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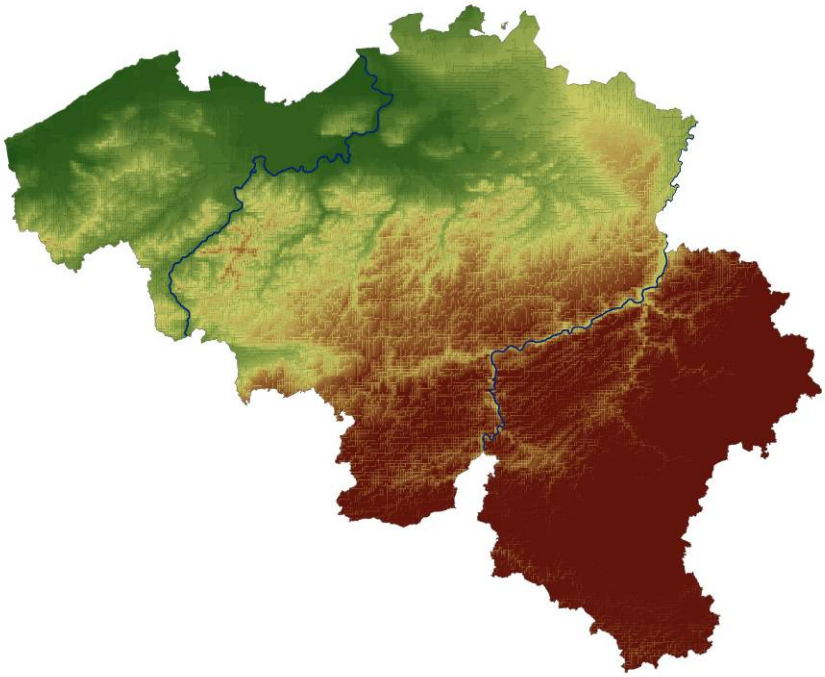
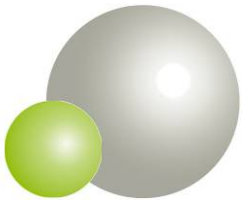
SURVEILLANCE OF THE TERRITORY &
NATURAL RADIATION SERVICE

Radiological Monitoring in Belgium
Summary report 2010



- October 2011 -



Federal Agency for Nuclear Control

Health and Environment Department

Territorial Monitoring & Natural Radiation Service

Territorial Radiological Monitoring Unit

Ravensteinstreet, 36. B-1000 Brussels - Belgium
Website: http://www.fanc.fgov.be

Email: info@fanc.fgov.be

Authors:

Lionel SOMBRE, PhD, responsible for the Territorial Radiological Monitoring

Tel.: +32 2 289 21 54 – Fax: +32 2 289 21 52
Email: lionel.sombre@fanc.fgov.be

Jurgen Claes, MSc. Eng., Environmental Radioactivity Expert – Radiological Monitoring
Tel. : +32 2 289 20 91 – Fax : +32 2 289 21 52
E-mail : jurgen.claes@fanc.fgov.be

Mrs Michelle BOUCHONVILLE, scientific assistant.

Tel.: +32 2 289 21 64 – Fax: +32 2 289 21 52
Email: michelle.bouchonville@fanc.fgov.be

Departmental Secretariat: **Tel.: +32 2 289 21 51 – Fax: +32 2 289 21 52**

The following persons have contributed to this report:

- **Michel DESMEDT, Eng., responsible for the TELERAD network**
- **André POFFIJN, PhD, Environnemental Radioactivity Expert – Natural Radiation**
- **Boris DEHANDSCHUTTER, PhD, Environnemental Radioactivity Expert – Natural Radiation**
- **Stéphane PEPIN, PhD, Environnemental Radioactivity Expert – Natural Radiation**

Co-operation with outside institutions

The following institutions and their respective collaborators provided the basic data for this report:

Avenue de l'Espérance, 1 - 6220 Fleurus - Tel : + 32 71 82 95 56 - Fax : + 32 71 81 38 12

Director: Jean-Michel Vanderhofstadt (Tel. : 32 71 82 92 90)

Head of the Metrology and Environmental radioprotection Department: B. Deconninck

Responsible for metrology/dosimetry : C. De Lellis
Assistant : T. Dieudonné
Responsable for radiochemistry: D. Tomasevszky

Laboratory technicians: N. Cecchetto, A Deckers, A. Demoulin, K.Marcadieu et F. Willocq

Boeretang, 200 - 2400 Mol - Tel. : + 32 14 33 25 90 – Fax : +32 14 31 89 36

General Director: Éric van Walle (Tel. : +32 14 33 25 90)

Project Manager of the expert group Low-level radioactivity measurements: P. Vermaercke

Mesures de Faible Radioactivité :

Supervision and reporting: L. Sneyers
Sampling & preparation of samples: B. Bouwens, A. Isenborghs, B. Ruts, E. Tessens et R. Verkoyen
Supervision of measurements: Ch. Hurtgen, F. Verrezen, M. Bruggeman et L. Verheyen
Measurements: S. Cools, E. Dupuis, A. Isenborghs, K. Jacobs, L. Jansen, H. Loots, K. Smits, W. Van Baelen, M. Vanuytven, B. Vennekens, M. Verbist, L. Verheyen et D. Verstrepen

Food Safety Center, Boulevard du Jardin Botanique, 55 - 1000 Bruxelles

DG Control Policy: Tel. : +32 2 211 85 81 – Fax : +32 2 211 86 30

General Director: Herman Diricks, ir (Tel. : +32 2 211 85 75)

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PREFACE

Radioactivity. A word that often causes concern because of the threat to health it suggests. Nevertheless, we are surrounded by radioactivity without even being aware of it:

- *Natural* radioactivity which reaches us from the cosmos or which is present in the earth's crust, in the waters of the oceans and even in our bodies, and;
- *Artificial* radioactivity, i.e. radioactivity resulting from human activities. Here, a distinction can be made between these activities accompanied by – very weak – discharges of radioactive material into the environment, as in the operations of nuclear reactors to produce electricity, for instance, nuclear medicine through its waste and discharges of radioactive substances by patients, and those which normally entail no discharge such as medical imaging and the sterilisation of surgical equipment or certain foodstuffs. Of course, the sterilisation process does not contaminate the equipment or food and does not make them radioactive.

However surprising it may be, it is in fact natural radiation that constitutes the principal source of exposure of the population to ionizing radiation - under normal conditions and not taking account of medical applications. We are exposed to radiation on a daily basis.

Yet radioactivity, whether it is the result of human activities or of natural origin, is not without risk for humans and the environment. That is why practices involving radioactive substances are strictly regulated. Discharges of radioactivity into the environment, in particular, are strictly limited because they have to comply with strict standards.

However, while regulations reduce the risk, they do not eliminate it entirely. For this reason, the level of radioactivity in the environment has to be regularly monitored to enable appropriate action to be taken where needed. Moreover, enforcing strict regulations does not guarantee that the population will not be exposed, at one time or another, to levels of radiation significantly higher than the level of natural radiation.

Indeed, the possibility of radioactive discharges beyond the authorised limits, or of incidents and even accidents resulting in the dispersal of radioactive substances into the environment cannot be ruled out. Furthermore, radioactivity evidently does not recognise national frontiers: a nuclear accident in another country, even far away, might result in not insignificant contamination on Belgian territory, as was the case in several countries following the Chernobyl accident of 26 April 1986.

In Belgium, the permanent monitoring of the radiological situation of the territory was introduced as a mandatory requirement by EURATOM in 1957 by means of regulations that oblige the Member States to ensure continuous radiological monitoring of their populations and communicate the results of these controls. This monitoring requirement was incorporated into Belgian law in 1963 and was implemented at the end of the 1960s shortly before the first industrial nuclear reactors went into service.

This radiological monitoring of the territory, which originally fell within the competence of the Service for Protection against Ionizing Radiations (SPIR) at the Ministry of Social Affairs, Public Health and the Environment, has since 2001 been performed under the responsibility of the Federal Agency for Nuclear Control, which is charged, in particular, with *controlling the radioactivity of the territory as a whole* and *controlling the doses of ionizing radiation*

received by the population, and which it endeavours to carry out with total objectivity and transparency[1].

[1] Articles 70 and 71 of the Royal Decree of 20 July 2001 on the general regulations for the protection of the population, workers and the environment against the dangers of ionizing radiation.

BASIC KNOWLEDGE RELATING TO RADIOACTIVITY AND EXPOSURE TO RADIATION

Most atoms are stable: they endure indefinitely without external action. Others have a structure or an excess of energy which makes them unstable: these are *radioelements,* which can be of natural or artificial origin. Their nuclei are spontaneously transformed until they attain a structure in equilibrium by emitting radiation (energy or particles) on each transformation: they are *radioactive*. This invisible phenomenon is irreversible: after one or more transformations, the radioelement stabilises into a stable element once and for all.

Types of radiation There are three main types of radiation emitted by radioelements: *alpha*, *beta* and *gamma*. Their characteristics are very different, with the two first comprising charged particles while the third is electromagnetic in nature (photons), like light, but transporting more energy.

Ionizing radiation By virtue of the electric charge or energy it carries, the radiation emitted by the nucleus is capable of modifying the atoms of the matter it passes through by making them absorb energy or lose a unit of electrical charge, thus transforming them into ions: these are said to be *ionizing.* Deprived of an electron, the atom charges positively and becomes chemically reactive, which can entail lesions and harmful biological effects in living cells.

Unit of radioactivity The unit of measurement of *radioactivity* is the *Becquerel* (Bq), which is equal to one nuclear disintegration per second. A source of radioactivity with an activity of 1 Bq corresponds to a quantity of radioactive substance in which one of the nuclei disintegrates every second. The waters of the oceans, for example, have a natural radioactivity of 12 Bq per litre and the human body, which is also radioactive, has a natural radioactivity of about 120 Bq per kilo, essentially due to the potassium 40 contained in food (about 70 Bq per kilo). In contrast, the radioactivity of radium, a metal discovered in 1898 by Pierre and Marie Curie, is 37 billion becquerels per gram. Radioactivity is measured by extremely sensitive physical methods which enable values of less than one becquerel to be detected.

Unit of measurement of the biological effect Knowing the radioactivity of a radioactive source does not, however, make it possible to foresee the significance of the effects it will entail for someone exposed to such radiation: the biological effect of ionising radiation varies depending on the nature and energy of the radiation, the duration of exposure and the part of the body exposed.

For tissues, this effect is estimated in terms of the *equivalent dose,* which corresponds to the *absorbed dose* expressed in *Grays* (Gy) – i.e. the quantity of energy deposited by the radiation per unit of mass of matter (1 joule deposited in one kilogram of matter) – multiplied by a coefficient taking account of the nature of the radiation and expressing its biological impact on the tissue (equivalent to 1 for photons – gamma and X rays - and electrons – beta rays, 5 to 20 for neutrons, 5 for protons and 20 for alpha particles and heavy ions). Thus, with an equal absorbed dose, the biological effects can be very different according to the type of radiation because, constituted of much heavier particles, alpha radiation will have a much more marked effect than beta radiation. On the other hand, it will be less penetrating.

For the whole body, the effect of ionising radiation is estimated in terms of the *effective dose*, which is calculated from the product of the equivalent dose received at the level of each organ by a risk coefficient specific to each of them and by adding the partial results obtained. This quantity is often erroneously referred to as the "dose". The equivalent and effective dose unit is the *Sievert* (Sv), generally expressed by sub-multiple, thousandths or millionths of a sievert (mSv or μSv respectively).

Dose limits In Belgium, the *statutory dose limits* for ionising radiation are based on European directives, which are themselves based on the recommendations of international organisations. Thus, for the population, the effective dose limit is 1 mSv per year. This does not take account of natural radiation or radiation used for medical purposes. The European directive of 1998 on drinking water stipulates moreover that the total annual dose resulting from the ingestion of drinking water must not exceed 0.1 mSv.

INTRODUCTION

The radiological monitoring of the territory constitutes "environmental screening", so to speak. It is hoped that nothing will be measured or, to put it more precisely, nothing significant. And this is what is actually observed most of the time: artificial radioactivity is much lower than natural radioactivity, with measurements and analyses only revealing extremely weak levels – traces – of radioactivity.

Year after year, this monitoring shows that the radiological situation for Belgium is in general terms excellent. It also reflects the efforts, undertaken by the operators of facilities carrying out activities likely to have a radiological impact on the environment, to reduce these impacts. The operators are not only required to do everything to ensure that their discharges remain below the authorised limits but must also limit their releases to a minimum level (ALARA-principle). By doing this, the operators do not entail a radiological burden for the public.

The radiological monitoring of the territory comprises two complementary parts:

- *Global monitoring of the territory* outside the zones where significant nuclear activity is carried out. It indicates, in particular, the level of radioactivity to which the population is naturally subjected. It particularly covers zones far away from nuclear sites such as the coastal region as well as the so-called "reference" zones such as the Brussels conurbation, which is the largest urban area in Belgium with 10% of the population (and the region of Vielsalm programmed in 2007);
- *Close monitoring around sites* where an activity liable to have a radiological impact on the environment is carried out. This essentially concerns the following sites:

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

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

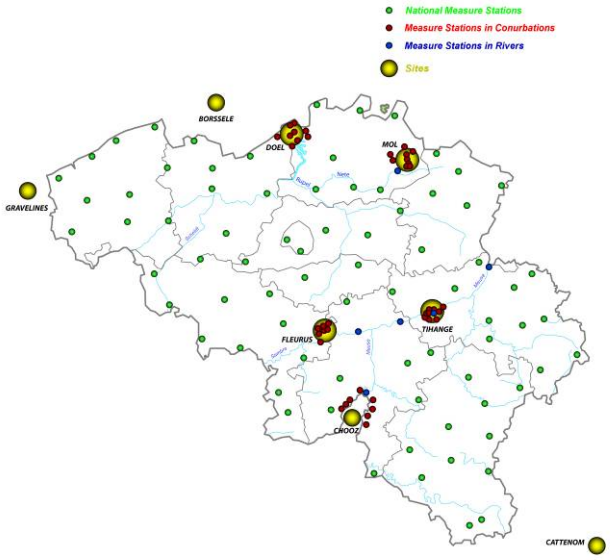
  1. ensuring that the legal and regulatory provisions concerning environmental contamination remain respected,
  2. checking through the control of discharges into the environment that these comply with the standards and authorised limits,
  3. if necessary, assessing the potential doses received by particular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

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

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

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

The TELERAD network is primarily *a measurement and early warning network.* Its 219 radioactivity measuring stations constantly measure the overall radioactivity of the air, atmospheric dusts and river waters (Meuse, Sambre and Molse Nete). These stations are linked to a centralised system which they alert automatically if they detect any abnormal rise in radioactivity levels. The TELERAD network is supplemented by meteorological masts (10 meters and 30 meters) that measure wind speed and direction and by a set of mobile measuring stations that can be deployed at any location on the territory.



In the event of a nuclear accident, the discharge of radioactive substances into the atmosphere could lead to the launch of the nuclear emergency plan foreseen by the authorities. The TELERAD network would then play a crucial role in assessing the gravity of the accident, taking decisions, optimising interventions and measures to be implemented to avert the effects of the accident and, subsequently, to remedy them, as well as informing the population on an ongoing basis.

In normal circumstances, the TELERAD network measures the ambient dose rate due to gamma radiation. This dose rate is linked to the level of natural radioactivity, also called background radiation.

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

The samples are taken for the Agency by specialised teams from SCK•CEN and IRE-Elit. The frequency of sampling has been defined in such a way as to be in possession of information that is as useful as possible, while taking account of technical and material constraints. The samples are then analysed in the laboratories of these institutions in order to determine the nature and level of radioactivity contained in them in very precise terms.

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

Between 2002 and 2004, the Agency reviewed its entire sampling and measurement programme in order to completely harmonise it with international requirements. The 1998 European directive on drinking water had imposed stronger controls, with new requirements in terms of control and 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 relies on more or less 5,000 samples annually, which are subjected to almost 29,500 alpha, beta and gamma radioactivity analyses. In relation to the Belgian population and nuclear installations, the scope of this programme is within the average of the programmes of other countries with nuclear power stations, such as the United Kingdom and France.

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

This report summarises the results of the monitoring programme obtained for 2010. After a short introduction to the TELERAD network and the key concepts of the radiological monitoring programme, it gives a summary of the radioactivity measurements carried out in:

- the Meuse and Sambre basins;
- the Scheldt and Nete basins;
- the maritime zone;
- the 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. The historical impact of installations in operation plants generating a supply of natural radioactivity in the environment is also treated. The raw data are available on request, as are reports specific to the radiological monitoring of the food chain.

SUMMARY

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 radioelements 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 almost 5,000 samples giving rise to more or less 29,500 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 (^{226}Ra). 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 ^{226}Ra. On the other hand, the – measurable – radiological impact of these installations in the north-east of the country has declined sharply in recent years.

1. THE CONTINUOUS RADIOLOGICAL MONITORING OF THE TERRITORY: THE TELERAD NETWORK

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.

1.1 OBJECTIVES OF THE NETWORK

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.

1.2 TELERAD: RADIOLOGICAL INSTRUMENT

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).

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.

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.

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.

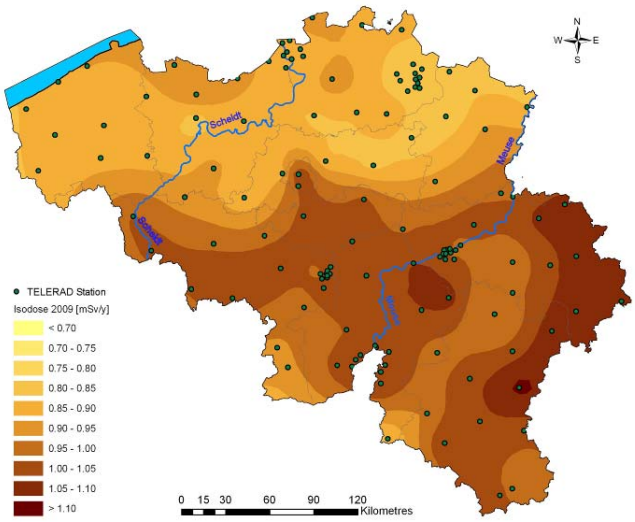
1.3 TELERAD: METEOROLOGICAL INSTRUMENT

Along the borders and around nuclear sites, TELERAD also has 9 meteorological measuring instruments (wind speed and direction) installed on 10 m masts. There are also 4 additional 30 m meteorological masts located near the nuclear sites (wind speed and direction, pluviometry, sunshine) – photograph on the left.

These data are essential to detect quickly the origin of any foreign source of radioactivity and, depending on the wind speed and direction, to forecast what regions may be over-flown by a radioactive cloud and at what time this will happen.

Finally, the TELERAD network is supplemented by a set of 24 mobile stations for the measurement of ambient gamma radioactivity. These stations can be installed in places to be subjected to more detailed examination.

1.4 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 1mSv/year, that it varies from 0.7 mSv/year in the north to 0.9 mSv/year overall in Flanders and 1.1 mSv/year overall 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).

2. UNDERSTANDING THE TERRITORIAL RADIOLOGICAL MONITORING PROGRAMME

2.1 ORIGIN OF THE RADIOACTIVITY MEASURED IN BELGIUM

The radioactivity that can be measured in Belgium and everywhere in the world has two origins: a *natural* origin and an *artificial* origin.

Natural radioactivity is due to *cosmic radiation* itself, which comprises two components: a relatively constant component, the primary galactic radiation consisting of very energetic particles – 85% protons, 12.5% helium and 1% heavier atoms such as iron and nickel, 1.5% electrons and a variable, the solar radiation or the solar wind which follows an eleven year cycle and which also fluctuates randomly when there are big solar flares that release an important flow of lower energy particles which can also reach the Earth.

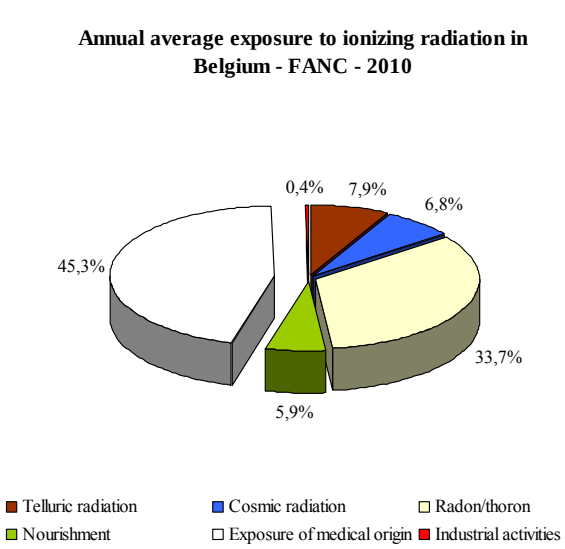
All these particles pass through the high layers of the atmosphere which partially "filter" them in order to reach the ground and living organisms and create a family of so-called "cosmogenics" such as ^{7,10}Be, ^{32,33}P, ^{22}Na, ^{35}S, ^{39}Cl, ^{26}Al, ^{14}C and ^{3}H.

This natural radioactivity also has a terrestrial component: *telluric radiation* which is generated by natural radioelements present in the ground and underground water such as:

- The primary constitutive elements of the solar system, i.e. namely radioelements with very long physical periods or half-lives (time required for half of the radioactivity to disappear) such as ^{235,238}U, ^{40}K, ^{232}Th, ^{187}Re, ^{138}La, ^{147}Sm, ^{190}Pt;
- The elements brought about directly or indirectly by nuclear reactions due to the incidental cosmic radiation, such as ^{239}Pu, ^{237}Np, ^{30}Cl, ^{90}Sr and other fission products generated by the neutrons (and the 'cosmogenic' elements referred to previously, generated by the cosmic radiation itself).

In addition to this natural radioactivity, there is artificial radioactivity generated by human military, industrial, research and medical activities. A number of these activities are carried out in Belgium:

- The nuclear industry (including that located abroad but situated close to our borders, such as Gravelines, Chooz and Cattenom the nuclear power stations in France and Borssele in the Netherlands) represented by the nuclear power stations of Doel on the Scheldt (four power reactors) and Tihange on the Meuse (three power reactors), as well as the facilities of Belgoprocess 1 and 2, Belgonucléaire, FBFC international and IRE;
- The NORM industry such as the facility producing feed phosphates at Tessenderlo;
- Nuclear research in laboratories such as those of SCK•CEN and universities;
- In recent years, the radiological services (and in a lesser extent the nuclear medicine) in hospitals are mainly responsible for the increasing part of the average exposure of the population, particularly among the older age groups in Belgium, rising from a typical 25 %-30 % around the year 1995 to more than 45 % at the year 2006 and following (2.1 mSv/year).



The entirety of this radioactivity is responsible for the overall exposure of people living on the territory of Belgium (5.06 mSv/y). This exposure or dose – expressed in mSv – is essentially due to natural radioactivity and exposures of medical origin. Each state has a duty to monitor the levels of natural and artificial radioactivity to which its population is potentially subjected. This obligation is clearly specified in the legal texts defining the legal and regulatory framework applicable in Belgium.

2.2 LEGAL AND REGULATORY FRAMEWORK

The legal and regulatory framework applicable in Belgium with regard to radiological monitoring of the territory comprises two parts: the national legal framework and the European regulatory framework. The obligations associated with these frameworks have a direct impact on the direction assigned to the programme for radiological monitoring of the territory as well as on its scope. In both cases, the federal authority FANC is responsible for implementing all the means necessary to meet the regulatory requirements.

2.2.1 National legal framework:

The Federal Agency for Nuclear Control (FANC) is a public body endowed with a legal personality (category C public interest institution), established by the law of 15 April 1994 *on the protection of the population and the environment against the dangers resulting from ionising radiation and relating to the Federal Agency for Nuclear Control* (Articles 21 and 22). This statute grants it broad independence, which is essential for exercising impartially its responsibilities towards society.

The FANC has been fully operational since 1st September 2001, with the royal decree of 20 July 2001 concerning the *General regulations for the protection of the population, workers and the environment against the dangers of ionising radiation (GRPIR)* coming into force on that date. This decree renders the implementation of the law of 15 April 1994 effective and specifies the conditions and modalities for the execution of the Agency's duties. It comprises the greater part of the Belgian regulations with regard to protecting the population and environment against the dangers of ionising radiation.

Under the decree, the Agency 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 cooperation agreement of 8 September 1998, relating to the Chooz nuclear power station situated on the Meuse in France close to the border with Belgium, provides for ensuring the full monitoring on Belgian territory of all the ways of radioactivity transfer around the nuclear site as well as the periodic exchange of results between states.

The articles 4 and 9 of the GRPIR define the regulative framework concerning the "professional activities involving natural radiation sources" (NORM industries). On the basis of these articles, FANC can require a follow up of the environmental impacts of certain sectors of the NORM industry.
The article 72bis of the RGPRI on *interventions and lasting exposures* defines the regulative framework for sites historically contaminated by radioactive substances. This article gives the FANC the task to assure the possible implementation of a surveillance of the related exposures.

2.2.2 International legal framework:

European Commission:

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

This covers the new provisions on monitoring the food chain resulting from the post-Chernobyl protection measures, post-Fukushima as well as the 2000/473/EURATOM[2] recommendation concerning Article 36 of the EURATOM treaty, which stipulates under point 4 that the Member States must communicate to the Commission the data necessary for monitoring radioactivity in the "mixed regime" in order to obtain overall information on the ingestion of radioactivity by humans through the food chain and, thus, on the doses released.

Belgium will also need to deal quickly with the obligation to control a large number of catchments, springs, etc.. for the production of drinking water, particularly in Wallonia. Indeed, the EC decided to treat the aspects "radioactivity" in the context of the EURATOM Treaty through a new Council Directive - specific - which should come into force during 2012. The technical annexes dealing with radioactivity, completed for many years, are directly incorporated into this new Directive as well as radon and its decay products with a long half-life (^{210}Po and ^{210}Pb). Natural spring waters, bottled and those distributed in large packages (fountains, cubitainers, ...) are included in the Directive. The former Directive 98/83/EC of 3 November 1998 will be renewed but will deal only with aspects of biology and chemistry of drinking water.

The mandatory transposition in national legislation (RGPRI) of the new Council Directive on the quality of water intended for human consumption is going to make official the control and monitoring of the radiological quality of water intended for human consumption.

OSPAR (OSlo-PARis) Convention:

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

[2] *Commission recommendation on the application of Article 36 of the EURATOM treaty concerning the monitoring of levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole*

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

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

The first ministerial meeting of the OSPAR Commission in Sintra, Portugal in 1998 adopted Annex V to the Convention in order to extend the co-operation of the contracting parties and to cover all human activity which could harm the marine environment of the North-East Atlantic. However, programmes and measures on fisheries management issues cannot be adopted under the Convention.

The OSPAR declaration on the protection of the North Sea and the North-East Atlantic signed in Sintra on 23 July 1998 provides for a drastic reduction in radioactive discharges into the marine environment in order to achieve concentrations "close" to zero for artificial radioactivity and "near" background levels for added natural radioactivity on account of human industrial activity.

It should also be taken into account that the European Commission is increasingly supportive of the OSPAR strategy to the extent that, among other things, it urges the Member States to invest in fundamental research programmes concerning the impact of radioactivity in the marine environment (flora, fauna and humans) and it has very recently adopted the idea of an overall marine strategy (concerning all European seas), particularly for radioactivity, which in this case embraces the OSPAR objectives in full.

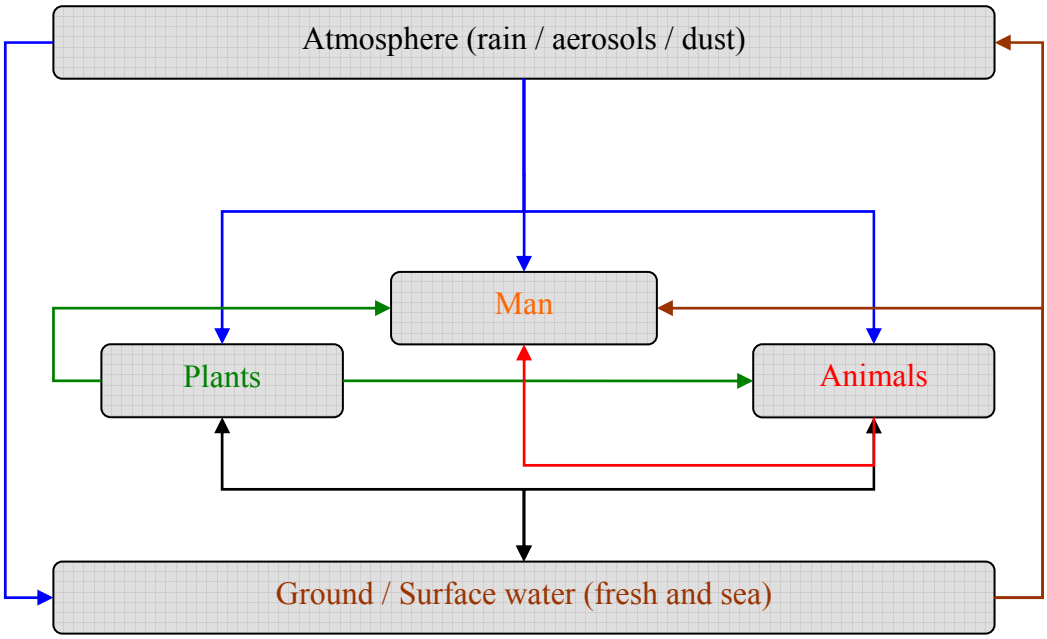
Finally, the conferences of environmental protection specialists on ionising radiation held at the International Atomic Energy Agency (IAEA) since the end of 2001 have confirmed the trends expressed above once again.

2.3 PROGRAMME FOR THE RADIOLOGICAL MONITORING OF THE TERRITORY

The development of the legislative approaches described above has led to a broadening of the concept of radiological monitoring of the environment in the direction of protecting the environment itself including all its components (especially the marine environment) in addition to humans. To achieve this, the focus has switched away from the notion of the dose considered in radiation protection in favour of that concerning the concentration of radioactive elements, to be determined by a large number of measurements conducted on a very broad sample of components of the environment (air, water, soil, living beings).

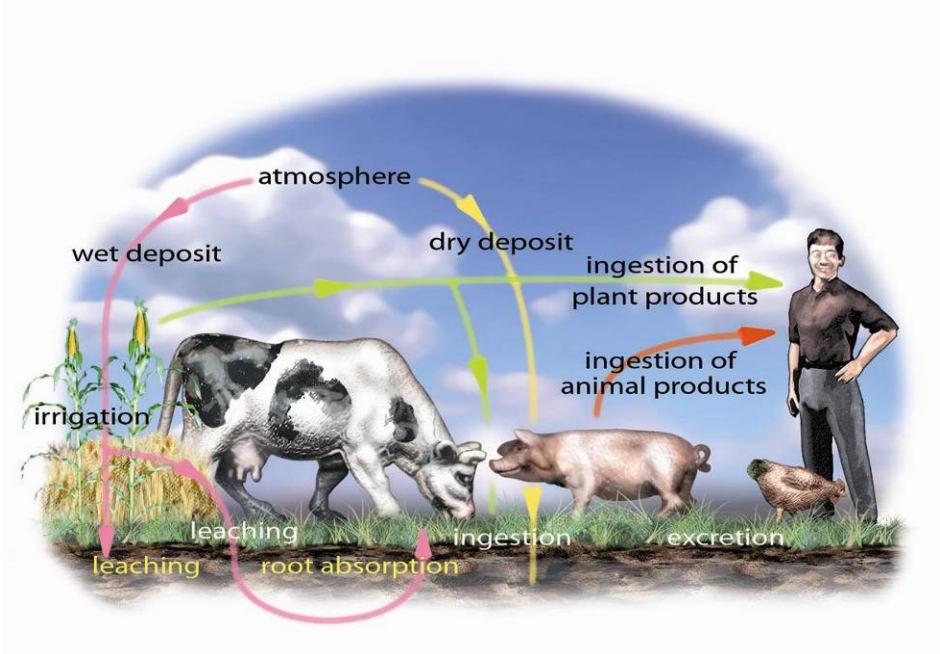
As already explained, the radiological monitoring of the territory is carried out through a programme of radiological surveillance relying on sampling and analyses (measurements of radioactivity) as well as the automatic TELERAD network, which essentially conducts measurements of dose rates at fixed points. These major means of monitoring are organised in such a way as to cover the entire territory and permit the exposure of the population to be monitored according to the various possible ways of exposure.

As illustrated by the following simplified diagram, natural and artificial radioactivity can circulate in the environment by passing from one area to another to finally reach a person through inhalation, ingestion or contamination through wet or dry deposits (rain, aerosols dust).



Depending on its chemical nature, this radioactivity is more or less concentrated in particular areas, e.g. in the clays (constituent of the soils, sediments) for the radiocaesiums which "follow" the movements of the potassium regarded as their "chemical analogue". In animals, the radiocaesiums tend to be concentrated in the muscles (meat). The radiostrontiums, for their part, follow their chemical analogue – calcium, and accumulate in the osseous structures of living beings.

The following diagram illustrates the path that radioactivity can follow to contaminate the food chain and people.



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

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

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

- In the surroundings of IRE: iodine (^{131}I) because it may be produced by this site;
- In the waters of the Sambre, Meuse and Scheldt: iodine (^{131}I) by virtue of their receiving waste water from the hospitals in the major urban areas adjacent to them;
- In the Molse Nete: transuranic elements – ^{234,235,238}U, $^{238,(239+240)}$Pu, ^{241}Am, in addition to the usual array of gamma emitters (fission and activation products including radiocaesiums) by virtue of this watercourse receiving liquid discharges from the nuclear installations of the Mol-Dessel site via the liquid waste treatment installations of Belgoprocess 2;
- In the Nete basin: ^{226}Ra by virtue of this stream draining the waters of the Grote Laak and Winterbeek where the Tessenderlo facility producing feed phosphates (NORM industry) discharges its process water enriched with radium;
- In milk and drinking water: ^{90}Sr (fission product originating in nuclear reactors and nuclear fuel reprocessing plants) to meet the requirements of Article 36 of the EURATOM treaty;
- In control meals: ^{14}C produced in nuclear reactors is always verified in the context of reporting to the EC under "Article 36" of the EURATOM treaty;
- In samples of marine fauna and flora (shrimps, mussels, seaweed): transuranic elements – ^{234,235,238}U, $^{238,(239+240)}$Pu, ^{241}Am, in addition to the usual array of gamma emitters (including radiocaesiums), ^{90}Sr, ^{99}Tc and organic ^{3}H as indicators of activities of the nuclear power industry – nuclear power and reprocessing plants – used nuclear fuel reprocessing plants – La Hague (France) and Sellafield (United Kingdom);
- Under Article 36 of the EURATOM treaty: natural "control" radioelements such as (cosmogenic) ^{7}Be required by the EC, ^{40}K present everywhere in the environment and in the human body (at a level of around 60 to 70 Bq/kg).

2.4 DESCRIPTION OF THE TERRITORIAL RADIOLOGICAL MONITORING NETWORK

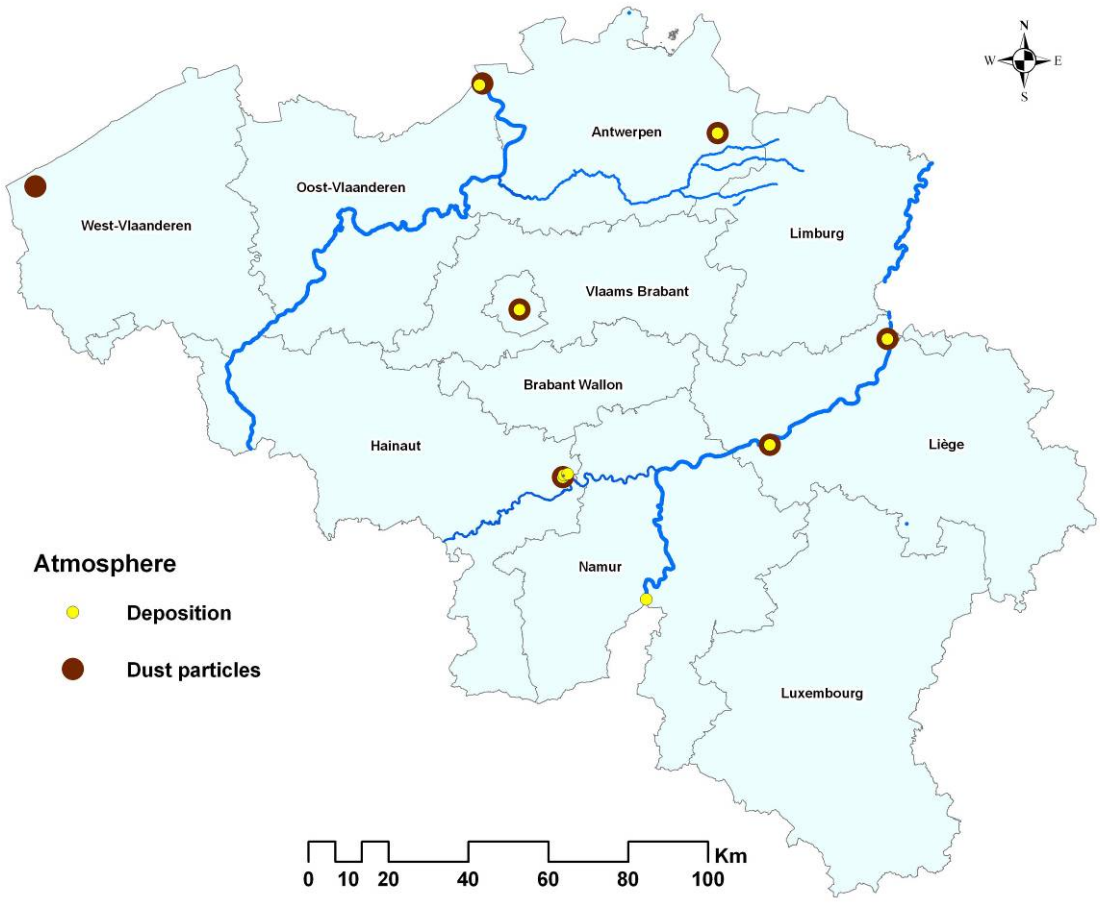
The monitoring network comprises a series of zones, i.e. locations where samples are taken and subsequently brought to the laboratory to be prepared and then measured to determine their level of radioactivity. More than 5,000 samples are taken each year on which around 29,500 radioactivity analyses are conducted.

2.4.1 The main lines of the network:

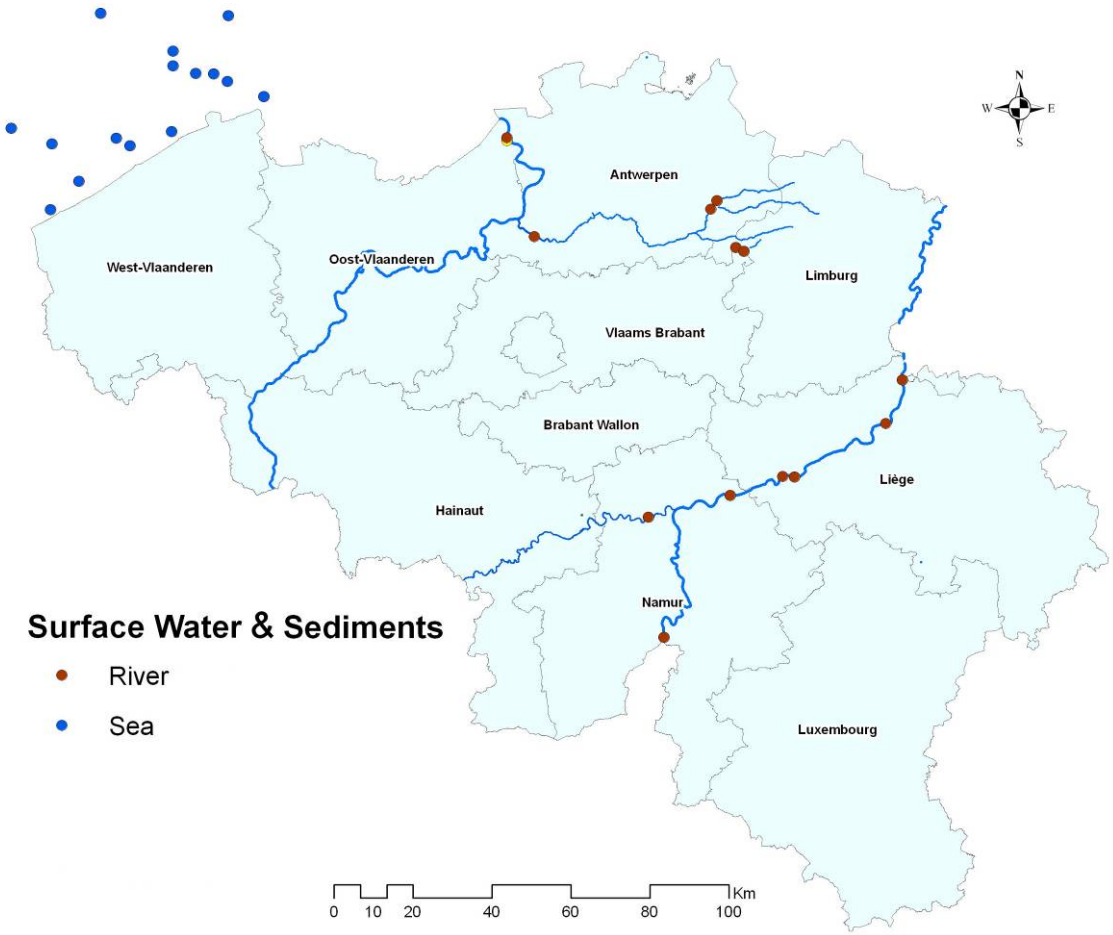
The main lines of the radiological monitoring network relate to:

- Monitoring the atmosphere in the vicinity of the nuclear sites and in the reference zone, in Coxyde (at the Nord Sea coast end the West coast of West-Flanders) and in Lixhe at the Meuse (nearby the border of The Netherlands) by means of sampling air dusts and surface deposits (dry and/or wet deposits which is respectively deposit of particles in tank collectors with known surface area containing a thin layer of water to trap the fine particles or deposit of the particles in those same tank collectors but via the rain);

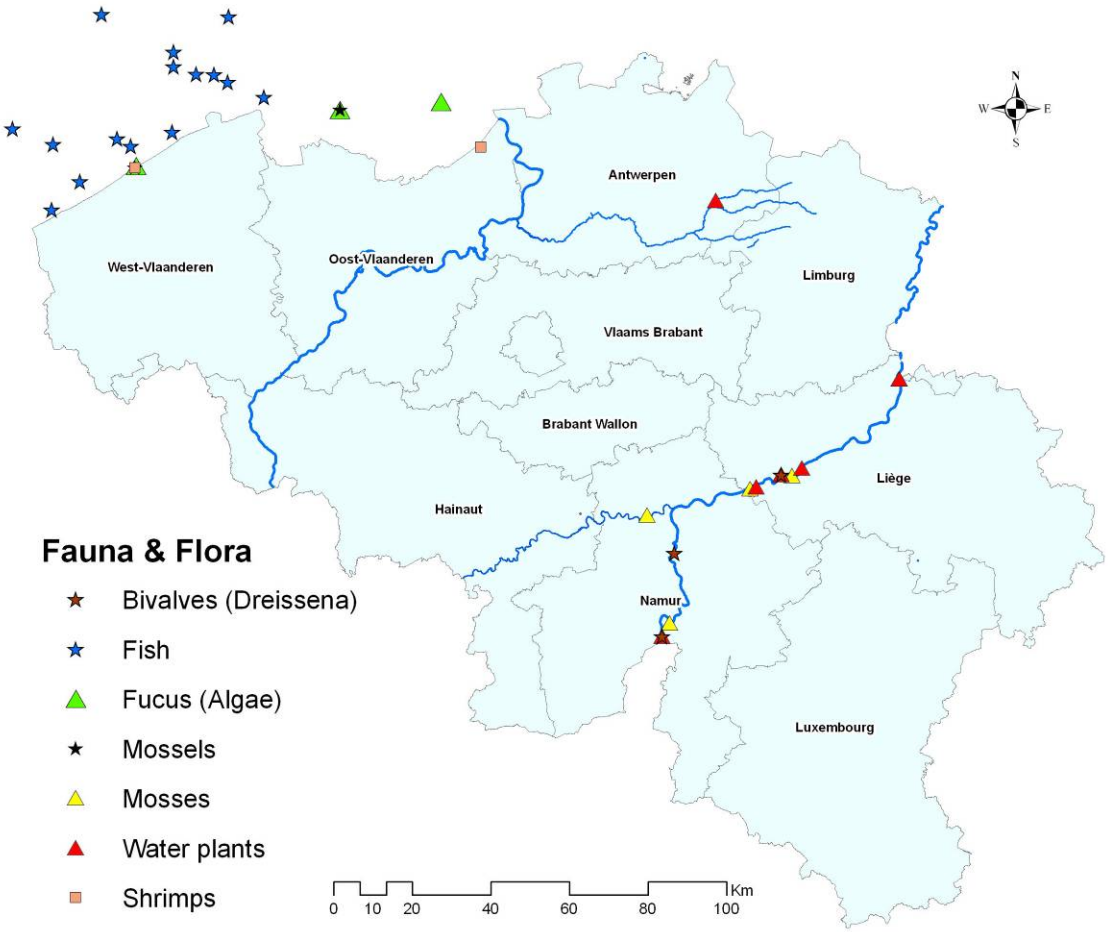
Sampling points for air dusts (brown) and precipitations (yellow)



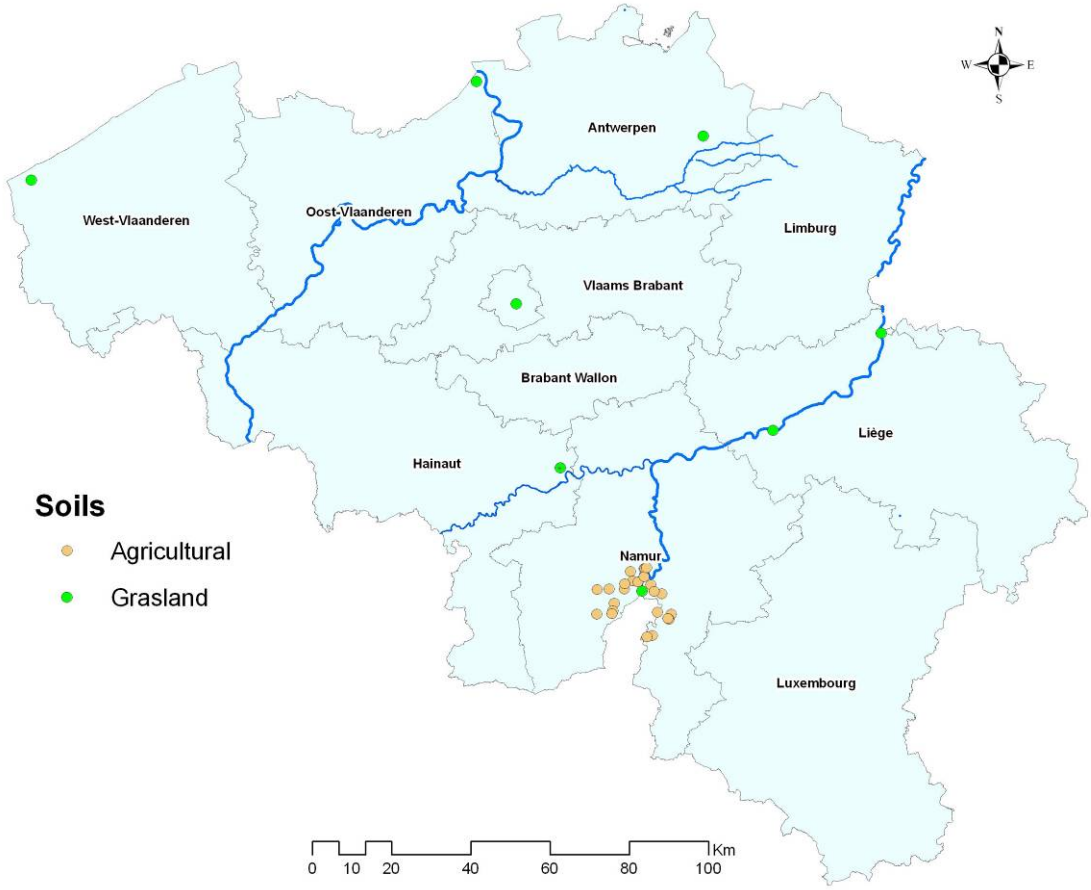
- Monitoring <u>surface water</u> and <u>sediments</u> in fresh – rivers (Sambre, Meuse, Grote Laak, Winterbeek, Molse Nete, Ruppel and Scheldt) and marine water – North Sea;



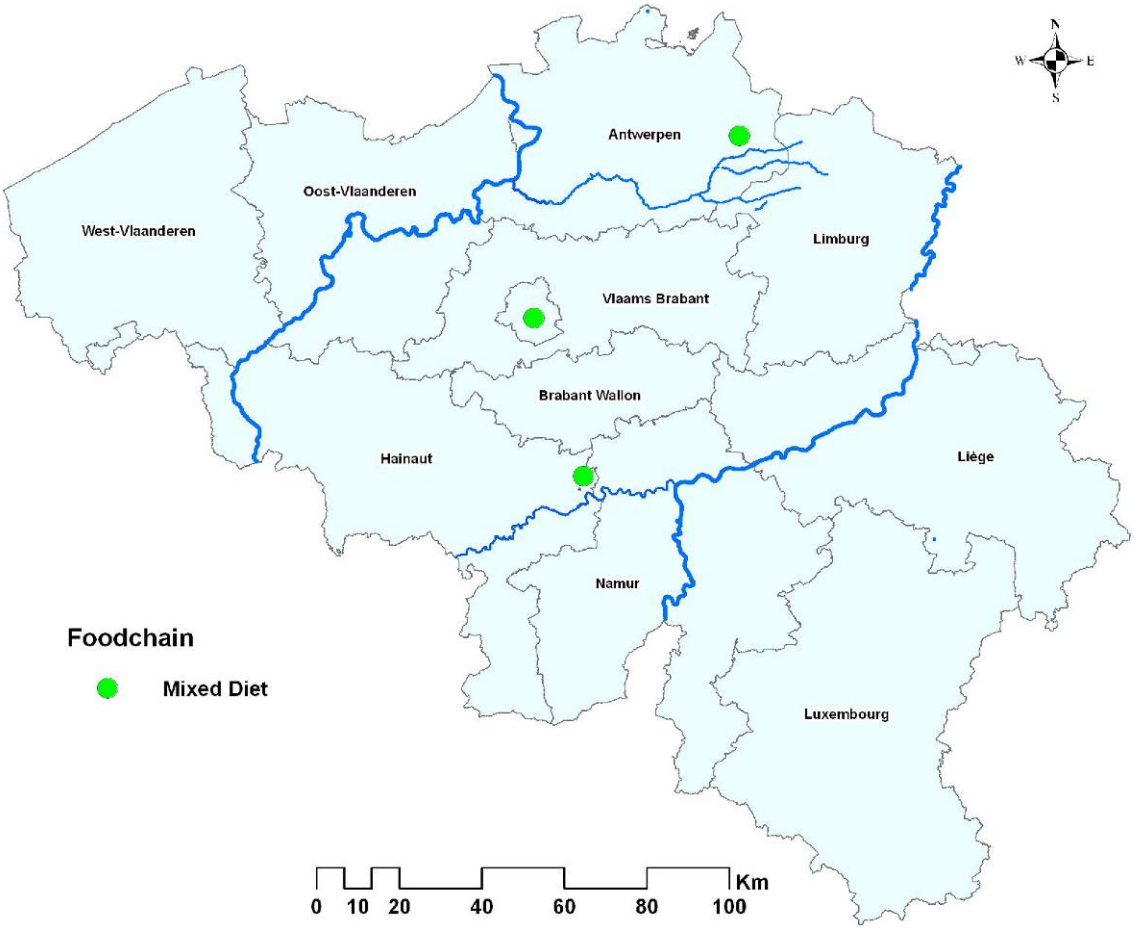
- Monitoring the living environment by searching for radioactivity in aquatic fauna and flora in fresh and salt water (bio-indicators of the presence of radioactivity);

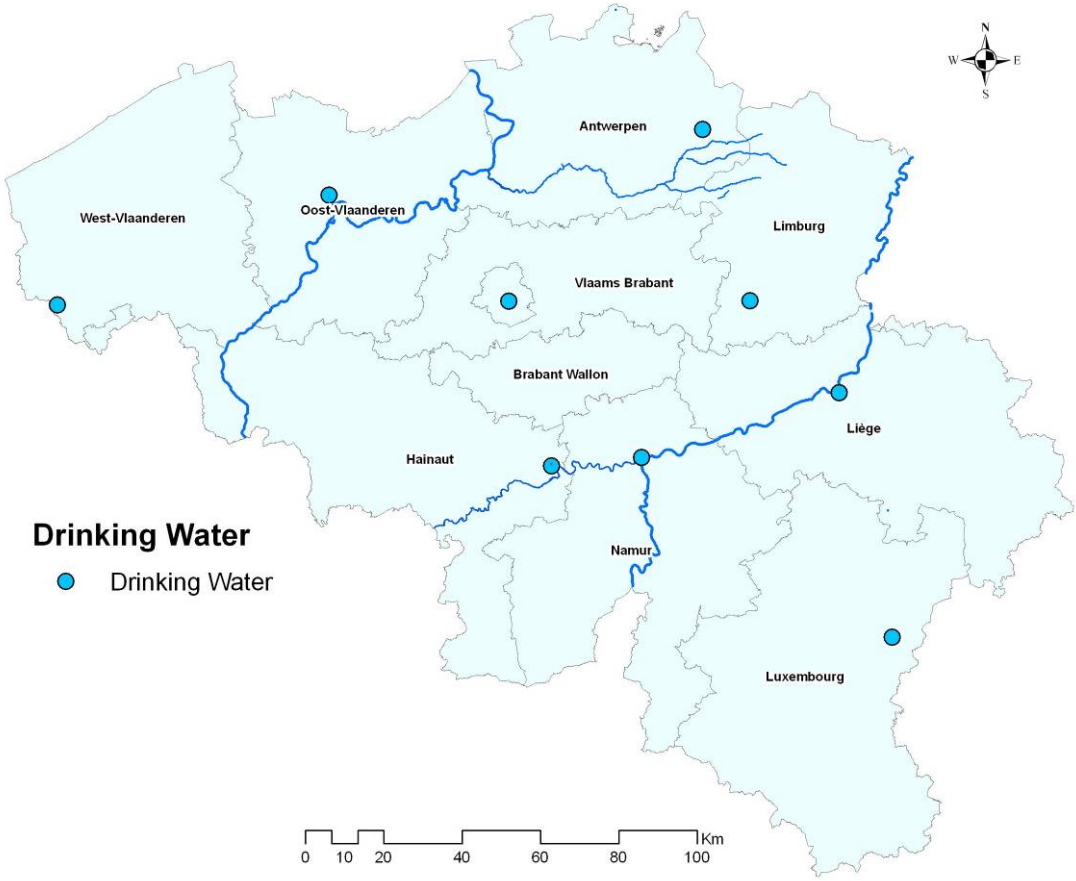


- Monitoring <u>terrestrial zones</u>, i.e. soils sampled in the immediate vicinity of nuclear sites and certain control regions (sea coast, Ardennes, Brussels Capital region);



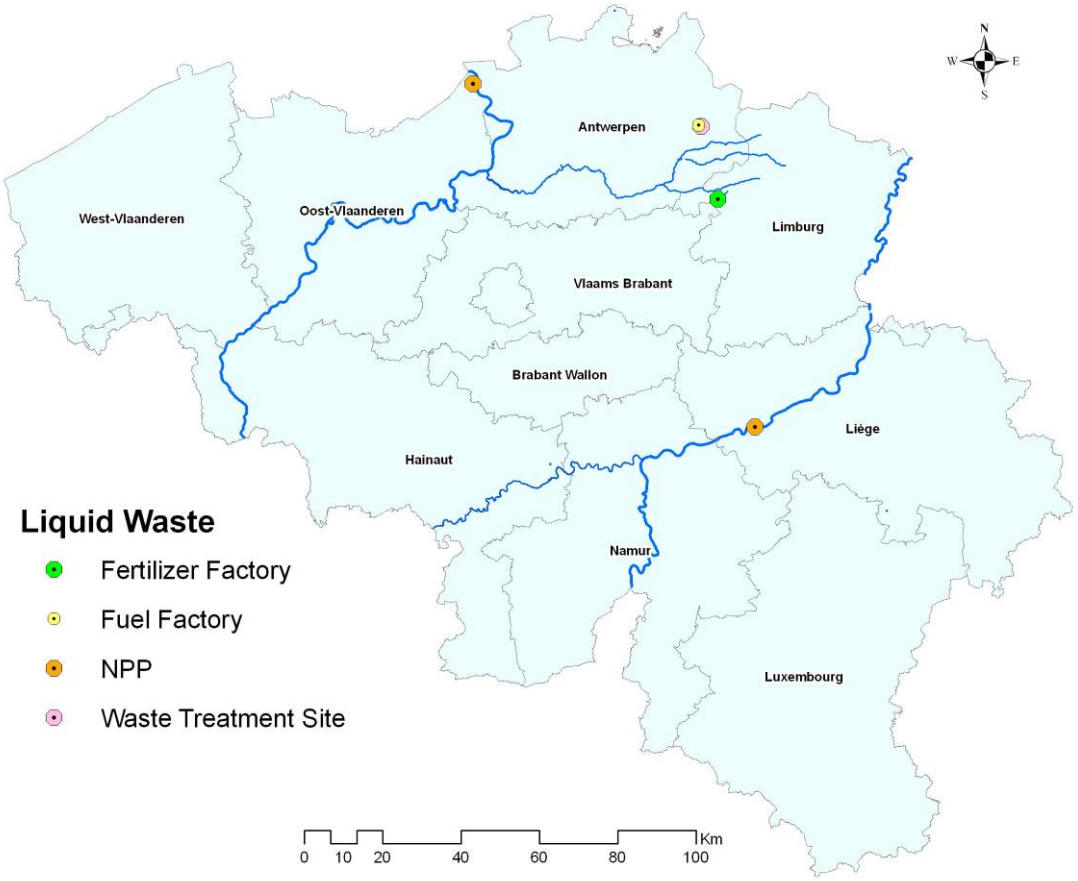
- Monitoring the food chain by checking milk (supermarkets and dairies which collect from a large number of farms, several thousands in Flanders and in Wallonia), drinking water and foodstuffs, with samples taken from markets and retail outlets and also a Belgian representative meals;





Drinking water sampling points

- Monitoring the atmospheric and liquid discharges of nuclear facilities (nuclear power stations, Mol-Dessel site) and NORM industries (Tessenderlo - discharges of ^{226}Ra);



The territorial monitoring programme has given priority to monitoring the possible major routes of contamination of the environment (river basins and maritime zone) as well as those of direct human contamination (food chain). All or part of the areas referred to above are monitored depending on the regions and the presence of nuclear or non-nuclear industries.

2.4.2 Vectors of transfer of monitored radioactivity

The radiological monitoring programme monitors a whole series of compartments in which samples are taken for analysing the radioactivity.

The following tables summarise the work carried out. The maps presented under 2.4.1 above localise the sampling locations set out in the tables.

The basin of the Meuse and the Sambre

This basin receives liquid discharges from several nuclear and non-nuclear sites:

- *Nuclear sites:*
  - ◊ Tihange nuclear power station (3 reactors) situated along the Meuse between Huy and Ampsin,
  - ◊ the IRE site at Fleurus close to the Sambre,
- *Non-nuclear sites:*
  - ◊ Hospitals of major urban areas such as Namur and Liege.

1,890 samples are taken from the overall basin, on which more than 7,800 measurements are conducted for radioactivity.

Radiological monitoring programme for the Sambre – Meuse basin

Zone		Basin and location of sampling points		Type of measurement	Frequency of sampling
		Sambre	Meuse		
Atmosphere	dusts	close to the IRE site (Fleurus)	close to the Tihange site Lixhe	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{95}Zr, ^{95}Nb, (^{131}I near to the IRE)	every 4 weeks
				Spectrometry total β: on paper filters after 5 days decay	daily
	surface deposits (tanks)	close to the IRE site (Fleurus)	Heer-Agimont close to the Tihange site Lixhe	Spectrometry γ (untreated water) : ^{7}Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{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
				^{131}I (filtered deposits) close to IRE	every 4 weeks

Radiological monitoring programme for the Sambre – Meuse basin (cont.)

Zone		Basin and location of sampling points		Type of measurement	Frequency of sampling
		Sambre	Meuse		
Soil	permanent meadow (superficial soil – 5 cm + grass cut short)	close to the IRE site (Fleurus)	close to the Chooz site close to the Tihange site Lixhe	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 ^{131}I close to IRE	Annually
	agricultural soils agricultural plant production		around the boot of Chooz (24 points)	Spectrometry γ, α, ^{90}Sr, ^{226}Ra Spectrometry γ, ^{90}Sr, ^{3}H, ^{14}C	Annually
River	water	Floriffoux	Heer-Agimont, Andenne, Huy, Ampsin, Monsin, Lixhe	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra Spectrometry β total, total α ^{3}H, ^{40}K, ^{90}Sr (^{131}I near to the IRE)	every 2 weeks
	sediments	Floriffoux	Heer-Agimont, Andenne, Ampsin, Lixhe	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, (^{131}I close to IRE)	every 4 weeks
	aquatic plants, mosses, bivalves	Floriffoux	Heer-Agimont/ Hastière/ Waulsort, Andenne, Huy, Ampsin/Amay, Lixhe	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 ^{3}H organic	quarterly

The basin of the Scheldt and the Nete

This basin receives liquid discharges from several nuclear and non-nuclear sites:

- *Nuclear sites:*
  - ◊ Doel nuclear power station (4 reactors) situated along the Scheldt near Doel,
  - ◊ SCK•CEN site at Mol,
  - ◊ sites of Belgoprocess, Belgonucléaire and FBFC International at Mol and Dessel,
- *Non-nuclear sites:*
  - ◊ Hospitals of large urban areas such as Antwerp,
  - ◊ Feed phosphates facility near Tessenderlo.

Near 1,050 samples are taken from the overall basin, on which around 5,350 measurements of radioactivity are conducted.

Radiological monitoring programme for the Scheldt – Nete basin

Zone		Basin and location of sampling points		Type of measurement	Frequency of sampling
		Scheldt	Nete		
Atmosphere	dusts	close to the Doel site	close to the Mol site	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb	every 4 weeks
				Spectrometry total α near Mol	daily
				Spectrometry total β: on paper filters, after 5 days decay	daily
	surface deposits (tanks)	close to the Doel site	close to the Mol 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	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 (superficial soil – 5 cm + grass cut short)	close to the Doel site	close to the Mol 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	Annually
				Spectrometry α: $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am near Mol	
River	water	near Doel	Grote Nete Molse Nete	Spectrometry γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra	every 2 weeks
				Spectrometry total β , total α, ^{3}H, ^{40}K	
			Grote Laak & Winterbeek	Spectrométrie γ: ^{7}Be, $^{134\text{-}137}$Cs, $^{141\text{-}144}$Ce, $^{103\text{-}106}$Ru, ^{95}Zr, ^{95}Nb, ^{226}Ra	every 2 weeks
				Spectrométrie β total, α total, ^{40}K	
			Ruppel (Boom)	Spectrometry γ: ^{226}Ra	every 4 weeks
	sediments	near Doel	Grote Laak & Winterbeek Grote Nete	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	every 4 weeks
			Molse Nete	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	every 4 weeks
				^{90}Sr, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am	
	aquatic plants		Molse Nete	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	quarterly
				^{90}Sr, $^{234\text{-}235\text{-}238}$U, $^{238\text{-}(239+240)}$Pu, ^{241}Am, ^{3}H organic, ^{99}Tc	
	shrimps	estuary downstream from Doel (Kieldrecht)		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	quarterly
	bivalves, seaweeds	estuary/North Sea (Hoofdplaat & Kloosterzande)		^{90}Sr, $^{238\text{-}(239+240)}$Pu, ^{241}Am, ^{3}H organic, (^{99}Tc for seaweed)	

The maritime zone: Belgian coastal region

The coastal region receives liquid discharges from several nuclear and non-nuclear sites:

- *Nuclear sites:*
  - ◊ Gravelines power station located in France near the sea between Calais and Dunkirk, La Hague reprocessing plant;
- *Non-nuclear sites:*
  - ◊ Hospitals in urban areas such as Ostend.

Close to 450 samples are taken from the overall maritime zone, on which around 1,850 measurements are conducted for radioactivity.

Radiological monitoring programme for the maritime zone

Zone		Location of sampling points	Type of measurement	Frequency of sampling
Atmosphere	dusts	Coxyde	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{95}Zr, ^{95}Nb	every 4 weeks
			Spectrometry total β: on paper filters after 5 days decay	daily
Soil	permanent meadow (superficial soil – 5 cm + grass cut short)	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: $^{134\text{-}137}Cs$, $^{57\text{-}58\text{-}60}Co$, ^{54}Mn	quarterly
			^{40}K	
			Spectrometry β total & α total	
			Spectrometry α: $^{238\text{-}(239+240)}Pu$	
	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	quarterly
			Spectrometry α: $^{238\text{-}(239+240)}Pu$	
	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	quarterly
			^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic, ^{99}Tc	
	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	quarterly
			^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic	
	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	quarterly
			^{90}Sr, $^{238\text{-}(239+240)}Pu$, ^{241}Am, ^{3}H organic, ^{99}Tc	

The reference zone: the region of Brussels Capital

The choice of reference zones is dictated by the wish to situate these sampling stations on Belgian territory in a geographic situation that shields them from potential discharges of artificial and/or natural radioactivity resulting from human activities. On the other hand, a criterion like population density is also important.

Within this framework, the Brussels urban area has been selected as a representative zone. This area contains a large part of the population with one million inhabitants ($1/10^{th}$ of the total Belgian population).

Close to 390 samples are taken, on which around 630 measurements are conducted for radioactivity.

Radiological monitoring programme for the reference zone of Brussels Capital

Zone		Location of sampling points	Type of measurement	Frequency of sampling
Atmosphere	dusts	Brussels	Spectrometry γ: ^{7}Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{95}Zr, ^{95}Nb, (^{131}I near to the IRE)	every 4 weeks
			Spectrometry total β: on paper filters after 5 days decay	daily
	surface deposits (tanks)	Brussels	Spectrometry γ (untreated water) : ^{7}Be, $^{134\text{-}137}Cs$, $^{141\text{-}144}Ce$, $^{103\text{-}106}Ru$, ^{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 (superficial soil – 5 cm + grass cut short)	Brussels	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

The food chain: drinking water, milk and foodstuffs

The monitoring of the food chain attempts to assess all the routes enabling the entry of radioactivity into humans as extensively as possible. This monitoring addresses:

- The radiological state of drinking water (national and European obligations – Directive 98/83/EC) is of primary importance;
- The radiological state of milk, which also constitutes a potentially sensitive vector in the case of radioactive contamination, especially in relation to the presence of ^{131}I, which passes rapidly from the grass to the cow to the milk – an important food in the diet of young children. Since the milk distribution chain is a rapid one, the iodine is quickly ingested by the population with the associated risks of irradiation of the thyroid;
- The radiological state of foodstuffs by means of ad hoc but varied sampling of products intended for consumption (plant and animal foodstuffs, etc).

The national territory can potentially be contaminated by all the nuclear and non-nuclear sites mentioned previously as well by illicit import of foodstuff originating from countries touched by the Chernobyl accident.

More than 860 samples are taken, on which close to 7,430 measurements are conducted for radioactivity. Added to these samples are those taken by the FASFC (Federal Agency for Safety of the Food Chain) within the framework of the co-operation between the two Agencies. Around 207 samples and 621 additional measurements are conducted in this frame.

Radiological monitoring programme for the food chain

	Zone	Location of sampling points	Type of measurement	Frequency of sampling
Drinking water	mains (tap)	Brussels (Brabant) Liège (Liege) Namur (Namur) Fleurus (Hainaut) Bastogne (Luxembourg) Ghent (East Flanders) Poperinge (West Flanders) Mol (Antwerp) Zepperen (Limburg)	Spectrometry total α & total β , ^{3}H, ^{40}K Where screening values are exceeded by 0,1 Bq/l in total alpha and 1 Bq/l in total beta, complete spectrometry analyses (γ, α, β)	quarterly
Milk	dairies/farms	Brussels region (Brabant) 1 farm Fleurus region 75 dairies Tihange region 118 dairies Doel region 1 dairy Dessel region1 1 dairy Chooz region 42 dairies	Spectrometry γ: of which $^{134\text{-}137}Cs$, ^{131}I, ^{40}K ^{90}Sr	weekly every 4 weeks
Foodstuffs	vegetables meat fish various (mushrooms, flour, etc.)	national territory among small and large scale retailers	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
	control meal	company canteens: Mol (SCK•CEN), Fleurus & Brussels (CARREFOUR)	Spectrometry γ: of which $^{134\text{-}137}Cs$, ^{40}K ^{90}Sr and ^{14}C	monthly quarterly

Monitoring discharges from nuclear sites

The monitoring programme also implements a network for measuring effluents from treatment plants for liquid waste discharged into the environment. These samples are taken by the operator as well as by the body commissioned by the Agency to measure radioactivity.

The nuclear power sites (Doel and Tihange), the Mol-Dessel sites (Belgoprocess 2 – the liquid waste treatment plants of SCK•CEN, Belgoprocess, Belgonucléaire – and FBFC) are under this monitoring programme. As the IRE site does not release radioactive liquid waste to the environment, it has not been included in this monitoring in the past.

Close to 300 samples are taken, on which around 5,430 measurements are performed.

Radiological monitoring programme for following up discharges from nuclear sites

Nuclear site concerned	Type of measurement	Frequency of sampling
Tihange power station Doel power station	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	monthly
FBFC site	Spectrometry total β, total α ^{226}Ra, $^{234-235-238}U$, $^{238-(239+240)}Pu$, ^{241}Am	weekly
Mol-Dessel site (Belgoprocess 2)	Spectrometry γ: $^{134-137}Cs$, ^{54}Mn, $^{(57)-58-60}Co$, ^{131}I Spectrometry total β, total α ^{3}H, ^{90}Sr, $^{234-235-238}U$, $^{238-(239+240)}Pu$, ^{241}Am	weekly

Monitoring discharges from NORM industries

The discharges of the Tessenderlo Chemie site (fabrication of feed phosphates) in the Winterbeek are regular monitored at the vicinity of the discharge release point and this on a weekly basis.

Around 52 samples are taken, on which more than 830 measurements are conducted for radioactivity.

Radiological monitoring programme for following up discharges from NORM industries

NORM site concerned	Type of measurement	Frequency of sampling
Tessenderlo Chemie	Complete γ spectrometry ^{226}Ra, $^{234-235-238}U$, ^{40}K	weekly

3. THE BASIN OF THE MEUSE AND THE SAMBRE

The Meuse and the Sambre receive radioactive discharges from several nuclear (3 power reactors at Tihange, IRE at Fleurus) and non-nuclear sites (hospitals in big urban areas such as Namur and Liege).

As already pointed out in chapter 2 point 2.4, a whole range of samplings is carried out in this region:

- Atmospheric category: taking samples of dusts in the air (aerosols and particles deposited on filters), rain and dry or wet deposits close to the IRE, Tihange and Lixhe, harvesting of precipitation (wet and dry deposition) in the same places as the dust from the air but also near the site of French nuclear Chooz (Heer-Agimont just at the Franco-Belgian border);
- Soil category: sampling near the Tihange and IRE nuclear sites as well as in the Belgian agricultural zones around the boot of Givet (Chooz nuclear site);
- River category: water, sediments and samples of fauna and flora from the Sambre and Meuse.

Generally:

The results obtained show that, apart from tritium, which is regularly in evidence in the waters of the Meuse, the radiological situation of the basin does not call for any particular comments.

More precisely:

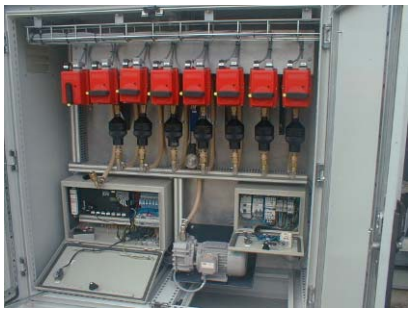
- The air in Belgium and, in particular, around nuclear installations does not present any radiological problem. The levels measured are all lower or close to the – very low – detection thresholds of the measuring equipment;
- The measurements of the radioactivity of rain show that very small quantities of radioactivity (mainly due to natural radioactivity) can be detected by virtue of the very low detection thresholds reached by the measuring equipment;
- The impact of nuclear facilities on river water is negligible and without consequence for human health;
- Only tritium is regularly detected in the Meuse water (a few dozen Bq) and as far as the other radioelements are concerned, usually the levels reported are barely higher than the detection thresholds of the measuring equipment.

3.1 ATMOSPHERIC RADIOACTIVITY

Analysing air dusts is an effective method of detecting any discharge of radioactive substances into the atmosphere. Aerosols (particles > 0.5 µm), which are one of the forms of atmospheric discharge from nuclear facilities, essentially contain fission products (β emitters) re-condensed on a particle nucleus.

This method of detecting radioactivity of the air was especially used for monitoring atmospheric nuclear tests when they were practised ("fallout") as well as for following-up the passage of radioactive clouds after the Chernobyl accident.

Dusts can be deposited directly on the ground (dry deposit) or washed out by the rain (wet deposit).



The collect of air dusts is realized by using pumps, air is passing through a filter which impacts dusts on a filter (photo on the left – automatic system and on the right – manual one).

Dusts are also sampled in deposit tanks where they are trapped via a thin layer of water spread over a known surface area (photo on the right).

All these apparatus represents important and complementary elements of a radiological monitoring network.

Indeed, rains which wash the atmosphere are a good means of checking the quality of the ambient air as well as its possible radioactive contamination.

The following table summarises all the results obtained for the sections of the atmosphere studied close to the nuclear sites of IRE, Tihange site and of a "control site" - Lixhe - located away from any nuclear facility near the border with the Netherlands: dust from the air and rain collected in deposit tanks, as near of the nuclear site of Chooz (Heer-Agimont Belgium) with measurements of precipitation collected in deposit tanks.

These controls, conducted close to the IRE, Tihange and Chooz (Heer-Agimont at the French-Belgian border on the Meuse) nuclear facilities show that the radiological situation of the air is excellent in the vicinity of these sites.

Radioactivity measurements of the atmosphere (air and rain) in the Sambre – Meuse basin

	Air dusts (Bq/m^3)		Deposit tanks (Bq/m^2)	
	measurement	DL	measurement	DL
γ	NM	~ 10^{-5} ~ 2 10^{-5} → ^{134,137}Cs ~ 2 10^{-4} → ^{106}Ru	NM	< 5 1,8 to 4,0 → ^{134,137}Cs 20 to 35 → ^{106}Ru
^{7}Be	(2 to 9) 10^{-3}		NM (traces)	20 to 50
β total	(0.5 to 1.3) 10^{-3}	0.5 to 2 10^{-3}	0,5 to 22,0 (filtrate) 1,2 to 6,0 (filter deposits)	0,6 to 2,0 0,9 to 1,5
^{131}I		0.4 to 4 10^{-1}	NM Fleurus NM Tihange, Heer-Agimont, Lixhe	6 to 9 20 to 26
^{3}H	-	-	NM 250 to 650 (IRE – Mediris en janvier/février)	distillat : 50 to 80
α total	-	-	traces : 0,6 to 4,6 (filtrate) Traces : 0,8 to 7,0 (filter deposits)	0,7 to 1,2 0,9 to 1,5

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

In greater detail:

- Natural radioactivity is mainly responsible for the – very low – level of radioactive contamination of the atmosphere. The ^{7}Be (cosmogenic natural radioelement) sought at the request of the EC – Art. 36 of the EURATOM Treaty – is measured. The values measured are of the same order of magnitude as those observed in other European countries (Sweden, Luxembourg, France, Germany, Austria, Italy, etc.), where they vary in general from 1 to 30 10^{-3} Bq/m^3;
- Apart from any accident scenario, the radiological impact of the nuclear installations on the atmosphere and indirectly on the environment are always negligible or cannot be measured: only traces of beta emitters (total β measurements) – mainly of natural origin – are detectable;
- In the vicinity of IRE at Fleurus, watersamples taken from the deposit tanks installed on the site close to the Sterigenics building, near building B12 situated further away and at a farm situated a few kilometres outside the site, do not reveal any presence of radioactive iodine (the detection limit is approximately 6 to 9 Bq/m^2);
- This aspect of the monitoring of atmospheric radioactivity is supported by the data of the continuous measurements carried out by all the "air" stations distributed across the territory as part of the TELERAD automatic monitoring network.

Summary:

- Natural radioactivity is mainly responsible for the level of air radioactivity;
- The Tihange nuclear power station and the nuclear facilities of the IRE site do not create – during routine operations - any measurable impact on their environment;
- The impact of the Chooz nuclear site cannot even be measured and can therefore be regarded as zero.

3.2 RADIOACTIVITY OF THE SOIL

Radioactive contamination of soil is mainly due to the fallout of radioactive substances present in the atmosphere (most often associated with very fine particles or aerosols) through dry or wet deposits (washing out of the atmosphere by rain).

Soil samples are taken once a year close to the IRE, Tihange and Chooz nuclear sites as well as near the Dutch border in Lixhe. In places, the possible depositing of radioactivity is checked by taking samples of grass (surface deposits).

Around the boot of Givet, on Belgian territory, a more exhaustive control is aimed at checking the radiological state of the agricultural zones and their plant production. This monitoring falls within the framework of the Franco-Belgian agreement on the Chooz nuclear power station and the exchange of information in the event of any incident or accident. This agreement makes provisions concerning crisis situations requiring the Nuclear Emergency Plan to be launched as well as regular exchanges of information dealing particularly with radiological measures practised in Belgium and France.

The analyses relate to the detection of gamma, beta and alpha emitters. Detection limits can vary depending on the quantity and density of the soil sampled, the geometry used for carrying out the measurements and the global level of activity of the sample.

The table below summarises all the results obtained for the soils.

Measurements of soil radioactivity in the Sambre – Meuse basin (meadows/ topsoils) and of agricultural production around the boot of Givet

	Close to nuclear site		Around the boot of Givet (Chooz)			
	Permanent meadows (Bq/m^2)		Agricultural zones (Bq/kg dry) *		Agricultural production (Bq/kg dry)	
	measurement	DL	measurement	DL	measurement	DL
γ	NM	25 to 40	NM	< 1	NM	< 1
^{137}Cs	400 to 1200 150 (Lixhe)	30	4.0 to 16.0		traces : ≤ 2.5	0.1 to 1.0
^{90}Sr				7.0 to 9.0		0.7 to 5.0
^{14}C					≤ 1 (Bq/g C)	
^{3}H org.					traces	4.0 to 19.0
^{40}K	(2.6 to 3.4) 10^4		300 to 800		130 to 1100	
^{226}Ra	(2.1 to 2.7) 10^3		30 to 55		0.6 to 0.6	0.4 to 2.0
^{228}Ra	(2.1 to 2.5) 10^3				0.5 to 7.7	0.8 to 5.0
^{228}Th	(2.2 to 3.2) 10^3		36 to 54		0.14 to 9.90	0.6 to 1.5
^{235}U ^{238}U			1.1 to 3.5 24 to 34	0.6 to 0.7 ~ 4		
$^{238,(239+240)}Pu$			NM	0.3 to 0.7		
^{241}Am			NM	0.6 to 0.9		

NM: non-measurable, measurement lower than or equal to the detection limits (DL)
** the density of the soils varies from 1.6 to 1.8 kg/l, depth of sampling: 20 cm*

In greater detail:

- The results firstly show the very considerable prevalence of natural radioactivity emitted by the potassium 40 of the soils which follows stable potassium (^{40}K represents 0.0119% of the total potassium), with the concentration varying from one soil to another, as well as depending on the seasons. The natural alpha emitters ($^{226,228}Ra$, $^{234,235,238}U$, ^{228}Th) are also detected on a regular basis;
- As far as artificial radioactivity is concerned, traces of ^{137}Cs are measured around the boot of Givet which are due to the fallout from the Chernobyl accident and the much older fallout from atmospheric nuclear tests (which reached their peak in the 1960s). That is explained by the persistence of radio-caesium in the environment due to its physical half life of ~ 30 years (half life = time required for 50% of the radioactivity to disappear);

  Another artificial radioelement that has been come across is ^{90}Sr. This beta emitter (half life of ~ 29 years) is still present in the biosphere as a result of nuclear weapon tests in the atmosphere. Meadows display greater concentrations (compared to other vegetation) for a given type of soil;

  Note also that in 2010, only for 2 of the 24 (2 of the 25 in 2009) samples of plants showed traces of ^{3}H. In 2005, 5 samples of 24 and in the period of 2006-2007, 18 out of 24 showed such traces. In 2008, only 5 samples were positive. These detections of

^{3}H since 2005 may be linked to the decrease of the detection limits DL (Bq/kg dry matter) which went down from 50-90 in the period 2002 to 2004, to 40-60 in 2005, to 23-38 from 2006 to 2009 and to 4-19 in 2010.

The summary table below shows the trend since 2001, of the results for ^{3}H in plants:

Campaign	Case of detection of ^{3}H in plants	Detection limits in case of absence of detection (Bq/kg MS)	Mean of concentrations observed in case of detection (Bq/kg MS)
2001	0 / 30	25	/
2002	0 / 30	54 to 75	/
2003	0 / 30	58 to 68	/
2004	0 / 24	60 to 95	/
2005	5 / 24	40 to 58	63
2006	18 / 24	23 to 26	54
2007	18 / 25	23 to 25	34
2008	5 / 24	23 to 29	56
2009	2 / 25	23 to 38	49
2010	2 / 24	4 to 19	10

It shows that in 2001, ^{3}H - if it was present in the plants - was only present in concentrations of less than 25 Bq/kg of dry matter. From 2002 to 2004, it was impossible to determine whether there had been any change, due to the higher detection limits.

Since 2005, it has been proved that ^{3}H is indeed present in the plants, which could already have been the case from 2001 to 2004, except that it could not be verified. Since 2006, the return of the detection limit to around 25 - 30 Bq/kg and around 4 – 19 Bq/kg of dry matter in 2010 has permitted to measure the tritium content with sufficient accuracy.

It seems, since 2006, that ^{3}H has been detected less frequently whereas the detection limits remained at the same level. One can assume that this illustrates that less tritium is present in the environment.

- Artificial transuranic alpha emitters (Pu and Am) are not measurable.

Summary:

- Natural radioactivity is mainly responsible for the level of radioactive soil contamination;
- Neither the Tihange nuclear power station nor the nuclear facilities of the IRE site or the Chooz site have any significant measurable impact on the soil.

3.3 RIVER RADIOACTIVITY

Two rivers are concerned: the Meuse and the Sambre. The Meuse receives radioactive discharges from the French nuclear site at Chooz, as well as from the Tihange and IRE sites via its tributary, the Sambre. These two rivers also collect radioactive discharges from the hospitals and laboratories of large urban areas such as Namur, Huy, Liège and Charleroi.

The Meuse constitutes, after treatement, a source of drinking water for a substantial section of the Belgian and Dutch populations. In this respect, total alpha and beta radioactivity are performed. Gamma spectrometry measurements are also carried out.

These controls are all the more important on account of the imminent application of European Council new EURATOM Directive concerning the quality of water intended for human consumption.

The water is automatically sampled by independent collectors (PPMOS) installed in the containers of the TELERAD river station (photographs opposite).

In order to assess the fixing potential of the radioactivity of matter in suspension and fine particles of sediments which constitute an important compartment for fixing radioactive elements, analyses are conducted on sediments collected monthly in sedimentation tanks (photo on the right).

These tanks are installed in the containers of the TELERAD river station which measure in continuous the gamma radioactivity of the rivers.

These tanks constantly collect suspended particles in the water via a bypass on the water pumping circuit of the TELERAD stations.

The samples also cover the aquatic biocenosis: mosses (*Cinclidotus danubicus*), aquatic plants (if available of *Salix sp*. type) and bivalve molluscs (*Dreissena polymorpha*), which are good biological indicators or "bio-indicators" of the presence of radioactivity. Mosses and aquatic plants are particularly sensitive to liquid discharges in the short and medium term because these organisms have a high potential for concentrating stable or radioactive chemical elements. *Dreissena*, like all filtering bivalves, are very good integrators of radioactivity over medium time spans (of the order of one month).

The water, sediment and biocenosis sampling and radioactivity control points were chosen in such a way as to enable verification of the impact of the nuclear facilities along the course of the Meuse and the Sambre:

- The Floriffoux (*Flo*) site incorporates the discharges of Fleurus (IRE) and of Charleroi on the Sambre river;
- The sites of Heer-Agimont (*H-Ag*), Waulsort (*Wau*) or Rivière (*Riv*) for the Meuse fauna and flora incorporate the discharges of the French nuclear power station at Chooz as well as those from the hospitals situated in France in the Meuse basin;

- The Andenne (*And*) site incorporates the intake from the Sambre as well as the discharges from the hospitals of the Namur and Charleroi urban areas;
- The Huy (*Huy*) site provides a radiological picture of the river upstream from the Tihange power station;
- The Ampsin (*Amp*) or Amay (*Ama*) sites and Flémalle (*Flé*) for the Meuse flora, located just downstream from the Tihange nuclear power station, enables the impact of the Tihange liquid discharges on the Meuse to be checked against the Huy data;
- The Monsin (*Mon*) site, downstream from Liège, incorporates, in turn, the intake from the Liège hospitals;
- The Lixhe (*Lix*) site incorporates all the Belgian intakes at the Dutch border.

The following table summarises the results obtained.

Radioactivity measurements in the rivers of the Sambre – Meuse basin

	Waters (Bq/l)		Sediments (Bq/kg dry)		Fauna (*D. polymorpha)* (Bq/kg fresh)		Flora (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL	measurement	DL
γ	NM	≤ 1	NM	< 3			NM	0.7 to 11
^{137}Cs	NM	0.12 to 0.16	2 to 6 (Flo) 6 to 15 (H-Ag) 7 to 14 (And) 7 to 17 (Amp) 7 to 14 (Lix)	2 to 3			NM (mosses) NM (plants)	0.8 to 3.0 5 to 13
^{131}I	NM	0.7 to 1.0	NM (Flo, H-Ag, And, Amp, Lix)	50 to 100			mosses NM plants NM (Flo, H-Ag) ~ 40 (And) ~ 10 (Huy) ~ 20 (Amp) ~ 10 (Flé) ~ 20 (Lix)	4 to 20 20-50 ~ 3 ~ 7 ~ 5 ~ 7 ~ 50
^{3}H	NM (Flo) 10 to 36 (H-Ag) 7 to 35 (And, Huy) 15 to 80 (Amp) 13 to 40 (Mon) 10 to 40 (Lix)	2.6 to 2.8					mosses 30 to 65 (Flo, H-Ag) 30 (And) 40 to 50 (Huy) 80 to 230 (Amp) 140 to 190 (Lix) plants NM (Flo, And, Huy, Flé, Lix) 20 to 25 (H-Ag) 70 (Amp)	~ 30 2 to 3 ~ 30 ~ 17 ~ 15

Radioactivity measurements in the rivers of the Sambre – Meuse basin (cont.)

total α	traces (Flo, H-Ag, And, Huy, Amp, Mon, Lix)	0.04 to 0.05			
^{226}Ra			30 to 70	Mosses : 2.5 to 8 Plants : 8 to 35 35 to 80 (H-Ag)	3 to 6 ~ 5 ~ 25
^{228}Ra			30 to 90	Mosses : 2 to 8 Plants : 10 to 60	4 to 15 20 to 50
total β (residual)	NM (Flo, H-Ag, And, Huy, Amp, Mon, Lix)	0.05 to 0.06			
^{40}K	0.11 to 0.27 (Sambre) 0.05 to 0.19 (Meuse)		350 to 750	350 to 1350 (mosses) 200 to 950 (plants)	

NM: non-measurable, measurement less than or equal to the detection limits (DL)
total β residual: total β apart from ^{40}K

In greater detail:

- The results obtained show that the presence of natural radioactivity and, as far as artificial radioactivity is concerned, mainly ^{3}H is detected in the waters on a regular basis: levels of ^{3}H, which can reach 80 Bq/l, are measured downstream from the nuclear power stations;
- In sediments: ^{40}K fluctuates between 350 and 750 Bq/kg dry, while $^{226\text{-}228}$Ra ranges between 30 and 90 Bq/kg dry (^{228}Th from 40 to 70 Bq/kg dry);
- Traces of ^{131}I are rarely highlighted in sediments collected downstream of large urban areas (hospital discharges);
- In flora: ^{40}K is measured in concentrations from 220 to 1,350 Bq/kg wet in the mosses and aquatic plants;
- The ^{3}H is detected in the dried samples of moss and plants collected along the river banks in amounts of about 70 to 230 Bq/kg dry matter downstream of the nuclear site of Tihange.

Summary:

- Natural radioactivity (^{40}K, and to a lesser extent ^{226,228}Ra and ^{228}Th) is mainly responsible for the level of radioactive contamination in the different river sections;

- The Tihange nuclear power station, the one at Chooz in France and the nuclear facilities of the IRE site do not have a significant impact on the rivers;
- Only ^{3}H is routinely measured in the Meuse water, though it remains at concentrations below the parametric value of 100 Bq/l defined in European Council Directive 98/83/EC of 3 November 1998 concerning the quality of water intended for human consumption that will be replaced by the new EURATOM Council Directive of the EC to be published in 2012.

4. THE BASIN OF THE NETE AND THE SCHELDT

The Scheldt receives radioactive discharges from several nuclear sites (4 power reactors at Doel, SCK•CEN at Mol, the sites of Belgoprocess, Belgonucléaire and FBFC at Mol and Dessel) and non-nuclear sites (hospitals in big urban areas such as Antwerp, feed phosphate facility near Tessenderlo).

A whole range of samples are taken in this region near the nuclear sites of Doel on the Scheldt and Mol-Dessel near the Molse Nete, as well as the non-nuclear site of Tessenderlo near the Grote Laak and the Winterbeek, all tributaries of the Grote Nete, itself a tributary of the Ruppel, which flows into the Scheldt:

- Atmospheric category: sampling of air dusts (filters), rain and dry or wet deposits near the Mol-Dessel and Doel sites;
- Soil category: sampling near the Mol-Dessel and Doel nuclear sites;
- River category: waters, sediments and samples of the flora and fauna of the Grote Laak, the Winterbeek, the Molse Nete, the Grote Nete, the Ruppel and the Scheldt near Doel.

Generally:

- The air in the vicinity of the nuclear installations does not present any radiological problem. The levels measured are all lower or close to the – very low – detection thresholds of the measuring equipment;
- The measurements of the radioactivity of rain show that very small quantities of radioactivity (mainly due to natural radioactivity) can be detected by virtue of the detection thresholds reached by the measuring equipment;
- The radiological situation of the Scheldt is good;
- The impact of the nuclear facilities on the waters of the rivers is negligible and without consequence for human health. Nevertheless, the water of the Nete (Molse Nete) basin needs be subjected to stricter controls on account of the liquid discharges of artificial radioactivity from the Mol-Dessel site and radium discharges from the installations at Tessenderlo (Grote Laak, Winterbeek). The levels of ^{226}Ra (and its concentration in sediments and sludge) needs be specially monitored for the Grote Laak and the Winterbeek;

More precisely:

- The radioactivity of certain radioelements (including ^{3}H) in the Molse Nete is abnormally high even though the nuclear industrial activities in the region of Mol-Dessel comply with the stipulated discharge limits;
- Natural radioactivity due to ^{226}Ra (highly radiotoxic with a very long physical period – 1620 years, with gaseous ^{222}Rn, ^{210}Pb as descendants – 22 years physical period) in the Grote Laak and Winterbeek as well as in the Grote Nete (and to a lesser extent in the Ruppel) is not negligible. On the other hand, the situation of the hydrographic network of the Nete needs to be monitored very carefully:

- The radiological anomalies observed for ^{226}Ra constitute a greater problem in reality: a high level of pollution through heavy metals. Although the companies discharging into these watercourses have made great efforts to treat their waste water so as reduce the impact on the ecosystem, the quantities of radioactivity they discharge, which come on top of a "history", are still not negligible and need to be reduced.

  Even though these waters cannot be used as such for human consumption, it cannot be completely ruled out that harmful biological effects may occur through inundating inhabited and agricultural zones (banks, dredging spoil deposit zones, etc.) which may be locally contaminated, especially chemically, with the risk of transfer to the food chain. Significant contamination of the banks has already been observed, in particular, along the Grote Laak and the Winterbeek, the flow of which is almost completely regulated by the liquid effluents of the Tessenderlo complex.

4.1 ATMOSPHERIC RADIOACTIVITY

The following table summarises all the results obtained for the atmospheric categories studied: air dusts, rain collected in pluviometers and deposit tanks.

These controls are carried out close to the Doel and Mol-Dessel nuclear facilities and do not reveal any radiological problems.

In greater detail:

- Natural radioactivity is mainly responsible for the – very low – level of radioactive contamination of the atmosphere. ^{7}Be (a natural cosmogenic radioactive element) is very closely monitored;
- The impact of nuclear installations on the atmosphere and indirectly on the environment is negligible or cannot even be measured: only traces of alpha and beta emitters (measurements in total α and β) – mainly of natural origin – are detectable near the Doel and Mol-Dessel nuclear sites;
- This aspect of the monitoring of atmospheric radioactivity is supported by the data of the continuous measurements carried out by all the "air" stations distributed across the territory as part of the TELERAD automatic monitoring network.

Summary:

- Natural radioactivity is mainly responsible for the level of air radioactivity;
- The Doel nuclear power station and the nuclear facilities of the Mol-Dessel site do not have a measurable impact in the atmosphere.

The following table summarises the results obtained.

Measurements of atmospheric radioactivity (air and rain) in the Nete – Scheldt basin

	Air dusts (Bq/m^3)		Deposit tanks (Bq/m^2)	
	measurement	DL	measurement	DL
γ	NM	~ 10^{-5}	NM	2 to 16 1.7 to 2.5 → $^{134,137}Cs$
^{7}Be	(1.0 to 3.5) 10^{-3}		10 to 150	~ 10
total β	(0.2 to 0.6) 10^{-3}	0.05 10^{-3}	2 to 40 Mol (filtrate) 2.5 to 6.5 Doel (filtrate) 1.0 to 9.0 (filter deposits)	
^{3}H			NM	500 to 1000
total α	(10 to 30) 10^{-6} Mol-Dessel	~ 4 10^{-6}	0.3 to 1.8 Mol (filtrate) 0.3 to 1.1 Doel (filtrate) 0.1 to 1.1 Mol (filter deposits) 0.5 to 3.5 Doel (filter deposits)	~ 0.2

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

4.2 RADIOACTIVITY OF THE SOIL

The soil samples are taken once per year close to the Doel and Mol-Dessel nuclear sites. The possible deposit of radioactivity is checked by means of grass samples (surface deposits).

The analyses relate to the detection of gamma, beta and alpha emitters. Detection limits can vary depending on the quantity and density of the soil sampled, the geometry used for carrying out the measurements and the global level of activity of the sample.

In greater detail:

- The results firstly show the very considerable prevalence of natural radioactivity emitted by the potassium 40 of the soils which follows stable potassium (^{40}K represents 0.0119% of total potassium), with the level varying from one soil to another, as well as depending on the seasons. The natural alpha emitters ($^{226,228}Ra$, $^{234,235,238}U$, ^{228}Th) are also detected on a regular basis;
- As far as artificial radioactivity is concerned, traces of ^{137}Cs are measured in the soils which are due to the fallout from the Chernobyl accident and the much older fallout from atmospheric nuclear tests (which reached their peak in the 1960s).

  The artificial transuranic alpha emitters (Pu and Am) are not measurable.

The table below summarises all the results obtained for the soils.

Soil radioactivity measurements (meadows/topsoils) of the Nete – Scheldt basin

	Doel site (Bq/m^2)	Mol-Dessel site (Bq/m^2)	
	measurement	measurement	DL
γ	NM	NM	15 to 25
^{137}Cs	300 to 350	200 to 230	~ 18
^{40}K	(24 to 26) 10^3	(8 to 9) 10^3	
^{226}Ra ^{228}Ra	(1,4 to 1,5) 10^3	350 to 550	
^{228}Th	(1,4 to 1,5) 10^3	330 to 370	
^{235}U ^{238}U		NM 300 to 480	~ 23
$^{238,(239+240)}Pu$		NM	30 to 40
^{241}Am		NM	~ 4

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

Summary:

- Natural radioactivity (K, Ra, U, Th) is mainly responsible for the level of radioactive contamination of the soils;
- In the Mol-Dessel region, only natural radioactivity (uraniums) is detectable. There is no evidence of detectable quantities of heavy elements belonging to the americium and plutonium family which might have been discharged by the site facilities, including those of Belgoprocess 1 (Cilva - solid waste incinerator, Pamela – highly radioactive waste vitrification plant), those of Belgoprocess 2 (former SCK•CEN liquid waste treatment plant) and those of Belgonucleaire involved in the discharges of alpha and Pu emitters. It should be noted that FBFC International – a plant manufacturing nuclear fuel enriched with ^{235}U and at present MOX – is not concerned here by virtue of its discharges being negligible in terms of activity;
- The Doel nuclear power station and the nuclear facilities of the Mol-Dessel site do not have any measurable impact on their surroundings (by the way of the atmospheric releases).

4.3 RADIOACTIVITY OF THE RIVERS

Several rivers are concerned: the Molse Nete is a watercourse which receives the discharges of Belgoprocess 2 and the liquid radioactive effluent treatment plant of the Mol-Dessel site; the Grote Laak and the Winterbeek, which receive the discharges of the site manufacturing feed phosphates at Kwaad-Mechelen and Tessenderlo (discharges of ^{226}Ra); the Grote Nete, into which all these watercourses flow; the Ruppel, where the Grote Nete ends and, finally, the Scheldt, which drains the entire Nete basin. It receives the discharges from the Doel nuclear power station as well as the radioactive discharges of the Antwerp hospitals and laboratories. The Scheldt ends in an estuary area before flowing into the North Sea.

Belgoprocess 2 (former SCK•CEN liquid discharge treatment plant) receives all the liquid radioactive waste of the other installations of the Mol-Dessel site (SCK•CEN, Belgoprocess, Belgonucléaire, FBFC) for treatment prior to discharge. The discharges into the Molse Nete must not exceed 25 GBq/month of alpha, beta and gamma radioactivity according to the following formula:

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] ≤ 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])

Total alpha and beta radioactivity is checked in these waters. Gamma spectrometry analyses and specific measurements of radium are carried out. The freshly deposited sediments on the river beds and close to the banks (sedimentation trays) are also analysed.

The samplings also cover the aquatic biocenosis: mosses (*Cinclidotus danubicus)*, fresh water plants and algae (if available), as well as marine mussels (*Mytilus edulis*), shrimps (*Crangon sp.*) - as regards the Scheldt estuary part - which are good biological indicators or "bio-indicators" of the presence of radioactivity.

The water, sediment and biocenosis sampling and radioactivity control points were chosen in such a way as to enable verification of the impact of the nuclear and non-nuclear facilities along the water courses referred to above.

- On the Winterbeek (*Win*) near the Tessenderlo chemie discharge channel;
- On the Grote Laak (*GLa*) near the Tessenderlo chemie discharge points;
- On the Molse Nete (*MNe*) near the discharge point of the outlet channel of Belgoprocess 2 at the Mol-Dessel site;
- On the Grote Nete (*GNe*) near Geel, which drains the preceding watercourses;
- On the Ruppel (*Rup*) near Boom;
- On the Scheldt (*Esc*) near Doel;
- Further in the estuary for fauna (shrimps and marine oysters) and flora (algae – *Fucus vesiculosus*): Kieldrecht region near Doel, Kloosterzande and Hoofdplaat situated on the estuary section of the Scheldt to the north of the Belgian-Dutch border (*Estu*).

The results obtained show that the presence of natural radioactivity (^{226}Ra in the Grote Laak and the Winterbeek) is detected regularly and, as far as artificial radioactivity is concerned, mainly ^{3}H in the Molse Nete.

In greater detail:

- In the waters of the Molse Nete, the articifial radioactivity is due to ^{3}H, which fluctuates from 8 to 250 Bq/l. Only traces of transuranic elements are detected ($^{238,(239+240)}$Pu and ^{241}Am) with detection limits in the vicinity of ~ 10^{-4} Bq/l. The natural radioactivity is due to ^{40}K (a few Bq/l) and to the ^{234,238}U with concentrations of 0.001 to 0.004 Bq/l, as well as ^{235}U with concentrations of 0.0001 to 0.0002 Bq/l;
- In the sediments, the radioactivity is mainly of natural origin (K and Ra). Radium is easily detectable – especially in the Grote Laak and the Winterbeek (discharge points) with concentrations of 150 to 950 Bq/kg dry matter. The levels decrease further into the basin towards the Scheldt. Recent sediments of the Molse Nete displays traces of artificial radioactivity (mainly ^{137}Cs with concentrations of 110 to 300 Bq/kg, transuranic elements – Pu and Am respectively, with levels ranging from 3 to

70 Bq/kg and 15 to 130 Bq/kg and ^{99}Tc with 150 to 400 Bq/kg) coming from the liquid discharges of Belgoprocess 2 (discharges which comply with the authorised limits) and from possible resuspension of older deposits. This radioactivity quickly becomes very difficult to detect further away from the discharge point;

- The main source of radioactivity in flora and fauna is ^{40}K. The presence of ^{137}Cs is measured (up to 2.5 Bq/kg) in the Molse Nete (mosses and aquatic plants). This is indicative of discharges of artificial radioactivity from the Mol-Dessel site (discharges carried out by the Belgoprocess 2 installation). In the estuary environment (Scheldt), traces of ^{226}Ra are detected in the marine flora and fauna.

The following table summarises the results obtained.

Radioactivity measurements in the Nete - Scheldt basin rivers

	Waters (Bq/l)		Sediments (Bq/kg dry)		Fauna (Bq/kg fresh)		Flora (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL	measurement	DL
γ	NM	≤ 1	NM	< 4	NM (Estu)	< 1	NM (MNe, Estu)	< 1
^{60}Co			2.5 to 10.8 (MNe) 1.1 to 3.5 (GNe) 0.8 to 1.4 (Esc)	~ 6 ~ 1.5 ~ 1	NM (Estu)	~ 0.5	NM	~ 0.6 (MNe) ~ 0.3 (Estu)
^{137}Cs	NM	~ 0.2	traces : 3 to 8 (Win, GLa) 110 to 300 (MNe) 10 to 70 (GNe) 7 to 10 (Esc)	2 to 4	NM (Estu)	~ 0.4	0.6 to 2.5 (MNe) NM (Estu)	~ 0.5 ~ 0.3
^{131}I	NM	0.8 to 0.9	NM (Win, GLa, MNe, GNe) NM (Esc)	300 to 1000 ~ 90	NM (Estu)	~ 10	NM (MNe, Estu)	10 to 20

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

Radioactivity measurements in the Nete - Scheldt basin rivers (cont.)

	Waters (Bq/l)		Sediments (Bq/kg dry)		Fauna (Bq/kg fresh)		Flora (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL	measurement	DL
total α	0.2 to 1.2 (Win, GLa) 0.01 to 0.04 (MNe) 0.01 to 0.04 (GNe) 0.06 to 0.11 (Esc)	~ 0.2 ~ 0.01 ~ 0.01 ~ 0.08						
^{241}Am	traces (MNe) (0.02 to 3.5) 10^{-2} (Esc)	~ 1.1 10^{-4}	15 to 130 (MNe)		NM (Estu)	~ 3 10^{-2}	Traces (MNe) 2 to 3 (Estu)	~ 0.03 ~ 0.02
$^{238,(239+240)}Pu$	traces (MNe) NM (Esc)	~ 1.0 10^{-4} (8 to 11) 10^{-5}	3 to 70 (MNe)		NM (Estu)	~ 0.02	NM (MNe) NM (Estu)	~ 0.01 ~ 0.02
^{226}Ra	0.03 to 0.90 (Win, GLa) 0.007 to 0.019 (Rup) 0.008 to 0.014 (Esc)		160 to 950 (Win) 150 to 550 (GLa) 30 to 105 (MNe) 30 to 65 (GNe) 45 to 55 (Esc)	~ 10	NM (Estu)	~ 0.8	NM (MNe) 1.2 to 2.3 (Estu)	~ 1
total β	0.7 to 2.3 (Win) 2.0 to 6.0 (GLa) 0.2 to 0.4 (MNe) 0.22 to 0.32 (GNe) 1.5 to 4.8 (Esc)	~ 0.9						
^{3}H	8 to 250 (MNe) 20 to 150 (GNe) 7 to 11 (Esc)	~ 13 ~ 10 ~ 11			NM (Estu)	~ 3	NM (MNe) NM (Estu)	~ 3 ~ 2
^{90}Sr	NM (Win, GLa, Esc)	0.03 to 0.04	NM (MNe)	~ 6	NM (Estu)	~ 0.9	NM (MNe, Estu)	~ 0.6
^{99}Tc			150 to 400 (MNe)	~ 130			NM (MNe, Estu)	~ 15

Radioactivity measurements in the Nete - Scheldt basin rivers (cont.)

	Waters (Bq/l)		Sediments (Bq/kg dry)		Fauna (Bq/kg fresh)		Flora (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL	measurement	DL
^{40}K	NM (Win) 2 to 9 (GLa) 11 to 15 (MNe) 3 to 5 (GNe) 2 to 6 (Esc)	~ 4	100 to 340 (Win, GLa) 100 to 300 (MNe) 200 to 400 (GNe) 450 to 620 (Esc)		35 to 55 (crevettes) 35 to 94 (huîtres)		70 to 130 (MNe) 130 to 170 (Estu)	

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

Summary:

- Natural radioactivity (^{40}K and to a lesser extent ^{226}Ra and ^{228}Th) is mainly responsible for the level of radioactive contamination in the different sections of the rivers;
- The Doel nuclear power station does not have any measurable impact on the Scheldt;
- The ecological situation of the Molse Nete is problematic from the point of view of chemical contamination in general. From the radiological point of view, this watercourse contains abnormally high levels of artificial radioactive elements (tritium and caesium among others), the result of industrial nuclear activity at the Mol-Dessel site, which nevertheless adheres to the discharge limits set for it. However, the situation seems to have improved over the past few years;

  This observation must be balanced by remarking that these waters cannot be used for human consumption as such. On the other hand, they inundate agricultural zones which may therefore be contaminated locally – especially in chemical terms (banks, dredging spoil deposit zones, etc.). The input of chemical and radioactive contaminants needs to be reduced in the future.

5. THE MARITIME ZONE: THE BELGIAN COASTAL REGION

In addition to directly receiving the liquid effluents from the French nuclear facilities (Gravelines nuclear power station via the English Channel; those of Paluel and Flamanville and the Hague reprocessing plant) and English nuclear installations (Dungeness, Bradwell and Sizewell power stations), the North Sea is also the final destination of several rivers themselves receiving radioactive effluents, including the Meuse and the Scheldt for Belgium.

That is why it is closely monitored by all the riparian countries that are signatories to the Oslo and Paris conventions (OSPAR).

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 elements, 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 categories monitored are:

- Land category: taking of soil samples (meadows) near Coxyde;
- Marine category: 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 artifical radioactivity (^{137}Cs and transuraniums in fish) are sometimed detected (at the level of the detection limits of the measuring equipment), they remain entirely negligible.

5.1 RADIOACTIVITY OF THE ATMOSPHERE

The table below summarises all the results obtained for the dust particles.

Atmosphere radioactivity measurements (air) of the Belgian coast

	Air dust particles (Bq/m³)	
	measurement	DL
γ	NM	~ 10^{-6} ~ 2 10^{-6} (^{134,137}Cs) ~ 2 10^{-5} (^{106}Ru)
^{7}Be	(0.7 to 1.3) 10^{-3}	
total β	(0.9 to 2.6) 10^{-4}	
^{40}K	NM	~ 3 10^{-5}

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

The results obtained show clearly that the air in the region of Coxyde (Belgian littoral) poses not a single radiological problem. The measured values are all below or in the neighbourhood of the – very low – detection limits of the equipment. Only natural radioactivity can be sufficiently measured.

Summary:

- The natural radioactivity is mainly responsible for the – very low - level of radioactive contamination of the atmosphere. ^{7}Be is monitored very closely (natural cosmogenic radioactive element).
- This aspect of controle of the atmospheric radioactivity is confirmed by the data of continuous measurements performed by all "air measuring stations", spread on the territory within the framework of the automatic monitoring network TELERAD.

5.2 RADIOACTIVITY OF THE SOIL

Soil samples are taken at Coxyde once a year. The possible deposit of radioactivity is checked by means of grass samples (surface deposits).

The analyses relate to the detection of gamma, beta and alpha emitters. Detection limits can vary depending on the quantity and density of the soil sampled, the geometry used for carrying out the measurements and the global level of activity of the sample.

In greater detail:

- The results firstly showed the very considerable prevalence of natural radioactivity emitted by the potassium 40 of the soils which follows stable potassium (^{40}K represents 0.0119% of total potassium), with the level varying from one soil to another as well as depending on the seasons. The natural alpha emitters ($^{226,228}Ra$, ^{228}Th) are also detected on a regular basis;
- As far as artificial radioactivity is concerned, traces of ^{137}Cs are measured in the soils which are due to the fallout of the Chernobyl accident and much older fallout from atmospheric nuclear tests (which reached their peak during the 1960's). The artificial transuranic alpha emitters (^{241}Am) are not measurable.

The table below summarises all the results obtained for the soils.

Soil radioactivity measurements (meadows/topsoils) of the Belgian coast

	Coxyde site (Bq/m^2)	
	measurement	DL
γ	NM	18 to 50
^{137}Cs	440 to 500	
^{40}K	(12.5 to 14.0) 10^3	
^{226}Ra ^{228}Ra	420 to 600	
^{228}Th	470 to 530	

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

Summary:

- Natural radioactivity (K, Ra, Th) is mainly responsible for the level of radioactive contamination of the soils;
- ^{137}Cs is detected, which is normal since, as already mentioned, this comes from the fallouts of atmospheric testing of nuclear weapons during the sixties, as well as the passing of the Chernobyl radioactive cloud. On the other hand, the levels measured are logically lower than those found in the Sambre-Meuse basin, where the deposits due to Chernobyl were somewhat greater than in Flanders.

5.3 RADIOACTIVITY OF THE MARINE ENVIRONMENT

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).

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

Samples of sea water are taken with the help of "Niskin" bottles (photo on the right).

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.

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.

The following table summarises the results obtained.

Radioactivity measurements for the marine environment : waters and sediments

	Waters (Bq/l)		Sediments (Bq/kg dry)	
	measurement	DL	measurement	DL
γ	NM	~ 0.2	NM	0.4 to 2.5
^{137}Cs	NM	0.22	0.5 to 1.3	~ 0.4
^{60}Co	NM	0.23	NM	~ 0.6
total β	12 to 13			
^{40}K	9 to 14		200 to 350	
α total	traces	~ 0.3		
$^{226,228}Ra$	traces	0,5 to 0,9	7 to 15	
$^{238,(239+240)}Pu$	NM	~ 1,0 10^{-4}	NM	~ 0,6

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 fresh)		Fauna (mussels and shrimps) (Bq/kg fresh)		Fauna (flat fish) (Bq/kg fresh)	
	measurement	DL	measurement	DL	measurement	DL
γ	NM	< 2	NM	< 2	NM	< 1
^{137}Cs	NM	~ 0.7	NM	0.5 to 0.7	NM	~ 0.6
^{60}Co	NM	~ 0.6	NM	0.5 to 0.7	NM	~ 0.6
^{131}I	NM	~ 25	NM	~ 15	NM	~ 50
^{90}Sr	NM	~ 0.8	NM	~ 0.9	NM	~ 1.3
^{40}K	100 to 155		30 to 90		70 to 90	
^{3}H	NM	~ 2	NM	3 to 4	NM	~ 3
^{99}Tc	NM	~ 17			NM	~ 19
$^{226,228}Ra$	0.4 to 2.4	~ 0.2	NM	1.0 to 2.5	NM	1.3 to 2.5
$^{238,(239+240)}Pu$	NM	~ 0.016	NM	0.01 to 0.02	NM	~ 0.02
^{241}Am	NM	~ 0.009	NM	~ 0.04	NM	~ 0.03

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 elements 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.

6. THE REFERENCE ZONE

The sampling stations were chosen on Belgian territory with regard to their geographic situation which shields them from potential discharges of artificial and/or natural radioactivity due to human activity and which accounts for a large part of the population.

In this respect, the Brussels urban area with its one million inhabitants ($1/10^{th}$ of the total Belgian population) was chosen as a reference zone.

The categories monitored are:

- Atmospheric category: samples of air dusts and rain;
- Soil category.

Generally: the results obtained clearly show that the radiological situation of the Brussels urban area is excellent.

6.1 ATMOSPHERIC RADIOACTIVITY

The following table summarises all the results obtained for the atmospheric categories studied: air dusts, rain collected in pluviometers and deposit tanks.

Radioactivity measurements for the atmosphere (air and rain) of the reference zone

	Air dusts (Bq/m^3)		Deposit tanks (Bq/m^2)	
	measurement	DL	measurement	DL
γ	NM	$\sim 10^{-5}$ $2.7\ 10^{-5}$ ($^{134,137}Cs$) $2.5\ 10^{-4}$ (^{106}Ru)	NM	3 to 10 3 to 4 ($^{134,137}Cs$) ~ 30 (^{106}Ru)
^{7}Be	$(2.5 \text{ to } 10.4)\ 10^{-3}$		traces : 1 to 20	~ 50
total β	$(0.6 \text{ to } 1.5)\ 10^{-3}$	$\sim 6\ 10^{-3}$	1.5 to 6.0 (filtrate) traces (filter deposits)	~ 1 1 to 2
^{40}K	$(0.5 \text{ to } 2.6)\ 10^{-3}$		40 to 400	~ 60
^{3}H			NM (distillate)	~ 90
total α			traces (filtrate) traces (filter deposits)	1 to 2

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

The results obtained clearly show that the air in the Brussels urban area (Royal Meteorological Institute of Belgium - MRI - Uccle-Brussels) does not present any radiological problem. The levels measured are all lower than or close to the – very low – detection limits of the measuring equipment. Only natural radiation is detected.

Summary:

- Natural radioactivity is mainly responsible for the – very low – level of radioactive contamination of the atmosphere. ^{7}Be (a natural cosmogenic radioactive element) is very closely monitored;
- This aspect of the monitoring of atmospheric radioactivity is supported by the data of the continuous measurements carried out by all the "air" stations distributed across the territory as part of the TELERAD automatic monitoring network (located in Brussels, Uccle, Dilbeek and Zaventem).

6.2 RADIOACTIVITY OF THE SOIL

The soil samples are taken once a year on the Royal Meteorological Institute of Belgium site in Brussels. The possible deposit of radioactivity is checked by means of grass samples (surface deposits).

The analyses relate to the detection of gamma, beta and alpha emitters. Detection limits can vary depending on the quantity and density of the soil sampled, the geometry used for carrying out the measurements and the global level of activity of the sample.

In greater detail:

- The results firstly show the very considerable prevalence of natural radioactivity emitted by the potassium 40 of the soils which follows stable potassium (^{40}K represents 0.0119% of the total potassium), with the concentration varying from one soil to another as well as depending on the seasons. The natural alpha emitters (^{226,228}Ra, ^{228}Th) are also detected on a regular basis;
- As far as artificial radioactivity is concerned, traces of ^{137}Cs are measured in the soil which are due to the fallout from the Chernobyl accident and much older fallout from atmospheric nuclear testing (which reached its peak in the 1960s). The artificial transuranic alpha emitters (^{241}Am) are not measurable.

The table below summarises all the results obtained for the soils.

Summary:

- Natural radioactivity (^{40}K, ^{226,228}Ra, ^{228}Th) is mainly responsible for the level of radioactive contamination of the soil;
- ^{137}Cs is detected because, as already mentioned, it comes from the fallout of atmospheric nuclear weapons testing in the sixties as well as the passage of the Chernobyl radioactive cloud. On the other hand, the levels measured are logically lower than those found in the Sambre – Meuse basin, where the deposits due to Chernobyl were somewhat lower.

Soil radioactivity measurements (meadows/topsoils) of the reference zone

	MRI (Uccle-Brussels) site (Bq/m^2)	
	measurement	DL
γ	NM	~ 30
^{137}Cs	400 to 460	~ 10
^{40}K	(25 to 27) 10^3	
^{226}Ra ^{228}Ra	2.1 to 2.3 10^3	
^{228}Th	2.1 to 2.3 10^3	

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

7. THE FOOD CHAIN: DRINKING WATER, MILK AND FOODSTUFFS

From the beginning of the 60's, the ISP (the former IHE – Institut d'Hygiène et Epidémiologie - Institute of Hygiene and Epidemiology) conducted a study of the radiological contamination of the food chain. This programme was taken over by the SPIR (Service of Protection against the Dangers of Ionising Radiations at the Ministry of Social Affairs, Public Health and the Environment) and has been run by the FANC since 2001.

Samples of mains water, foodstuffs such as milk, meat, salt and fresh water fish, plus vegetables and company canteen meals (control meals) are collected regularly. These samples are then analysed and their radionuclide levels determined.

The artificial radioactivity of foodstuffs mainly comes from the presence of long life fission products such as ^{90}Sr and ^{137}Cs, which result essentially from nuclear testing which took place in the atmosphere in the 1960s.

In the event of an accident (such as that in Chernobyl), an increase in radiological contamination will be caused, in particular, by any presence of ^{131} I in the short term and of ^{137}Cs, ^{134}Cs, ^{90}Sr, or possibly ^{103,106}Ru, etc. in the long term.

Checks are carried out in Belgium on the following categories:

- Drinking water: samples taken from the distribution networks (tap water) at points spread evenly throughout Belgium so as to meet the EC obligation to establish a tightly knit (numerous points, classical radioactivity measurements) and widespread control network (small number of points, measurements of very low level radioactivity – Article 35/36 of the EURATOM treaty);

- Milk: samples also taken throughout Belgium from dairies and farms, once again to meet the EC obligation to establish a tightly knit and widespread control network;

- Foodstuffs: samples are taken from supermarkets and markets, while sea fish is controlled from fisheries on the Belgian coast;

- "Control" meals: samples are taken from company canteens on a monthly basis for each region of Belgium, i.e. Brussels Capital region, Flanders and Wallonia (EC obligation Art. 35/36 of the EURATOM treaty – establishing a tightly knit and widespread network).

Generally, this monitoring programme shows and confirms after several decades of observations that there is no evidence of any influence of nuclear facilities on foodstuffs and that the radiological state of the "housewife's shopping basket" is excellent in Belgium.

7.1 RADIOACTIVITY OF DRINKING WATER

Up to 1998, there were no European standards for the radioactivity of drinking water where the "ALARA" principle – "As Low As Reasonably Achievable" – applied. A WHO recommendation nevertheless set the following levels:

7800 Bq/litre in ^{3}H, 5 Bq/litre in ^{90}Sr, 20 Bq/litre in ^{60}Co, 6 Bq/litre in ^{131}I, 10 Bq/litre in ^{137}Cs, 1 Bq/litre in $^{226,228}Ra$, 0.1 Bq/litre in ^{232}Th, 4 Bq/litre in $^{234,238}U$, 0.3 Bq/litre in ^{239}Pu, etc.

Since November 1998, the European Commission issued ***Council directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption***. This directive deals with the microbiological, chemical and radioactive aspects. As far as the last point is concerned, the technical annexes specifying the analyses to be carried out as well as the directive's modalities of application are still in the process of being finalised.

On the other hand, the directive specifies two parametric values to be complied with: ***100 Bq/litre in tritium*** (^{3}H) and an ***annual total indicative dose – TID of 0.1 mSv*** (in its calculation, this dose does not take account of the contribution of tritium ^{3}H, potassium ^{40}K, radon ^{222}Rn or daughter elements lead ^{210}Pb and polonium ^{210}Po, most important from a radiological point of view). The dose is calculated on the basis of an annual ingestion of 730 litres of water for adults or children over the age of 10.

During 2011, the European Commission has decided to withdraw aspects "radioactivity" from the Directive 98/83/EC (which must also be renewed) and works on a specific radioactivity Directive to be issued under the EURATOM Treaty: Draft Council Directive on the protection of the public's health from radioactive substances contained in water intended for human consumption. The draft Directive accurately reflects the technical annexes were developed to be integrated into the Directive 98/83/EC.

With regard to the necessity of calculating the total indicative dose or not, two approaches have been included in the technical annexes based on "screening" values. The Member States can opt for either depending on their customs and preferences in the matter of radiological monitoring of the environment and their populations. These "screening" values will facilitate control of the water and avoid the pointless duplication of costly analyses while still ensuring that the water distributed actually meets the standards. In both cases, the parametric value of 100 Bq/litre for tritium also serves as a "screening" value.

- The first approach, the so-called *"global"* approach, is based on an assessment of the overall natural and artificial radioactivity with screening values of 0.1 Bq/litre in total alpha and 1 Bq/litre in total beta. These values enable the water to be screened quickly. If these levels are exceeded, it is then necessary to check whether natural radioactivity is responsible for the levels measured and, conversely, to analyse a maximum number of radioelements (beta and alpha spectrometries).

  This is the approach followed in Belgium under its programme for the radiological monitoring of drinking water (together with systematic gamma spectrometry analyses).

- The second approach, the so-called *"specific analyses of radionuclides"* approach, is based on the measurement of a certain number of radioelements (uranium; in β: ^{14}C and ^{90}Sr; in α: $^{239+240}Pu$ and ^{241}Am; in γ: ^{60}Co, $^{134\text{-}137}Cs$ and ^{131}I), the levels of which

must be lower than 20% of the reference concentration value (a concentration which would alone lead to a dose of 0.1 mSv).

If any of the screening values are exceeded, complete analyses in α, β and γ have to be carried out to calculate the total indicative dose using the conversion factors of the Basic Safety Standards set out in Directive 96/29/EURATOM (for an annual ingestion of 730 litres of water for adults and children over the age of 10).

Belgium, which has hundreds of catchment points, especially in small Walloon communities, will have to put a general plan in place for monitoring its water so as to be able to apply and abide by this new directive.

The radiological monitoring programme already monitors the quality of the water distributed by the country's biggest water distributors. The provinces where controls are undertaken are the following: Brabant (Brussels), Liege (Liege), Namur (Namur), Hainaut (Fleurus), Luxembourg (Bastogne), East Flanders (Ghent), West Flanders (Poperinge), Antwerp (Mol) and Limburg (Zepperen).

The control of radioactivity covers the total alpha, total beta, ^{226}Ra and ^{40}K (natural) emitters as well as tritium ^{3}H (artificial). The following table summarises the results obtained in the monitoring of drinking water.

Analysis of the table shows:

- Only ^{3}H and ^{40}K can be detected, with the measurements barely higher than the detection limits of the measuring equipment when they are significant;
- In some places, the total α levels exceed the screening value of 0.1 Bq/litre, which represents a caution threshold. Nevertheless, the TID never reaches the parametric value of 0.1 mSv/year;
- The mains water is therefore completely drinkable and fully meets European standards.

Summary:

- The radiological impact of the nuclear industry on distributed drinking water is not measurable: it meets the new standards put in place by the European Directive on drinking water;
- It should be noted that the greater part of beta radioactivity is explained by the presence of ^{40}K, a natural radioactive element whose contribution must not be taken into account when calculating the dose to which humans are subjected;
- A closer analysis of the monitoring programme results shows that although the water intended for human consumption generally complies with the standards, special attention must be paid at particular points (especially at Poperinge and at Fleurus) to the total alpha emitter content, with the greatest input coming from ^{226}Ra (natural), which sometimes exceeds the screening value of 0.1 Bq/litre. Even though this does not lead to the TID being exceeded, this water must be subjected to more particular monitoring. Ideally, the source should be traced in order to identify the collecting point(s) at the origin of these excessively high concentrations of radium.

Radioactivity measurements for drinking water

	Radioactivity of the water (Bq/l)	DL (Bq/l)	"Screening" value (Bq/l)
^{3}H	NM (Bastogne, Fleurus) 7 to 19 (Namur) NM (Mol, Zepperen, Poperinge) NM (Liège) 5 to 18 (Bruxelles) 6 to 12 (Gand)	~ 3 ~ 3 ~ 9 ~ 3 ~ 9 ~ 9	100
total β (residual) *	traces : 0.04 to 0.08 (Bastogne, Fleurus, Namur, Liège) 0.04 to 0.07 (Mol) 0.04 to 0.14 (Zepperen) 0.19 to 0.23 (Poperinge) 0.12 to 0.24 (Gand, Bruxelles)	~ 0.01	1
^{40}K	0.03 to 0.05 (Bastogne, Fleurus) 0.04 to 0.10 (Namur) 0.10 to 0.11 (Mol) 0.16 to 0.29 (Zepperen, Poperinge) 0.07 to 0.11 (Gand, Bruxelles) 0.06 to 0.07 (Liège)		NA
total α	NM (Mol) 0.04 to 0.07 (Zepperen) **0.25 to 0.46 (Poperinge)** NM (Bastogne, Namur) **0.11 to 0.30 (Fleurus)** 0.04 to **0.15** (Gand) 0.02 to 0.09 (Bruxelles) 0.04 to 0.05 (Liège)	0.01 to 0.04	0.1
^{226}Ra	NM (Zepperen, Bruxelles, Liège) **0.11 to 0.12 (Poperinge)** 0.02 to 0.03 (Gand) 0.02 to 0.07 (Fleurus)	0.01 to 0.02	0.1

NM: non-measurable, measurement less than or equal to the detection limits (DL)
NA: non applicable - * total β residual: total β apart from ^{40}K

7.2 RADIOACTIVITY OF MILK

Milk is a staple product for infants, in particular, as well as an important biological indicator of the transfer of radionuclides to humans via the food chain. That is why it is subjected to particular monitoring. Regular monitoring of the radioactivity of milk coming from dairies is preferable to sampling foods consumed, which is often too uncertain. This measurement reflects very well the total average ingestion of artificial radionuclides by the population since the dairies spread across the area collect the milk produced by the cows, which play an "integrator" role in relation to the radioactivity deposited or fixed in the plants consumed. The contamination of milk therefore gives a fairly true and quick picture of the state of radioactive contamination of a region.

Routinely, the detection of ^{137}Cs present in a weighted mixture of milk can be sufficient to calculate the effective dose rate due to diet. Nevertheless, milk is also collected from farms and dairies. The dairies included for taking the samples are located in a radius close to the

nuclear power stations (20km) depending on the extent of their production. They cover practically the entire dairy production of the region. The farms are located in the line of the prevailing winds close to the nuclear sites.

Each month, a national mixture is carried out from the main Belgian dairies. This mixture is weighted according to the relative size of each of them.

The radionuclides mainly checked in the milk samples are: ^{40}K for natural radioactivity and ^{90}Sr, $^{134,137}Cs$ and ^{131}I for artificial radioactivity (beta and gamma emitters).

In greater detail:

- The results relating to the natural radioactivity of milk show that the average content of a litre of milk remains constant at around 47-58 Bq. The other artificial radionuclides are practically undetectable;
- The milk distributed in Belgium fully meets the limits set by the European Commission: maximum 370 Bq/kg in ^{134}Cs and ^{137}Cs in milk and products derived from milk (Council Regulation on Radiation Protection no. 737/90 of 22 March 1990 extended by regulations no. 686/95 of 28 March 1995 and no. 616/2000 of 20 March 2000).

The following table presents a summary of the results obtained.

Radioactivity measurements for milk according to region

	National territory	Sambre – Meuse basin		Nete – Scheldt basin		
	National mixture	Fleurus, Tihange regions	Chooz region	Mol – Dessel region	Doel region	
	measurement (Bq/l)					DL (Bq/l)
$^{134,137}Cs$	NM	NM	NM	NM	NM	0.2 to 0.6
^{131}I	NM	NM	NM	NM	NM	0.7 to 2.7
^{90}Sr	NM	0.03 to 0.07	0.03 to 0.07	NM	NM	0.03 to 0.05
^{40}K	46 to 53	46 to 54	46 to 54	50 to 54	45 to 54	

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

Summary:

- Artifical radiation cannot be measured for $^{134,137}Cs$ and ^{131}I and is hardly detectable for ^{90}Sr (residue of "fallout" from atmospheric nuclear tests, with measurements at the level of the detection limits);
- The nuclear installations have no impact on the radiological quality of milk;
- Natural radioactivity is greater by far.

7.3 RADIOACTIVITY OF FOODSTUFFS

Samples of different foodstuffs are taken on the national territory by targeting small retail outlets and supermarkets, markets, abattoirs, fishmongers, etc.

The report includes data obtained as part the surveillance of the territory programme (over 860 samples resulting in approximately 7,430 measurements of radioactivity) increased by those provided by the Federal Agency for Security of the Food Chain (207 samples), resulting in approximately 620 additional radioactivity measurements. Thus, nearly 1,070 food samples were tested and the data analyzed and interpreted.

Common staple vegetables are collected: lettuce, leeks, celery, cauliflowers, Brussels sprouts, white cabbages, red cabbages, broccoli, beans, carrots, chicory, asparagus, tomatoes, cucumbers, peppers, salsifies, turnips, eggplant, zucchini, spinach, beets, fennel, pumpkins, onions, rutabagas, potatoes, cultivated mushrooms, wild mushrooms, etc.

Common staple of fruits are also collected: pears, appels, nectarines, kiwis, plums, mangos, melons, oranges, bananas, berries, strawberries, blackberries, grapes, etc.

Meat is also analysed from markets and abattoirs: beef, veal, horse, pork, sheep, goat, rabbit, lamb, poultry (including chicken, turkey, pheasants, ducks, geese, ostriches, etc.), roe and wild boar season. Snails and frog legs are also controlled. The organs concentrate radionuclides differently in the same animal. These differences are linked to the metabolic paths taken by the radioactive elements to penetrate and possibly settle in the organism. As an example, caesium mainly settles in the muscles (and in the bones over the longer term), while strontium behaves like calcium and, for its part, settles in the bony structures. The physiological factors of concentration, i.e. the differences in fat and water levels of the organs, can also influence the mechanism of radionuclide concentration. In general, however, the edible part is constituted of muscles. It is therefore sufficient, for example, to look into the radio-caesium content of the muscles (meat) in order to obtain a general idea of the quantity of radioactivity that may be transferred to humans.

Fish from fisheries are also taken into account: fresh water fish (tilapias, silurids, etc.) and deep-sea marine fish (tuna, swordfish, bream, bass, cod, herring, whiting, ray, sea trout, mullet, ocean perch, pollack, salmon, etc) and fish living on the bottom (plaice, sole, etc.).

In greater detail:

- The data analysed reveal a good radiological state of the foodstuffs consumed. Indeed, the samples display practically no detectable artificial radioactivity (the greater part of the samples measured have non-measurable levels of radioactivity, since they are lower than or equal to the detection limits of the measuring equipment);
- The results obtained adequately confirm the positive record revealed for the previous years: the foodstuffs circulated in Belgium as well as national production are of an excellent radiological level, with no problems noted. Furthermore, these foodstuffs fully meet the limits set by the European Commission: maximum concentration of 600 Bq/kg in ^{134}Cs and ^{137}Cs (Commission regulation on Radiation Protection no. 737/90 of 22 March 1990 extended by regulations no. 686/95 of 28 March and no. 616/2000 of 20 March 2000).

The following table presents a summary of the results obtained.

Radioactivity measurements for foodstuffs in Belgium (Bq/kg fresh)

	Vegetables & fruits		Sea fish		Fresh water fish	
	measurement	DL	measurement	DL	measurement	DL
^{137}Cs	NM	0.1 to 0.9	traces (0.2 to 3.0) up to 5 flatfishes	0.2 to 0.9	NM	~ 0.7
^{90}Sr	NM	1.0 to 2.0	NM	4 to 5		
^{226}Ra	traces	0.5 to 2.0	traces	1.2 to 1.5		
^{40}K	40 to 250		60 to 130		60 to 120	

	molluscs crustaceans (marine)		Red meat (beef, veal, horse, pig, sheep, rabbit, game)		White meat (poultry)	
	measurement	DL	measurement	DL	measurement	DL
^{134}Cs	NM	0.4 to 1.2	NM traces (up to 13 game)	0.5 to 1.0 0.7 to 1.2	NM	0.6 to 0.9
^{137}Cs			NM	0.6 to 3.0		
^{90}Sr	NM	0.8 to 1.5	traces	0.9 to 2.2	NM	1.1 to 1.9
^{40}K	40 to 140 (molluscs) 150 to 240 (crustaceans)		65 to 145		65 to 140	

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

Summary:

- The measurements carried out on everyday foodstuffs in Belgium do not call for any particular comments with regard to their radiological state. This control is nevertheless necessary because it constitutes a good tool for detecting a nuclear incident or accident, with the products measured often playing the role of indicators of radioactive pollution;

7.4 RADIOACTIVITY OF CONTROL MEALS

Samples of "control" meals are taken from canteens, supermarkets restaurant or company restaurants (mess) in the Brussels Capital region, Flanders and Wallonia on a monthly basis (EC obligation under Art. 35/36 of the EURATOM treaty – establishing a closely knit and widespread network) for radiological analyses.

The following table presents the results of these controls.

Radioactivity measurements for control meals (Bq/meal)

	Brussels (Drogenbos - CARREFOUR)		Wallonia (Fleurus - canteen)		Flanders (Mol- mess SCK•CEN/VITO)	
	measurement	DL	measurement	DL	measurement	DL
$^{134,137}Cs$	NM	0.02 to 0.03	NM	0.09 to 0.11	NM	0.29 to 0.31
^{90}Sr	NM	~ 0.3	traces ** (0.04 to 0.06)	~ 0.03**	NM	~ 0.4
^{40}K	30 to 50		40 to 65		30 to 55	
^{14}C	NM*	~ 1*	0.21 to 0.24*	< 0.04*	NM*	~ 1*

NM: non-measurable, measurement less than or equal to the detection limits (DL)
** expressed in Bq ^{14}C / g of stable C*
*** expressed in Bq/kg dry matter*

Summary:

The results obtained confirm the observation drawn from the analysis of the radioactivity of foodstuffs: no radiological problem for Belgian consumers.

8. MONITORING DISCHARGES FROM NUCLEAR SITES AND NORM INDUSTRIES

The effluents from liquid waste treatment installations are controlled under the territorial radiological monitoring programme. These controls are conducted on samples taken by the operator and/or the institute charged by the Agency to measure radioactivity.

The operators of nuclear power stations also provide declarations on atmospheric discharges via the chimneys. These discharges are not controlled directly via the territorial radiological monitoring programme but, rather, by FANC under its site controls (controls on the serviceability of the installations and compliance with operating permits).

The sites monitored are:

- Nuclear power sites (Doel and Tihange);
- Sites of Mol-Dessel (Belgoprocess 2 – former SCK•CEN liquid waste treatment installation, Belgoprocess, Belgonucléaire and FBFC International);
- IRE site: does not produce radioactive liquid waste in the environment but may reject noble gases and gaseous iodines in a controlled manner in accordance with its operating permit. The IRE is a public utility foundation and a major producer of radioisotopes used in nuclear medicine for diagnosis and therapy;
- Tessenderlo NORM industry (production unit for feed phosphates), which discharges ^{226}Ra into the Grote Laak and the Winterbeek. The follow-up of these discharges was integrated into the general surveillance program of the Belgian territory. Furthermore, other NORM sites or historically contaminated sites are also followed, either through measurements performed by the utility or through punctual interventions by the FANC.

Generally, the analysis of atmospheric and liquid discharges from the nuclear sites indicates that all these installations adhere to the limits imposed on them and more, in that the discharges are very much lower than the limits in question.

Only the discharges of tritium are significant, mainly the liquid ones, which represent around 37 % (Tihange) and 50 % (Doel) of the maximum authorised values. It should be noted that these levels are on the decline compared with those of the 1985-1990 period, when they were at a maximum of 47 % for Tihange and 67 % for Doel.

The liquid discharges into the Molse Nete are less negligible and make it particularly necessary to monitor this eco-system. The presence of a chemical industry at Tessenderlo and its discharges of ^{226}Ra strengthen the obligation to monitor the radio-ecological status of this region.

8.1 ATMOSPHERIC DISCHARGES OF NUCLEAR INSTALLATIONS

Atmospheric discharge is produced by the following sites:

- Nuclear power plant sites (nuclear power plants of Doel and Tihange);
- Sites of Mol-Dessel (SCK•CEN, Belgoprocess and FBFC International);

- Site of Fleurus (IRE).

8.1.1 Nuclear Power Plants:

There are no noticeable radiological problems: all of the emissions remain largely below the prevailing limits, especially with regard to the rare gases, iodine's and aerosols.

The following table gives an overview of the results available:

Measurement of the radioactivity present in the atmospheric discharge produced by the nuclear power plants of Tihange and Doel, expressed in a percentage of the legally specified yearly limits

	Tihange		Doel	
	Percentage	Limit	Percentage	Limit
Rare Gases	0.23	2.22 10^6 GBq	0.00145	3.00 10^6 GBq
Aerosols (β-γ)	0.00	1.11 10^5 MBq	0.0043	1.50 10^5 MBq
Iodines	0.07	1.48 10^4 MBq	0.44	1.50 10^4 MBq
^{3}H	13.25	5.55 10^4 GBq	2.75	8.90 10^4 GBq

Summary: on the basis of these results, it may be stated that there are no noticeable radiological problems.

8.1.2 Other Nuclear Sites:

Site of SCK•CEN:

The atmospheric discharges of alpha, beta and gamma emitters, iodine, tritium and rare gases produced by the installations of the SCK•CEN, are controlledly released through several chimneys: « nuclear reactors BR1, BR2 and BR3 (in dismantling), VENUS research reactor, high and medium activities laboratory LHMA, laboratory of Pu warm chemistry and laboratory of Low activity L.Sch, the building of temporary radioactive waste storage CBZ».

More in detail:

The data obtained are summarized in the table below.

Measurement of the radioactivity present in the atmospheric discharge produced by the nuclear site of the SCK•CEN, expressed in kBq per year (% of the limit)

	Total α	Total β–γ	^{131}I	HTO	Rare gases
BR 1		99.1 (0.0010)	1710 (0.0059)		268 10^8
BR 2	4.17 (0.0025)	101 (0.0065)	357 (0.0176)	1.99 10^9 (0.17)	555 10^6 (0.0913)
BR 3		13.6 (0.0003)			
VENUS				3.27 10^5 (65.41)	
LHMA	1.05 (0.0005)	3.83 (0.0002)			
Pu	3.34 (0.0014)	13.7 (0.0002)			
L.Sch	12.3 (0.0031)	110.0 (0.0033)			
CBZ	1.41 (0.0028)	7.19 (0.0037)			

Summary: there are no noticeable radiological problems. Monthly limits are likewise applicable and are also largely complied with.

Site of Belgoprocess:

The atmospheric discharges of alpha and beta emitters and of tritium produced by the installations of Belgoprocess, are controllably released through several chimneys, mainly: « AD, FLK, BRE, 280 » of building 2 (BP2) and « 120, 110, 131, 137 and 155 » of building 1 (BP1).

More in detail:

The data obtained are summarized in the table below.

Measurement of the radioactivity present in the atmospheric discharge produced by the nuclear site of Belgoprocess 2 in Mol-Dessel, expressed in kBq per year (% of the limit)

	Total Alpha	Total Beta	Tritium
AD	27.0 (0.142)	51.8 (0.00043)	$3.0\ 10^5$ (0.00017)
FLK	14.3 (0.035)	98.4 (0.00038)	
BRE	2.6 (0.0069)	12.7 (0.000058)	
280	15.8 (0.17)	59.2 (0.00296)	$3.46\ 10^5$ (0.865)

Measurement of the radioactivity present in the atmospheric discharge produced by the nuclear site of Belgoprocess 1 in Mol-Dessel, expressed in kBq per year (% of the limit)

	Total Alpha	Total Beta	Tritium
120	$5.5\ 10^2$ (0.05)	$6.5\ 10^2$ (0.0006)	
110	9.9 (1.01)	35.0 (0.0135)	
137	30.7 (1.53)	$5.89\ 10^2$ (0.0059)	$2.71\ 10^4$ (0.0027)
131	5.92 (0.0059)	19.8 (0.0020)	
155	7.3 (0.0182)	44.0 (0.00147)	

Summary: there are no noticeable radiological problems. Monthly limits are likewise applicable and are also largely complied with.

Site of FBFC International:

The atmospheric discharges of *FBFC International*, a nuclear fuel and MOX assembly facility, are released through two chimneys situated on buildings 2 and 5 of the site. Its alpha emission is subject to the following licenses:

- Building 2: 190 kBq/year;
- Building 5: 320 kBq/year.

With an instant volumic limit of 0.013 Bq/m³ (GRPIR).

More in detail:

The data obtained are summarized in the following table.

Measurement of the radioactivity present in the atmospheric discharge produced by the nuclear site of FBFC International in Mol-Dessel, expressed in kBq in total alphas

	Total discharge	Limit	Percentage of the limit
Building 2	22.2 ± 6.5	190	11.7 ± 3.4
Building 5	14.9 ± 8.7	320	4.6 ± 2.7

Summary: there are no noticeable radiological problems.

Site of IRE:

Atmospheric releases of the IRE are made from chimneys located on three buildings B4, B17 and B6D. Most of releases are performed via the chimney located on the B4 building.

Site atmospheric discharges must comply with the following permissions:

Discharge limits for Iodine (^{131}I equivalent):

- in 7 days discharge can not exceed 3,170 MBq;
- 35 days on slippery: the discharge can not exceed 7,200 MBq;
- over the year: the release may not exceed 41,800 MBq.

Discharge limits in the Xenon (^{133}Xe equivalent):

- in 24 hours: discharges may not exceed 91 TBq;
- 35 days on slippery: the discharge may not exceed 357 TBq;
- over the year: the release may not exceed 3,714 TBq.

Radioactivity measurements of annual atmospheric releases of the nuclear site of the IRE

	Total discharge	Limit	Percentage of the limit
Equivalent ^{131}I (MBq)	4,054.57	41,800	9.7
Equivalent ^{133}Xe (TBq)	2,008.02	3,714	54.07

The limits for iodine releases fluctuate between 0.73% and 8.44% of the weekly limit, and between 2.2% and 11.6% of the of 35 days slippery limit.

The limits for xenon discharges fluctuate between 22.5% and 85.8% of the of 35 days slippery limit.

In summary: the site of the IRE is in compliance with its operating authorizations.

8.2 LIQUID DISCHARGES OF NUCLEAR INSTALLATIONS

The following sites discharge into rivers:

- Nuclear power sites (Doel nuclear power station into the Scheldt and Tihange into the Meuse):

- Sites of Mol-Dessel (Belgoprocess 2 - former SCK•CEN liquid waste treatment installation, Belgoprocess, Belgonucléaire and FBFC International - into the Molse Nete).

8.2.1 Nuclear power stations:

The liquid discharge limits set for the *Tihange site*, three reactors with a total capacity of 3,022 MWe, are 1.48 10^5 GBq in ^{3}H and 8.88 10^5 MBq in beta-gamma emitters; for the *Doel site*, four reactors of a total capacity of 2,910 MWe, they are set at 1.04 10^5 GBq in ^{3}H and 1.50 10^6 MBq in beta-gamma emitters.

In greater detail:

- For the Tihange nuclear power station: the most significant liquid discharges in terms of activity are made up of tritium: in the order of 37 % of the authorised limit. The beta-gamma emitter discharges are, however, mostly lower than the limit, i.e. around 1 % of said limit;
- For the Doel nuclear power station: the most significant liquid discharges in terms of activity are made up of tritium, representing 50 % of the limit. The beta-gamma emitter discharges are, once again, mostly lower than the limit, i.e. around 0.3 % of said limit.

The following table summarises the available data.

Radioactivity measurements for liquid discharges from the Tihange and Doel nuclear power stations, expressed in a percentage of the legally specified yearly limits and quantities discharged

	Tihange		Doel	
	Percentage	Limit	Percentage	Limit
^{3}H	37.2	1.48 10^5 GBq	49.8/	1.04 10^5 GBq
total β-γ	0.57	8.88 10^5 MBq	0.26	1.50 10^6 MBq
	Quantity (MBq)		Quantity (MBq)	
total β	0		0.70	
total α	1.09 10^{-3}		0	

Summary: no radiological problem indicated on the basis of these results.

8.2.2 Other nuclear sites:

Mol-Dessel site:

The liquid discharges from the Mol-Dessel nuclear site enter the Molse Nete via the installations of Belgoprocess 2. These discharges have to adhere to 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] ≤ 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 detectable, as also attested by the radioactivity measurements taken in the river (water, sediments, fauna and flora). These controls at the source and in the environment need to be maintained.

In greater detail:

- The data show that the total weighted discharges represent 0.2 % of the annual limit;
- Measurements conducted on the gamma and beta emitters of the effluents discharged show that radioactive elements such as ^{137}Cs (from 1.0 to 30.0 Bq/l), ^{3}H (from 3.3 10^{2} to 1.1 10^{5} Bq/l), ^{90}Sr (from 0.2 to 0.7 Bq/l) and ^{60}Co (0.4 to 5.0 Bq/l), ^{99}Tc (20 to 80 Bq/l);
- The discharges in total alpha range from 0.2 to 3.0 Bq/l, with those in total beta around 2.0 to 15.0 Bq/l;
- As far as the transuranic elements are concerned, traces of ^{241}Am are detected (for limits of the order of 0.1 to 0.2 Bq/l). $^{239,240}Pu$ are routinely detected at levels below to 1.1 Bq/l (mostly between 0.02 and 0.08 Bq/l). The same observation can be made for ^{238}Pu.

The following table summarises the data obtained.

Radioactivity measurements for liquid discharges from the Mol-Dessel nuclear sites, expressed in percentages of the statutory limits and in quantity (GBq) – Belgoprocess 2 discharges

	Percentage	Weighted quantity (GBq)	Annual discharge limit
Weighted total	0.198	0.296	150 GBq
total α		0.0394	
^{90}Sr-^{90}Y		0.0098	
^{3}H		0.0554	
^{60}Co		0.008	
^{134}Cs		0	
^{137}Cs		0.164	
total β		0.0197	

Summary: the site fully complies with the discharge limit.

FBFC International site:

The liquid discharges of ***FBFC International***, a manufacturer of nuclear fuel and assembler of MOX fuel elements, enter a sink located on the site. These discharges do not reach the Molse Nete. They are nevertheless monitored regularly (every month).

In greater detail:

Measurable quantities of alpha emitters are discharged every month: from 0.4 to 1.0 Bq/l (a decrease is recorded compared to 2001-2002). It should be noted that the detection limits are of 0.1 to 0.2 Bq/l, which indicates that these discharges are barely measurable. The site can't discharge more than20 Bq/l in total alpha (GRPIR).

The following table summarises the data obtained.

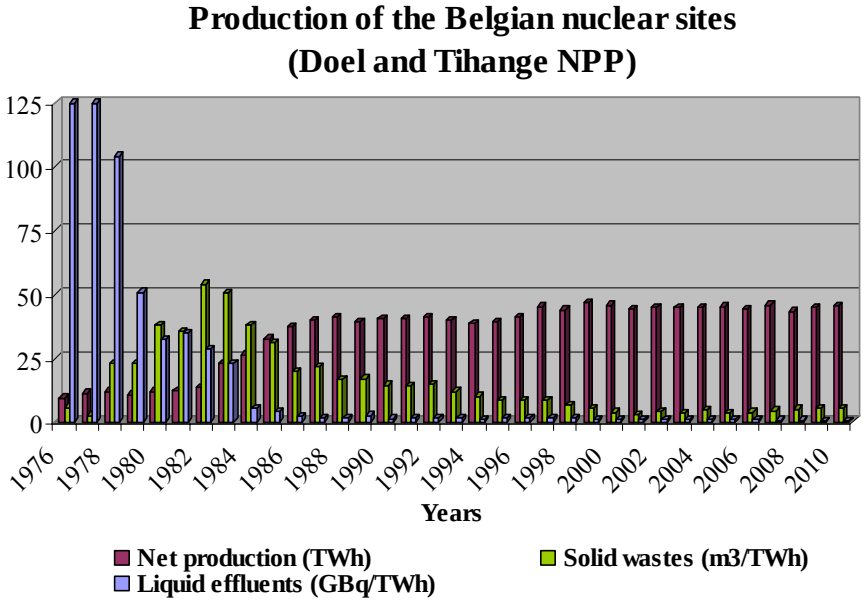
Radioactivity measurements for liquid discharges from the FBFC International Mol-Dessel nuclear site expressed in Bq/l (DL: detection limit)

Radioactive element	measurement	DL	Total discharge (MBq)
total α	0.6 to 3.0	~ 0.1 to 0.2	3.43
total β	0.6 to 1.7	~ 0.1	
^{234}U	0.05 to 0.80	~ 0.08	
$^{235,236}U$	0.008 to 0.16	~ 0.08	
^{238}U	0.01 to 0.28	~ 0.09	
^{241}Am	traces ($1.1\ 10^{-3}$ to $3.8\ 10^{-2)}$	~ $2\ 10^{-3}$	
^{238}Pu	traces ($3\ 10^{-3}$ to $1\ 10^{-2}$)	~ $5\ 10^{-3}$	
$^{239+240}Pu$	traces ($2\ 10^{-3}$ to $4\ 10^{-2}$)	~ $5\ 10^{-3}$	

Summary: no radiological problem to report.

8.2.3 Electrabel data on nuclear power stations:

Another interesting point to note concerns the quantity of liquid and solid waste (removed for treatment by the ONDRAF - National Organisation for Radioactive Waste and Enriched Fissile materials) generated by nuclear power stations (following chart).



While the total production of electricity has remained more or less constant at around 45 TWh in recent years, the quantity of radioactivity discharged in the liquid effluents has sharply declined: from around 42 GBq in 2003 and 2004, it decreased to 37 GBq in 2005, to less than 35 GBq in 2006, less than 30 GBq in 2007, less than 28 GBq in 2008, to 21 GBq in 2009 for reach around 17 GBq in 2010 (0.37 GBq/TWh).

This observation is even more amplified by the volume of solid waste generated per TWh removed for treatment by the ONDRAF: current volumes are around 5.44 m^3/TWh.

This shows the efforts made by Belgian electrical engineers 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 B.A.T. – "Best Available Technology" – concept with regard to liquid and solid waste.

8.3 NORM INDUSTRIES AND HISTORICALLY CONTAMINATED SITES

Belgium accounts for several active NORM industries, especially in the sector of phosphate production. The residues of these industries are in some cases disposed of in *mono-landfills*. As one is dealing in this case with significant amounts of material – several million m³ - the impact of these mono-landfills on the environment may not necessarily be neglected. This of course justifies the implementation of a system for surveillance of these sites.

Furthermore, in Belgium, there exist also a number of sites that were contaminated by radioactive substances as a consequence of past activities – one speaks about historically contaminated sites or legacy sites. Besides those sites related to the NORM industry – like the historical disposal sites for phosphogypsum -, one counts also some sites related to the past activities of radium extraction.

8.3.1 NORM industries in activity:

The majority of "NORM" sites in Belgium are related to phosphate industries

8.3.1.1 Sites related to the activities of Tessenderlo Chemie NV

Tessenderlo Chemie NV products in particular animal feed phosphates from sedimentary North African origin. The dissolution of phosphate ore is carried out using hydrochloric acid. The end result is the production of large amounts of calcium fluoride. The calcium fluoride is treated as waste and land filled.

Until the 90s, a significant proportion of radium present in the phosphate ore was discharged via the waste water releases. The concentration of radium in the waste water could reach at that time 20 to 25 Bq/l. To reduce this concentration, the process of co-precipitation with barium was used: this led to a marked decrease in the concentration of radium in water.

Since 2000, releases operated by *Tessenderlo Chemie* have been measured directly in the discharge channel which flows into the Winterbeek river. The total amounts of alpha emitters are detected in trace amounts (0.3 to 4.4 Bq/l depending of the month), those of total beta emitters range from 1.7 to 5.4 Bq/l, the concentration of ^{226}Ra varies between 0.5 and 4.1 Bq/l.

This natural radioactivity is hence being artificially added into the Nete basin, originally through the Grote Laak and presently also through the Winterbeek into the Demer basin.

Significant concentrations of radium in the waste water released up to the 90s led to deposition of radium in the sediments of Laak and Winterbeek. The dredging of these rivers and sediment disposal on their banks has led to the contamination of these banks. Concentrations of radium in the order of a few Bq/g were found. Figure 1 shows the gamma radiation measurements made by FANC on the banks of these rivers. Values can reach ten times the local natural background radioactivity level.

The decrease in the concentration of radium in the water discharge was matched by the increase of the concentration in the solid residues (calcium fluoride). This concentration has now reached just over 10 Bq/g.

Fig. 1: measurements of gamma radiation (in counts per second) along the banks of the Winterbeek river.

In addition, the mono-landfill (Fig. 2) "Veldhoven" on which *Tessenderlo Chemie NV* dumps its solid waste is also subject to a monitoring program. The total alpha activity in groundwater samples are measured using two piezometers. Between 2004 and 2009, these activities ranged from values below 15 mBq/l and a maximum value of 139 mBq/l. The concentration of radon in the air on and around the landfill is also followed.

The table below shows the values of radon concentration for the period 2008-2010. It shows the average values of concentration in the areas S1 and S2 of the landfill which are no longer in exploitation, on the S3 area currently in operation and in the environment of the landfill. A measuring point is located on a "historic" landfill located inside the premises of the enterprise (see below). Note that the maximum value recorded is 160 Bq/m^3, more than 15 times the normal concentration in this region (~ 10 Bq/m^3). The values in the environment are however of the order of the local natural background.

Radon concentration in and around the mono-landfill "Veldhoven" of *TESSENDERLO CHEMIE* (Bq/m^3)

	2008	2009	2010
Zones S1and S2	160	80	65
Zone S3	14	20	20
In the environment	11	10	10
On the historical landfill	53	60	30

Fig. 2: Aerial view of the mono-landfill of *TESSENDERLO CHEMIE*

Besides the still active mono-landfill "Veldhoven", TESSENDERLO CHEMIE also owns some other mono-landfills that are no longer in operation. As the exploitation of these "historic" mono-landfills had been stopped before 1990, the radium concentration is significantly lower but still reached values of about 3 Bq/g.

In 2010, FANC has performed measurements of external radiation on the surface of two of these historic landfills: the "Kepkensberg" landfill and the landfill located within the premises of the company.

These measures of external radiation are illustrated on Figures 3 and 4.

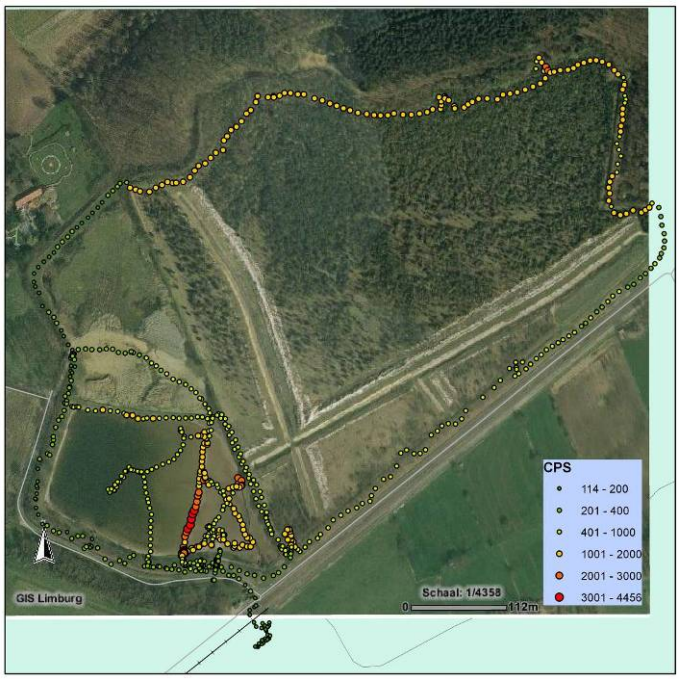


Fig. 3: measurements of gamma radiation (in counts per second) on the surface of the mono-landfill "*KEPKENSBERG*"

Measurements of radon in soil were also performed on the Kepkensberg landfill. The measured values range between 420 and 1,550 kBq/m^3.

Fig. 4: measurements of gamma radiation (in counts per second) on the surface of the site of *TESSENDERLO CHEMIE* facility located at Ham

8.3.1.2 Sites related to the activities of PRAYON sa

The company PRAYON currently owns two production sites: one in Puurs between Brussels and Antwerp, and the other in Engis near Liege. The company produces phosphoric acid and fertilizers; it uses the process of dissolution by sulfuric acid, which leads to the production of phosphogypsum residue.

Currently, the production of the site of Puurs is made directly from phosphoric acid, so that only marginal quantities of phosphogypsum are produced. The site of Engis uses as raw materials mainly phosphate ores for magmatic origin. They have a concentration of natural radioactive elements significantly lower than the sedimentary phosphates.

PRAYON operates near its production site of Engis a mono-landfill where are dumped the surpluses of phosphogypsum from the production process. The levels of ^{226}Ra in groundwater samples are followed through six piezometers. The maximum value measured in 2010 was 13 mBq/l. These values are of the order of magnitude of background concentrations.

In addition to this mono-landfill in operation, one also finds around the site of Engis an "historical" phosphogypsum stack on which FANC performed in 2010 monitoring measurements. External radiation measurements are shown in Figure 5. Radon concentrations in soil were also measured and rise up to 101 kBq/m^3 in ^{222}Rn and 83 kBq/m^3 in ^{220}Rn.

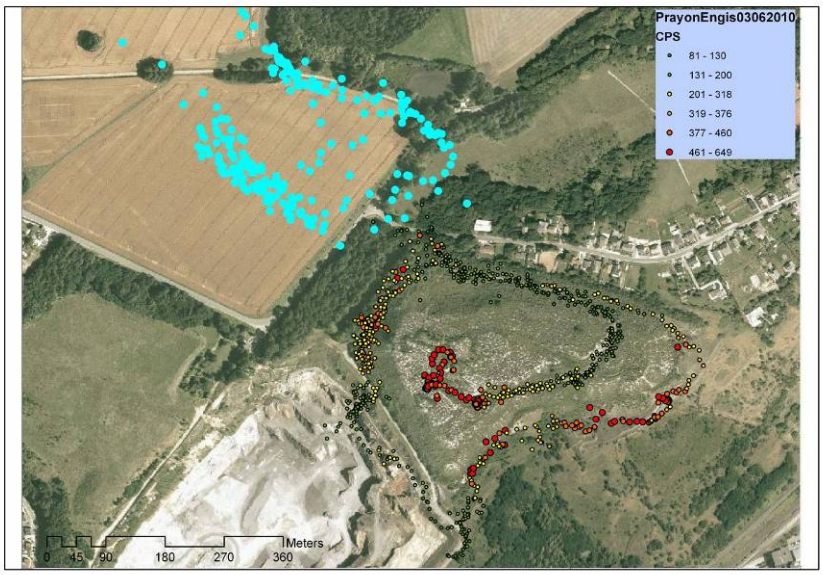


Fig. 5: measurements of gamma radiation (in counts per second) on the surface of the historical phosphogypsum stack of Engis. Blue points are artefacts.

The production site of Puurs currently no longer operates landfills, but there are in the region a number of old phosphogypsum stacks related to historic PRAYON-Rupel activities.

Some of these landfills have been converted: one of them has become a recreational area (provincial domain "De Schorre" at Boom). FANC has found via field measurements that, in some parts of this area, the phosphogypsum appears at the surface as illustrated in Fig. 6.

Fig. 6: measurements of gamma radiation (in counts per second) on the surface of the site of the provincial domain "*DE SCHORRE*" at Boom

External radiation measurements were made on other former stacks in the region such as shown on Fig. 7. A value of total alpha emitter's concentration was measured in groundwater from one of these landfills; it reaches 0.2 Bq/l.

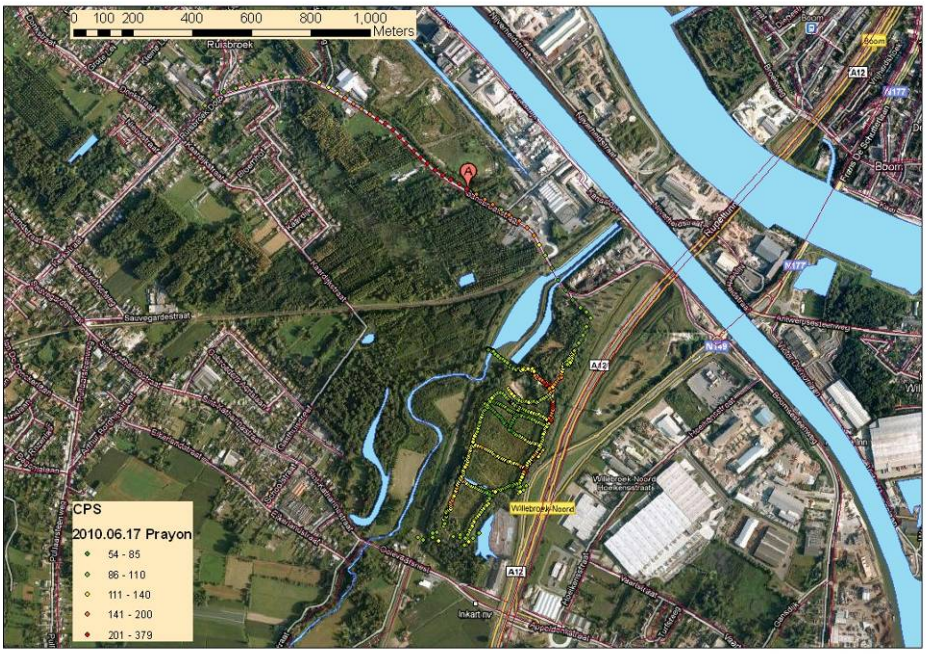


Fig. 7: measurements of gamma radiation (in counts per second) in the Rupel region

8.3.1.3 Other phosphogypsum stacks: the site of the former NILEFOS facility in Ghent

The phosphogypsum stack located on the boundary of the municipalities of Zelzate and Ghent was operated from 1925 to 2009 firstly by Rhodia, then by NILEFOS company. This company was declared bankrupt in 2009. The area of the landfill covers approximately 65 ha and the total volume of phosphogypsum is estimated to ~ 18 millions tonnes.

The abandonment of the stack following the bankruptcy of the company led FANC to perform environmental measurements on the landfill in 2010. The results of the measurements of external radiation are shown on Fig. 8. The figure also mentions the values of concentration of radon, thoron and radium-226 in soil. The dose rate at the surface may reach up to 5-7 times the local background level. The concentrations of radium-226 are quite variable: it can reach 6.9 Bq/g. Note that contamination also occurred outside of the landfill, within the perimeter of the old production units. A dose rate of 50 µSv/h was measured locally few centimeters from the ground surface.

The concentration of radium-226 in groundwater reaches 10-30 mBq/l.

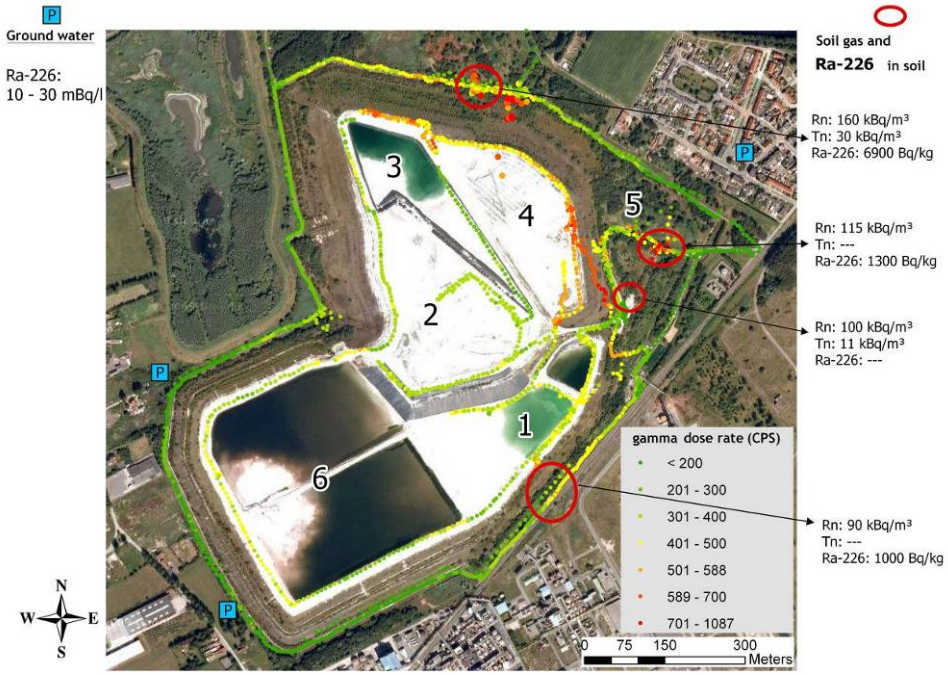


Fig. 8: general view of the phosphogypsun stack of the former NILEFOS Company

After the bankruptcy of the company NILEFOS, the stack was taken over by another company that intends to continue operating by accepting external inputs of phosphogypsum. As part of this recovery, an environmental impact report was introduced in 2010 to the competent authority. FANC plans to continue monitoring the radiation on and around the landfill.

8.3.2 Other « NORM » sites and companies

8.3.2.1 Extraction of ferro-niobium

The metallurgical company SADACI in Ghent produced ferro-niobium in the years 1960-1970. The slag wastes from the extraction processes were disposed of on land adjacent to the production units. These slag show significant concentrations of thorium-232 and radium-226; these concentrations can reach respectively 60 Bq/g and 12 Bq/g. These concentrations are however rather inhomogeneous and the contamination is dispersed around the company and under some of the buildings constructed more recently. Figure 9 shows a view of the external radiation on this site. The dose rate at the surface can reach up to 6 µSv/h.

In addition to measurements of dose rate, measurements of radon and thoron in soil were also performed. They amount respectively to 7 and 21 kBq/m^3; the local background values are about 10 kBq/m^3; only the thoron concentration is greater than the background value which reflects the significant concentration of thorium-232 in the slag; the high density of these slag explains why the exhalation of radon and thoron remains limited.

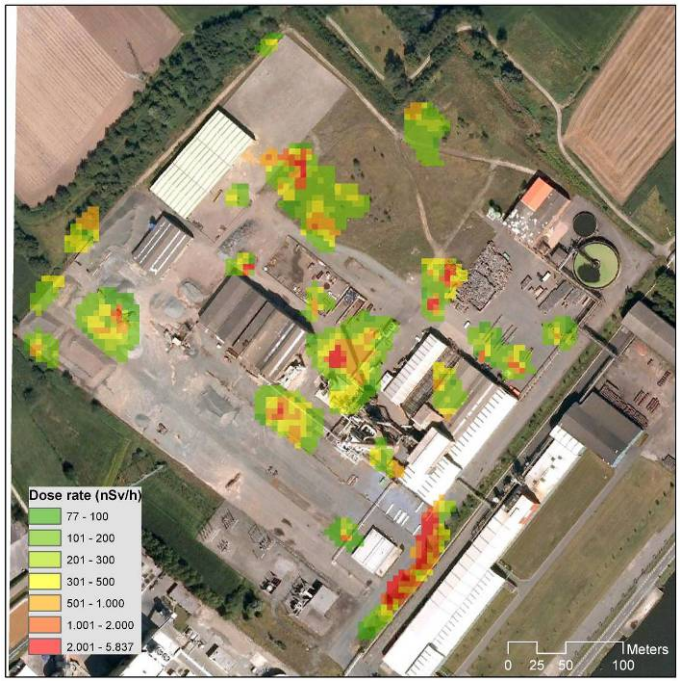


Fig. 9 : surface dose rate on the site of the company SADACI

Measurements of total alpha concentrations were performed with help of several piezometers. In the 11 samples taken from the shallow piezometers, only one sample showed a concentration of total alpha greater than 0.1 Bq/l (0.25 Bq/l). But, of the 17 samples taken from deep piezometers, 10 had a concentration of total alpha greater than 0.1 Bq/l with a maximum value of 0.9 Bq/l.

8.3.2.2 Other sites

As part of the collaboration agreement between FANC and SPAQUE[3], measurements of external radiation were performed on a few "NORM" sites of Wallonia: the former metallurgical site AMS NORD in Charleroi, the former colliery BONNE FORTUNE in Ans, the former glass manufacturing factory and chemicals facility in Auvelais. The increases above natural background are generally very low (less than twice the background) with a few local increases due to refractory materials, for instance on the site of AMS NORD. These measurements are illustrated on Figures 10 to 13.

[3] Société Publique d'Aide à la Qualité de l'Environnement.

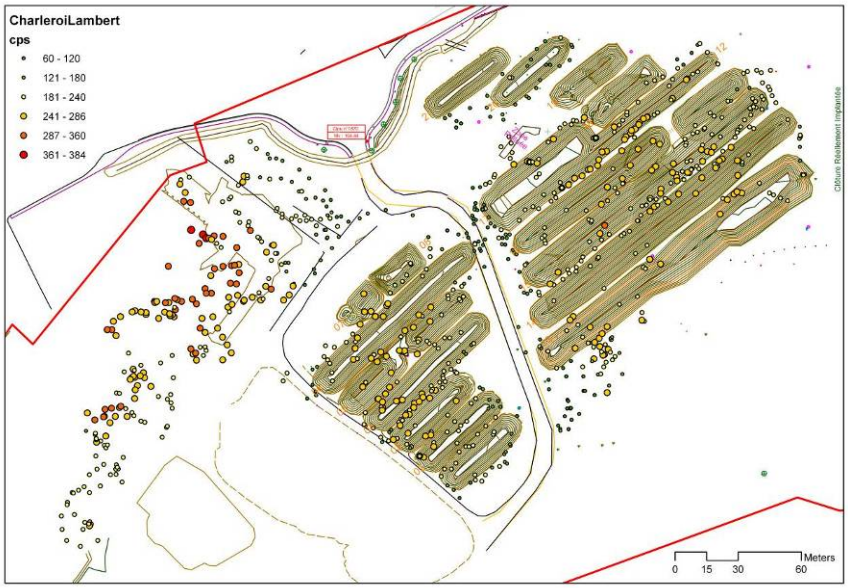


Fig. 10: gamma radiation (in counts per second) on the surface of the site of AMS NORD in Charleroi.

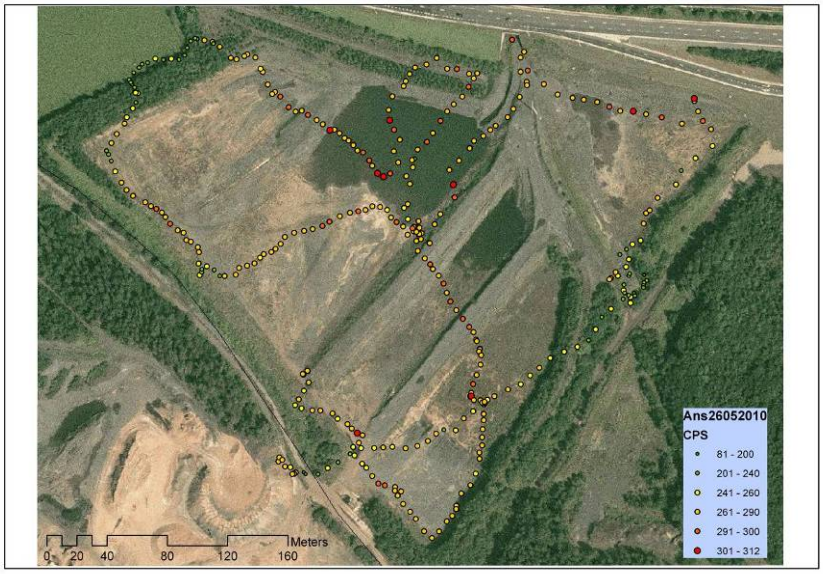


Fig. 11: gamma radiation (in counts per second) on the surface of the site of former colliery BONNE FORTUNE in Ans

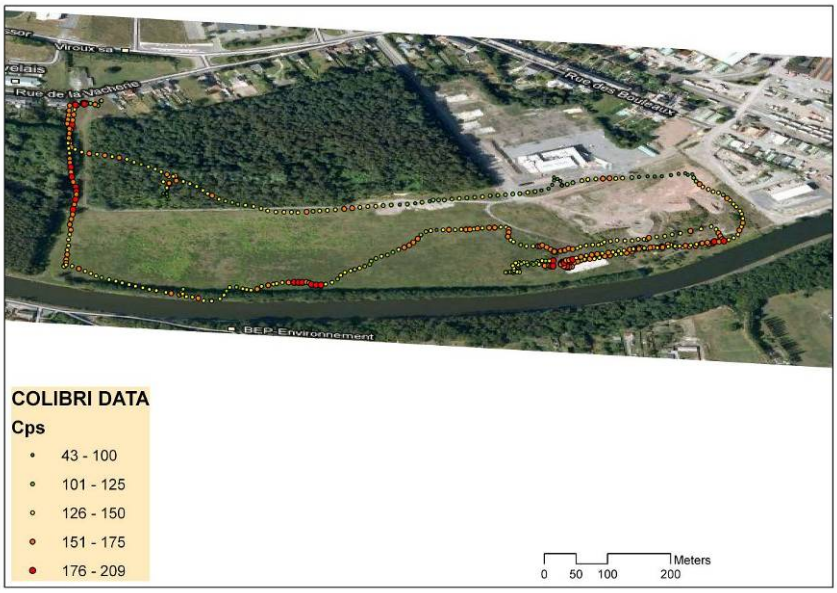


Fig. 12: gamma radiation (in counts per second) on the surface of the former glass manufacturing factory in Auvelais.

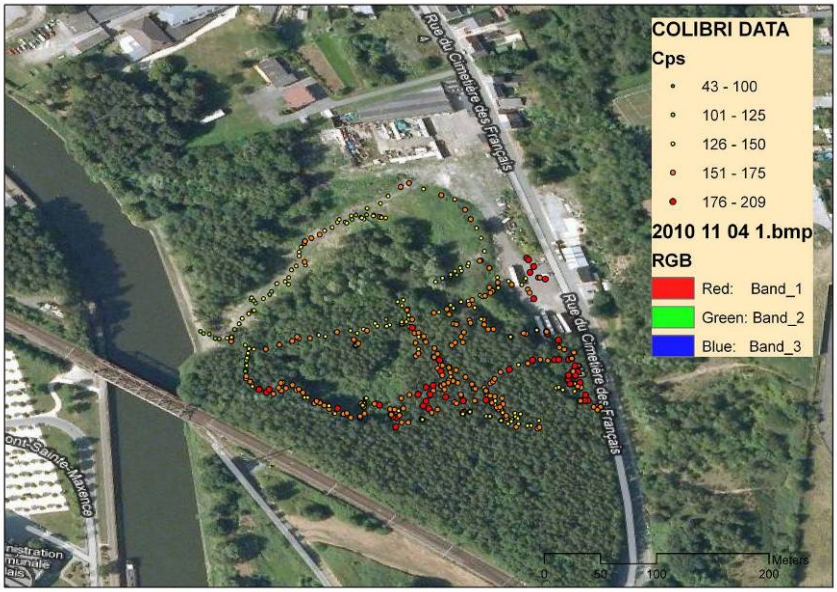


Fig. 13: gamma radiation (in counts per second) on the surface of the former chemicals facility in Auvelais

In summary, the current radiological impact of the NORM industries still active in Belgium is limited. However, the activity levels of the residues dumped on their mono-landfill by TESSENDERLO CHEMIE and high concentrations of radon at the surface of this mono-landfill require a radiological monitoring of this mono-landfill. In particular, after the end of the exploitation of this landfill, any new allocation of the site will require a detailed radiological impact study.

In addition, monitoring of historical "NORM" dumpsites is also necessary: although the current environmental impact is also limited, any change in allocation of these landfills should be subject to a risk analysis. The exhalation rate of radon from phosphogypsum is important and a possible conversion of these former phosphogypsum stacks for construction purposes

(whether residential houses or workplaces) could lead to a significant exposure if no precaution against the infiltration of radon has been taken in the construction of these buildings.

8.3.3 Other contaminated historical sites: sites linked to the former radium extraction activities in Olen

Between 1922 and 1969, the metallurgical plant of the former UNION MINIÈRE (now UMICORE) located in Olen (province of Antwerp) was active in the extraction of radium and uranium and the production of radium sources. In addition to its radium extraction activities, the company was also active in the production of other metals, including cobalt. Part of the production wastes (tailings, radium needles, ...) and decommissioning wastes were disposed in an authorized storage facility: UMTRAP (*Uranium Mill Tailings Remedial Action Project*).

Between 2006 and 2008, the banks of the river Bankloop that had been contaminated as a result of the company's activities have been subject to remediation. Materials resulting from the remediation project were disposed in another authorized storage facility.

These two licensed facilities are located on the site of the company and are subject to a radiation monitoring program imposed by the regulator. The radon concentrations in open air, the radium concentrations in surface water and groundwater are measured around each plant.

The table below shows the minimum and maximum values for each measured variable in 2010. The variations are related to the location of measurement points and weather conditions.

	UMTRAP			**Storage facility "Bankloop"**		
	# measurement points	Min	Max	# measurement points	Min	Max
Rn-222 concentration open air (Bq/m^3)	3	38	92	6	9 (= background)	81
Ra-226 concentration surface water (mBq/l)	2	10,2	26	2	12,5	121
Ra-226 concentration groundwater (mBq/l)	4	1,1	15,7	4	9,9	161
Ra-226 concentration percolate (mBq/l)	0	-	-	1	< 5	7,8

In addition to the materials stored in these two licensed facilities, one can find on and around the site of the company a number of sites with significant radium contamination and which must still be subject to a remediation process.

In particular, some production wastes and decommissioning wastes from the radium extraction unit had also been dumped on two landfills, the dumps D1 and S1.

D1 shows the most important levels of contamination: the average activity concentration of Ra-226 for the entire volume of the landfill (217,000 m^3) is between 5 and 20 Bq/g, but the maximum concentration of some "hot spots" approaches 1 kBq/g. Analysis of groundwater conducted in 2008 around the two landfills D1 and S1 show maximum concentrations in filtered water of 220 mBq/l in U-238 and 409 mBq/l in Ra-226. As the number of measurements is very limited, we can not draw clear conclusions on the representativeness of these values. In the past, radon concentration in different parts of the surface of the landfill D1 was measured; the values are very high: they vary between 180 and 1,330 Bq/m^3 at 0.5 m height. Both landfills are however not accessible to the public: the current radiological impact is thus not significant.

Radium contamination can also be found outside of these two dumps, particularly inside the premises of the factory itself.

In summary, the current radiological impact of the sites contaminated by past radium extraction activities does not require urgent action. However, it could become significant in case of change in allocation of the land concerned.

9. OVERALL CONCLUSIONS

The revision of the entire programme for the radiological monitoring of the territory – which was implemented from 2003 to 2004 and was based on an effort to harmonise the libraries of radioelements measured for the overall territory as well as taking account of the requirements of international bodies (European Commission, OSPAR with respect to the Sintra agreements under the policy of protecting the North Sea and the North-East Atlantic) – has enabled the different regions of the country to be better monitored while taking account of their specific features. Comparisons between sections of each region and between regions themselves have been made easier.

An analysis of the results obtained within the framework of the radiological monitoring of the Belgian territory of 2010 gives rise to the following comments:

Overall:

The discharge limits in force are very well respected by the operators of nuclear installations.

The radiological monitoring of the territory also clearly shows that, under normal conditions and excluding medical exposure, the dose rate depends above all on the nature of the soil, with the rocky soils of the south of the country emitting more radon than those of the north (sandy). It is for this reason, for example, that the dose rate measured in Wallonia (Ardennes) is greater than that measured in the vicinity of the Doel nuclear power station, whose impact on the environment is negligible.

The radiological contamination levels of the samples measured are generally extremely low and, for this reason, the greater part of the data obtained are not significant. Natural radioactivity (^{40}K and ^{7}Be) is by far the most prominent and more present than most artificial beta-gamma emitters. The monitoring programme demonstrates its value and ability to "finely" monitor the impact of radioactive elements on the environment and consequently on humans: "traces" of artificial radioactivity, considerably lower than natural radioactivity, are routinely detected.

Although this situation is reassuring at the health level, it becomes awkward with regard to capitalising on the results: indeed, significant measurements justify a more exact and quantifiable description of the radiological situation. Radioactivity transfer parameters can then be drawn up to facilitate calculations of the doses to which the population is subjected. That then implies increasing the volumes or masses of the samples in order to be able to "drop down" to very low level measurements, which are alone capable of providing significant and, hence, reliable values. The European Commission moreover demands this type of endeavour from the Member States in relation to certain measurements (establishing a widespread network of measuring points aimed at detecting very low levels of radioactivity).

In greater detail:

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 higher charge of both artificial and natural radioactivity (^{226}Ra) enhanced by human activity. This concerns the entire Laak-Winterbeek-Nete hydrographic network.

The monitoring of the northeast of Belgium reveals that some nuclear installations in the Mol-Dessel region have a measurable, although small, radiological impact on the environment and

that it is also true for the feed phosphate industry in the Tessenderlo region. This means that the sediments of the Molse Nete contain a significant level of fission products (^{137}Cs) and heavy artificial radionuclides in the form of traces of transuranic elements ($^{239+240}$Pu, ^{241}Am). ^{226}Ra activity is also relatively high in the sediments of the Grote Laak and the Winterbeek in the vicinity of Tessenderlo.

On the other hand, the – measurable – radiological impact of the nuclear installations in the northeast of the country and feed phosphate production has nevertheless declined sharply in recent years.

The Federal Agency for Nuclear Control have decided to install in 2011 new automatic and continuous measuring stations for gamma radiation present in surface water. Continuous data will be used among others to demonstrate more fully more fully that Belgium is meeting its national and international obligations under the OSPAR convention and Articles 35/36 of the EURATOM (EC) Treaty.