Radiological monitoring of the territory

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1. Origin of the radioactivity measured in Belgium

Radioactivity has two origins: a *natural* origin and an *artificial* one.

Natural radioactivity consists of 3 main categories of radioactive elements:

- Radionuclides with a very long lifespan (equal to or greater than a billion years) and which have subsisted since the formation of the earth; they were probably synthesized by nuclear reactions in a stellar explosion prior to the solar system. This category includes several tens of nuclides (potassium-40 (^{40}K), uranium-238 (^{238}U), thorium-232 (^{232}Th), uranium-235 (^{235}U), etc). These elements are found everywhere in our environment, and particularly in soils and rocks. This is called the terrestrial exposure;
- Radionuclides produced by the decay of the previous ones, and in particular the long decay chains of ^{238}U, ^{232}Th and ^{235}U. Some of these radionuclides have a particular role such as isotopes of thorium (^{230}Th and ^{228}Th) or isotopes of radon (^{222}Rn and ^{220}Rn);
- Radionuclides produced by nuclear reaction in the upper atmosphere under the action of cosmic rays (carbon-14 (^{14}C), tritium (^{3}H), beryllium-10 (^{10}Be), etc.). These elements diffuse in the atmosphere and can be found in all organic and inorganic materials. This is called cosmogenic exposure.

Artificial (anthropogenic) radioactivity is generated by human military, industrial, medical and research activities. Following activities are present in Belgium:

- The nuclear industry represented by the 4 nuclear power plant reactors at Doel on the Scheldt and the 3 reactors at Tihange on the Meuse, the facilities of Belgoprocess 1 and 2 and IRE. We also include the nuclear industry located abroad but close to the Belgian borders such as the Gravelines, Chooz and Cattenom nuclear power plants in France, Borssele in the Netherlands;
- The NORM industry;
- Nuclear research in laboratories such as those of SCKCEN and universities;
- Radiological departments and nuclear medicine in hospitals are responsible for an increasing share of the average population's exposure to ionizing radiation. Efforts to optimize the dose to patients and the gradual modernization of the radiological equipment tend to limit this average exposure (1.53 mSv/year in 2015).

All of these sources of radioactivity are responsible for the overall exposure of people to ionizing radiation in Belgium (~ 4.0 mSv/year). This exposure or dose (expressed in mSv) is mainly due to natural radioactivity and medical exposures (Figure 1). Each state must control the levels of natural and artificial radioactivity to which its population is potentially exposed. This obligation is specified in legal texts which define the legal and regulatory framework applicable in Belgium.

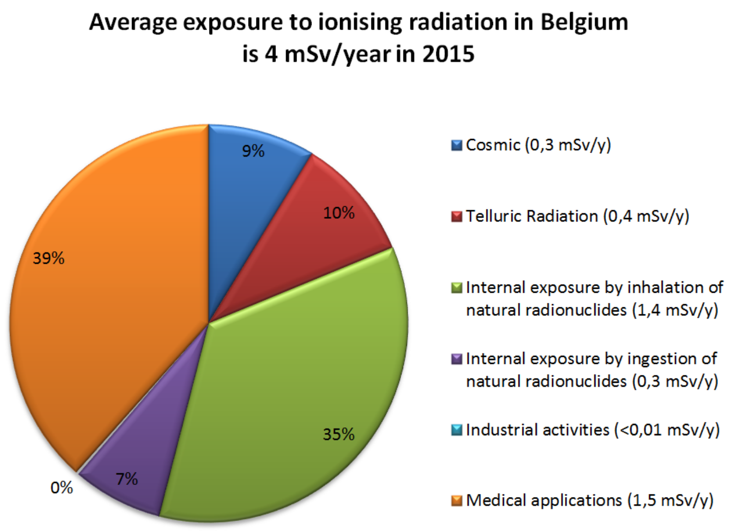

Figure 1. Origin of the different forms of exposure to ionizing radiation in Belgium.

2. Legal and regulatory framework

Each Member State of the European Union is required to ensure radiological monitoring of the territory and the populations (Articles 35 and 36 of the EURATOM Treaty and European Directive 2013/51/EURATOM.

This obligation is reflected under Articles 21 and 22 of the Law of 15 April 1994 and by Articles 70 and 71 of the General Regulations. They provide that the control of the radioactivity of the territory as a whole and of the doses received by the population are the responsibility of the Federal Agency for Nuclear Control (FANC).

As part of its missions, FANC therefore initiates radiological monitoring programmes in Belgium.

International regulatory expectations

At the international level, the Agency actively contributes to the development and application of various international regulations or directives, for example:

- Articles 35 and 36 of the EURATOM Treaty which requires that each Member State establishes the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards and the Commission have the right of access to such facilities to verify their operation and efficiency (Art.35); that the appropriate authorities periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed (Art.36);

- Article 37 of EURATOM which requires that each Member State provides the Commission with such general data relating to any plan for the disposal of radioactive waste in whatever form will make it possible to determine whether the implementation of such plan is liable to result in the radioactive contamination of the water, soil or airspace of another Member State;
- Directive 2013/51/EURATOM of the Council of the European Union of 22 October 2013 setting the requirements for the protection of the health of the population with regard to radioactive substances in water intended for human consumption;
- Regulation 1627/2000, which modifies regulations EC1661/1999 of July 27, 99 and 737/90 of March 22, 1990, relating to the conditions of importation of agricultural products originating in third countries following the accident which occurred in the Chernobyl nuclear power plant. This regulation provides for a strengthening of the control of certain products in the food chain;
- The OSPAR convention, which was adopted and signed by the ministers of the environment of its member states in Sintra (Portugal) in 1998 - replacing the Oslo and Paris Conventions related to the protection of North-East Atlantic - obliges contracting parties take, individually and jointly, the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to develop strategies, plans or (monitoring) programmes for the conservation of that maritime area; for the FANC, this is predominantly in the context of liquid radioactive discharges in rivers that eventually flow into the North Sea;
- The Franco-Belgian agreement on the Chooz nuclear power plant, signed in Brussels in September 1998, provides for regular exchanges of information concerning the radiological measurements carried out in Belgium and France around Chooz, as well as provisions relating to crisis situations that may require the triggering of the Nuclear Emergency Plan.

3. Philosophy of radiological monitoring of Belgian territory

Legislative approaches broaden the notion of radiological monitoring of the environment towards the protection, in addition to people, of the environment itself including all its components such as the marine environment. To do this, we move away from the notion of dose - taken into account in radiation protection - and replace it with radionuclide concentrations determined by a large number of measurements carried out on many samples of different environmental components (air, surface and drinking water, soil, fauna, flora and food chain products).

Radiological monitoring of Belgian territory is carried out in three complementary ways:

- **A sampling programme** which is based on numerous periodic samples of several components of the aforementioned environment across the territory, and particularly around nuclear sites, the Brussels-Capital region and the Belgian coast, followed by radioactivity analyses;
- **A NORM sampling programme** which is also based on numerous samples, but particularly targets certain non-nuclear industrial sites, landfills as well as building materials which all have enhanced natural radioactivity;
- **An automated TELERAD network** which essentially continuously measures dose rates at numerous fixed points.

This surveillance covers the entire territory and makes it possible to monitor the exposure of the population according to its various possible exposure routes. Figure 2 explains the exposure pathways and shows that natural and artificial radioactivity circulate in the environment, passing from one compartment to another, and finally reaching humans by inhalation, ingestion or contamination by dry or wet deposition (rain, aerosols, dust). It is therefore a matter of ensuring that the various activities that generate radioactivity on Belgian territory do not exceed the legal limits set by the regulations.

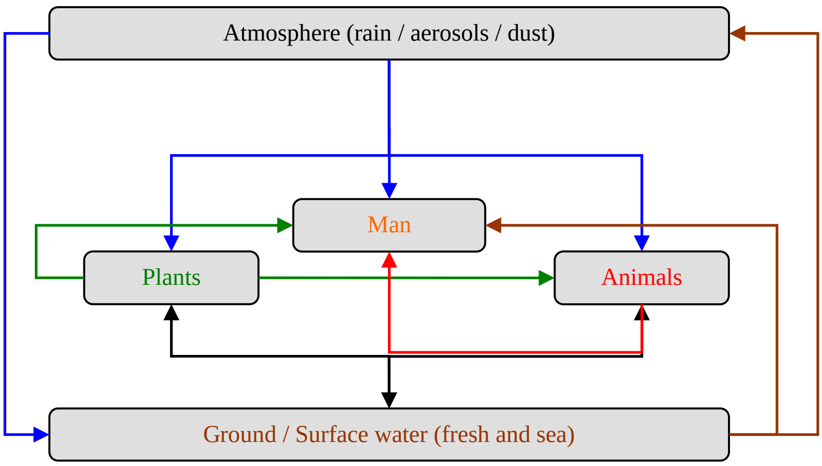

Figure 2. Circulation of radioactivity in the environment before reaching humans.

Depending on its chemical nature, the radioactivity will be more or less concentrated in certain compartments such as, for example, in clays (constituents of soils, sediments) for the radiocesiums which "follow" the movements of potassium regarded as their “chemical analogue”. In animals, radiocesiums tend to concentrate in muscles (meat). The radiostrontiums follow their chemical analogue - calcium and accumulate in the bone structures of living things. Figure 3 illustrates the path that radioactivity can follow to contaminate the food chain and that of humans. Radiological monitoring will target the major routes of possible contamination of the environment (river basins and maritime area) as well as those of direct contamination of humans (food chain).

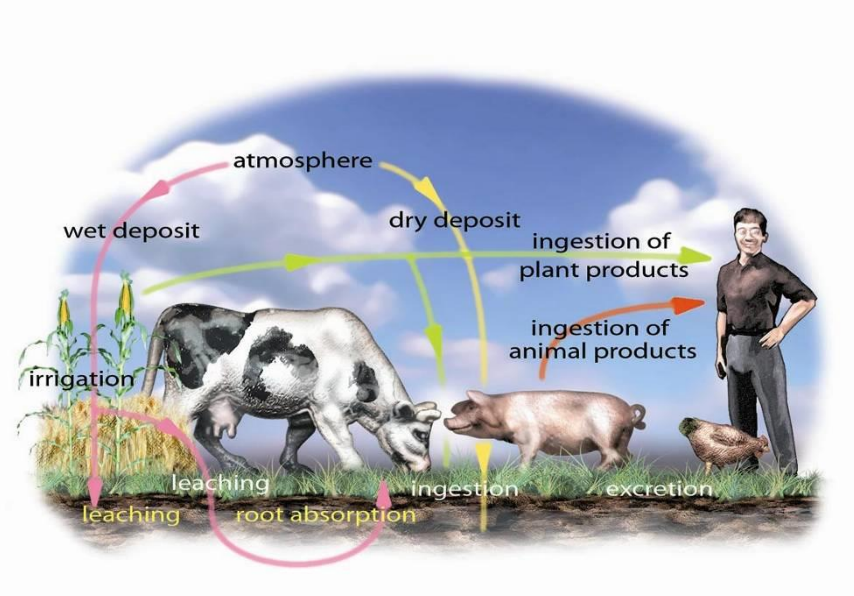

Figure 3. Pathway of radioactivity that will eventually contaminate the food chain and humans.

To meet its primary mission of controlling and protecting the population and the environment, FANC has developed its territory surveillance programme which takes into account Belgian nuclear sites and those of neighbouring countries, but also requests and demands from international institutions and conventions to which Belgium adheres.

4. The sampling programme in practice

To respond optimally to these missions, the sampling programme adapts to the local specificities of the Belgian territory. Thus, the monitoring network is made up of a set of zones, locations in which samples are taken periodically to measure their radioactivity. For each of these zones, the list of radionuclides investigated, the frequencies and locations of samples are adjusted to adapt to the types of installations present on the nuclear sites, to the types of practices or even to the more specific nature of some of them. These areas are:

- The area around the Tihange nuclear site (Tihange nuclear power plant; class 1 site);
- The area around the Fleurus nuclear site (IRE; class 1 site);

- Belgian territory around the French nuclear site of Chooz (Chooz nuclear power plant; class 1 site);
- The area around the Mol-Dessel nuclear site (SCKCEN, Belgoprocess 1 and 2; class 1 sites);
- The area around the Doel nuclear site (Doel nuclear power plant; class 1 site);
- The Brussels-Capital region (reference area);
- The Belgian coast.

In these areas, the sampling programme particularly analyses:

- the atmosphere through sampling of air dust and/or surface deposits (tank collectors with known surface area containing a thin layer of water to trap the fine particles (dry deposition) or by rain washout (wet deposition).
- permanent grassland soils and/or agricultural soils and agricultural crop production (around Chooz). Radiocontamination of soils is mainly due to the fallout of radioactive materials present in the atmosphere (often associated with very fine particles or aerosols) by dry or wet deposition (leaching of the atmosphere by rain).
- waters, river or marine environment sediments as well as freshwater and marine fauna (bivalves, shrimps and fish) and aquatic flora (freshwater plants and mosses, marine algae) which are bioindicators of the presence of radioactivity.
- milk from local dairies/farms. The dairies selected for sampling are located within a radius close to the nuclear power plants (20 km) depending on the size of their production. They integrate practically all of the region's milk production. The farms selected are located in the axis of the prevailing winds near nuclear sites.
- foodstuffs: fish, meats, fruits and vegetables by means of a one-off but varied sampling of products intended for consumption purchased in shops, markets, slaughterhouses and fishmongers (samples taken from a set of markets and retailers in Wallonia, Flanders and the Brussels-Capital region). Radiological analyses are also carried out by the Federal Agency for the Safety of the Food Chain (FASFC) which targets particular border entry points for imports from non-European countries, customs agencies, slaughterhouses, farms, warehouses, manufacturers and wholesalers, etc. All these checkpoints are accessible to this agency as part of its missions.
- control meals/mixed diet (samples collected in canteens and restaurants located in Wallonia, Flanders and in the Brussels-Capital region).
- drinking water (analysed in each province and in Brussels).

The sampling programme also measures the radioactive liquid effluents themselves which are discharged by nuclear facilities into the environment. These samples are taken by the operator of the nuclear site as well as by the laboratories carrying out the analyses for this programme. Thus, the effluents from the nuclear power plants of Doel and Tihange as well as those from the Mol-Dessel site (including Belgoprocess 2 - liquid radioactive waste treatment facility - and FBFC currently being dismantled) are analysed.

Summary tables with the list of the radionuclides sought, the location and the frequency of samples are available below for each zone. A fuller explanation concerning the analyses of the food chain is also provided.

1. The area around the Tihange nuclear site

The programme monitors the discharges emitted by the 3 reactors of the Tihange nuclear power plant located along the Meuse between Huy and Ampsin, as well as by several large agglomerations (Namur, Liège) including many hospitals or research centres (Table 1). The Meuse also receives contamination from its tributary, the Sambre.

Table 1. Radiological monitoring programme for the territory around the Tihange nuclear site.

<table>
<tr><th colspan="2">Zone</th><th>Location of sampling points</th><th>Type of measurement</th><th>Frequency</th></tr>
<tr><td rowspan="2">Atmosphere</td><td>dust</td><td>close to the Tihange nuclear site

Lixhe
(BE-NL border)</td><td>Spectrometry γ:
^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb,

Spectrometry total β:
on paper filters after 5 days decay</td><td>every 4 weeks

daily</td></tr>
<tr><td>surface deposits (tanks)</td><td>close to the Tihange nuclear site

Lixhe
(BE-NL border)</td><td>Spectrometry γ (untreated water):
^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb

Spectrometry total β, total α, ^{3}H, ^{90}Sr
(filtered water)

Spectrometry total β, total α
(filter deposits)</td><td>every 4 weeks

every 4 weeks

every 4 weeks</td></tr>
<tr><td>Soil</td><td>permanent meadow</td><td>close to the Tihange nuclear site

Lixhe
(BE-NL border)</td><td>Spectrometry γ:
^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn,
^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th</td><td>annually</td></tr>
<tr><td rowspan="3">River
(Meuse)</td><td>water</td><td rowspan="3">Andenne
(downstream Sambre + upstream power plant)

Huy
(upstream power plant)

Ampsin
(downstream power plant)

Lixhe
(BE-NL border)</td><td>Spectrometry γ:
^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb,
^{226}Ra, ^{131}I

Spectrometry total β, total α, ^{3}H, ^{40}K, ^{90}Sr</td><td>every 2 weeks</td></tr>
<tr><td>sediments</td><td>Spectrometry γ:
^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn,
^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th</td><td>every 4 weeks</td></tr>
<tr><td>aquatic plants, mosses, bivalves</td><td>Spectrometry γ:
^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn,
^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th

^{3}H organic</td><td>quaterly</td></tr>
<tr><td colspan="2">Liquid discharges from nuclear sites</td><td>Tihange power station</td><td>Spectrometry γ:
^{7}Be, ^{51}Cr, ^{54}Mn, $^{(57)-58-60}$Co, ^{59}Fe, ^{65}Zn, ^{95}Nb,
^{95}Zr, $^{134-137}$Cs, $^{103-106}$Ru, $^{141-144}$Ce, ^{131}I,
^{110m}Ag, ^{113}Sn, ^{123m}Te, $^{124-125}$Sb,

Spectrometry β: ^{3}H</td><td>every 2 weeks
(26 samples)</td></tr>
</table>

Particular radionuclides are investigated in this area. For example, iodine (^{131}I) is analysed in the waters of the Meuse because it can come from wastewater from hospitals located in the large towns bordering this river. In addition, natural "control" radionuclides are analysed such as ^{7}Be (cosmogenic) or ^{40}K, which is present everywhere in the environment and in the human body (at a rate of approximately 60 to 70 Bq/kg).

2. The area around the Fleurus nuclear site

The programme monitors the discharges emitted by the Fleurus nuclear site (IRE) as well as by several large agglomerations such as Charleroi, crossed by the Sambre, which includes many hospitals or research centres (Table 2).

Table 2. Radiological monitoring programme for the territory around the Fleurus nuclear site.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	dust	close to the IRE site	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I Spectrometry total β: on paper filters after 5 days decay	every 4 weeks daily
	surface deposits (tanks)	close to the IRE site	Spectrometry γ (untreated water): ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I Spectrometry total β, total α, ^{3}H, ^{90}Sr (filtered water) Spectrometry total β, total α (filter deposits) ^{131}I (filter deposits)	every 4 weeks every 4 weeks every 4 weeks every 4 weeks
Soil	permanent meadow	close to the IRE site	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th ^{131}I	annually
River (Sambre)	water	Floriffoux or Mornimont (downstream IRE)	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra Spectrometry total β, total α, ^{3}H, ^{40}K, ^{90}Sr ^{131}I	every 2 weeks
	sediments		Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th, ^{131}I	every 4 weeks
	aquatic plants, mosses, bivalves		Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th ^{3}H organic	quaterly

The programme specifically monitors iodine (^{131}I) throughout this area corresponding to the vicinity of the IRE as it is produced by this site and could be released. Iodine is also analysed in everything related to the Sambre because it could come from wastewater from hospitals located in Charleroi. Natural “control” radionuclides such as ^{7}Be or even ^{40}K are also analysed.

3. The Belgian territory around the French nuclear site of Chooz

The programme monitors the releases emitted by the French nuclear power plant of Chooz and its potential impact on Belgian territory (Table 3). Around the boot of Givet, in Belgian territory, extensive soil control also aims to verify the good radiological condition of agricultural areas and their crop production. This control is part of the Franco-Belgian agreement on the Chooz nuclear power plant and the exchange of information in the event of an incident or accident.

Table 3. Radiological monitoring programme for the territory around the French nuclear site at Chooz.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	surface deposits (tanks)	Heer-Agimont (BE-FR border)	Spectrometry γ (untreated water): ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I	every 4 weeks
			Spectrometry total β, total α, ^{3}H, ^{90}Sr (filtered water)	every 4 weeks
			Spectrometry total β, total α (filter deposits)	every 4 weeks
Soil	permanent meadow	in Belgium close to the Chooz site	Spectrometry γ : ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th	annually
	agricultural soils	around the boot of Chooz (24 points)	Spectrometry γ, α, ^{90}Sr, ^{226}Ra	annually
	agricultural crop production		Spectrometry γ, ^{90}Sr, ^{3}H, ^{14}C	
River (Meuse)	water	Heer-Agimont/ Rivière (BE-FR border)	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra	every 2 weeks
			Spectrometry total β, total α, ^{3}H, ^{40}K, ^{90}Sr	
	sediments		Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th	every 4 weeks
	aquatic plants, mosses, bivalves		Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra,^{228}Th	quaterly
			^{3}H organic	

As in the other areas, natural "control" radionuclides such as ^{7}Be or ^{40}K are also analysed.

4. The area around the Mol-Dessel nuclear site

The programme monitors the discharges emitted by the Mol-Dessel nuclear site which contains the SCKCEN research centre as well as Belgoprocess, responsible for the treatment and storage of radioactive waste from nuclear power plants, the industrial sector, hospitals, laboratories and dismantling operations (Table 4).

Table 4. Radiological monitoring programme for the territory around the Mol-Dessel nuclear site.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	dust	close to the Mol-Dessel site	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb Spectrometry total α near Mol Spectrometry total β: on paper filters, after 5 days decay	every 4 weeks daily daily
	surface deposits (tanks)	close to the Mol-Dessel site	Spectrometry γ (untreated water): ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I Spectrometry total β, total α, ^{3}H, ^{90}Sr (filtered water) Spectrometry total β, total α (filter deposits)	every 4 weeks every 4 weeks
Soil	permanent meadow	close to the Mol-Dessel site	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: $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am near Mol	annually
River (Molse Nete)	water	Molse Nete	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra Spectrometry total β, total α, ^{3}H, ^{40}K	every 2 weeks
	sediments		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, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am	every 4 weeks
	aquatic plants		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, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am, ^{3}H organic, ^{99}Tc	quaterly
Liquid discharges from nuclear sites		FBFC site	Spectrometry total β, total α ^{226}Ra, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am	every 4 weeks (13 samples)
		Belgoprocess 2 site	Spectrometry γ: $^{134\text{-}137}$Cs, ^{54}Mn, $^{(57)\text{-}58\text{-}60}$Co, ^{131}I Spectrometry total β, total α ^{3}H, ^{90}Sr, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am, ^{99}Tc	weekly

Particular radionuclides are also investigated in this area. In the Molse Nete: $^{234,235,238}U$ and transuranic isotopes ($^{238,(239+240)}Pu$, ^{241}Am) in addition to the usual panoply of gamma emitters (fission and activation products including radiocesiums) because this river receives liquid discharges from the nuclear installations of the Mol-Dessel site via the liquid waste treatment facilities of Belgoprocess 2. In the Nete and Demer basins: ^{226}Ra because these rivers drain the water from the Grote Laak and Winterbeek where the Tessenderlo food phosphates manufacturing plant (NORM industry) used to discharge its ^{226}Ra-enriched process water. Natural "control" radionuclides such as ^{7}Be or ^{40}K are also analysed.

5. The area around the Doel nuclear site

The programme monitors the discharges emitted by the 4 reactors of the Doel nuclear site, located along the Scheldt, near Antwerp, as well as discharges emitted by large agglomerations such as Antwerp which include many hospitals (Table 5).

Table 5. Radiological monitoring programme for the territory around the Doel nuclear site.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	dust	close to the Doel site	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb Spectrometry total β: on paper filters, after 5 days decay	every 4 weeks daily
Atmosphere	surface deposits (tanks)	close to the Doel site	Spectrometry γ (untreated water): ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I Spectrometry total β, total α, ^{3}H, ^{90}Sr (filtered water) Spectrometry total β, total α (filter deposits)	every 4 weeks every 4 weeks every 4 weeks
Soil	permanent meadow	close to the Doel site	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: $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu,	annually
River (Escaut)	water	near Doel	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra Spectrometry total β, total α, ^{3}H, ^{40}K	every 2 weeks
River (Escaut)	sediments	near Doel	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, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am	every 4 weeks
River (Escaut)	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 seaweeds)	quaterly
Liquid discharges from nuclear sites		Doel power station	Spectrometry γ: ^{7}Be, ^{51}Cr, ^{54}Mn, $^{(57)\text{-}58\text{-}60}$Co, ^{59}Fe, ^{65}Zn, ^{95}Nb, ^{95}Zr, $^{134\text{-}137}$Cs, $^{103\text{-}106}$Ru, $^{141\text{-}144}$Ce, ^{131}I, ^{110m}Ag, ^{113}Sn, ^{123m}Te, $^{124\text{-}125}$Sb Spectrometry β: ^{3}H	every 2 weeks (26 samples)

Particular radionuclides are also investigated in this area. Iodine (^{131}I) is analysed in the water of the Scheldt because it can come from the wastewater of hospitals located in cities such as Antwerp. In samples of aquatic flora and fauna (shrimps, mussels, algae): ^{234,235,238}U and transuranic isotopes ($^{238,(239+240)}$Pu, ^{241}Am) in addition to the panoply of gamma emitters (including radiocesiums), ^{90}Sr, ^{99}Tc and ^{3}H as markers of nuclear industry activities (nuclear powerplants and reprocessing plants at La Hague (France) and Sellafield (United Kingdom)). Natural control radionuclides such as ^{7}Be or ^{40}K are also analysed.

6. The Brussels-Capital region

The programme monitors the Brussels-Capital region as a reference area for Belgian territory. Indeed, the aim is to periodically take samples that are not influenced by potential releases of artificial and/or natural radioactivity operated by humans in their activities throughout the territory. In addition, the high population density (1/10 of the total population of Belgium) also makes it an interesting representative area (Table 6).

Table 6. Radiological monitoring programme for the Brussels Capital reference area.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	dust	Brussels	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb Spectrometry total β: on paper filters after 5 days decay	every 4 weeks daily
	surface deposits (tanks)	Brussels	Spectrometry γ (untreated water): ^{7}Be, $^{134-137}$Cs, $^{141-144}$Ce, $^{103-106}$Ru, ^{95}Zr, ^{95}Nb, ^{131}I Spectrometry total β, total α, ^{3}H, ^{90}Sr (filtered water) Spectrometry total β, total α (filter deposits)	every 4 weeks every 4 weeks every 4 weeks
Soil	permanent meadow	Brussels	Spectrometry γ: ^{7}Be, $^{134-137}$Cs, $^{(57)-58-60}$Co, ^{54}Mn, ^{65}Zn, ^{110m}Ag, ^{40}K, $^{226-228}$Ra, ^{228}Th	annually

7. The Belgian coast

The programme monitors the North Sea which receives liquid discharges from several nuclear sites (French nuclear power plants at Gravelines, located near the sea between Calais and Dunkirk, Paluel and Flamanville, English nuclear power plants at Dungeness, Bradwell and Sizewell, reprocessing plant of La Hague (France) and Sellafield (United Kingdom)) and non-nuclear sites (hospitals and research centres in large urban areas). The North Sea is also the end point of several rivers which themselves receive radioactive effluents from nuclear sites (Chooz, Tihange, Doel, Fleurus and Mol-Dessel) such as the Meuse or the Scheldt. This explains why it is closely monitored by the riparian countries (Table 7).

Table 7. Radiological monitoring programme for the maritime area.

Zone		Location of sampling points	Type of measurement	Frequency
Atmosphere	dust	Coxyde	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb Spectrometry total β: on paper filters after 5 days decay	every 4 weeks daily
Soil	permanent meadow	Coxyde	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	annually
North Sea	water	off the coast (Belgica campaign), 16 locations	Spectrometry γ: including $^{134\text{-}137}$Cs, $^{57\text{-}58\text{-}60}$Co, ^{54}Mn ^{40}K Spectrometry total β, total α Spectrometry α: $^{238\text{-}(239+240)}$Pu	quaterly
	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	quaterly
	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	quaterly
	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	quaterly
	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	quaterly

Particular radionuclides are also investigated in this area. For example, in samples of marine flora and fauna (shrimps, mussels, seaweeds): $^{234,235,238}U$ and transuranic isotopes ($^{238,(239+240)}Pu$, ^{241}Am) in addition to the usual panoply of gamma emitters (including radiocesium), ^{90}Sr, ^{99}Tc and organic ^{3}H as markers for the activities of the nuclear power industry (nuclear powerplants and reprocessing plants at La Hague (France) and Sellafield (United Kingdom)). Natural “control” radionuclides such as ^{7}Be or ^{40}K are also analysed.

8. The food chain: drinking water, milk, foodstuffs and control meals

The programme monitors the food chain products throughout Belgium to assess as broadly as possible all the routes of entry of radioactivity in humans (Table 8). The food chain can potentially be contaminated on Belgian territory by all the nuclear and non-nuclear sites mentioned as well as by the import of food from countries affected by incidents or accidents such as the Chernobyl and Fukushima accident. We particularly analyse:

- Drinking water ;
- Milk because it is a sensitive vector in the event of radioactive contamination such as iodine ^{131}I which passes rapidly from grass to cows and is found in milk. As the milk distribution chain is rapid, iodine would be quickly ingested by the population with the associated risks of irradiation of the thyroid ;
- Foodstuffs ;
- Control meals.

Table 8. Radiological monitoring programme of the food chain throughout Belgium.

Zone		Location of sampling points	Type of measurement	Frequency
Drinking water	tap water	Brussels (Brussels Capital) Wavre (Walloon Brabant) Liège (Liège) Namur (Namur) Fleurus (Hainaut) Libramont (Luxembourg) Ghent (East Flanders) Leuven (Flemish Brabant) Poperinge and Reningelst (West Flanders) Mol (Antwerp) Hasselt (Limburg)	Spectrometry total α, total β, ^{3}H, ^{40}K, ^{222}Rn, ^{226}Ra When screening values are exceeded (0.1 Bq/L for total α and 0.2 Bq/L for residual β = total β - ^{40}K): complete spectrometry analyses (γ, α, β)	quaterly
Milk	dairies/ farms	Brussels region Fleurus region Tihange region Doel region Mol-Dessel region Chooz region	Spectrometry γ of which $^{134\text{-}137}Cs$, ^{131}I, ^{40}K ^{90}Sr	weekly every 4 weeks
Foodstuffs	vegetables meat fish	small and large scale retailers in Wallonia, Flanders and Brussels Capital	Spectrometry γ of which $^{134\text{-}137}Cs$, ^{40}K ^{90}Sr	4 samples monthly of meat, fish, vegetables 4 samples annually of meat, fish, vegetables
Mixed diet	control meals	company canteens: Mol (SCKCEN), Fleurus & Brussels (Carrefour®)	Spectrometry γ of which $^{134\text{-}137}Cs$, ^{40}K ^{90}Sr and ^{14}C	monthly quaterly

The radionuclides mainly investigated in milk, foodstuffs and mixed diet are ^{40}K (for natural radioactivity) and ^{90}Sr, $^{134,137}Cs$ and ^{131}I (for artificial radioactivity). The ^{14}C carbon (produced in nuclear reactors but also naturally present albeit in very low abundancy) is also analysed in control meals.

Directive 2013/51/EURATOM sets the requirements for the protection of the health of the population with regard to radioactive substances in water intended for human consumption. This directive was transposed into federal legislation via the Royal Decree of 31 May 2016, supplemented by the technical Agency Decree (FANC) of 24 November 2016.

To apply and comply with these regulations, Belgium, which owes hundreds of water collection points, has set up a large-scale monitoring programme in which any supplier of water intended for human consumption (water producer and/or producer of foodstuffs) must submit an annual self-monitoring programme to FANC and carry out periodic radioactivity analyses at its expense. To do this, a web-based data exchange platform brings together the suppliers of water intended for human consumption, the laboratories in charge of these analyses and FANC. The self-monitoring programme is specific to each supplier and takes into account the volumes of water per day, its origin (surface water, aquifers, etc.) and its end use (incorporation into food (ingestion), cleaning of devices (contact water), etc.)

The analyses of radioactivity in drinking water are made to meet the requirements of the directive which sets 3 reference levels to be respected:

- ^{3}H < 100 Bq/L;
- ^{222}Rn < 100 Bq/L;
- Total Indicative Dose (TID) < 0.1 mSv/year.

The TID does not take into account in its calculation the contribution of ^{3}H, ^{40}K, ^{222}Rn and short-lived radon decay products. This dose is calculated on the basis of an annual ingestion of 730 litre of water for adults or children over 10 years old and can be determined using the conversion factors available in Directive 96/29/EURATOM.

In practice, to determine whether the water exceeds the TID reference level of 0.1 mSv/year, a “global” approach is applied which states that if total α is less than 0.1 Bq/L and residual β (= total β - ^{40}K) is less than 0.2 Bq/L, we can guarantee that the TID is also less than 0.1 mSv/year.

If the reference value of ^{3}H (100 Bq/L) is exceeded, complete spectrometric analyses of the artificial radioelements (α, β, γ) must be carried out.

In the event that at least one screening value (0.1 Bq/L in total α and 0.2 Bq/L in residual β) and/or the reference value of ^{222}Rn (100 Bq/L) is exceeded, complete spectrometric analyses of natural radioelements are carried out and if these do not explain the exceedances of the screening values, complete spectrometric analyses of the artificial vectors (α, β, γ) must be carried out.

If the reference value of ^{3}H (100 Bq/L) is exceeded and at least one screening value is exceeded and/or the reference value of ^{222}Rn (100 Bq/L) is exceeded, complete spectrometry analyses of natural and artificial radioelements (α, β, γ) must be carried out.

Legend:

^{3}H = tritium; ^{7}Be = beryllium-7; ^{14}C = carbon-14; ^{40}K = potassium-40; ^{51}Cr = chromium-51; ^{54}Mn = manganese-54; $^{(57)-58-60}Co$ = cobalt-57(-58,-60); ^{59}Fe = iron-59; ^{65}Zn = zinc-65; ^{90}Sr = strontium-90; ^{95}Nb = niobium-95; ^{95}Zr = zirconium-95; ^{99}Tc = technecium-99; $^{134-137}Cs$ = cesium-134(-137); $^{103-106}Ru$ = ruthenium-103(-106); $^{141-144}Ce$ = cerium-141(-144); ^{131}I = iodine-131; ^{110m}Ag = metastable silver-110; ^{113}Sn = tin-113; ^{123m}Te = metastable tellurium-123; $^{124-125}Sb$ = antimony-124(-125); $^{226-228}Ra$ = radium-226(-228); ^{228}Th = thorium-228; $^{234-235-238}U$ = uranium-234(-235,-238); $^{238-(239+240)}Pu$ = plutonium-238(-239+240); ^{241}Am = americium-241.

More information about discharges...

AFCN website (discharges): Rejets radioactifs | AFCN - Agence fédérale de Contrôle nucléaire (fgov.be)