,3	51,3	50,0	53,3	45,9	35,3
Normalised to capacity (TBq/GWa)	17,0	17,4	11,1	13,7	9,9	12,4	14,9	14,2	16,2	18,9	14,7	18,7	17,8	19,0	16,4	12,6
UNSCEAR ranges (TBq/GWa)	7,9 - 80															

3. Annual aerial emissions (Bq/a)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
H-3 (TBq/a)	0,052	5,665	0,017	0,326	1,026	0,710	0,030	0,476	1,975	2,927	2,609	2,939	2,449	2,935	3,250	2,393
H-3 Normalised to capacity (TBq/GWa)	0,019	2,041	0,006	0,117	0,370	0,256	0,010	0,169	0,696	1,031	0,919	1,033	0,841	1,008	1,116	0,822
Total B-G (TBq/a)	2,40E-06	0	0	1,40E-06	5,00E-06	1,03E-05	7,00E-07	6,00E-07	5,19E-05	4,00E-06	3,30E-06	8,50E-06	6,50E-06	1,32E-04	8,43E-05	8,42E-02
Total B-G Norm. To capacity (TBq/GWa)	8,65E-07	0	0	5,04E-07	1,8E-06	3,71E-06	2,48E-07	2,13E-07	1,83E-05	1,41E-06	1,16E-06	2,99E-06	2,23E-06	4,53E-05	2,9E-05	2,89E-02
Iodine (TBq/a)	1,37E-05	3,10E-06	8,52E-06	4,10E-06	9,40E-06	2,80E-06	5,50E-06	1,84E-05	3,63E-05	3,36E-05	5,91E-05	6,19E-05	6,64E-05	1,06E-04	3,63E-05	3,19E-02
Iodine (Norm. To capacity TBq/Gwa)	4,94E-06	1,12E-06	3,07E-06	1,48E-06	3,39E-06	1,01E-06	1,95E-06	6,53E-06	1,28E-05	1,18E-05	2,08E-05	2,18E-05	2,28E-05	3,64E-05	1,25E-05	1,10E-02
Noble Gases (TBq/a)	3,31E+00	2,66E+00	9,54E-02	2,60E-02	3,31E-01	7,75E-01	2,54E-02	7,07E-02	1,15E-01	1,35E-02	1,70E-02	1,58E-02	4,35E-02	3,65E+01	3,58E+01	2,92E+01
Noble Gases (Norm. to capacity TBq/GWa)	1,19E+00	9,58E-01	3,44E-02	9,37E-03	1,19E-01	2,79E-01	9,02E-03	2,51E-02	4,05E-02	4,75E-03	5,99E-03	5,55E-03	1,49E-02	1,25E+01	1,23E+01	1,00E+01

C-14 is not measured and estimated to 5,55E+02 GBq/a (according to literature** that mentions 5 Ci/a (18.5 GBq/a) for 1000 MWe installed)

4. Radiation doses to the public

Effective Dose (mSv/a)***	1992 to 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Water pathway	0,0023	2,34E-03	2,34E-03	1,30E-03	1,00E-03	7,00E-04	6,00E-04	1,00E-03	1,00E-03	9,46E-04	9,08E-04	9,07E-04	1,56E-03	1,08E-03	7,68E-04
% of dose limit (1 mSv/a)	0,23	0,23	0,23	0,13	0,10	0,07	0,06	0,10	0,10	0,09	0,09	0,09	0,16	0,11	0,08
Air pathway	0,0087	8,70E-03	8,70E-03	8,70E-03	8,60E-03	8,50E-03	8,60E-03	9,00E-03	9,00E-03	9,00E-03	9,08E-03	8,90E-03	9,80E-03	9,93E-03	9,52E-03
% of dose limit (1 mSv/a)	0,87	0,87	0,87	0,87	0,86	0,85	0,86	0,90	0,90	0,90	0,91	0,89	0,98	0,99	0,95

* Value of "other radionuclides" (= total Beta-Gamma) reported as mentioned in the 'instructions for the reporting format for liquid discharges of radioactive substances from nuclear installations' (point 8)
** Investigations into the emission of C-14 compounds from nuclear facilities,
J. Schwibach, H. Riedel und J. Bretschneider, november 1978, Commission of the European Communities
*** given for an adult. Calculated by NUREG 1.109, DCF ICRP-72

ANNEX 2

Other Nuclear Sites (BP)

1. Site Characteristics

By: Claes Jurgen
Sombre Lionel

Name of facility	Belgoprocess (BP)
Type of facility	Wastes treatment and storage centre
Location	Belgium (Mol-Dessel)
Receiving water	Molse Nete

2. Discharge and emission data
annual liquid discharges, MBq/a

Year		1998	1999	2000	2001	2002	2003 **[7]**	2003 **[8]**	2003 **[9]**	2004
Tritium	**[1]** MBq	1,30E+06	3,34E+06	2,34E+06	2,29E+06	2,16E+06	4,95E+05	1,52E+06	2,01E+06	2,20E+06
	[2] MBq	1,30E+03	3,34E+03	2,34E+03	2,29E+03	2,16E+03	4,95E+02	3,79E+01		5,51E+01
Total-α	**[1]** MBq	33,6	21,3	80,8	98,7	83,2	5,9	53,6	59,5	46,4
	[2] MBq	168,2	106,5	404,1	493,4	416,0	29,5	134,0		116,0
Total-β	**[1]** MBq	2316,3	1430,0	2438,1	2110,4	1373,1	233,6	281,8	515,4	281,8
	[2] MBq	2316,3	1430,0	2438,1	2110,4	1373,1	233,6	28,2		28,2
Co 60	**[1]** MBq							43,0	43,0	63,0
	[2] MBq							43,0		63,0
Sr/Y 90	**[1]** MBq	178,7	149,9	108,6	111,6	63,0	18,4	73,9	92,3	117,6
	[2] MBq	1340,3	1124,3	814,5	837,0	472,5	138,0	29,6		47,0
I 131	**[1]** MBq	3,5	5,1	8,0	3,3	4,2	1,7		1,7	
	[2] MBq	10,6	15,2	23,9	10,0	12,5	5,0			
Cs 134	**[1]** MBq							18,0	18,0	19,0
	[2] MBq							27,0		28,5
Cs 137	**[1]** MBq							383,0	383,0	324,0
	[2] MBq							574,5		486,0
Ra 226	**[1]** MBq	0,030	0,032	0,032	0,032	0,033	0,011		0,011	
	[2] MBq	8,9	9,5	9,7	9,5	9,9	3,4			
GBq released	per annum **[3]**	1,30E+03	3,35E+03	2,34E+03	2,29E+03	2,16E+03	4,95E+02	1,52E+03	2,01E+03	2,20E+03
TBq released	per annum **[4]**	5,144	6,029	6,032	5,748	4,446	0,904	0,874	1,778	0,824
		[5]	**[5]**	**[5]**	**[5]**	**[5]**	**[5]**	**[6]**	**[5] + [6]**	**[6]**

Year		2005	2006	2007	2008	2009	2010	2011	2012	2013
Tritium	**[1]** MBq	2,37E+06	2,49E+06	1,89E+06	2,70E+06	2,29E+06	2,22E+06	2,02E+06	1,34E+06	1,84E+06
	[2] MBq	5,93E+01	6,23E+01	4,72E+01	6,75E+01	5,73E+01	5,55E+01	5,05E+01	3,34E+01	4,61E+01
Total-α	**[1]** MBq	41,5	8,6	11,1	14,5	16,0	15,8	29,6	45,2	5,4
	[2] MBq	103,7	21,6	27,6	36,2	40,0	39,5	74,0	113,0	13,6
Total-β	**[1]** MBq	213,9	129,4	155,1	151,4	187,9	197,0	148,1	187,3	129,4
	[2] MBq	21,4	12,9	15,5	15,1	18,8	19,7	14,8	18,7	12,9
Co 60	**[1]** MBq	109,0	26,0	99,0	4,0	9,0	8,0	21,8	12,6	13,1
	[2] MBq	109,0	26,0	99,0	4,0	9,0	8,0	21,8	12,6	13,1
Sr/Y 90	**[1]** MBq	69,1	57,1	65,6	33,8	20,5	24,5	30,8	16,9	12,7
	[2] MBq	27,6	22,8	26,2	13,5	8,2	9,8	12,3	6,8	5,1
I 131	**[1]** MBq									
	[2] MBq									
Cs 134	**[1]** MBq	56,0	15,0	0,0	0,0	0,0	0,0	11,1	7,1	7,6
	[2] MBq	84,0	22,5	0,0	0,0	0,0	0,0	16,7	10,7	11,4
Cs 137	**[1]** MBq	315,0	80,0	96,0	144,0	96,0	109,0	146,3	230,5	24,6
	[2] MBq	472,5	120,0	144,0	216,0	144,0	163,5	219,5	345,7	36,9
Ra 226	**[1]** MBq									
	[2] MBq									
GBq released	per annum **[3]**	2,37E+03	2,49E+03	1,89E+03	2,70E+03	2,29E+03	2,22E+03	2,02E+03	1,34E+03	1,84E+03
GBq released	per annum **[4]**	0,878	0,288	0,360	0,352	0,277	0,296	0,410	0,541	0,139
		[6]	**[6]**	**[6]**	**[6]**	**[6]**	**[6]**	**[6]**	**[6]**	**[6]**

[1] Amount of the radionuclide in MBq
[2] Weighted Amount of the radionuclide in MBq being [1] multiplied by its weighting coefficient
[3] Being the total amount of activity in TBq released
[4] Being the total amount of ponderated activity in TBq released
[5] Total Weighted Amount in TBq according former formula
0,001[H3] + 5[α] + 1[β] + 7,5[Sr90] + 3[I131] + 300[Ra226]
applicable until March 2003
[6] Total Weighted Amount in TBq according actual formula
2,5E-05[H3] + 2,5[α] + 0,1[b] + 1[Co60] + 0,4[Sr/Y90] + 1,5[Cs134] + 1,5[Cs137]
with [b] = total beta ([β]) activity - [[Sr/Y90] + [Co60] + [Cs134] + [Cs137]]
applicable from April 2003

[7] Activity values for the months January, February and March calculated according formula [5].
[8] Activity values for the months April until December calculated according formula [6].
[9] Sum of the activities [7] and [8], being the amount for the whole year 2003.

3. Discharge and emission data
annual gaseous discharges, Bq/a

Releasepoint		Altitude Chimney (m)	2003		2004		2005		2006		2007		2008	
			alpha	beta	alpha	beta	alpha	beta	alpha	beta	alpha	beta	alpha	beta
BP site 1	Building 120	80	1,71E+06	1,41E+06	5,34E+06	1,15E+06	2,93E+06	6,26E+05	2,08E+06	9,72E+05	1,44E+06	4,02E+05	1,46E+06	9,42E+05
	Building 110	17	9,43E+03	3,16E+04	9,97E+03	3,28E+04	1,37E+04	4,61E+04	1,13E+04	3,94E+04	1,11E+04	3,73E+04	1,17E+04	3,95E+04
	Building 137	-	3,29E+04	2,41E+05	4,46E+04	4,87E+05	6,21E+04	1,07E+06	4,13E+04	1,54E+06	4,97E+04	3,42E+05	7,29E+04	1,33E+06
	Building 155	30					7,73E+03	3,94E+04	1,05E+04	1,30E+05	1,24E+04	1,04E+05	8,94E+03	4,11E+04
	Building 131	-									6,30E+03	2,26E+04	8,37E+03	2,84E+04
BP site 2	Gen. Services	15	3,11E+04	5,15E+04	3,92E+04	7,59E+04	3,11E+04	6,00E+04	2,66E+04	3,47E+04	2,10E+04	3,31E+04	2,76E+04	4,44E+04
	FLK	19	2,58E+04	4,64E+04	4,27E+04	7,53E+05	1,91E+04	2,85E+04	1,51E+04	2,65E+04	8,50E+03	3,33E+04	1,37E+04	3,37E+04
	BRE	19	2,65E+03	6,14E+03	3,02E+03	4,90E+03	1,21E+03	7,26E+03	1,54E+03	5,91E+03	1,91E+03	1,20E+04	3,31E+03	7,48E+03
	280	30	1,56E+04	1,38E+04	1,92E+04	4,21E+04	1,52E+04	1,02E+05	1,31E+04	7,96E+04	9,16E+03	4,82E+04	1,34E+04	7,27E+04
BP Total		-	1,83E+06	1,80E+06	5,50E+06	2,55E+06	3,08E+06	1,98E+06	2,20E+06	2,83E+06	1,56E+06	1,03E+06	1,62E+06	2,54E+06

Releasepoint		Altitude Chimney (m)	2009		2010		2011		2012		2013	
			alpha	beta	alpha	beta	alpha	beta	alpha	beta	alpha	beta
BP site 1	Building 120	80	6,41E+05	1,11E+06	5,51E+05	6,51E+05	1,10E+06	6,17E+05	1,53E+06	6,99E+05	3,22E+05	7,72E+05
	Building 110	17	1,15E+04	3,96E+04	9,94E+03	3,50E+04	2,65E+03	8,57E+03	3,02E+03	2,19E+04	2,17E+03	1,80E+04
	Building 137	-	3,52E+04	2,43E+06	3,07E+04	5,89E+05	1,29E+04	8,31E+05	1,10E+04	1,94E+06	9,18E+03	2,59E+06
	Building 155	30	8,59E+03	5,13E+04	7,30E+03	4,38E+04	2,19E+03	4,21E+04	3,01E+03	3,70E+04	2,32E+03	2,26E+04
	Building 131	-	5,74E+03	1,77E+04	5,92E+03	1,98E+04	1,50E+03	5,14E+03	1,56E+03	5,45E+03	1,30E+03	4,32E+03
BP site 2	Gen. Services	15	2,83E+04	6,01E+04	2,70E+04	5,18E+04	5,60E+03	2,24E+04	7,64E+03	1,74E+04	4,76E+03	1,41E+04
	FLK	19	1,54E+04	5,82E+04	1,43E+04	9,84E+04	2,25E+03	1,34E+04	2,44E+03	9,01E+03	2,58E+03	9,44E+03
	BRE	19	5,30E+03	1,01E+04	2,57E+03	1,27E+04	7,27E+02	3,14E+03	7,84E+02	2,66E+03	8,31E+02	1,52E+03
	280	30	1,25E+04	6,07E+04	1,58E+04	5,92E+04	4,46E+03	9,43E+03	3,91E+03	5,75E+03	8,05E+03	4,01E+04
BP Total		-	7,64E+05	3,84E+06	6,65E+05	1,56E+06	1,13E+06	1,55E+06	1,56E+06	2,74E+06	3,53E+05	3,47E+06

4. Radiation doses to the public

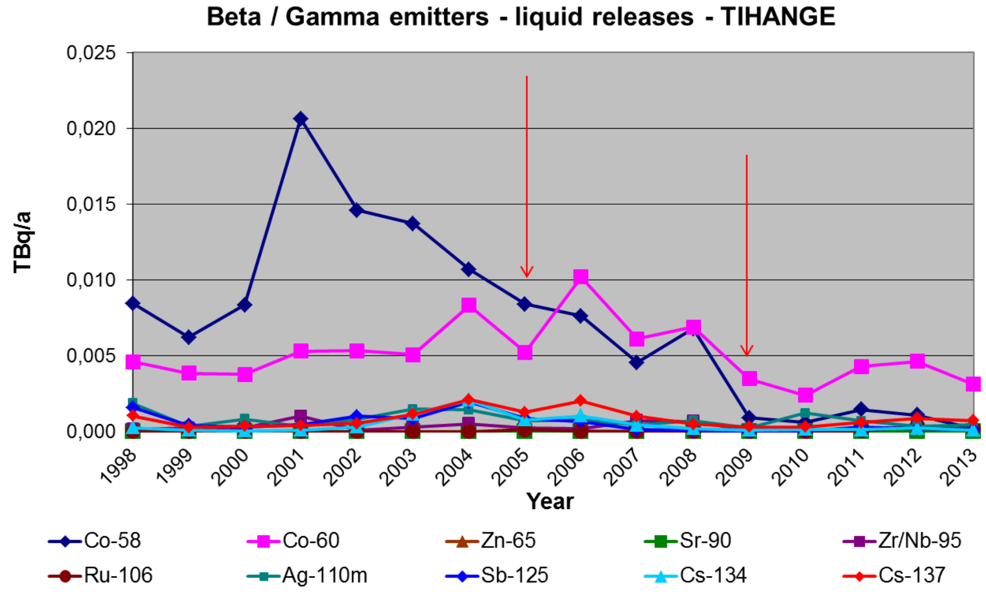
Effective Dose (mSv/a)*	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Water pathway	8,75E-05	6,83E-05	6,32E-05	6,16E-05	6,71E-05	5,68E-05	4,74E-05	6,11E-05	5,19E-05	5,00E-05	4,90E-05	3,70E-05	4,10E-05
% of dose limit (1 mSv/a)	0,00875	0,00683	0,00632	0,00616	0,00671	0,00568	0,00474	0,00611	0,00519	0,005	0,0049	0,0037	0,0041
Air pathway**	1,00E-03	1,20E-02	1,30E-02	2,50E-02	9,10E-03	9,10E-03	7,80E-03	8,30E-03	8,00E-03	7,50E-03	8,00E-03	9,70E-03	9,50E-03
% of dose limit (1 mSv/a)	0,10	1,20	1,30	2,50	0,91	0,91	0,78	0,83	0,80	0,75	0,80	0,97	0,95

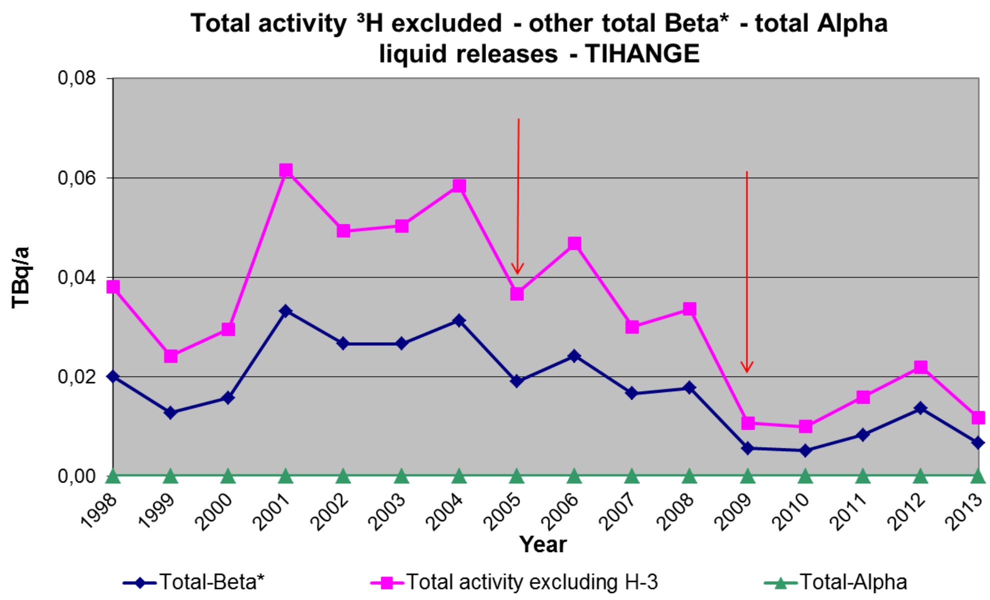
* given for an adult. Calculated by NUREG 1.109, DCF ICRP-72
** for the total site Mol-Dessel (Belgoprocess, SCK•CEN, FBFC, Belgonucléaire, IRMM)

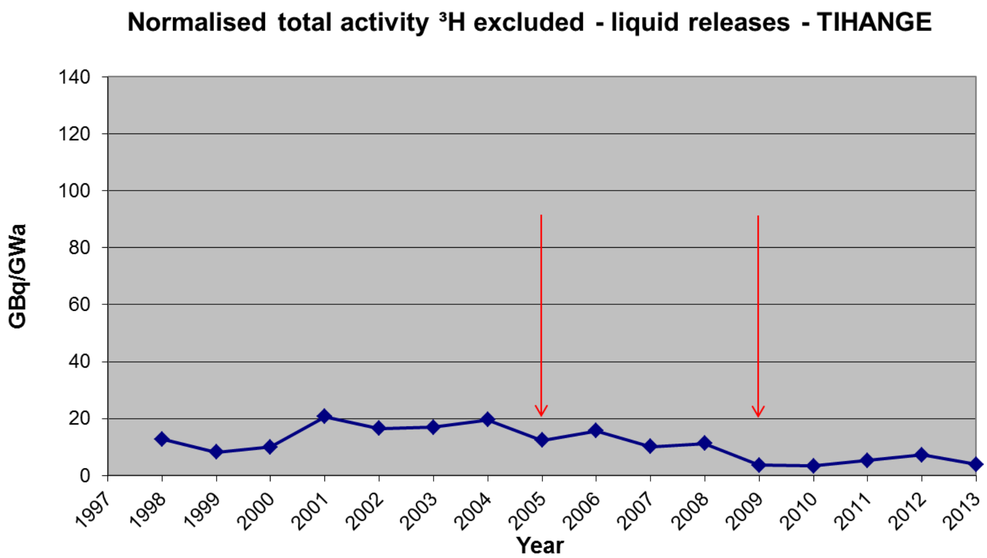
ANNEX 3

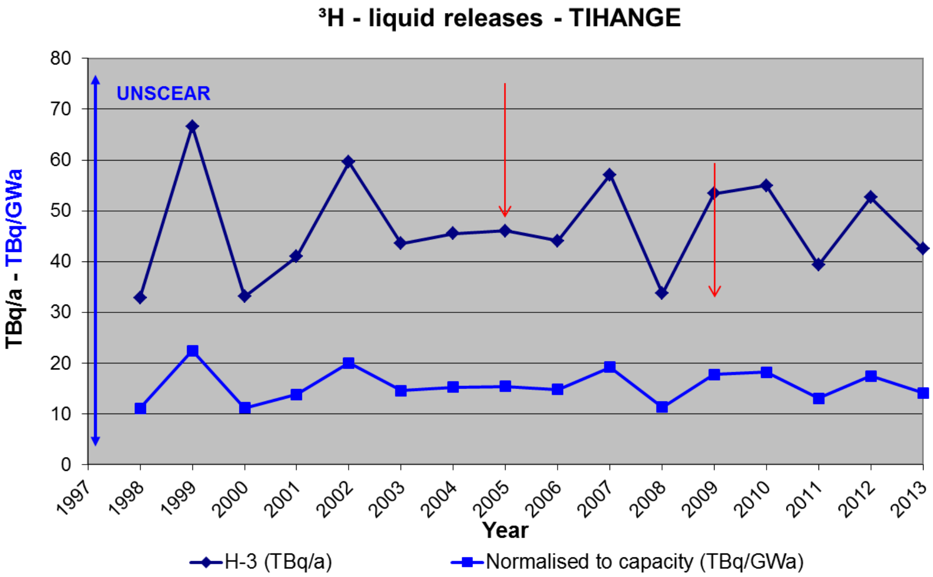
Trend line figures

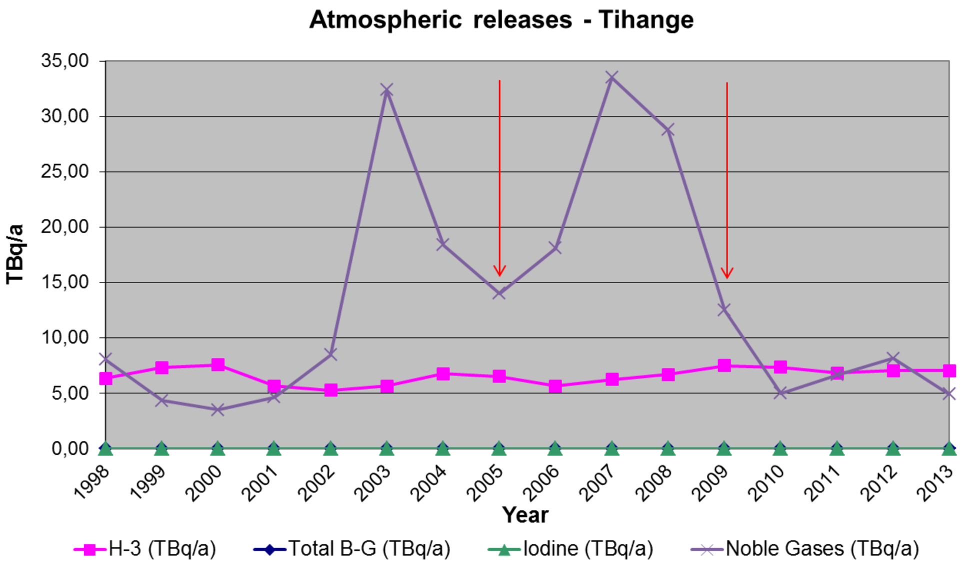
Tihange NPP


Beta / Gamma emitters - liquid releases - TIHANGE
TBq/a
0,025
0,020
0,015
0,010
0,005
0,000
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Co-58
Co-60
Zn-65
Sr-90
Zr/Nb-95
Ru-106
Ag-110m
Sb-125
Cs-134
Cs-137

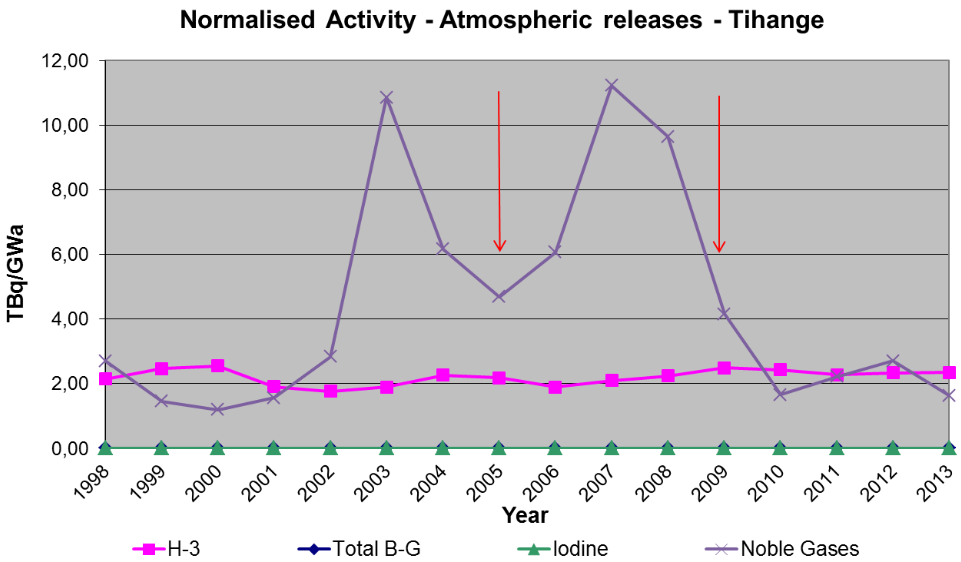

Total activity ³H excluded - other total Beta* - total Alpha
liquid releases - TIHANGE
TBq/a
0,08
0,06
0,04
0,02
0,00
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Total-Beta*
Total activity excluding H-3
Total-Alpha


Normalised total activity ³H excluded - liquid releases - TIHANGE
GBq/GWa
140
120
100
80
60
40
20
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year

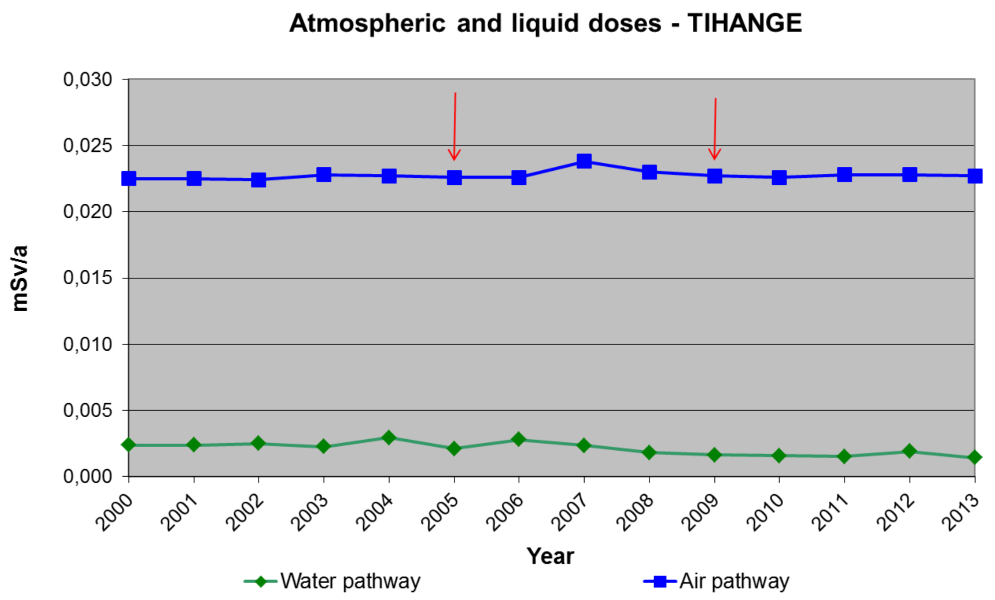


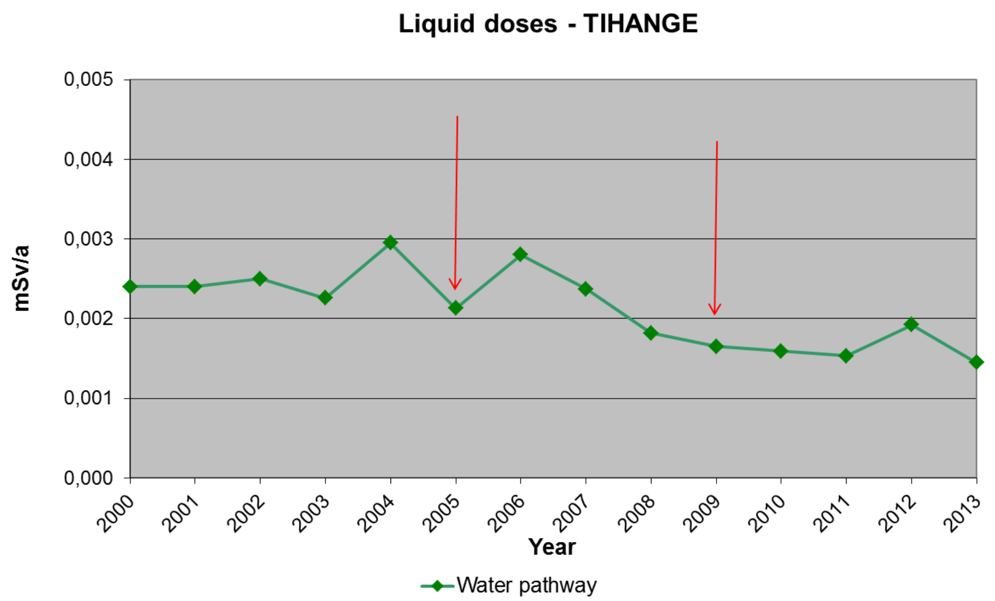


Note[7]

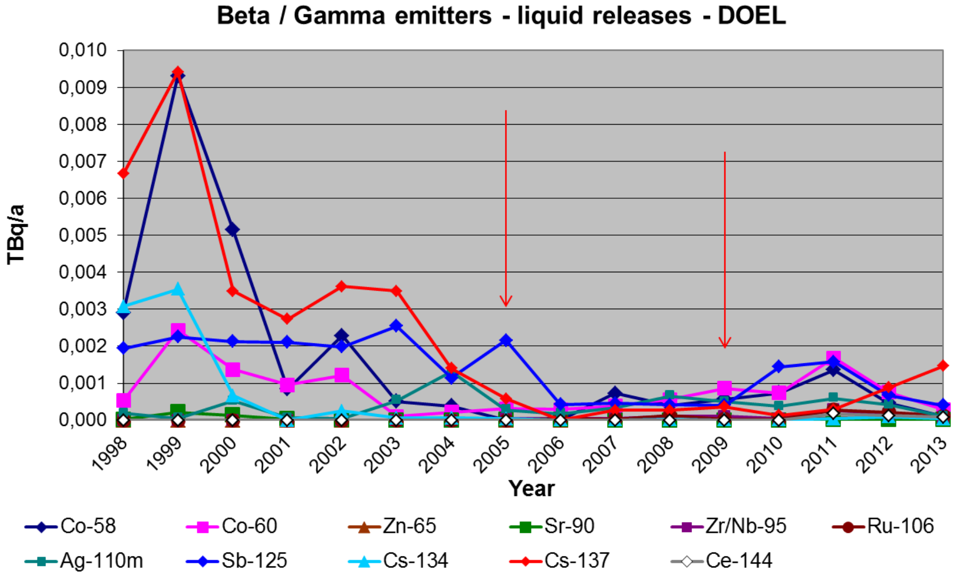


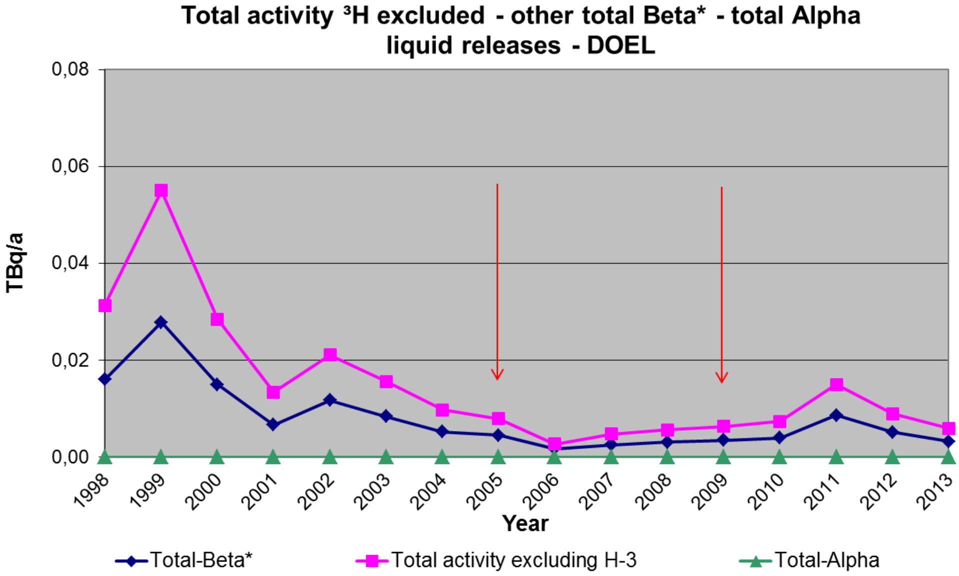
[7] Peaks 2003 and 2007 were caused by minor fuel assemblies defects (Tihange 1 and 3). Leaking fuel elements were detected by means of wet sipping tests when removed during outages and replaced by tight ones Full leakages mean also the possible releases of small amounts of fissile material. It needs some more cycles to remove all the "free" uranium from the reactor vessel and the primary circuits by means of RCVS (very low mesh filter cartridges and ion exchange mixed bed resins.


Atmospheric and liquid doses - TIHANGE
mSv/a
0,030
0,025
0,020
0,015
0,010
0,005
0,000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway
Air pathway

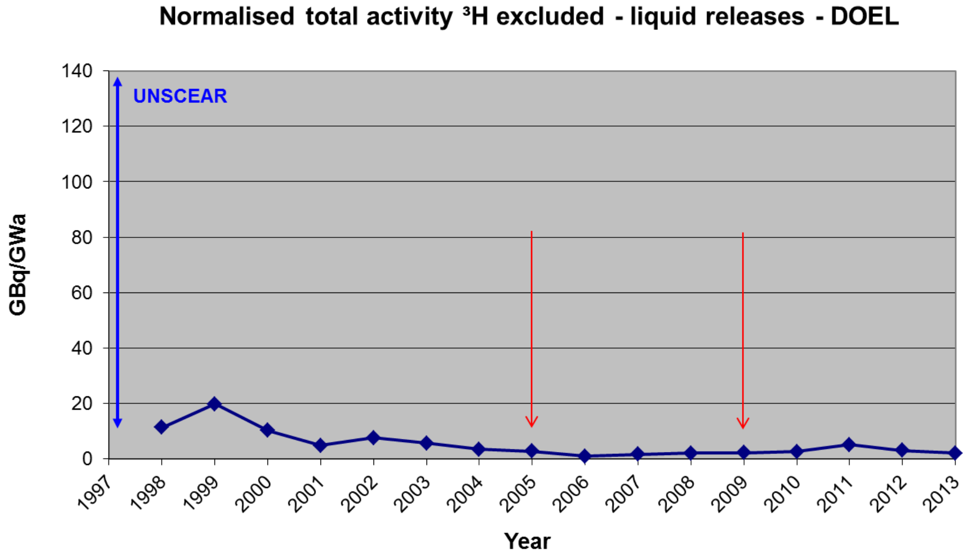

Liquid doses - TIHANGE
mSv/a
0,005
0,004
0,003
0,002
0,001
0,000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway

Doel NPP

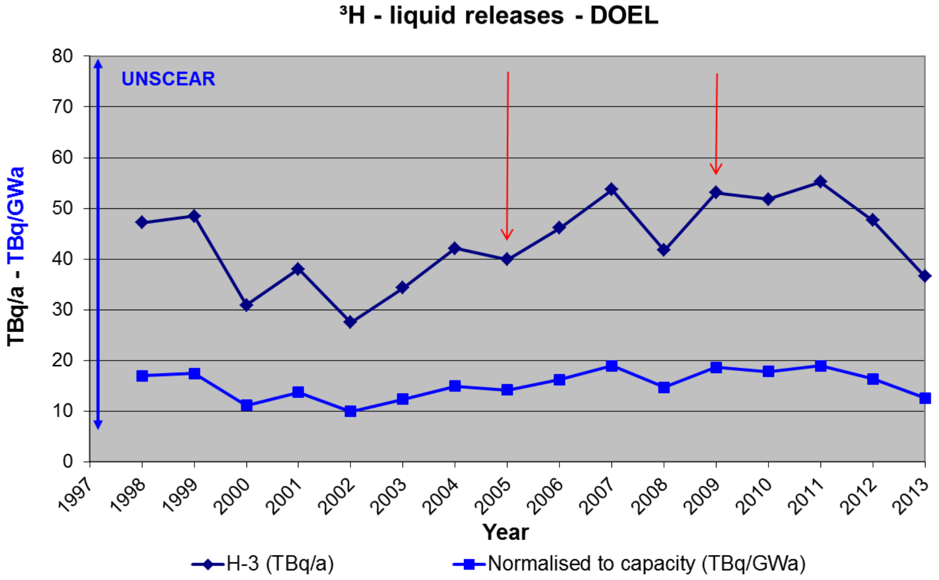


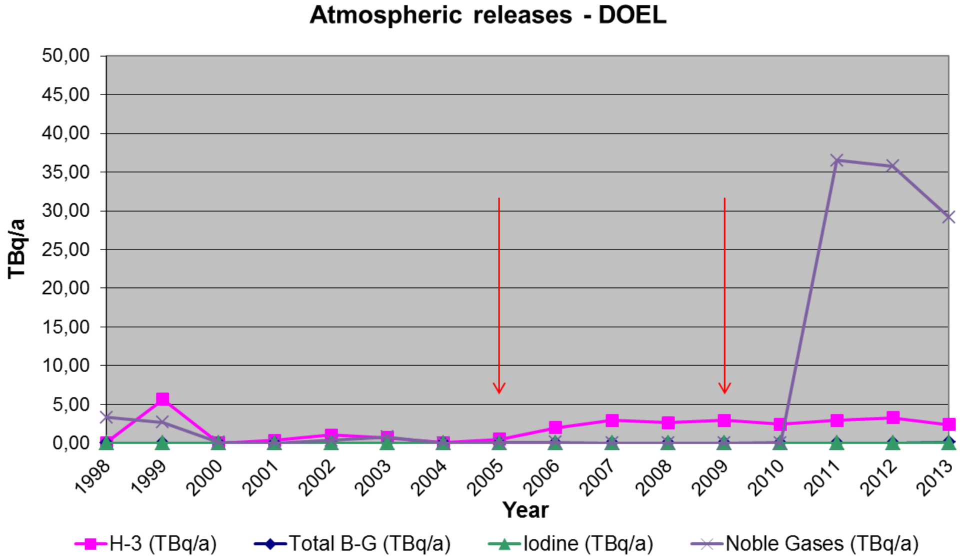


Note[8]

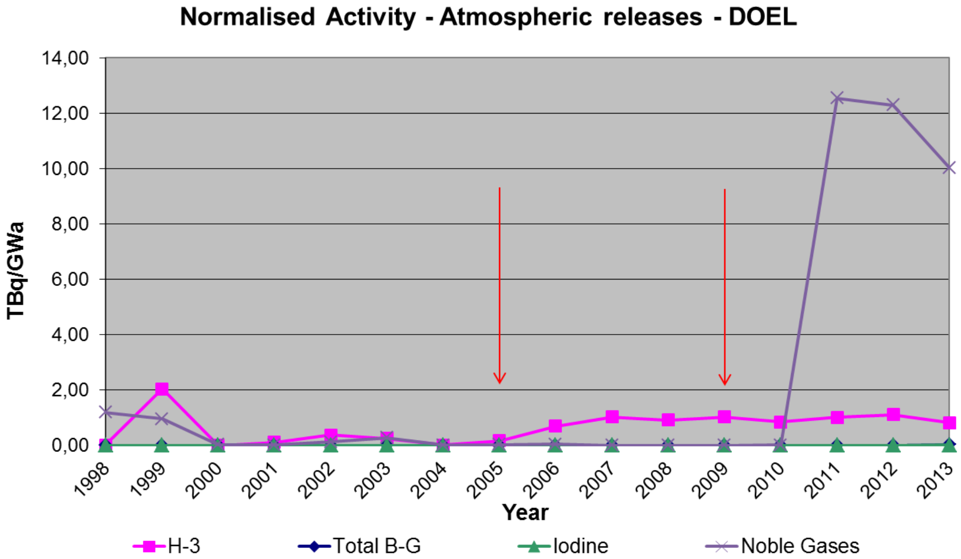


[8] The increase in liquid released activity (excluding tritium) is caused by frequent occuring technical problems with the evaporators in the WAB (water and waste treatment facility). Problems were solved in 2012/2013 with improvement and corrective projects.



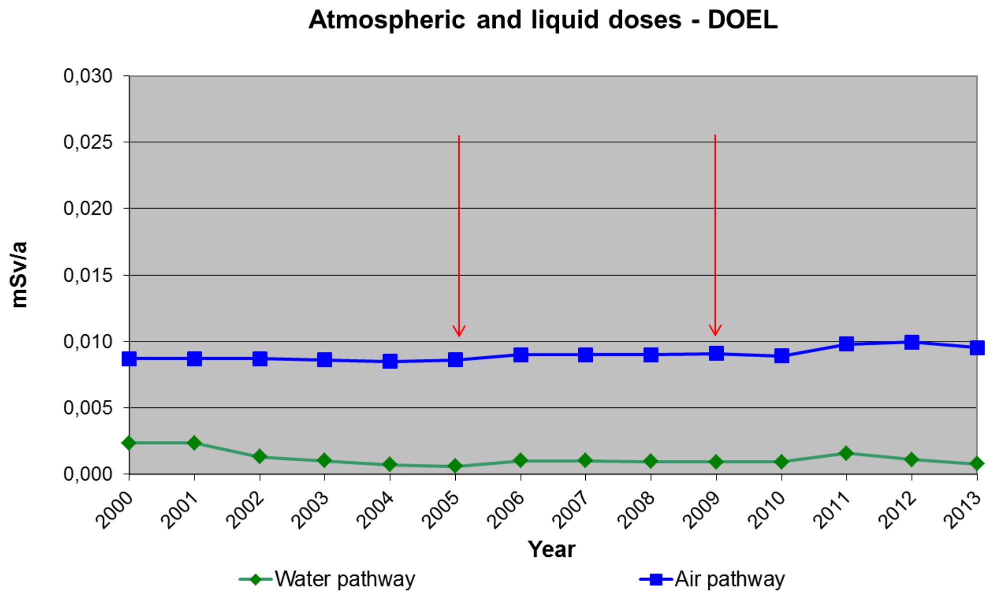


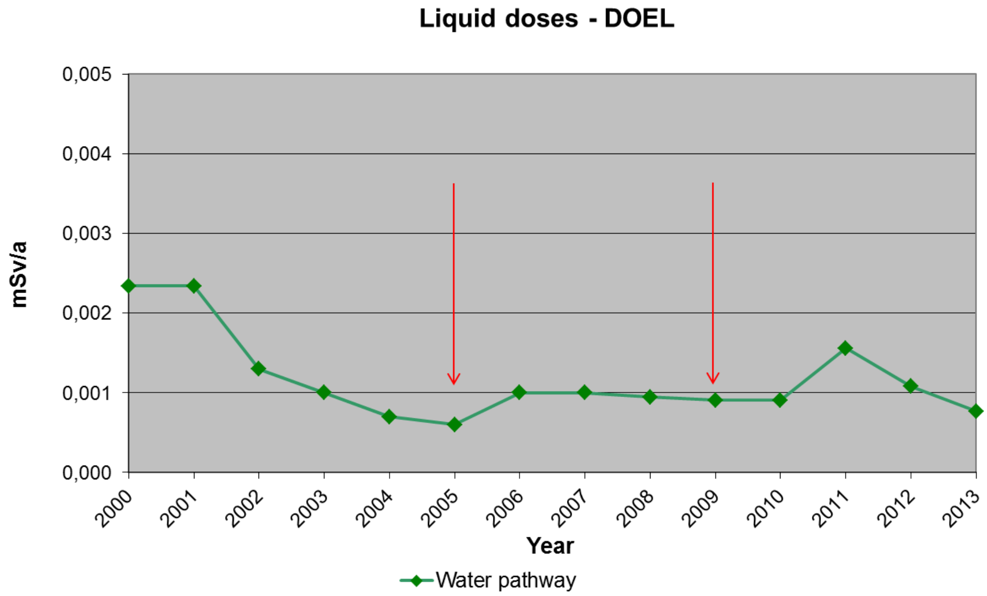
NOTE[9]



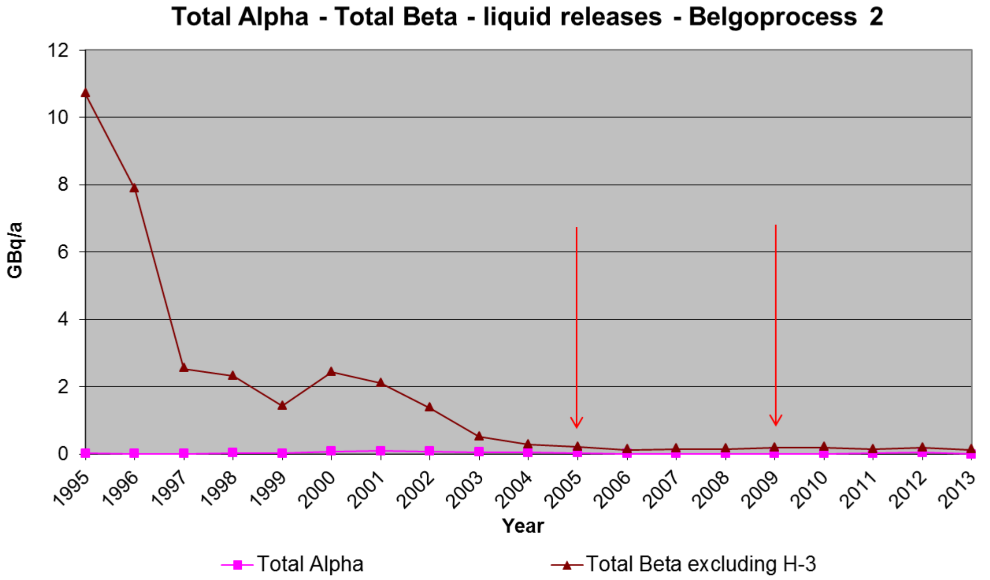
---

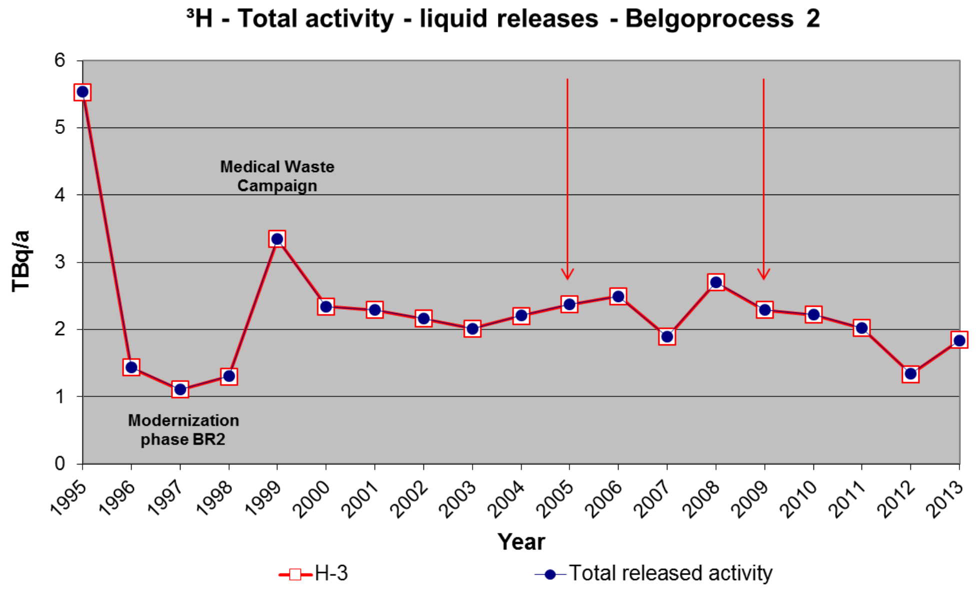
[9] The increase of the released (reported) activity in atmospheric discharges (noble gasses and aerosols) in 2011 is due to the new autorisation license/method of reporting which incorporates the EC Recommandations. Before, measurements below detection limit were reported as "zero", now they are reported as 1/4 of the DL. This new method has a great impact, especially for the noble gasses (factor 1000). The decrease of the released aerosols in 2012-2013 regarding 2011, is due to adaptation of the confidence interval of the spectrometric analyses, done in agreement with FANC, to bring it in line with the current ISO standard.

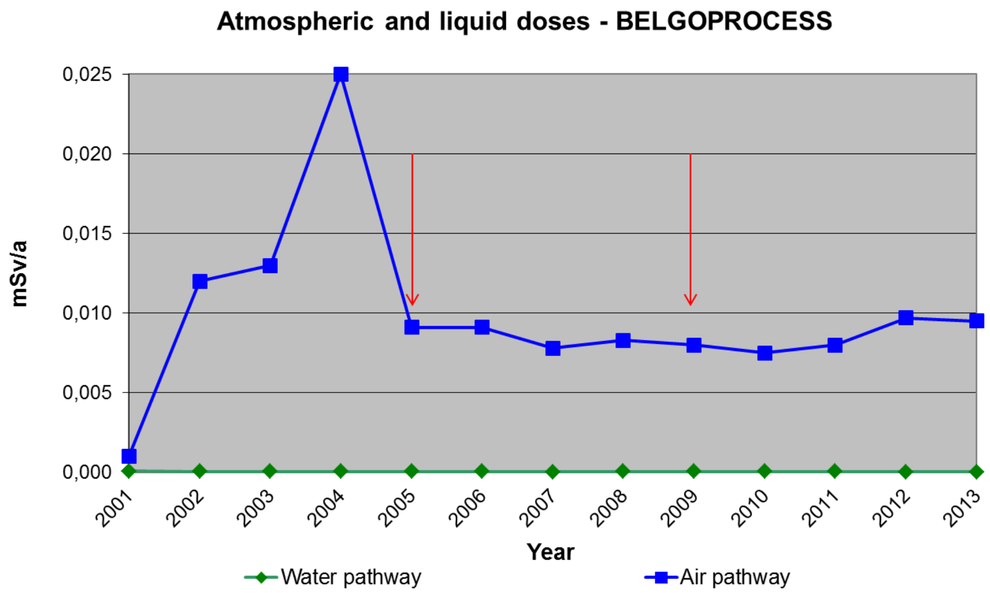

Atmospheric and liquid doses - DOEL
mSv/a
0,030
0,025
0,020
0,015
0,010
0,005
0,000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway
Air pathway

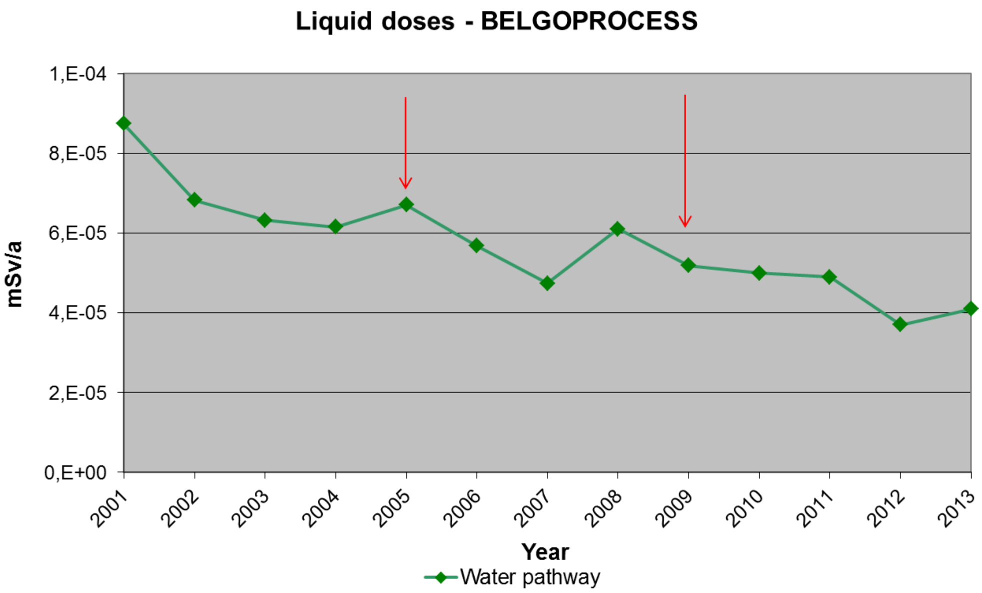

Liquid doses - DOEL
mSv/a
0,005
0,004
0,003
0,002
0,001
0,000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway

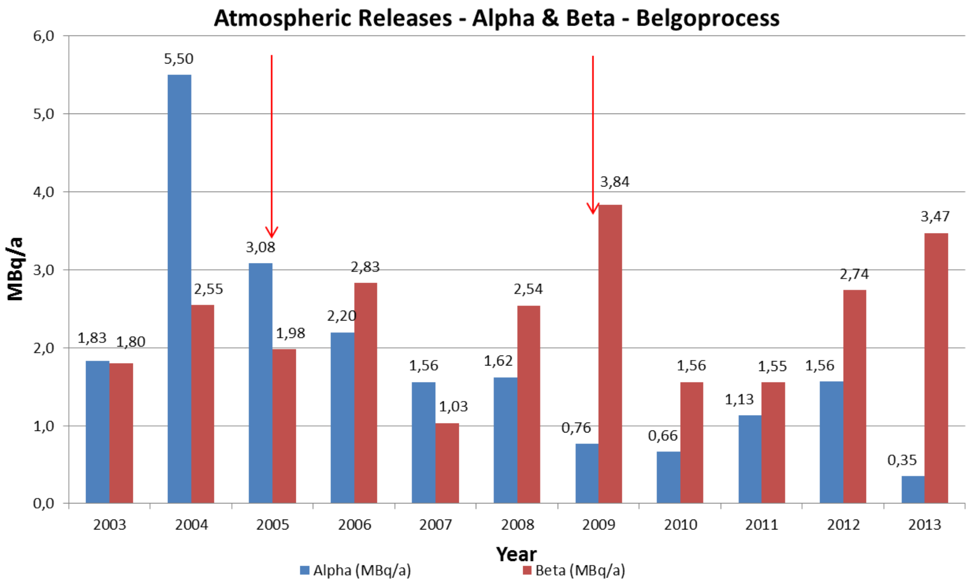
Belgoprocess 2 Nuclear Site


Total Alpha - Total Beta - liquid releases - Belgoprocess 2
GBq/a
12
10
8
6
4
2
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Total Alpha
Total Beta excluding H-3


³H - Total activity - liquid releases - Belgoprocess 2
TBq/a
6
5
4
3
2
1
0
Medical Waste Campaign
Modernization phase BR2
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
H-3
Total released activity


Atmospheric and liquid doses - BELGOPROCESS
mSv/a
0,025
0,020
0,015
0,010
0,005
0,000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway
Air pathway


Liquid doses - BELGOPROCESS
mSv/a
1,E-04
8,E-05
6,E-05
4,E-05
2,E-05
0,E+00
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Water pathway


Atmospheric Releases - Alpha & Beta - Belgoprocess
MBq/a
6,0
5,0
4,0
3,0
2,0
1,0
0,0
1,83
1,80
5,50
2,55
3,08
1,98
2,20
2,83
1,56
1,03
1,62
2,54
0,76
3,84
0,66
1,56
1,13
1,55
1,56
2,74
0,35
3,47
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Alpha (MBq/a)
Beta (MBq/a)

OSPAR COMMISSION

Victoria House
37-63 Southampton Row
London WC1B 4DA
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7242 3737
e: secretariat@ospar.org
www.ospar.org

OSPAR's vision is of a clean, healthy and biologically diverse North-East Atlantic used sustainably

ISBN 978-1-909159-94-5
Publication Number: 663/2015