OSPAR COMMISSION

Protecting and conserving the North-East Atlantic and its resources

French Implementation Report of PARCOM Recommendation 91/4 on radioactive discharges

Radioactive Substances Series

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EXECUTIVE SUMMARY
INTRODUCTION
PART I – GENERAL INFORMATION

EXECUTIVE SUMMARY

The control of nuclear safety and radiation protection in France has been completely revised since 2006. The 13th June 2006 Act concerning transparency and security in the nuclear field, called the "transparency and nuclear safety" - "TSN Act" (now codified in books I and V of the Environment Code), extensively overhauled the Basic Nuclear Installations legal system - BNI legal system. It has in particular given this system an "integrated" nature, that is to say that it seeks to prevent the hazards and detrimental effects of any type that the BNIs could create: accidents - whether nuclear or not, pollution - whether radioactive or not, waste – whether radioactive or not, etc.

Amended decree 2007-1557 of 2nd November 2007 concerning BNIs and regulation of the nuclear safety of the transport of radioactive substances, known as the "BNI Procedures" decree, defines the framework in which the BNI procedures are carried out and covers the entire lifecycle of a BNI, from its authorization decree to commissioning, to final shutdown and decommissioning.

These foundation texts have been supplemented by the ministerial Order of 7th February 2012 setting the general rules relative to basic nuclear installations, called the "BNI" ministerial order, and ASN (French nuclear safety authority) resolution 2013-DC-360 of 16th July 2013 as amended on September 29, 2016 relating to the control of detrimental effects and of the impact on health and the environment of BNI.

France has fully incorporated the best available techniques (BAT) into its legislative and regulatory texts. The best available techniques appear in the front rank of the principles that control nuclear activities in France.

Even if the radiologic impact associated with liquid radioactive discharges is very low, France is determined that its regulatory framework and operator practices will led, through the application of the best available techniques, to achieve a high level of control over radioactive discharges and to obtain reductions in discharges, in line with the OSPAR strategy. France will ensure that this approach is applied in a fully transparent manner, and will involve the various stakeholders. Although that in general effluents discharges decrease, France considers that the reduction of radioactive discharges continues in line with technical progress. This is achieved by proceeding with the overhaul of the discharges permits of the basic nuclear installations. France requires that the limits be set as low as the best available techniques will allow, taking into account feedback from experience with the discharges produced at the facilities.

France has set up a system for monitoring environmental radioactivity that meets the objectives of the OSPAR strategy both in terms of coverage of the French portion of the OSPAR area, and of the quality of the monitoring data provided under the agreement concerning the program for monitoring radioactive substances in the marine environment.

RECAPITULATIF

Le contrôle de la sureté nucléaire et de la protection contre les radiations en France a été complètement révisé depuis 2006. La loi du 13 juin 2006 relative à la transparence et à la sécurité en matière nucléaire, appelée « transparence et sécurité nucléaire » - « Loi TSN » (désormais codifiée dans les livres I et V du Code de l'environnement), a révisé radicalement le régime juridique concernant les installations nucléaires de base - régime juridique INB. Elle a en particulier donné à ce système une nature « intégrée » c'est-à-dire cherchant à empêcher les risques et les effets nuisibles quels qu'ils soient que les INB pourraient entraîner: accidents - qu'ils soient nucléaires ou non, pollution - qu'elle soit radioactive ou non, déchets – qu'ils soient radioactifs ou non, etc.

Le décret n° 2007 1557 du 2 novembre 2007 modifié, relatif aux INB et au contrôle, en matière de sûreté nucléaire, du transport de substances radioactives, dit décret « Procédures INB », définit le cadre de travail dans lequel les procédures INB sont appliquées et couvre le cycle de vie complet d'une INB, de son décret d'autorisation à sa fermeture définitive et son démantèlement, en passant par sa mise en service.

Ces textes fondateurs ont été complémentés par l'arrêté du 7 février 2012 fixant les règles générales relatives aux installations nucléaires de base, dit arrêté « INB » et la Décision de l'ASN (Autorité de sûreté nucléaire) Nº 2013-DC-0360 du 16 juillet 2013 modifiée le 29 septembre 2016 relative à la maîtrise des nuisances et de l'impact sur la santé et l'environnement des INB.

La France a intégré pleinement les meilleures techniques disponibles (BAT) dans ses textes juridiques et réglementaires. Les BAT sont au premier rang des principes contrôlant les activités nucléaires en France.

Même si les impacts radiologiques liés aux rejets radioactifs liquides sont très faibles, la France est convaincue que son cadre de travail réglementaire et ses modes opérationnels permettront, grâce à l'application de BAT, de parvenir à un niveau élevé de contrôle et de réduction des rejets radioactifs, conformément à la stratégie OSPAR. La France s'assurera que cette approche est appliquée d'une manière tout à fait transparente et impliquant les diverses parties prenantes. Dans l'ensemble, les rejets d'effluents ont diminué et la France considère que la réduction des rejets radioactifs se poursuit en accord avec les progrès techniques. Ceci est réalisé en effectuant une révision des permis de rejet des INB. La France demande que les limites soient fixées au niveau le plus bas permis par les BAT, en tenant compte des informations en retour sur l'expérience acquise quant aux rejets produits dans les installations.

La France a mis en place un système de surveillance de la radioactivité environnementale qui respecte les objectifs de la stratégie OSPAR aussi bien du point de vue de la couverture de la partie française de la zone OSPAR que de la qualité des données découlant de la surveillance recueillies dans le cadre de l'accord sur le programme de surveillance des substances radioactives dans le milieu marin.

Application of the BAT (Best Available techniques) to the ORANO Cycle LA HAGUE facilities

The methods selected by the operator to minimise the radioactive discharges and emissions from the ORANO Cycle La Hague site are based upon a continuous approach. The foundations of this one are the technical and economic evaluation of the new solutions offered by research developments, for both processes and technology. The management method for liquid discharges remains the "new effluent management", which is based on using evaporators that concentrate radioactivity sent to vitrification and purify the distillate that is either recycled into the process or discharged practically free of radioactivity.

The records of the period confirm the efficiency of this method, with very low discharges to the sea as well as an extremely low impact on the representative person. The efficiency is also confirmed for the discharges resulting from exceptional operations such as dismantling and reconditioning of legacy waste where the same methods and processes as well as the same equipment are used with very low discharges to the sea.

Extensive R&D is ongoing to investigate more improvements in many fields, but though the considerable resources involved, the potential for improvement is now low.

These accomplishments show how the best techniques are continuously developed and used on the ORANO Cycle La Hague plants to improve the process and the abatement techniques as soon as they become available, with reductions in the volume and the activity of the effluents as well as in the corresponding impact that bring them at a level such that the objective of an industrial activity to perform without any harm neither to the workers nor to the population can be considered as reached.

Application of BATs (Best Available Techniques) to radioactive liquid discharges and to the environmental monitoring of the French EDF Nuclear Sites

Fifteen of the nineteen EDF NPPs in operation and four of the nine EDF reactors under decommissioning are concerned by an OSPAR area because of their authorized liquid radioactive discharges. All are part of the

French EDF nuclear fleet distributed on 20 sites. The renewal of discharges permits of the French NPPs has continued over the last ten years and the French regulator still takes advantage of these renewals to lower the limits concerning radioactive liquid discharges. In addition, and in association with strict effluent management, EDF has continued to implement better operating practices that have allowed to lower radioactive discharges, dividing by a factor of more than one hundred the liquid activity discharges for all radionuclides over 30 years, with the exception of Tritium and Carbon-14. And even though the liquid radioactive discharges has reached an asymptote, the efforts are still kept constant to maintain this low level of discharges.

Concerning Tritium and Carbon-14, and given the large volumes of water to be processed and the corresponding low volumic activity, there is still no industrial method for trapping them. However, an active watch is carried out and the potentially interested methods are studied.
As for NPPs in operation, the discharges of effluents of NPPs under decommissioning have been reduced as far as reasonably possible and at an acceptable cost. It has to be noted that the contribution of NPPs under decommissioning to the amount of liquid radioactive discharges is negligible in accordance with strict discharges permits whose limits are regularly optimized, based on the implementation of BAT approach in association with operating experience.

For NPPs in operation and those under decommissioning, measurements in the effluents must comply with regulatory requirements. They must also be consistent with the ISO/IEC 17025 standard or equivalent (BAT). They are performed using procedures approved by the operator and the French ASN (cross-check analysis, inter laboratory tests, internal audits and inspections by the Authorities). Because the results of the controls are used to assess the impact of discharges on the environment and public health, the quality of the measurements is of major importance and no effluent likely to be radioactive can be discharged prior to controlling that all the regulatory requirements are met.

Radioactivity controls and measurements are also performed in the environment of the NPPs in operation or under decommissioning within the framework of their monitoring program and radioecological survey. They show very low levels of artificial radioactivity in the environment, which for a major part comes from other sources. Consequently and as mentioned above, the radiological impact of a site on the public or the environment cannot be assessed from those measurements. It is therefore calculated on the basis of the total amount of radioactivity discharged taking into account the transfer mechanisms from the environment to humans. It allows to assess the level of exposure which is attributable to the radioactive discharges from one site and to compare it to the regulatory limit of public exposure as defined in the article R1333-11 of the French Public Health Code. The annual effective dose calculation takes into account site specific data such as weather conditions or dilution conditions in the receiving water compartment. The calculated dose (e.g.: for all radioactive liquid and gaseous discharges) are below 0.01 millisievert per year (< 0.01 mSv/y). These values can be compared with the exposure limit set to 1 mSv/y for a member of the public by the article R1333-11 of the French Public Health Code. This dose is also well below natural fluctuations of radioactivity in France and is below the average natural exposure level of around 2.9 mSv/y.

Application of the BAT (Best available techniques) to the radioactive discharges of the CEA (French Alternative Energies and Atomic Energy Commission) Paris-Saclay center

Even if the CEA's discharges cannot be detectable in the marine environment, due to the distance and to the fact they have been already diluted before arriving in the Seine, France is very attentive to the application of the BAT to deal with these discharges.

The program of denuclearization of the site of Fontenay-aux-Roses, which is still currently in progress, includes the cleanup and complete dismantling of the nuclear installations. This process is accompanied by smaller liquid effluent than during the operational phase and will fluctuate around the current level.

Radioactive liquid discharges to the environment have very low radiological activity and their characteristics are within authorized limits. Prior to the discharge, this effluent is treated to reduce its radioactivity. The most active liquid effluents coming from the installations are always in dedicated tanks specific to their nature and activity (truck transport). They are then transferred towards one of three treatment stations of the CEA - two of the three treatment stations being outside the OSPAR region i.e Cadarache and Marcoule and the third one is on Saclay site, which discharges are inside the OSPAR zone. Their subsequent treatment in a dedicated treatment station concentrates a large part of radioactive material into solid waste.

In the site of Saclay, the radioactive liquid effluent treatment station has benefited from a major renovation program during the last decade, which allows the treatment of approximately 1500 m3 of effluent per year. This installation benefits from best available technologies. It is equipped with a new evaporator benefiting from the latest technical progress and from feedback gained after many years. It benefits also from the new process of solidification of the evaporation concentrats by concreting, to guarantee a better safety towards the risk sets on fire. This new facility has improved the factors of decontamination of the radioactive effluents (more than 10 000 for the main alpha, beta or gamma radionuclide emitters, except the tritium and the carbon 14).

Since the start of the 1990s, there has been also a net reduction in liquid discharges of the site of Saclay, which varies from a factor 5 to 30 depending on the radionuclide or groups of radionuclides considered.

The remaining activity, which is below the authorized limits, can be ultimately discharged to the environment; after numerous controls being performed before and during the discharge and completed by monitoring of the environment. The continuous improvement of the performance of the installations and processes has led to the reduction of discharges into the environment over a number of years.

The exposure of population (defined as reference group in each site) due to annual liquid discharges is estimated for several scenarios every year. This evaluation ends with a value significantly lower than the "trivial" effective dose of 10 micro-Sievert per year and would be ever less when reaching the English Channel.

INTRODUCTION

Purpose of the Report

This report is submitted as part of an examination of the implementation of PARCOM Recommendation 91/4 on radioactive discharges, concerning which the contracting parties agreed: *"To respect the relevant Recommendations of international organizations and to apply the Best Available Technology to minimize and, as appropriate, eliminate any pollution caused by radioactive discharge from all nuclear industries, including research reactors and reprocessing plants, into the marine environment."*
According to Appendix 1 of the OSPAR Convention, for the purposes of OSPAR the best available techniques are defined as follows:

BEST AVAILABLE TECHNIQUES

1. In seeking the best available techniques, emphasis is placed on the use of technologies that do not produce wastes, if such are available.

2. The expression "best available techniques" means the very latest advances (state of the art) in processes, facilities, or methods of operation, that enable a decision as to whether a given constraining measure for discharges, emissions, or wastes is appropriate form a practical standpoint. To determine whether a series of processes, facilities, and methods of operation represents the best available techniques in general or in a specific case, special attention is given:

(a) To comparable processes, facilities, or methods that have given good results in recent trials;

(b) To technical advances and the development of scientific knowledge and understanding;

(c) To the economic feasibility of these techniques;

(d) To the time it would take to put them into operation, both in new facilities and in existing ones;

(e) To the nature and volume of the discharges and emissions in question.

3. It therefore follows that what constitutes "the best available technique" for a given process will change over time, depending on technical advances, economic and social factors, and the development of scientific knowledge and understanding.

4. If the reduction in discharges and emissions that results from the application of the best available techniques does not lead to acceptable results on the environmental level, additional measures must be implemented.

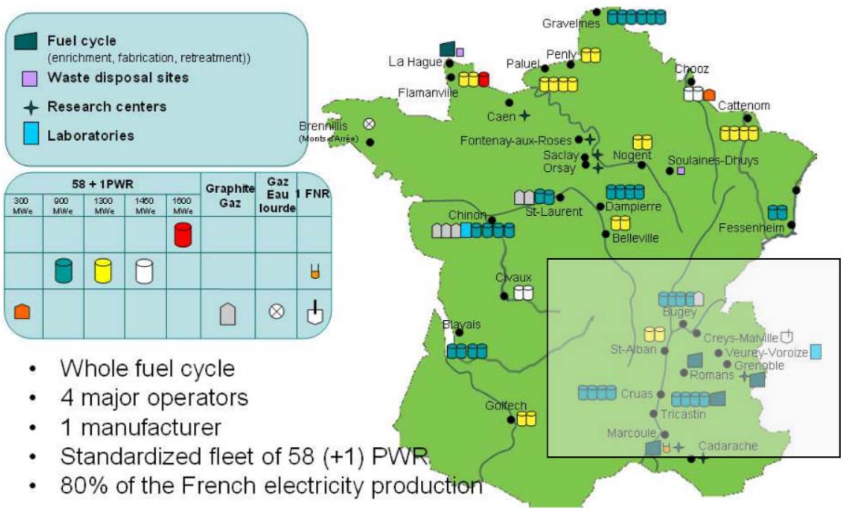
5. The term "techniques" means not only the technique applied but also the facility's method of design, construction, maintenance, operation, and dismantling.
The control of nuclear safety and radiation protection in France has been completely revised since 2006. The 13th June 2006 Act concerning transparency and safety in the nuclear field, called the "TSN Act" (now codified in books I and V of the Environment Code), extensively overhauled the Basic Nuclear Installations - BNI legal system. It has in particular given this system an "integrated" approach, that is to say that it seeks to prevent the hazards and detrimental effects of any type that the BNIs could create: accidents - whether nuclear or not, pollution - whether radioactive or not, waste – whether radioactive or not, etc. According to this law, environment is one of the interests that have to be protected in all circumstances, as long as safety, security, health and salubrity.
The amended decree 2007-1557 of 2nd November 2007 concerning BNIs and regulation of the nuclear safety of the transport of radioactive substances, known as the "BNI Procedures" decree, defines the framework in which the BNI procedures are carried out and covers the entire lifecycle of a BNI, from its authorization decree to commissioning, to final shutdown and decommissioning. This decree is regularly revised. It will soon integrate the Environment Code and will be updated taking into account practical feedback and new national regulations applicable to public information introduced by the ordonnance n°2016-1060 of the 3rd of August 2016 for the reform of the procedures for ensuring information and public participation in the preparation of some decisions that may have an impact on the environment.

These foundation texts have been supplemented by the Order of 7th February 2012 setting the general rules relating to basic nuclear installations, called the “BNI” order, and ASN (French nuclear safety authority) resolution 2013-DC-360 of 16th July 2013 relating to the control of detrimental effects and of the impact on health and the environment of BNI, which has been amended by resolution 2016-DC-0569 of 29th September 2016.
Therefore, this report applies to a situation in which the regulatory framework applicable to BNIs has been significantly reinforced.

French facilities in the OSPAR area

As of January 1, 2018, France had 127 basic nuclear installations, distributed over about forty sites. These include the following facilities discharging radionuclides within the OSPAR area:

- The La Hague spent fuel reprocessing plant;
- 15 nuclear power stations on 19 sites, thus including 44 of the 58 operating pressurized-water reactors in France;
- The research and development centers in Fontenay-aux-Roses and Saclay.



French nuclear facilities

Figure 1 : the French nuclear facilities (the facilities in dimmed part do not discharge into the OSPAR area)

PART I – GENERAL INFORMATION

1 The organization of nuclear safety and radiation protection control in France

Law No. 2006-686 of June 13, 2006 concerning transparency and nuclear safety, known as the TSN law and now codified in the Environment Code, caused a comprehensive reform of the organization of nuclear safety and radiation protection control in France. It relies on a variety of actors: State structures, forums for information and debate, and technical support organizations.

1.1 State structures

The control of nuclear safety and radiation protection involves all of the State's structures:

- Parliament, to define the major long-term options;
- The Government, especially the ministers responsible for nuclear safety and radiation protection, who have been assigned the power for overall regulation and for matters concerning the desirability of creating a basic nuclear installation;
- The prefects, responsible for protecting the population;
- Advisory authorities, which provide an outside view on significant decisions regarding nuclear safety and radiation protection;
- The Nuclear Safety Authority (ASN), which is the control and regulation authority;

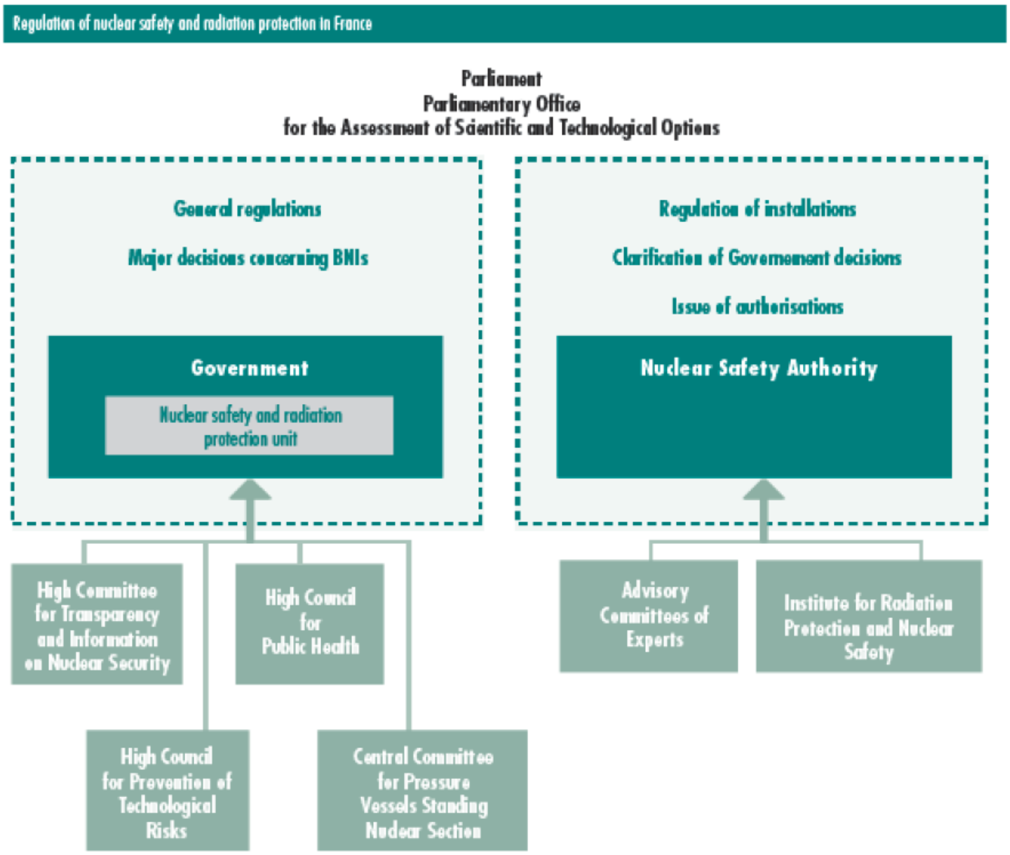


Figure 2 : The organization of nuclear safety and radiation protection control in France

1.1.1 Parliament

Parliament's principal role in the field of nuclear safety and radiation protection is to make laws. Two major Acts were passed in 2006: the above-mentioned TSN Act of 13th June 2006, on transparency and security in the nuclear field; and the Programme Act of 28th June 2006, on the sustainable management of radioactive materials and waste. In 2015, the Energy Transition for Green Growth Act was published (LTECV Act of the 17th of August 2015). The Act takes additional steps in terms of providing transparency and public information regarding nuclear safety. The purpose of this Act, that was also supplemented with the ordonnance n°2016-128 of the 10th of February 2016 concerning several nuclear proposals, was also to strengthen the Nuclear Safety Authority's regulatory resources and powers. Parliament's decisions are clarified by the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST), whose mission is to inform Parliament about the consequences of choices of a scientific and technologic nature - which include nuclear safety and radiation protection matters. For this purpose it gathers information, implements research programs, and conducts evaluations. Its work is available on the OPECST's website (http://www.senat.fr/opecst/).

1.1.2 The Government

The Government exercises regulatory powers. It is therefore in charge of laying down the general regulations concerning nuclear safety and radiation protection. The TSN Act also tasks it with making major decisions concerning BNIs, for which it relies on proposals or opinions from ASN. The Government can also call on advisory bodies such as the High Committee for Transparency and Information on Nuclear Safety (HCTISN).
The Government is responsible for civil protection in the event of an emergency.

1.1.3 Minister responsible for nuclear safety and radiation protection

On the advice of ASN and, as applicable, on the basis of an ASN proposal, the Minister responsible for nuclear safety defines the general regulations applicable to BNIs and take the major individual decisions concerning:

- the design, construction, operation, final shutdown and decommissioning of BNIs;
- the final shutdown, maintenance and surveillance of radioactive waste disposal facilities;
- the manufacturing and the operation of pressure equipment (PE) specifically designed for these installations.

The above-mentioned minister can suspend the operation of an installation on the advice of ASN if it presents serious risks.
Furthermore, the Minister(s) responsible for radiation protection also define(s) - on the basis of ASN proposals if necessary – the general regulations applicable to radiation protection.
The regulation of worker radiation protection is the responsibility of the Minister for labour.
Finally, the Ministers responsible for nuclear safety and for radiation protection approve the ASN internal regulations by means of a Government order. Each of them also approves ASN technical regulatory resolutions and certain individual resolutions (setting BNI discharge limits, delicensing a BNI, etc.) affecting their own particular field.
The MSNR (Nuclear Safety and Radiation Protection Mission), within the General Directorate for Risk Prevention at the Ministry for an ecological and solidary transition is tasked - in collaboration with ASN - with proposing Government policy on nuclear safety and radiation protection, except for defence-related activities and installations and the radiation protection of workers against ionising radiations.

1.1.4 High Committee for Transparency and Information on Nuclear Safety

The TSN Act created a High Committee for Transparency and Information on Nuclear Safety (HCTISN), an information, discussion and debating body dealing with the risks inherent in nuclear activities and the impact of these activities on human health, the environment and nuclear safety.
The High Committee can issue an opinion on any question in these fields, as well as on controls and the relevant information. It can also deal with any issue concerning the accessibility of nuclear safety information and propose any measures such as to guarantee or improve nuclear transparency. It can be called on by the Government, Parliament, the local information committees or the licensees of nuclear

facilities, with regard to all questions relating to the transparency of information about nuclear safety and its regulation and monitoring.
All of this work is available on its website: http://www.hctisn.fr.

1.1.5 Prefects

The Prefects are the State's representatives in the *départements*[1]. They are the guarantors of public order and play a particularly important role in the event of an emergency, in that they are responsible for measures to protect the general public. He issues his opinion on authorization request and, on the advide of ASN, calls on the Departmental Council for the Environment and Health and Technological Risks, to obtain its opinion on water intake, effluent discharges and other detrimental effects of BNIs.

1.1.6 Nuclear Safety Authority (ASN)

The TSN Act created an independent administrative nuclear safety authority (ASN) to monitor and regulate nuclear safety and radiation protection. ASN's missions comprises regulation, authorization and monitoring as well as providing support to the public authorities for management of emergencies and contributing to informing the general public.
ASN is made up of a commission and of various departments.
From a technical point of view, ASN relies on the expertise with which it is provided, notably by the Institute for Radiation protection and Nuclear safety (IRSN) and by Advisory Committees of Experts (GPEs).
ASN is consulted on draft decrees and ministerial orders of a regulatory nature and dealing with nuclear safety. It can take regulatory resolutions of a technical nature to complete the implementing procedures for decrees and orders adopted in the nuclear safety or radiation protection field, except for those relating to occupational medicine. These resolutions are subject to approval by the Ministers responsible for nuclear safety and for radiation protection.
ASN reviews BNI authorization or decommissioning applications, issues opinions and makes proposals to the Government concerning the decrees to be issued in these fields. It defines the requirements applicable to these installations with regard to the prevention of risks, pollution and detrimental effects. It authorizes commissioning of these installations and pronounces delicensing following completion of decommissioning. Some of these ASN resolutions require approval by the Minister responsible for nuclear safety.
ASN also issues the licenses provided for in the Public Health Code (CSP) concerning small-scale nuclear activities (including medical applications of ionizing radiations) and issues authorizations or approvals for radioactive substance transport operations.
ASN's resolutions and opinions are published in its Official Bulletin on its website (www.asn.fr).
ASN checks compliance with the general rules and specific requirements concerning nuclear safety and radiation protection applicable to nuclear activities.
ASN organizes permanent radiation protection monitoring throughout the national territory.
From among its own staff, it appoints nuclear safety inspectors, radiation protection inspectors and officers in charge of verifying compliance with pressure equipment requirements. It issues the required approvals to the organizations participating in the verifications and nuclear safety or radiation protection monitoring.
ASN takes part in managing radiological emergency situations. It provides technical assistance to the competent authorities for the drafting of emergency response plans, taking account of the risks resulting from nuclear activities.
When such an emergency event occurs, ASN verifies the steps taken by the licensee to make the facility safe. It assists the Government with all matters within its field of competence and submits its recommendations on the medical or health measures or civil protection steps to be taken. It informs the general public of the situation, of any releases into the environment and their consequences. It acts as the

[1] Administrative region headed by a Prefect

competent authority within the framework of international conventions, by notifying international organizations and foreign countries of the accident.
ASN participates in informing the public in its areas of competence.

1.2 Technical support organizations

Created by Act 2001-398 of 9th May 2001 and by decree 2002-254 of 22nd February 2002, Institute for Radiation Protection and Nuclear Safety (IRSN) was set up as an independent public industrial and commercial establishment, as part of the national reorganization of nuclear safety and radiation protection regulation, in order to bring together public expertise and research resources in these fields.
Since the Energy Transition for Green Growth Act was published (LTECV Act of the 17th of August 2015), the decree n°2016-283 of the 10th of March 2016 on the Institute for Radiation Protection and Nuclear Safety has strengthened the governance of the Institute.

IRSN reports to the ministers for the environment, health, research, industry and defence.
IRSN conducts and implements research programs in order to build its public expertise capacity on the very latest national and international scientific knowledge in the fields of nuclear and radiological risks. It is tasked with providing technical support for the public authorities with competence for safety, radiation protection and security, in both the civil and defence sectors.
IRSN also has certain public service responsibilities, in particular monitoring of the environment and of populations exposed to ionising radiation.
IRSN manages national databases (national nuclear material accounting, national inventory of radioactive sources, file for monitoring workers exposure to ionising radiation, etc.), and contributes to informing the public about the risks associated with ionising radiation.
ASN relies on the technical expertise provided by the IRSN and Advisory Committees of Experts (GPEs).

1.2.1 Advisory Committees of Experts (GPEs)

In preparing its decisions, ASN calls on the opinions and recommendations of eight Advisory Committees of Experts (GPE), with expert knowledge in the areas of waste, nuclear pressure equipments, medical exposure, non-medical radiation protection, reactors, transport, laboratories and nuclear plants and decommissioning.
ASN consults the GPEs in preparing its main decisions. In particular, they review the preliminary, provisional and final safety analysis reports for each BNI. They can also be consulted about changes in regulations or doctrine.
For each of the subjects covered, the GPEs examine the reports produced by IRSN, by a special working group or by one of the ASN departments. They issue an opinion backed up by recommendations.
The GPEs comprise experts nominated for their individual competence. They come from various backgrounds; universities, associations, appraisal and research organizations.

They can also be licensees of nuclear facilities or come from other sectors (industrial, medical, etc.).
Participation by foreign experts can help diversify the approach to problems and take advantage of experience acquired internationally.
Since 2009, as part of its commitment to transparency in nuclear safety and radiation protection, ASN has published the GPE letters of referral, the opinions of the GPEs and ASN’s position statements based on these opinions. IRSN for its part publishes the syntheses of the technical investigation reports it presents to the GPEs.

2 The legislative and regulatory framework for applying the best available techniques in France

2.1 The legal system applicable to basic nuclear installations (BNIs)

The legal system applicable to the BNIs was revised in depth by Act 2006-686 of 13th June 2006 on transparency and security in the nuclear field, called the "TSN" Act, and its application decrees, in particular amended decree 2007-1557 of 2nd November 2007, concerning BNIs and the regulation of the nuclear safety in the transport of radioactive substances, called the "BNI Procedures" decree.
Since 6th January 2012, the provisions of the three main acts that specifically concern the BNIs, namely the "TSN" Act 2006-686 of 13th June 2006 on transparency and security in the nuclear field, the Programme Act 2006-739 of 28th June 2006 relative to the sustainable management of radioactive materials and waste (called the "Waste" Act), and Act 68-943 of 30th October 1968 relative to civil responsibility in the field of nuclear energy (called the "RCN" Act) – are now codified in the Environment Code. The legal system was also modified in 2016 by the Ordonnance n° 2016-128 of the 10th of February 2016 concerning several nuclear proposals. The Energy Transition for Green Growth Act 2015-992 of 17th August 2015 takes additional steps in terms of providing transparency and public information regarding nuclear safety. It establishes the conditions for decommissioning facilities and storing waste in compliance with stringent safety and environmental protection requirements. The Act sets a ceiling on nuclear electricity generation capacity at 63.2 GW, which is the current level.

The Ordonnance n°2016-128 of the10th of February 2016 introduces a number of other advances in the areas of nuclear safety and transparency. In particular in the OSPAR convention context, it:

- transposes the European directive on radioactive wastes, reaffirming the ban on storing foreign radioactive wastes in France, and requiring the storage of waste of French origin on the national territory ;
- extends the transparency obligations of nuclear operators and reinforces their primary responsibility.

The regulatory provisions in effect (particularly those of the abovementioned "BNI procedures" decree of 2nd November 2007) will also be soon codified into the Environment Code.

2.1.1 Environment Code

The provisions of chapters III and V of part IX of book V of the Environment Code underpin the BNI licensing and regulation system.
The legal system applicable to BNIs is said to be "integrated" because it aims to cover the prevention or control of all the risks and detrimental effects, whether radioactive or not, that a BNI could create for man and the environment.
About fifteen decrees implement the legislative provisions of book V of the Environment Code, in particular decree 2007-830 of 11th May 2007 concerning the list of BNIs and decree 2007-1557 of 2nd November 2007, concerning BNIs and the regulation of the nuclear safety of the transport of radioactive substances, known as the "BNI Procedures" decree (see below).
The provisions of chapter II of part IV of book V of the Environment Code (drawn in particular from the codification of the "Waste" Act of 28th June 2006) introduce a coherent and exhaustive legislative framework for the management of all radioactive wastes.

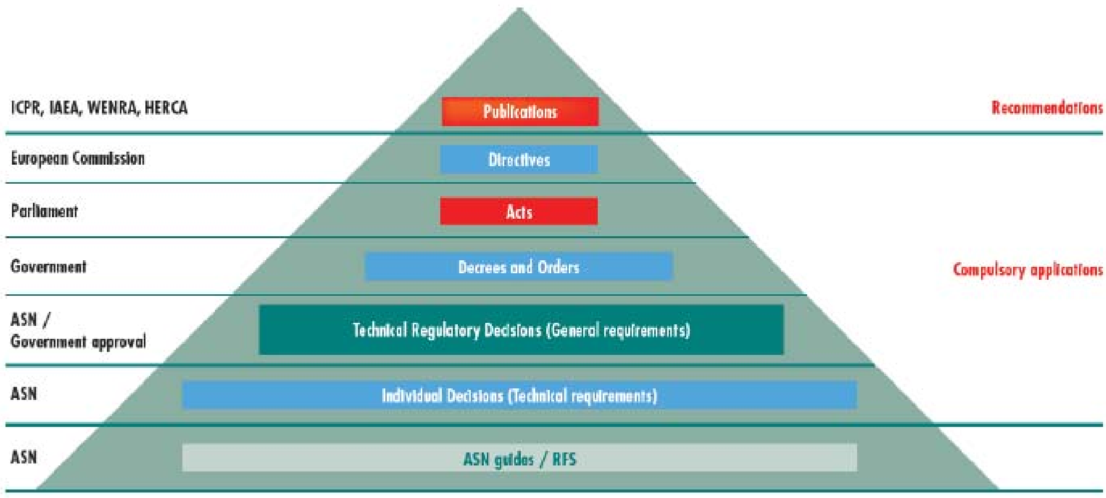


Figure 3 : Various levels of regulation in the field nuclear activities in France (orientations, recommendations): legally binding or non-binding nature

2.1.2 "BNI Procedures" decree of 2nd November 2007

The amended decree 2007-1557 of 2nd November 2007 concerning BNIs and regulation of the nuclear safety of the transport of radioactive substances, known as the "BNI Procedures" decree, implements the article L. 593-38 of the Environment Code. It defines the framework in which the BNI procedures are carried out and covers the entire lifecycle of a BNI, from its authorization decree to commissioning, to final shutdown and decommissioning. Finally, it explains the relations between the minister responsible for nuclear safety and ASN in the field of BNI safety.

The decree clarifies the applicable procedures for adoption of the general regulations and for taking individual decisions concerning BNIs. It defines how the Act is implemented with regard to inspections and administrative or criminal sanctions.

Finally, it defines the particular conditions for implementation of certain regimes within the perimeter of the BNIs.

Further to the codification of the "TSN" Act of 13th June 2006, this decree, like all the other implementing decrees of this Act, will be codified and be updated taking into account practical feedback and new national regulations applicable to public information[2] in the regulatory part of the Environment Code in the very near future.

2.1.3 Order of 7th February 2012 and ASN resolution 2013-DC-360 of 16th of July 2013

The order of 7th February 2012 setting the general rules relative to basic nuclear installations, called the "BNI" order, significantly reinforces the regulatory framework applicable to BNIs, as it details a large number of requirements and provides a legal basis for several of the requirements expressed by ASN further to the analysis of the stress tests demanded of the licensees following the Fukushima accident.

The majority of the provisions of the "BNI" order, which was published in the Official Journal of 8th February 2012, came into force on 1st July 2013, on which date the following orders taken under the former regulation was repealed:

[2] Regulation introduced par the ordonnance n°2016-1060 of the 3rd of August 2016 for the reform of the procedures for ensuring information and public participation in the preparation of certain decisions that may have an impact on the environment

- the order of 10th August 1984 concerning the quality of design, construction and operation of BNIs, called the “Quality” order;
- the order of 26th November 1999 stipulating the general technical requirements concerning the limits and procedures applicable to BNI water intake and discharges requiring licensing;
- the order of 31st December 1999 stipulating the general technical regulations designed to prevent and mitigate the harmful effects and external hazards resulting from operation of BNIs.

The “BNI” order of 7th February 2012 addresses the following main subjects: organization and responsibility of BNIs, demonstration of nuclear safety, control of detrimental effects and of the impact on health and the environment, waste management, emergency situation preparedness and management.
The control of detrimental effects and of the impact on health and the environment part (4th part of the order) takes up and supplements the provisions of the orders of 26th November 1999 and 31st December 1999. This part was complemented by the ASN resolution 2013-DC-360 of 16th July 2013 relating to the control of detrimental effects and of the impact on health and the environment of BNIs. This resolution was approved by the Government by the order of the 9th August 2013 which was published in the Official Journal of 21st August 2013. It has been revised recently, by resolution 2016-DC-0569 of the 29th of the September 2016, amongst others to clarify some points of the monitoring program of the environment to be implemented by nuclear operators around their facilities.
The “BNI” order of 7th February 2012 and the amended ASN resolution 2013-DC-360 of 16th July 2013 govern water intakes and effluent discharges, monitoring of the said intakes and discharges and of the environment, the prevention of pollution and detrimental effects, and the conditions of informing public and the authorities. The main new provisions are:
- use of the best available techniques within the meaning of the installation classified on environmental protection ground (ICPE (classified facilities) regulation);
- setting up of monitoring of emissions and the environment;
- limiting of discharges and noise emissions to the thresholds;
- the application, in general, of a number of ICPE ministerial orders to the equipment necessary for BNI operation;
- the production of an annual discharge forecast and an annual impact report by the licensee.

Additionally, ASN has adopted resolution 2017-DC-0588 of 6th April 2017 relative to the conditions for water intake and consumption, discharge of effluents and monitoring of the environment around PWR reactors, which was approved by ministerial order of 14th June 2017. This resolution contains the “generic” requirements concerning water intake, effluent discharges and their monitoring for NPPs, as well as those concerning information of the public and the authorities, which were previously contained in licensing decisions.

2.2 Best available techniques BATs

France has fully incorporated the best available techniques (BAT) into its legislative and regulatory texts and has the tools to control their application in the various phases of the lives of its facilities.
The best available techniques constitute one of the pillars that underpin the requirements regarding protection of the environment and sustainable development. In this regard, the best available techniques are introduced at the highest level of French legal texts, which provide, through the Environmental Code, that actions for the protection, development, restoration, rehabilitation, and management of the environmental heritage must comply **with the principle of preventive and corrective action, preferably at the source, against damages to the environment, by using the best available techniques.**

This requirement is imposed along with the following three other major principles:
- **The precautionary principle**, according to which a lack of certainty, in light of current scientific and technical knowledge, should not delay the taking of measured and effective steps aimed at

preventing a risk of serious and irreversible damage to the environment, at an economically acceptable cost;

- **The polluter-payer principle**, under which the costs resulting from measures to prevent or reduce pollution and to combat it should be borne by the polluter;
- **The participatory principle**, according to which everyone has access to information about the environment, including information about hazardous substances and activities, and the public is involved in the process of developing projects having a significant effect on the environment or on land-use planning.

These principles are included in The Environmental Charter which is a constitutional text, built in the 2004 block of constitutionality of French law, recognizing the fundamental rights and duties related to environmental protection.
The TSN Law provides that the best available techniques, along with the other major principles in the area of environmental protection, apply to nuclear activities. It also reaffirms the major principles in the area of radiation protection. It sets out the fundamental principle of the primary responsibility of the operator as regards the safety of its facility, written into international law, to be applied every day, and essential in order that each person, both operator and controlling authority, have a clear understanding of their responsibilities.
Accordingly, the best available techniques appear in the front rank of the principles that control nuclear activities in France.

The best available techniques are imposed in order of 7th February 2012 and ASN resolution 2013-DC-360 of 16th of July 2013 amended establishing the general technical requirements concerning the limits and methods of withdrawals and discharges subject to permitting that are carried out by basic nuclear installations. In particular, this order requires that the limits for discharges must be established on the basis of the best available techniques (article 4.1.2).

In BNIs regulation, the best available techniques are to be understood in the sense of the Directive on industrial emissions 2010/75/EU (IED) thereby fully encompassing the definition given in the OSPAR Convention:
"best available techniques" means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole:

(a) "techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
(b) "available techniques" means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
(c) "best" means most effective in achieving a high general level of protection of the environment as a whole;

Appendix III: Criteria for determining best available techniques

1. *the use of low-waste technology;*
2. *the use of less hazardous substances;*
3. *the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;*
4. *comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;*
5. *technological advances and changes in scientific knowledge and understanding;*
6. *the nature, effects and volume of the emissions concerned;*
7. *the commissioning dates for new or existing installations;*

8. *the length of time needed to introduce the best available technique;*
9. *the consumption and nature of raw materials (including water) used in the process and energy efficiency;*
10. *the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;*
11. *the need to prevent accidents and to minimize the consequences for the environment;*
12. *information published by public international organizations.*

3 Radioactive discharges from nuclear facilities

In France there is very little radiological impact from radioactive discharges produced by the nuclear industry, medical activities, or other industrial and research activities.
Nevertheless, although effluent discharges have been broadly reduced, France believes it is necessary in light of the objectives set by the OSPAR strategy to continue to aim at reducing radioactive discharges in France when possible, in line with technical advances. It contributes to these goals by setting limits for discharges and by requiring operators to use the best available techniques, while providing a fully transparent control process.
The ASN checks that the operators fulfill their responsibilities, starting with the design of the facility and continuing throughout its operation. It is vigilant concerning the optimization of discharges and the reduction of their impact.

3.1 Permitting of discharges from BNIs

3.1.1 The new BNI system

The TSN Law creates an integrated system based on a strong conception of nuclear safety, covering both the prevention of accidents and the protection of human health and of the environment. It defines the conditions for the issuance of a permit to build or to decommission a BNI, imposing measures concerning prevention and limits the importance they deserve. In particular, it recognizes the fact that in this area as in all others risk cannot be completely eliminated, and that the measures adopted are aimed at preventing or limiting the risks, in light of current scientific knowledge and techniques.
The BNI permitting and control system is governed by Decree No. 2007-1557 of 2nd November 2007 modified concerning basic nuclear installations and the control, as regards nuclear safety, of the transport of radioactive substances (see point 2.1).

The system provides that permits for the construction, final shutdown, and decommissionning of basic nuclear installations, which are issued as decrees, incorporate all of the issues, whether they concern nuclear safety, radiation protection, or protection of the environment, using an integrated approach. These authorizing decrees will therefore include the authorization of discharges from the BNI.
These authorizing decrees are supplemented by individual stipulations based on ASN resolutions which set out in particular, where needed, the requirements regarding withdrawals of water by the BNI and the discharge of radioactive effluents produced by the BNI. The specific stipulations setting the limits for discharges from the BNI into the environment are subject to ratification by the ministers responsible for nuclear safety.
The integrated approach required by this new system also applies to changes in the facilities and to reassessments of the facilities' safety. For these reassessments, Article L.593-18 of Enviromnent code (from TSN Law) stipulates that "the operator of a nuclear installation must periodically undertake a reassessment of the safety of its installation, in light of the best international practices...every ten years". This is called the periodic review process. This review meets a dual purpose: to examine thoroughly the state of the installation, taking into account its aging to verify that it complies with the applicable safety standards, and

also to improve its level of safety in order to integrate the feedback and technical progress made on the most recent facilities.

Implementation of the new BNI system enables problems related to effluent discharges to be considered during periodic review process.
For existing facilities, ASN resolution 2013-DC-360 of 16th of July 2013 modified requires that operators must periodically conduct a performance analysis of prevention and reduction of impacts caused by the nuclear facility in relation to the effectiveness of best available techniques including assessing performance differences. In case of discrepancy, operators perform a technico-economic study to improve the performance obtained by the implementation of these best techniques. When the best available techniques allow a significant reduction of the impacts and if it’s technically and economically feasible, ASN requires the operator to implement them by revising the individual stipulations related to discharges from the BNI.

3.1.2 Setting limit values

The first limits for discharges from French nuclear facilities had been set on the basis of an impact lower than the current thresholds for effects on health. It was then observed that the regulatory limits established in the past were not representative of actual discharges.
It was blatantly obvious that the optimization efforts required by the authorities and implemented by the operators had led to a substantial reduction in the discharges.
To establish regulatory limits that encourage operators to reduce their discharges, France requires that the limits be set as low as the best available techniques will allow, taking into account feedback from experience with the discharges produced by the facilities. Since the 2010’s, the ASN has undertaken an approach to revising the discharge limits such that they are close to actual discharge figures, thus encouraging the operators to keep up their efforts to reduce and control their discharges.
The lowering of discharge limit values is expressed in a reduction by the factor shown in the table below.

	Orano La Hague
Activation produts / fission products (excluding tritium)	12,7
Alpha emitters	12

Figure 4 : Reduction factors for the radioactive liquid discharge limits defined in discharge permits from1995 and 2018

Updating of the stipulations concerning discharges according to the principles described above for all the sites requires a sustained effort over several years (almost all French facilities are currently fully regulated by provisions made in application of the TSN Law, the rest of them are still regulated by provisions made in application of the former above-mentioned Decree No. 95-540). The improvements caused by the application of these provisions provide justification for continuing this approach.

3.2 The radiological impact of nuclear activities

In application of the optimization principle, the operator must reduce the radiological impact of its facility to values as low as reasonably possible, taking into account the economic and social factors.
The operator is required to evaluate annually the dosimetric impact caused by its activity, based on the real discharges. This obligation arises either from Article L.1333-8 of the Public Health Code or from the regulations concerning discharges from BNIs, depending on the case.

This evaluation covers discharges from identified outlets (stack, and discharge outfalls into the fluvial or marine environment). It also includes diffuse emissions and sources of radiological exposure to ionizing radiation present in the facility. The impact is estimated for identified reference groups. These are homogeneous groups of persons receiving the highest average dose among the entire population exposed at a given facility, under realistic scenarios.
This approach enables a comparison between the total dose and the acceptable annual dose limit for a member of the public (1 mSv/year) defined in Article R1333-11 of the Public Health Code.
Prior to authorization, the impact is evaluated on the basis of the required annual limit, considering the radionuclides likely to be discharged. This evaluation is reassessed each year, based on the activity of the radionuclides measured in the discharges, to which must be added the radiation exposure (due in particular to the storage of wastes). This evaluation is annually published in the ASN's annual report.

In France, liquid radioactive discharges produced by the nuclear industry have very little radiological impact.

As concerns medical uses of radioactivity, contaminated effluents from nuclear medicine departments are stored in decay tanks during at least 100 days before being discharged via the sewage system. This practical is considered to be the best available technique for managing liquid radioactive effluent from nuclear medicine, as it allows the radioactive discharges from the medical sector, amongst others in iodine-131, to be extremely low.

3.3 Control of radioactive discharges

Monitoring of the discharges from a facility is primarily the operator's responsibility. The provisions regulating discharges provide for controls that the operator must implement. These controls particularly concern effluents (monitoring of the discharges' activity, characterization of certain effluents before discharge, etc.). They also include provisions concerning monitoring of the environment (checking in the discharge stream, sampling of air, milk, grass, etc.). Lastly, measurements of related parameters are required where necessary (especially meteorology). The results of regulatory measurements must be recorded in registers which, in the case of BNIs, are sent to the ASN each month for checking.
In addition, BNI operators must regularly send a certain number of samples collected from the discharges to an independent laboratory for analysis. The results of these controls, called "cross" analyses, are sent to the ASN. The cross-analysis program defined by the ASN is designed to provide grounds for verifying that the results obtained by the operators are accurate. Cross-analysis control programs were established for the majority of facilities. It is currently a requirement of Order of 7th February 2012 and ASN resolution 2013-DC-360 of 16th July 2013 for all BNIs.
Lastly, ASN carries out unscheduled inspections to ensure that operators comply with regulatory provisions. During these inspections, the inspectors, who can be assisted by technicians from a specialized independent laboratory, check that the regulatory requirements are being met, have samples collected in the effluents and the environment, and have them analyzed by this laboratory. ASN carries out around 20 inspections with sampling per year.

Figure 5 : ASN inspections with sampling (Credit photo : ASN)

3.3.1 Accounting for BNI discharges

The reduction in the activity of radioactive effluents discharged by BNIs, the changes in the categories of radionuclides regulated under discharge permits, and the need to be able to calculate the dosimetric impact of discharges on the population led the ASN to make changes in 2002 to the accounting rules for radioactive discharges.
The principles underlying the accounting rules are the following:

- For each of the regulated categories of radionuclides, the activities discharged are based on the specific analysis of radionuclides and not on overall measurements;
- The detection limits to be complied with are defined for each type of measurement;
- For each BNI and each type of effluent, a so-called "reference" spectrum is defined, i.e., a list of radionuclides which are likely to be present in the effluent and whose activity must be systematically accounted for, whether or not it is greater than the decision threshold. These reference spectra, which are subject to change, are based on feedback from experience with previous analyses. When the activity is less than the decision threshold, the threshold figure is used in the accounting.
- Other radionuclides that may be locally present are included when their activity concentration is greater than the decision threshold.

As their discharge permits are renewed, these regulations have been progressively applied to almost all of the French nuclear facilities in the OSPAR area. These rules are currently a requirement of ASN resolution 2013-DC-360 of 16th July 2013 amended.

3.3.2 Tritium

Tritium discharges from nuclear facilities are subject to permitting via the decree authorizing the construction and operation of a nuclear installation. Their direct and indirect effects are evaluated during the impact study which is attached to the application for a permit submitted by the operator. Up to now, the medical authorities in France and abroad, as well as international health organizations, have agreed in considering that tritium has a low radiotoxicity. It is also accepted that it is not concentrated in food chains (no bioaccumulation) when found in the form of tritiated water.
Nevertheless France considers that its radiotoxicity and the technical possibilities for treating it should continue to be investigated periodically, which is fully consistent with the conclusions published by ICG Bremen. For this reason, the ASN wished to have a measured analysis of existing studies on this subject.
Therfore, thz ASN decided, at the end of 2007, to establish two independent discussion groups, bringing together scientists, operators, and associations, including French experts but also foreign ones:

- The "tritium impact" group, responsible for establishing an inventory of the scientific knowledge concerning tritium's impact on health and the environment;
- The "defense in depth” group, responsible in particular for investigating the state of the art regarding the technical possibilities for treating tritium and establishing an inventory of knowledge concerning its environmental impact.

The groups were formed of scientists, representatives of operators, stakeholders and the safety authorities. Their findings and recommendations were submitted in early April 2010 and are gathered on a White paper published on www.asn.fr/sites/tritium/. The studies highlight the small impact that tritium releases have in France. However, they do also show the need to carry out further study and research in order to supplement current data and knowledge on the behaviour of tritium in the environment.
The ASN has drawn up its action plan on the basis of the recommendations made by the two working groups.
This action plan includes four parts: measurements, control of discharges, environmental monitoring and impact assessment.

ASN has set up a pluralistic committee to monitor the action plan. Its last meeting was held on 4th October 2017.
Some actions started in 2011 were continued in 2017:

- ASN reviews annually tritium emissions from all French nuclear sites, which are published on the White Paper website www.asn.fr/sites/tritium/. This review also includes the dosimetric impact of each site and the tritium contribution to the total dose;
- the work to standardize the measurement of organically bound tritium conducted by the BNEN (Nuclear Equipment Standards Office);
- studies on behavior of tritium in the environment and on the impact on man and biota;
- the licensees have improved characterization of their discharges, showing that their content in organically bound tritium is very low;
- with regard to radiological impact, ASN has asked the licensees to supplement their impact assessments with a sensitivity study taking account of a doubling of the weighting factor used for tritium in the impact assessment.

3.4 Informing the public about discharges

The ASN considers that an essential issue in the regulation of discharges is to provide a suitable forum for the stakeholders.
The public is consulted during the permitting procedures, by means of a public inquiry. The ASN ensures that the implementation of the public inquiry process allows the public and the associations involved to make their views known.
In the event of a minor change in a facility leading to an increase in the limit value of the discharges, the Decree of 2nd November 2007 provides for local meetings of the Local Information Committee (CLI) and of the Departmental Council on Environment and Health and Technologic Risk (CODERST) concerning the new envisaged provisions.
The application file provided by the operator is also made available to the public on the Internet for getting observations from the public.
In addition, the Environment Code was recently amended. Henceforth, the public is consulted on any individual decisions including the requirements (ASN resolutions) regarding withdrawals of water by the BNI and the discharge of radioactive effluents produced by the BNI.
Over the lifetime of the facility, the ASN ensures that the operators submit an annual report concerning the impact of their facility on the environment. This report (whose content is defined in the ministerial Order of 7th February 2012 and ASN resolution 2013-DC-360 of 16th July 2013 amended) presents full information on discharges of effluents for the preceding year. It is sent to the Local Information Committee (CLI) for study.

In conclusion, although the radiologic impact associated with liquid radioactive discharges is very small, France is determined that its regulatory framework and operator practices will make possible, through the application of the best available techniques, to achieve a high level of control over radioactive discharges and to obtain reductions in discharges, in line with the OSPAR strategy.
France will ensure that this approach is applied in a fully transparent manner, and will involve the various stakeholders.

4 Monitoring radioactivity in the environment

The monitoring of radioactivity in the environment is an international concern, operating within two agreements:

- The Euratom Treaty which, in its Article 35, requires Member States to establish permanent control structures for radioactivity in the atmosphere, waters, and the soil, in order to ensure checks on compliance with basic standards for the protection of the health of populations and workers against the dangers resulting from ionizing radiation.

- The OSPAR Convention, whose strategy for a Joint Assessment and Monitoring Programme (JAMP) provides for the establishment of a program of monitoring for radioactive substances in the marine environment.
- In France, many actors are involved in environmental monitoring:
  - the nuclear facility licensees, who monitor their nuclear sites and their surroundings;
  - IRSN, who perform a monitoring of radioactivity in the environment within the national territory;
  - ASN, the Ministries (DGPR – General Directorate for Risk Prevention, DGS – General Directorate for Health, DGAL – General Directorate for Food, DGCCRF – General Directorate for Competition Policy, Consumer Affaires and Fraud Control, etc.), the State services and other public players tasked with ensuring national monitoring of the territory and/or carrying out inspection or monitoring assignments in specific sectors (foodstuffs, for example, in the case of the Ministry of Agriculture);
  - the approved air quality monitoring associations (local authorities), associations and private laboratories that conduct monitoring campaigns independently of the public authorities (CLIs, environmental protection associations).

The French National Network for Environmental Radioactivity Monitoring (RNM) federates all these players. It primary aim is to bring together and make available to the public, on a dedicated website www.mesure-radioactivite.fr, all the environmental measurements made in a regulatory framework on the French territory. The quality of these measurements is guaranteed by subjecting the measuring laboratories to an approval procedure, those approvals being granted by ASN. Since the decree of 4th june 2018 regarding to basic safety standards, all these measurements are automatically integrated in the RNM.

4.1 Monitoring of environmental radioactivity by the operators

Licensee prime responsibility includes monitoring the environment around nuclear sites in accordance with ministerial Order of 7th February 2012, ASN resolution 2013-DC-360 of 16th July 2013 amended and individual requirements (creation authorization decree, discharge license or ASN resolution) defining the samplings to be taken and the measures to be carried out, as well as their frequency, regardless of any additional arrangements made by the licensees for their own monitoring.
This environmental monitoring:

- gives a picture of the condition of the radiological and radio-ecological state of the facility's environment through measurement of regulated parameters and substances, whether or not radioactive, in the various compartments of the environment (air, water, soil) as well as in the various biotopes and the food chain (milk, vegetables, etc.): a zero reference point is identified before the creation of the facility and environmental monitoring enables any changes to be tracked throughout the lifetime of the facility;
- enables to verify that the impact of the facility on health and the environment is in conformity with the impact assessment;
- detects any abnormal increase in radioactivity as early as possible;
- ensures there are no facility malfunctions, amongst others by analyzing the ground water and checking licensees' compliance with the regulations;
- contributes to transparency and informing the public by transmitting monitoring data to the RNM.

All French nuclear facilities in the OSPAR area are subject to systematic environmental monitoring. The nature of this monitoring is adjusted to the risks and disadvantages that the facility might present for the environment, as described in the permitting documents and especially in the impact study.
Regulatory monitoring of the environment around BNIs is adapted to each type of installation, according to whether it is a nuclear power reactor, a plant, or a laboratory (figure 6).

SAMPLE	CONDITIONS ON RADIOACTIVE DISCHARGES	MONITORED PARAMETER	FREQUENCY	ANALYSIS (for all nuclear facilities)	ANALYSIS (for facilities emitting α emitters radionuclides)
Air at ground level	In case of atmospheric discharges	Volumic activity in air	Weekly to monthly	According to the discharges	
		Airborne dusts	Daily	Determination of gross β activity γ spectrometry if the gross β activity exceeds 2 mBq/m^3	Determination of gross α activity γ spectrometry if the gross α activity exceeds 2 mBq/m^3
			Monthly	γ spectrometry compiling all daily filters from the same sampling station	α spectrometry compiling all daily filters from the same sampling station
Ambient radioactivity		Ambient radioactivity in a 10 km radius around the facility	Continuous recording	Ambient γ dose rate	
Rainfall	In case of atmospheric discharges	Continuous collecting of rainwater	Every 2 weeks	Determination of gross β activity Tritium (HTO) Potassium concentration (for seaside sites)	Determination of gross α activity
Surface water	In case of liquid discharges	Activity in surface water	Hourly to monthly	Determination of gross β activity Tritium (HTO) Potassium concentration	Determination of gross α activity
Groundwater		Activity in groundwater	Monthly to annually	Determination of gross β activity Tritium (HTO) Potassium concentration	Determination of gross α activity
Terrestrial plants	In case of atmospheric discharges	Activity in plants sampled downwind from the facility, close to the facility (about 1 km)	Monthly to annually	γ spectrometry Tritium (HTO & OBT) Carbon 14	α spectrometry
Milk	In case of atmospheric discharges	Activity in milk produced in the vicinity of the plant (0-10 km)	Monthly to annually	γ spectrometry Tritium Carbon 14 Strontium 90	
Soil	In case of atmospheric discharges	Activity in superficial layers of soil	Annually	γ spectrometry	
Aquatic flora	In case of liquid discharges	Activity in aquatic flora sampled near the discharge point	Annually	γ spectrometry	

Aquatic fauna	In case of liquid discharges	Activity in aquatic fauna sampled near the discharge point	Annually	Freshwater :γ spectrometry, OBT & ^{14}C on fishes Seawater:γ spectrometry and OBT on crustaceans, molluscs and fishes, ^{14}C on fishes or molluscs	
Sediments	In case of liquid discharges		Annually	γ spectrometry	α spectrometry
Agricultural productions	In case of atmospheric discharges	Activity in main agricultural productions, especially downwind	Annually	Tritium (HTO & OBT) γ spectrometry	

Figure 6 : Parameters, samples and analyses required by ASN resolution 2013-DC-360 of 16th July 2013 amended for radiological monitoring of the environment around BNIs

4.2 Monitoring of environmental radioactivity on the national territory

One of the missions of IRSN is to ensure a monitoring of environmental radioactivity on the national territory.
It is ensured through measurement and sampling networks dedicated to:

- air monitoring (aerosols, rainwater, ambient gamma activity);
- monitoring of surface water (watercourses) and groundwater (aquifers);
- monitoring of the human food chain (milk, cereals, food intake);
- terrestrial continental monitoring (reference stations located far from all industrial facilities).

It uses two approaches for this:

- continuous on-site monitoring using independent systems (remote-monitoring networks) providing real-time transmission of results. This includes:
    - the Téléray network (ambient gamma radioactivity of the air); the density of detectors in the network is going to be increased around the nuclear sites in the zone of 10 to 30 km around the BNIs to reach around 400 detectors (there were 163 measurement detectors in 2012);
    - the atmospheric aerosols radioactivity measurement network;
    - the Hydrotéléray network (monitoring of the main water courses downstream of all nuclear facilities and before they cross national boundaries);
- processing and measurement in a laboratory of samples taken from the various compartments of the environment, whether or not close to facilities liable to discharge radionuclides.

Monitoring of the Atlantic, Manche, and North Sea coasts involves OSPAR regions 1, 2, and 3, as defined by the RSC.
The radioactivity levels measured in France are stable and situated at very low levels, generally at the detection sensitivity threshold of the measuring instruments. The artificial radioactivity detected in the environment results essentially from fallout from the atmospheric tests of nuclear weapons carried out in the 1960's, and from the Tchernobyl accident.

Traces of artificial radioactivity associated with discharges can be sometimes detected near installations. This can be added very local contaminations resulting from past industrial incidents or activities, and which do not represent a health risk.

The selection of environmental sampling stations and measurements is based on the following objectives:

- To contribute to an assessment of the environmental impact of various sources of radioactivity (evaluate the levels of radioactivity, monitor its development in space and time, and identify and characterize the sources of the radionuclides);
- To contribute to an evaluation of human radiologic exposure (in particular, to quantify radioactivity levels in foodstuffs);
- To contribute to the detection and monitoring of a possible radiologic event and to informing the public authorities;
- To contribute to compliance with the regulations (checking the conformance of practices with respect to the regulatory framework, and cross-checking the operator's own monitoring)
- In light of these objectives, the seacoast monitoring plan comprises:
    - Reference stations enabling characterization of the background noise and pollution sources other than the discharges from major nuclear facilities, and monitoring the contributions of major rivers;
    - Stations within the area of influence of nuclear facilities located on the coast, enabling a monitoring of the spatial distribution and development over time of the radiologic state of the marine environment.

Optimization of the monitoring program relies on knowledge acquired from radioecologic studies, feedback from experience with the monitoring networks, and use of dispersion models developed by the IRSN.

The radiologic monitoring program for the marine environment implemented by France on its seacoast provides a comprehensive response to the objectives set forth by the RSC under the OSPAR Convention. In particular it leads to the acquisition of extended time series of measurements, which are made available to the RSC for the preparation of periodic assessment reports. France thus annually provides the RSC with the following environmental measurements:

OSPAR Region	Station	Environmental and radionuclide categories				
		Seawater (surface)			Mollusks	Algae
		3H	137Cs	239,240Pu	239,240Pu	137Cs
1	Roscoff	A	A			S
	Brest	Q	A*			
	Concarneau	A	A			S
	Pornichet	S	A			
	Oléron	A	A			S
	Arcachon	A	A			
2	Carteret	Q			S	Q
	Goury	Q	Q	A	Q	Q
	Cherbourg	Q				

	Barfleur	Q			S	Q
3	Honfleur	S				S
	Mers les bains	S				S
	Wimereux	A	A			S
A: Annually, Q: Quaterly, S: Semi-annually						
*137Cs annually measured in Brest with a lower Limit of Detection						

Figure 7 : Sampling and measurements from monitoring of the French seacoast, representing the concentration data sent to RSC OSPAR

The sampling stations are shown on the following map:

Figure 8 : Sampling stations on the French seacoast sending measurements to RSC OSPAR

Twelve stations are distributed along the French seacoast, with a higher density in Manche where the majority of the coastal nuclear facilities are located.

This effort to optimize the collection of concentration data for OSPAR is accompanied by an effort to develop methods to make use of them as part of the RSC's work. In fact, France has played a key role in leading the Inter-sessional Correspondence Group (ICG-Stats) in recommending the statistical methods to be employed by RSC in compiling its periodic assessment reports on the implementation of the OSPAR strategy for radioactive substances. In particular, it has suggested rigorous methods for conducting statistical tests while taking into account the presence in the data series of values lower than the detection limits (Fiévet and Della Vedova, *Journal of Environmental Radioactivity*, 101:1-7, 2010). France has also played a key role in the application of these data for estimating the impact on the biota. These methods have been employed by the RSC since its third periodic assessment report.

4.3 The national network for environmental radioactivity measurement (RNM)

As part of the implementation of the Euratom 96/29 and 2013/59 directives laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation and the 2003/4/CE directive on public access to environmental information, France has established a national network for measuring radioactivity in the environment (RNM), designed to provide the public with the results of the monitoring of environmental radioactivity and with information concerning the nuclear industry's impact on health throughout the national territory. This database is intended to contribute towards informing the public through the development of an Internet portal enabling access to radioactivity measurements and their interpretation in terms of radiologic impact. The development and validation of the portal's contents were completed in 2009, and it was opened to the public in 2010 (www.mesure-radioactivite.fr/). The website allows everyone to have a grasp of the radioactivity monitoring carried out around his place of life. It has been entirely redesigned in 2016, so as to better meet visitors' expectations, either aimed at the general public, by offering a "guided" mode of consultation, or an "advanced" mode for a more informed public.

The public availability of the results from monitoring of environmental radioactivity, and information concerning the nuclear industry's impact on health throughout France, is ensured by the regulatory obligation imposed on institutional actors and on nuclear operators to publish the results of mandatory environmental monitoring on the national network's website. The regulations require that the mandatory monitoring measurements of radioactivity in the environment are carried out in approved laboratories.
Non-mandatory measurements carried out in approved laboratories (including the laboratories of associations) may also be published on the national network's website.

There are currently a total more than 2,5 million data on the website presenting results of measures in the various compartments (air, water, soil, fauna and flora) and in foodstuff. Around 300 000 new measurements are carried out each year in France.

In order to guarantee the quality of the measurements, only those taken by an approved laboratory or by IRSN may be communicated to the RNM (see § 4.4).

The website is organized showing the France's map on the homepage and can be used to obtain information about radioactivity (what is RNM? Why and how is radioactivity measured? how to use the site?), about the RNM (operation, actors of the network, regulatory framework, laboratory approval procedure, publications), plus access to a database containing all the radioactivity measurements taken nationwide (more than 2,500,000 measurements). The RNM management report is also available on it.

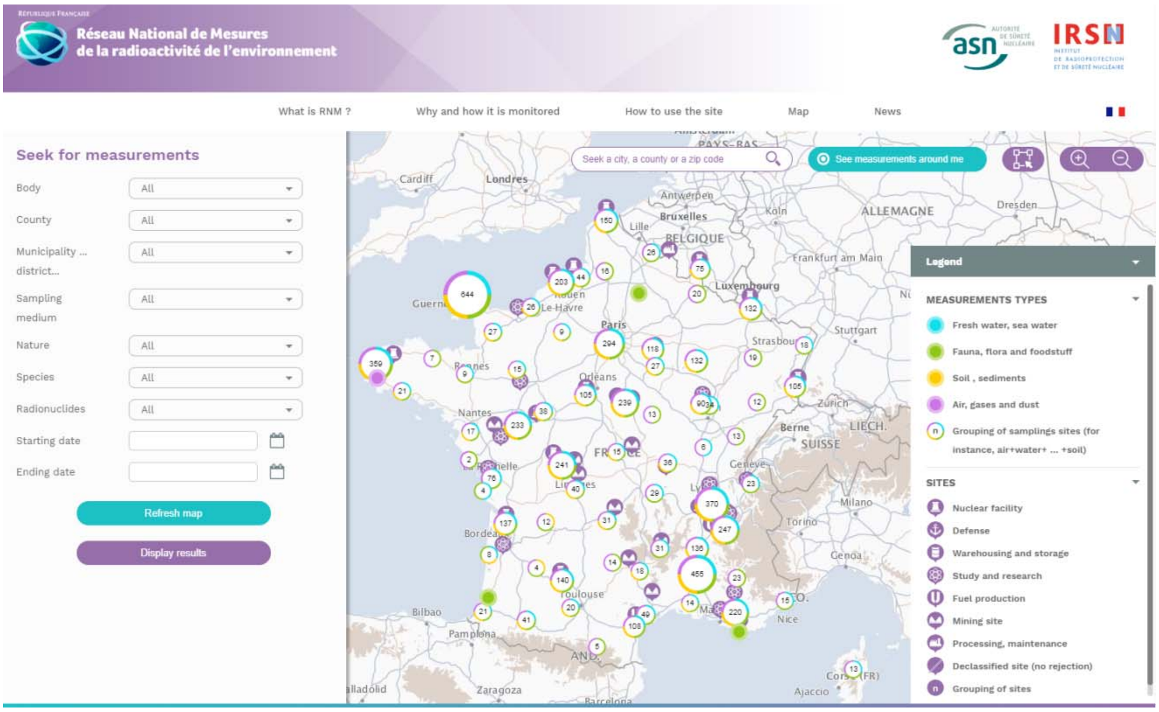


Figure 9 : National network for environmental radioactivity measurement website

Radiological monitoring of the environment in France helps to ensure the highest possible level of protection to the environment and the population. In this aim, the IRSN has published an annual Report on the Radiological State of the Environment in France since 2004. This report published at the end of 2012 was drawn for the first time using data from the RNM[3] (for 2010 and the first half of 2011).
At the end of 2015 it published a new report on the radiological state of the French environment for the years 2011 to 2014[4], as well as an update specifically addressing the marine environment of the Channel Sea[5]. A new version of the report containing all the data from the RNM has been issued in December 2018. With more than 300,000 measurements considered, the report provides the most comprehensive view possible of all the environmental radioactivity measurements taken by the various stakeholders. It is moreover supplemented by estimates of the radiological impacts of the main nuclear activities.
For most of the radionuclides observed close to the nuclear facilities (E.g. tritium, C-14, Cs-137, Sr-90 and isotopes of Pu), the concentrations include contributions from routine discharges and from the background (mainly from the former nuclear weapon tests in the atmosphere and the Chernobyl accident). For most of the radionuclides, the contribution of the routine discharges is measured usually at extremely low levels a few kilometres around the facilities and can be detected only with the best measurement techniques.

Doses received by the population around the facilities from all pathways are estimated very low; less than 1 µSv/y for the population close to NPPs and of the order of 8 µSv/y close to the La Hague reprocessing plant.

4.4 Quality of measurements in the environment

Articles R.1333-25 and R.1333-26 of the Public Health Code make provision for the creation of a National Network for Environmental Radioactivity Monitoring (RNM) and a procedure for having the radioactivity

[3] http://www.irsn.fr/FR/expertise/rapports_expertise/Documents/environnement/IRSN_surveillance_France_2010-2011.pdf

[4] http://www.irsn.fr/FR/expertise/rapports_expertise/surveillance-environnement/Documents/BR-2011-2014/index.htm

[5] https://www.irsn.fr/FR/expertise/rapports_expertise/Documents/environnement/IRSN_201501_Constat-Nord-Normandie-Aquatique-Methodo.pdf

measurement laboratories approved by ASN. The RNM procedures were defined by an ASN resolution (approved ASN resolution 2008-DC-0099 of 29th April 2008, that has been amended by ASN resolution 2015-DC-0500 of 26th February 2015).
This network is being deployed for two main reasons:

- to ensure the transparency of information on environmental radioactivity by making the results of this environmental monitoring and information about the radiological impact of nuclear activities in France available to the public;
- to promote a quality assurance policy for environmental radioactivity measurements.

In order to pursue a policy aimed at guaranteeing the quality of measurements of environmental radioactivity, a system for approving laboratories was introduced. These approvals are granted to the laboratories by ASN resolution, pursuant to Article L. 592-21 of the Environment Code.

The approvals cover all of the environmental matrices: water, soils and sediments, biologic matrices (fauna, flora, and milk), aerosols, and atmospheric gases. The measurements include the principal artificial and natural radionuclides, alpha, beta, and gamma emitters, and ambient gamma dosimetry.

In total, some fifty types of measurement can be covered by an approval. There are a corresponding number of inter-laboratory comparison trials. These trials are organized by IRSN over a five-year cycle, corresponding to the maximum duration of an approval's validity.

Besides making information about environmental radioactivity available to the public, France believes that the issue of the quality of the information is a primary concern, particularly in a context as sensitive as that of radioactivity in the environment. The importance of this matter becomes apparent when a comparison is made of the results obtained by the various actors supplying data to the national environmental radioactivity network. It is therefore essential to begin by ensuring the technical and organizational abilities of the laboratories.

This approach is very much in line with the quality objectives set by the strategy for a Joint Assessment and Monitoring Programme (JAMP).

4.4.1 Procedure for approving laboratories

The abovementioned ASN resolution 2008-DC-0099 of 29th April 2008, as amended in 2015, specifies the organization of the national network and sets the approval arrangements for the environmental radioactivity measurement laboratories.

The approval procedure includes:

- presentation of an application file by the laboratory concerned, after participation in an inter-laboratory test (ILT);
- review of it by ASN;
- review of the application files – which are made anonymous – by a pluralistic approval commission which delivers an opinion on them.

The laboratories are approved by ASN resolution, published in its Official Bulletin (www.asn.fr).
This resolution obliges BNI licensees to use approved laboratories to carry out the environmental radioactivity monitoring measurements required by regulations.
The approval commission is the body which, for the RNM, is tasked with ensuring that the measurement laboratories have the organizational and technical competence to provide the network with quality measurement results. The commission is responsible for giving ASN its proposed approval, refusal, revocation or suspension of approval. It decides on the basis of an application file submitted by the candidate laboratory and its results in the ILTs organized by IRSN.

The commission presided over by ASN comprises qualified persons and representatives of the State services, laboratories, standardizing authorities and IRSN. ASN resolution CODEP-DEU-2013-061297 of 12th November 2013, for appointing candidates to the environmental radioactivity measurement laboratory approval commission, renewed the mandates of the commission's members for a further five years.

4.4.2 Approval conditions

Laboratories applying for approval must set up an organization meeting the requirements of standard NF EN ISO/IEC 17025 concerning the general requirements for the competence of calibration and test laboratories. In order to demonstrate their technical competence, they must take part in ILTs organized by IRSN. The ILT program, which now operates on a five-yearly basis, is updated annually.
It is reviewed by the approval commission and published on the national network's website (www.mesure-radioactivite.fr).

The ILTs organized by IRSN can cover up to 70 laboratories in each test, including a few foreign laboratories.
To ensure that the laboratory approval conditions are fully transparent, precise assessment criteria are used by the approval commission. These criteria are published on the national network's website.
IRSN organized 70 ILTs since 2003 covering 58 types of approvals. Most of the approved laboratories specialized in water monitoring, with 57 laboratories holding up to 13 different approvals for monitoring of this medium. 31 laboratories are approved for measurement of biological matrices (food chain), atmospheric dust, air, or ambient gamma dosimetry. 31 laboratories deal with soils. Although most of the laboratories are competent to measure gamma emitters in all environmental matrices, only about ten of them are approved to measure carbon-14, transuranium elements or radionuclides of the natural chains of uranium and thorium in water, soil and biological matrices. In 2017, ASN issued 123 approvals or approval renewals. On 1st of January 2018, the total number of approved laboratories stood at 65, which represents 880 approvals of all types currently valid.
The detailed list of approved laboratories and their scope of technical competence is available on www.asn.fr.

In conclusion, France has set up a system for monitoring environmental radioactivity that meets the objectives of the OSPAR strategy both in terms of coverage of the French part of the OSPAR area, and of the quality of the monitoring data provided under the agreement concerning the program for monitoring radioactive substances in the marine environment.
EXECUTIVE SUMMARY

Application of the BAT (Best Available techniques) to the ORANO Cycle LA HAGUE facilities

The methods selected by the operator to minimise the radioactive discharges and emissions from the ORANO Cycle La Hague site are based upon a continuous approach. The foundations of this one are the technical and economic evaluation of the new solutions offered by research developments, for both processes and technology. The management method for liquid discharges remains the "new effluent management", which is based on using evaporators that concentrate radioactivity sent to vitrification and purify the distillate that is either recycled into the process or discharged practically free of radioactivity.

The records of the period confirm the efficiency of this method, with very low discharges to the sea as well as an extremely low impact on the representative person. The efficiency is also confirmed for the discharges resulting from exceptional operations such as dismantling and reconditioning of legacy waste where the same methods and processes as well as the same equipment are used with very low discharges to the sea.

Extensive R&D is ongoing to investigate more improvements in many fields, but though the considerable resources involved, the potential for improvement is now low and no new process could be put forth to set a new standard as Best Available Technique.

These accomplishments show how the best techniques are continuously developed and used on the ORANO Cycle La Hague plants to improve the process and the abatement techniques as soon as they become available, with reductions in the volume and the activity of the effluents as well as in the corresponding impact that bring them at a level such that the objective of an industrial activity to perform without any harm neither to the workers nor to the population can be considered as reached.

PART II - APPLICATION OF THE B.A.T. TO THE RADIOACTIVE DISCHARGES OF THE ORANO CYCLE LA HAGUE FACILITIES

Contents

1. Site Characteristics

1.1. Name of site

Établissement ORANO CYCLE de La Hague, formerly Établissement AREVA NC de La Hague.

The plants of the ORANO CYCLE de La Hague site

1.2. Type of facility

Spent nuclear fuel uranium and plutonium recycling facility and associated functions: interim storage pools, liquid effluent treatment unit, plutonium recovery unit in wastes, waste conditioning units, fission products vitrification units, interim storage for wastes before return to foreign customers or disposal in France, process control laboratory, discharge control laboratory, environmental control laboratory and associated internal logistics. Redundant facilities are being decommissioned and legacy waste recovered and conditioned.

1.3. Year of commissioning/licensing/decommissioning

The first reprocessing plant on the La Hague site, UP2, designed for the French natural uranium gas graphite reactor fuels with a capacity of more than 600 tU/y, came into operation in 1966 with the corresponding effluent treatment plant STE2 very soon after.

Because of the development of reactors using enriched uranium oxide and ordinary water (known as "light water reactors"), France proceeded to adapt its reprocessing plants to deal with the fuels used in the reactors of these series. It was in response to this requirement that a new "High Activity Oxide" head-end of UP2 (HAO) was brought into service in 1976 to carry out the preliminary operations of shearing and dissolution of "light water" fuels, with a corresponding reference capacity of 400 tU/y.

The later development in France and in the world of these light water reactors led COGEMA (became AREVA NC then ORANO CYCLE) to increase the reprocessing capacity. First, extensive modifications were planned to increase UP2-HAO plant reference capacity from 400 to 800 tU/y for light water reactor fuel. The implementation of these modifications, under the designation of UP2-800, was completed in 1994. Secondly, a completely new plant, with the same reference capacity (around 800 tU/y of light water reactor fuel), was designed and built on the same site, intended to be used only for the reprocessing of foreign reactor fuels during the first ten years of its operation. This plant came into operation in 1990.

These new plants were accompanied by a new effluent treatment plant, named STE3, which came into operation in 1987. For the first time, STE3 allowed the direct conditioning of waste resulting from the treatment of the effluents of the reprocessing operations.

The oldest units of UP2 being nearly 30 years old when UP2-800 started in 1994, some of them have been subject to refurbishment and a completely new plutonium tail end (purification, conversion and conditioning) using a new process equipment, named R4, was built and came into operation in 2002.

In addition, a new facility called ACC (hulls compaction facility), was set up and started in 2002 in order to decrease the volume of conditioned solid waste of both UP2-800 and UP3-A. This facility allows reducing the volume of technological and structural waste (hulls and end-pieces) by a factor of five.

On January 10th 2003, new authorisation decrees have been published for STE3, UP2-800, and UP3-A. The purpose was essentially to give some operational flexibility to the plants. The authorized capacity limit of the storage pools has been increased, the allowed production limit of each plant (UP2-800 and UP-3A) has been brought up to the usable capacity of 1,000 tU/y, the total production limit of the site being set at 1,700 tU/y. The industrial reprocessing of MOX fuels and new fuels (such as higher burn-up fuels as well as MTR fuels) is authorised as well as the treatment of products coming from the outside the site, provided that they are compatible with the facility process.

Though none of the changes induced significant modifications of the facilities, or any increase of the discharges, in order to take into account the progress of the techniques, apply the BAT principles and encourage the continuous improvement performed by the operator, the authorisation limits of the associated discharge application order (also published on January 10th 2003) were lowered for most of the nuclides, and applied to a finer cutting out of the types of discharges and radionuclides.

In compliance with the discharge order of January 10th 2003, which states that the discharge authorisation limits were to be reviewed after four years, a complementary ministerial order was set in force on January 8th 2007. It brought another set of significant reductions of the authorisation limits (presented in § 2.5).

By the end of 2015, the discharge order of 2003 was replaced by two ASN Resolutions. The first one, the ASN Resolution 2015-DC-0535 defines the conditions of water and discharges sampling; the second one defines the limits. The main change deals with the extension of the authorization of discharges for effluents of decommissioning, which were formerly limited to 2015. Besides, the discharges limits of two radionuclides were lowered: the limit of cesium 137 and the one of “other beta-gamma emitters” (for decommissioning discharges).

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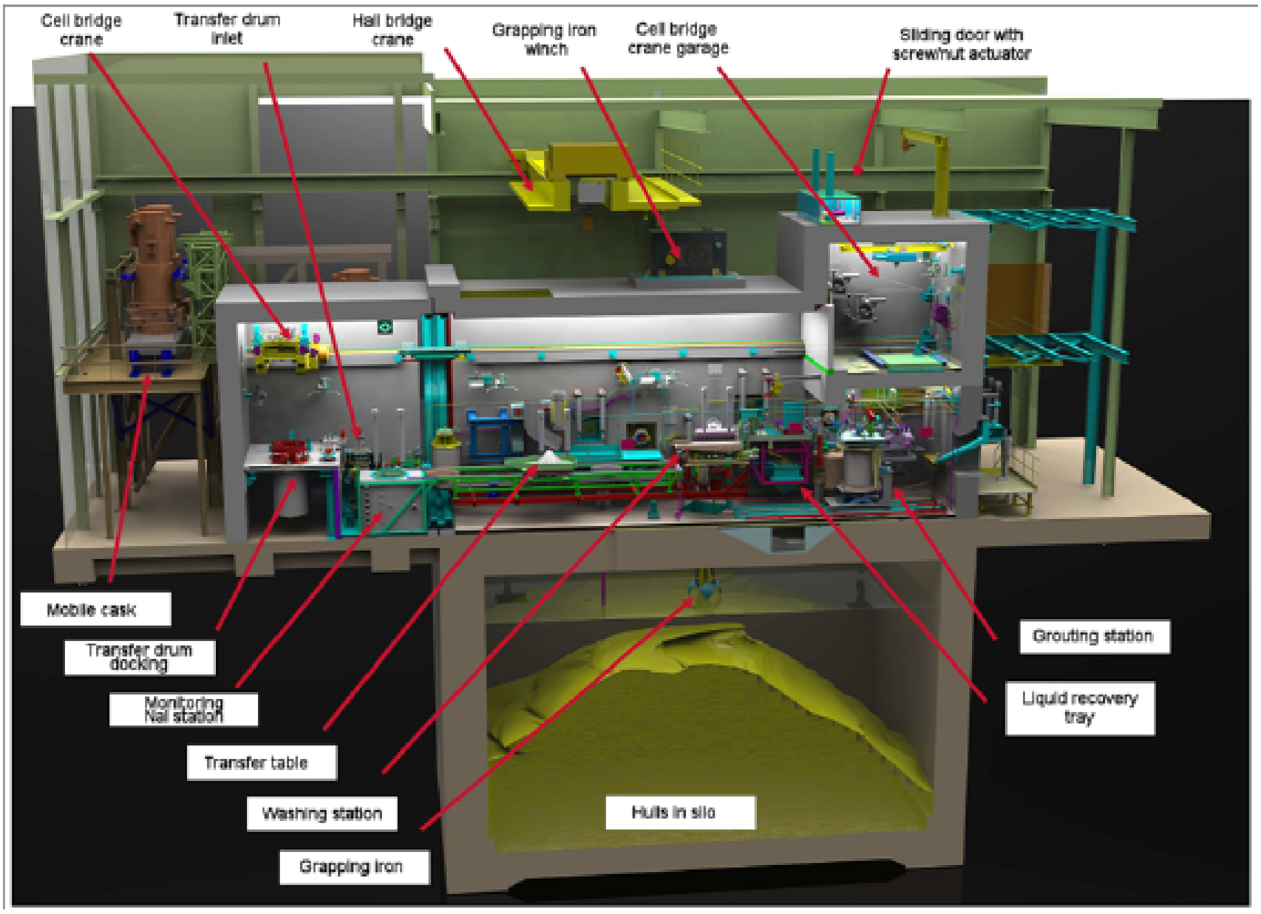
Concerning decommissioning, it has been undertaken on two pilot plants belonging to the French CEA, a small industrial isotope production plant, and one for the reprocessing of fast neutron reactor fuels, 1 kg/day capacity (decommissioning completed). The operation of this latter plant has ceased in 1979, the equipment has been rinsed from 1979 to 1981, then the equipment has been removed from 1989 to 1995 and the premises cleaned up from 1996 to 2001. The premises are now free from radiological control. One can enter them with civilian clothes, without the requirement of any monitoring. In several other buildings, the premises have been cleaned up and reused to install the equipment used in more elaborated processes.

The plants that came into operation in 1966 and 1976 have been submitted since 2003 to CDE standing for “Cessation Définitive d’Exploitation”, that is to say the final stop of the operation. It consists, using the normal process and maintenance equipment as well as the usual operating team, in removing as much as possible radioactive substances and contaminated equipments and sending them to their normally used destination, either in the process for reusable substances or to the waste for the others. Since this phase uses only the means intended for the normal operation, it does not require a specific ministerial decree, but an ASN Resolution. ASN checks that the operation is consistent with the original safety file.

The next stages, the MAD, standing for “Mise à l’Arrêt Définitif”, that is to say the final cessation of operation, and the DEM, standing for Démantèlement (decommissioning) are different in nature, requiring specific means for example for the decontamination of the structure of the buildings and other competences than those of the usual operating team. It thus requires a specific safety file and a new ministerial decree. For this purpose, AREVA NC (that succeeded to COGEMA) – and which has become ORANO CYCLE in 2018 - has submitted in February 2008 a file requiring such an order for the MAD/DEM of the HAO workshop, comprising a transportation cask unloading facility, a fuel storage pond and its filtering unit, a fuel shearing and dissolution unit, a clarification unit and two storage units for the structural debris of fuel. The setting of such a decree requires a public enquiry that has taken place in November 2008. The ministerial decree authorising the MAD/DEM on the Nuclear Facility N°80 (HAO workshop) has been signed by the Prime Minister on July 31st 2009 and the corresponding operations have immediately begun. Some of them generate exceptional discharges, authorised and reported as such.



Retrieval and conditioning of legacy waste: LWR hulls stored in the HAO silo

The framework of these operations of “MAD DEM” is defined by the ASN Resolution 2014-DC-0471.

Apart from the decommissioning activities, the other exceptional type of operation is RCD, standing for “Reprise et Conditionnement des Déchets” meaning retrieval and conditioning of legacy waste. Up to the 1990’s, some by-products, that had no agreed disposal channel, have been either stored in silos or conditioned in provisional form. This is for instance the case of the hulls from LWR fuels that were stored in bulk in the HAO silo. For safety and consistency reasons, it is important that these by-products are retrieved and conditioned in forms that allow them to be directed to agreed disposal channels. The framework of these operations of “RCD” is defined by the ASN Resolution 2014-DC-0472.

1.4. Location

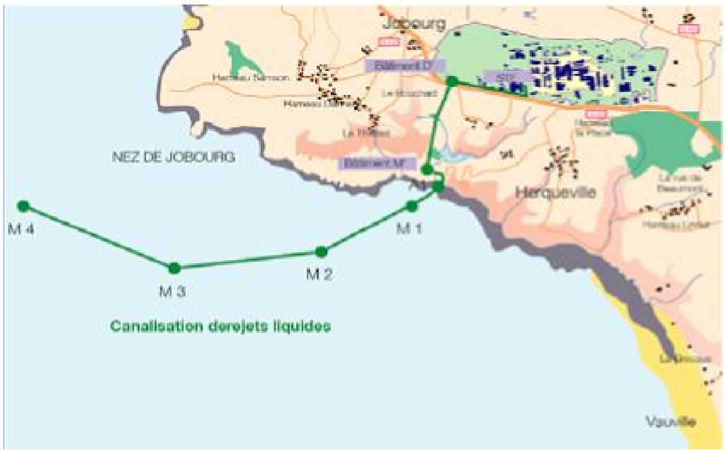
The plants are located on the northwest tip of the Cotentin peninsula, 6 km from the Cap de la Hague, 270 km west from Paris and 20 km west of the Cherbourg conurbation (nearly 90,000 inhabitants). The plants are located in the central part of the Jobourg plateau, at the highest point reaching 180 m above sea level. It covers an unbroken area of 2.3 square km.

1.5. Receiving waters and catchment area

Receiving water is the Channel, 1.5 km west from the Cap de la Hague at a place where the tidal streams have the highest velocity (up to 10 kt, that is to say around 5 m/s). Discharge of radioactive liquid effluent is carried out during a relatively short time, beginning at a precise moment before the high tide, to ensure the best dilution. The dilution rate is around 500,000 at a distance of 1 km from the end of the discharge pipe, and 1,000,000 in the vicinity of Goury, the nearest fishing harbour. The diluted activity is then transported to the North Sea by residual tidal currents.

ASN, relying on the regulations, sets the technical specifications applicable to the limits of the discharges submitted to authorisations. These require that the operator monitors radioactive discharges before and during the emission. Before the discharge the monitoring is aimed at:

- Verifying that the limits set for the discharge of the effluents are complied with, and, if these limits are not complied with, that the effluents are sent to appropriate treatment equipment;
- Determining the parameters of the discharges (agenda and flow), taking into account the regulations set in order to insure the optimal dispersion of the discharges, and particularly the limits set by the discharge authorisations.



The discharge point location

Thus, each emission is performed after the analysis of representative samples by the operator. The volume and radioactivity discharged are transcribed on a monthly register communicated inter alia to ASN.

A large number of streams having their source on the plateau flows from the northeast and southwest slopes to the sea. An important part of the southwest basin is collected in the Moulinets valley, in an impoundment built by the coast to hold 400,000 m^3 of fresh water used for supplying the plant process. The three major streams are submitted to the Discharges ASN Resolutions of 2015, defining radioactive and physicochemical concentration limits of the ORANO CYCLE La Hague site, and are carefully monitored. No radioactive effluent is discharged by the ORANO CYCLE plant in these streams.

1.6. Production

Annual production over the reporting period is displayed in the table below. The equivalent electrical energy, delivered during the spent fuel elements used in reactor that have been reprocessed during the considered year, is also displayed.

This indicator is more relevant than the mere tonnage of uranium treated, because:

- It represents the service rendered by the reprocessed fuel, and can then be used as a reference for the normalisation of the data, which are then freed from the variability of the service rendered,
- It is practically proportional to the fission products inventory of the spent fuel, which contains the most part of the radioactivity, and represents then the radioactive input to the process, i.e. the reference for the global decontamination factor of the plant.

These points are dealt with in § 2.3.3 below.

Tons of initial uranium	2012	2013	2014	2015	2016	2017
UP2-800	555	669	531	531	573	443
UP3-A	468	503	686	674	545	540
SITE TOTAL	1023	1172	1217	1205	1118	983
Equivalent Energy (GW.y)	39.3	47.5	48.5	48.0	43.2	39.6

Annual site production during the reporting period

It is worth noting that a part of the equivalent energy displayed corresponds to a service that has been rendered to some other contracting parties to OSPAR than France.

2. Discharges

2.1. Description of the systems put in place to reduce, prevent or eliminate discharges of radioactive substances to the marine environment

2.1.1. General principles

The general principles applied for the design and the operation are the following ones:

- Use of a very stringent system of containment to prevent losses, a minimum of two complete physical barriers being installed between the radioactive material and the environment.
- Use of the natural radioactive decay as a basis principle, in order to substantially decrease the activity of the short half-life radionuclides. Fuel, after reception, is driven towards storage pools, where it stays for an average period of around 5 years (as an example the ruthenium 106 residual activity is then reduced by a factor of 32 between the fuel arrival and the beginning of the reprocessing step).

- Optimisation of the destination of by-products (washing solutions, hulls rinsing effluents, solvent washing), the first priority being to recycle them as much as possible into the process.
- Second priority, for the by-products that cannot be recycled, being to send them as much as reasonably possible to solid waste (with a preference for vitrification, and to compaction and/or grouting if it is not possible to vitrify). The remainder is discharged in either the atmosphere or the sea, according to the technical possibilities, in order to minimise the impact on the representative persons.
- Exposure of workers and risks for population and workers are taken into account to balance the options, in consistency with the ICPR principles.

A transfer gallery

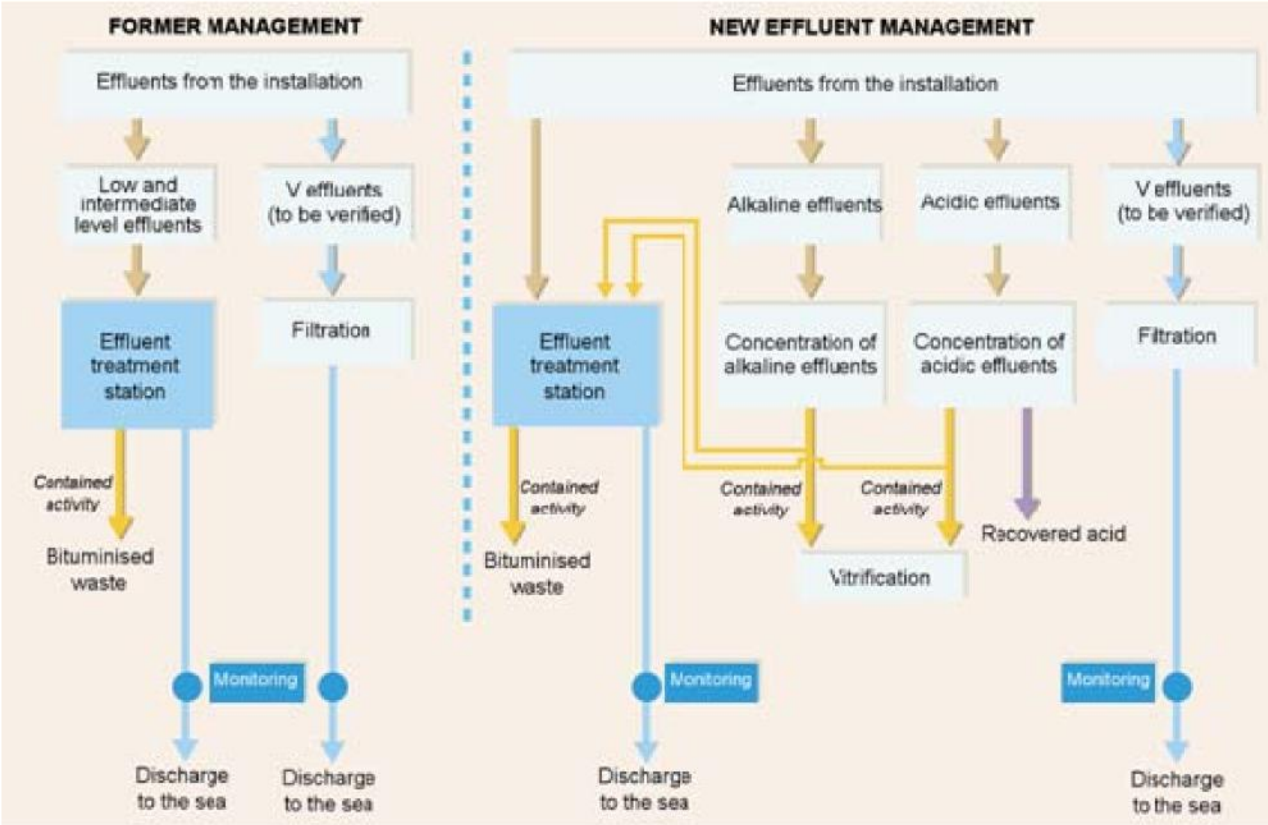
Consequently, the effluents are collected, then treated as much as possible to recover all reagents, which are purified and if necessary converted in order to recycle them into the process. The remainder is concentrated in such a way that the radioactive elements contained can be sent to solid waste, most of them to vitrification, which is the most compact and efficient way of conditioning radioactive elements in terms of material containment. Some processes that used to generate effluents that could not be concentrated or vitrified (such as some laboratory analyses effluents), have been substituted with other ones in order to withdraw some active flows.

Major fluxes concerned by recycling are vacuum groups condensates, washing or decontamination effluents, pool effluents, evaporator distillates, and solvent treatment effluents.

For instance, all aqueous solutions used to rinse structural elements (end-pieces and debris of cladding called hulls) are recycled to prepare the dissolution reagent from highly concentrated nitric acid, itself coming from recycling, concentrated and purified by evaporation after that other products (fission products, uranium and plutonium) have been removed from its flow in the process. This is also the case for spent solvent and diluent, which are purified from the radioactivity and the degradation products they contain by distillation under vacuum in a specific evaporator. The remaining fraction, in this case, cannot be vitrified and it is grouted as solid waste after calcination in a dedicated unit. This by-product recycling principle is a first and very important mean of reducing the discharges.

For the solutions that cannot be recycled, previous liquid effluents management was based on an activity level sorting out. High activity effluents were all sent to vitrification, medium and low activity effluents were collected and sent separately to the effluent treatment plant STE3, in the same batches whatever their origin, their acidity and their chemical content (provided they could be accepted by STE3 equipment and process). Very low activity effluents, in fact those which receive no activity in normal operation, called “V” effluents, meaning “to be verified”, were stored, controlled by batches to check that their activity was below the prescribed limits, then filtered and discharged to the sea between the active effluent discharges which take place during the high tidal stream periods.

2.1.2. The "new effluent management"



The former and new effluent management

In 1996, a "new effluent management" system has been introduced. The high activity effluents are still regularly sent to vitrification. The medium and low activity effluents are now collected separately on an acidity basis, the acid ones on one side, and the alkaline ones on the other side. Instead of being sent to the effluent treatment plant to be sorted out according to their activity level, they are concentrated in dedicated evaporators, for acidic effluents and for alkaline effluents respectively, which were installed in 1998 in UP3-A. The main part of the feed of the acidic and alkaline evaporators comes out as distillates, practically free of contamination, which are sent to the "V" effluents and discharged with them. The remaining concentrates take the whole radioactivity, becoming thus high activity effluents (of very little volume compared to the original ones) and are then sent to vitrification with these ones. This is a second and also very important mean not only of reducing effluents, but also of reducing solid waste volume, which contributes to the safety of the disposal.

This result is due to the fact that the concentration by distillation in evaporators is much more efficient than the chemical process. Since only very few by-products cannot be sent to the evaporators, the number of annual discharges from STE3 (that result from the chemical treatment of a complete batch) has been drastically reduced, from up to several hundreds to an average near one (up to two some years, none some years[6]). The practical consequence is that some discharges do not occur during the year the by-products were generated, because these had to wait for the batch to be completed to treat them.

As a result, the greatest part of the discharges is now under the form of very low activity V effluents, for which the activity is very often "less than" and is conservatively accounted for the threshold value.

These technical developments became possible in UP2-800 and UP3-A because of the significant improvements brought by the new implementation of the process in these plants. This one led to substantial reduction of the quantity and of the activity (better Decontamination Factors) of the effluents. Consequently, this permitted to concentrate the effluents in evaporators of reasonable size which were possible to install in free spaces of the plants.

The resulting effects of New Effluent Management implementation can be seen in diagram below.

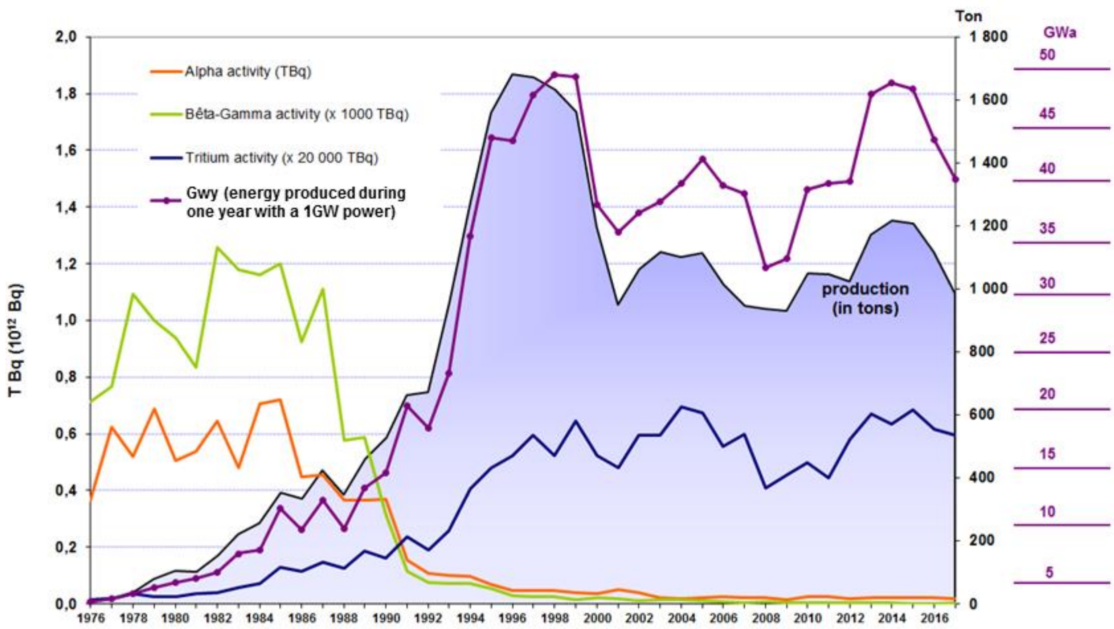


Diagram illustrating the releases reduction at la Hague plant

2.1.3. Other improvements

The case of the analytical laboratory analysis effluents is a specific one. The activity they contained represented a significant part of the alpha emitters and a minor part of the other emitters in the discharged liquid effluents before volume reductions began. After most of the volume reduction measures had been implemented, the other emitters' proportion became also significant. Most of them could not be recycled because the reagents used for the analysis led to compounds which were not compatible with the necessary treatments. The most important taken measures were to develop new technologies of automated on line measurements which do not need to take samples from the process, thus suppressing an effluent flow, and also to develop the use of the technology of plasma torch

6 For instance 2 in 2009, none in 2010 and 2011, 1 in 2012

spectrography. This technology needs only very small samples and does not use unusual reagents, suppressing the corresponding effluent flow. Some of the remaining plutonium solutions analyses were the cause of the high alpha activity content of the effluents coming from the analytical laboratory. Since 2001, a new plutonium recovery management on this flow allows a significant reduction of the alpha activity driven to the effluents from all of the laboratories and the sampling units of the ORANO CYCLE La Hague site.

Following the implementation of the better controlled process of STE3 (as described in previous BAT application Reports) since 1989, which led to substantial reductions of the activity of the discharges, the implementation of the principles described above brought new significant reductions, moreover with a lesser volume of solid waste. The radioactive elements instead of being bituminised or cemented, are sent to vitrified wastes accepting much higher activity concentrations. Thus, the substantial decrease of the discharges is not obtained at the detriment of the volume of solid waste, but together with a better compactness of these ones (3,000 bitumen drums have been replaced by less than one glass canister).

In 2002, the two workshops of UP2-400 that were still operated, MAU and MAPu (Medium Activity Uranium and Plutonium) have been replaced respectively by a part of T3 and the new R4 workshop. The replacement of pulsed columns or mixers-settlers by centrifugal extractors induces a lower degradation of the solvent, resulting in less effluent.

The replacement of UP2-400 units by more sophisticated facilities (R4 as the last example) led then to a significant reduction in beta emitters discharges to the sea, these decreased by a factor of two between 1999 and 2004.

Solvent and diluent are now continuously purified in the TEO (Organic Effluent Treatment) units, by distillation under vacuum. Aqueous effluents are sorted out according to their acidity, following the principles of the NGE (New effluent management) implemented in the UP3-A plant, and concentrated in dedicated evaporators. The concentrates that gather most of the radioactivity are dried and incorporated in the vitrified waste, the clean distillates are as much as possible recycled into the process. This allows the reduction of both the volume and activity of both the alpha and beta liquid discharges.

One point of the New Effluent Management has not been implemented. Since the beginning of the tests in 1996, it has appeared that sending the concentrates of the alkaline effluents concentration unit (CEB) to T7 (vitrification workshop of the UP3-A plant) was inducing foaming and plugging of the feeding unit of the vitrification workshop. These tests have been halted in January 2007. While awaiting a solution, the concentrates have been sent to STE3 for chemical precipitation treatment.

The piping above an effluent tank

This treatment being then the main remaining source of ruthenium discharges to the sea, extensive R&D has been launched to reduce these discharges. The source of the problem encountered in T7 has been identified as the presence of traces of degradation products of the solvent used in the process (organic-phosphoric compounds). The solution selected for further investigation is a chemical treatment of the concentrates in order to completely oxidise these compounds with hydrogen peroxide in presence of nickel (Fenton reagent) after acidification of the concentrates (see § 6, Additional Information, for the detail of the other solutions explored). The formal qualification of this process was achieved in 2004, after:

- Tests of industrial feasibility of the process;
- Optimisation of the process with inactive simulated solutions;
- Validation tests at a laboratory scale with real solutions taken from the T2 workshop;
- Qualification of the reference process, by comparison between inactive and active tests;
- Assessment of the impact of the process implementation, in terms of by-products, residual hydrogen peroxide, corrosion, radiolysis, criticality, calcination and vitrification.

The complementary equipment to install in T7 has then been designed, the administrative authorisation for its installation and active use has been required and obtained, the equipment has been installed and started. Several test campaigns have been performed in 2008, with a satisfactory performance level.

The results of these campaigns have been thoroughly analysed, in order to determine the optimum industrial production parameters. It appeared that the time required for the oxidisation reaction to be complete is in fact longer than expected and does not allow the treatment of the full flow of the alkaline effluents. Only around half of this flow can be sent to vitrification, the remainder being sent as previously to the chemical treatment. Moreover, the Fenton reagent is in the scope of the REACH regulations.

2.1.4. Results

These items show how the best techniques, concerning as well processes as abatement systems, are developed and used on the ORANO CYCLE La Hague plants as soon as they become available (that is to say *inter alia* once they have been qualified and authorised), and how they induce reductions in the volume and the activity of the effluents, which appear clearly in the table below, and in the corresponding impact.

Other techniques are being studied but not yet installed, as detailed in § 6, Additional Information.

2.2. Efficiency of abatement systems

Global efficiency of the system, relative to discharges, is measured through a transfer function Fn, which is the ratio of the outgoing activity to the activity of the same nuclide in the fuel entering the process. One often uses Decontamination Factor (DF), which is the reverse of the transfer function. Transfer functions for the marine pathway and for the radionuclides quoted above are shown in the table below:

	F sea
^{137}Cs	10^{-7}
^{99}Tc	10^{-4}
Pu	$<10^{-7}$

Transfer functions of nuclides

An overall transfer function for total alpha can be estimated at about 10^{-7} over the period.

Concerning total beta, no global transfer function can be drawn since abatement techniques do not have the same efficiency over the range of radionuclides covered.

Details about abatement techniques are given in Appendix 1. They reflect the current situation, with the improvements obtained upon STE3 chemical treatment, and the technical achievements since the setting up of new evaporators in R2/T2.

2.3. Annual liquid discharges

2.3.1. Nuclide-specific data (OSPAR Annual Report on Liquid Discharges)

Monitored discharge values are reported annually to OSPAR through the OSPAR Annual Report on Liquid Discharges.

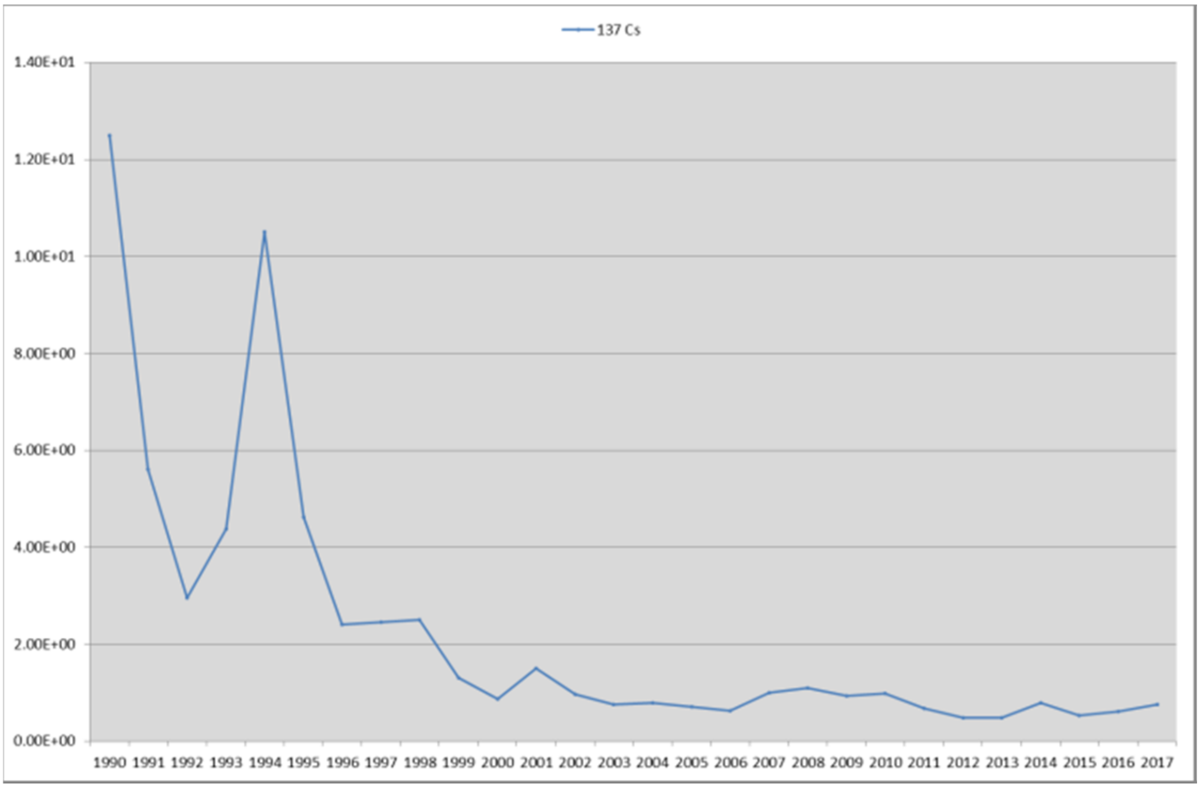
Annual liquid discharges for the last two periods and back to 2012 are displayed in the table below.

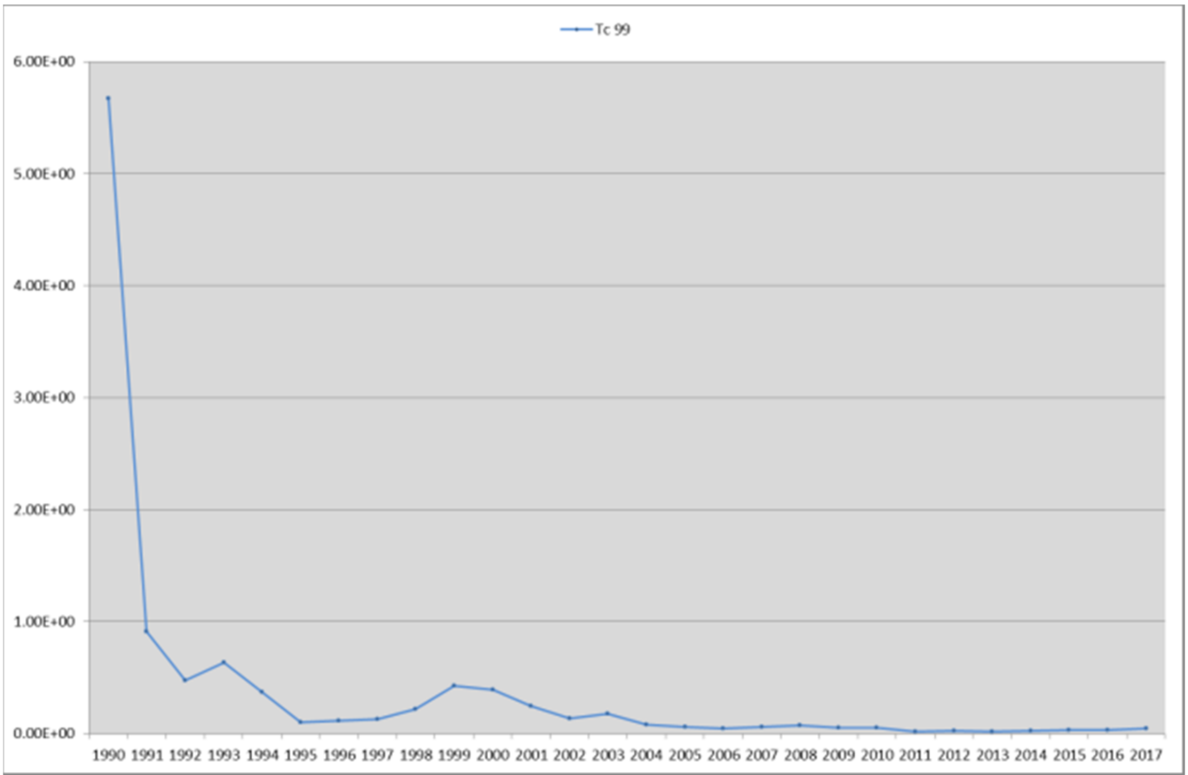
The status of the annual discharges can be found since 2004 in the annual report of environment monitoring which is required by the article 4.4.4 of the ministerial Order of 7th February 2012 modified) and by the article 5.3.1 of the ASN Resolution 2013-DC-0360, modified in 2016, by the Resolution 2016-DC-0569.

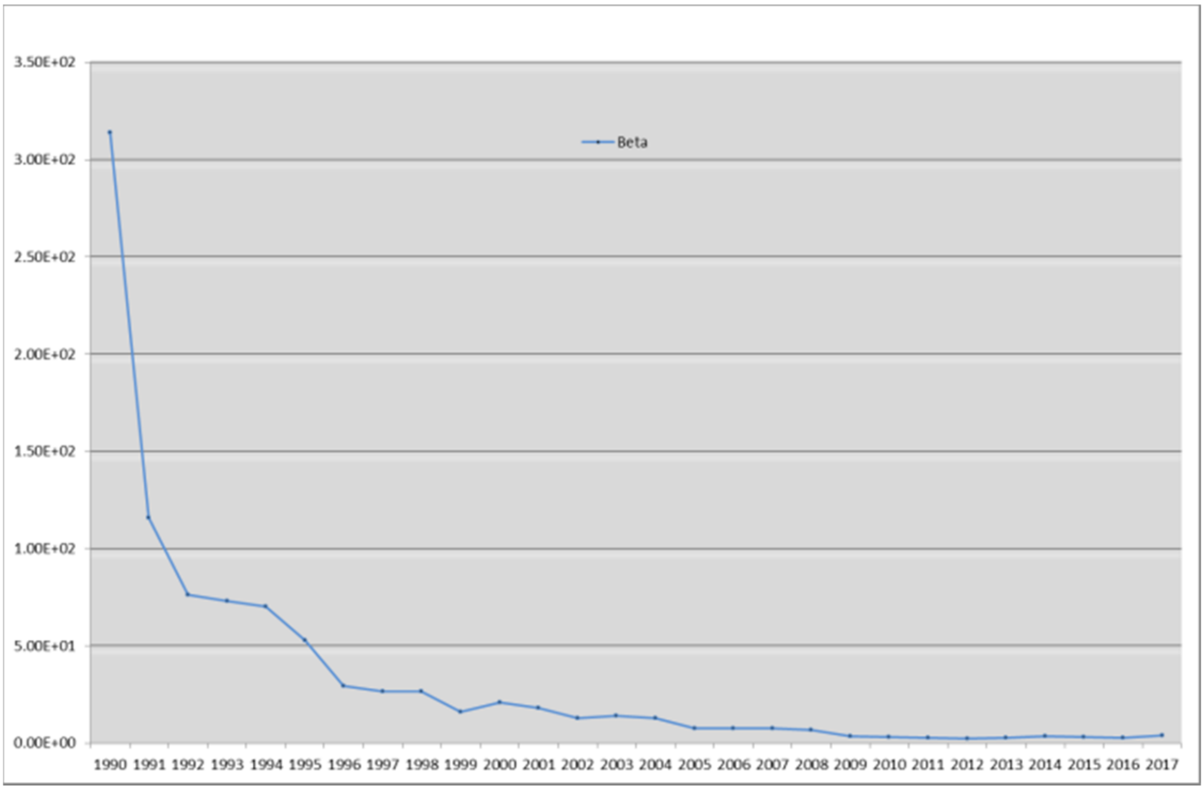
TBq/annum	2012	2013	2014	2015	2016	2017
3 H	1.20E+04	1,34E+04	1,27E+04	1,37E+04	1,23E+04	1,19E+04
14 C	7.10E+00	8,58E+00	8,32E+00	8,52E+00	7,55E+00	7,33E+00
54 Mn	3.10E-03	3,17E-03	3,63E-03	3,72E-03	2,39E-03	2,08E-03
57 Co	9.50E-05	1,10E-04	1,54E-04	1,09E-04	5,85E-05	5,36E-05
58 Co	4.10E-04	1,64E-03	1,52E-03	7,87E-04	4,97E-04	4,54E-04
60 Co	8.30E-02	7,56E-02	7,09E-02	5,85E-02	5,80E-02	5,98E-02
63 Ni	1.80E-02	2,02E-02	1,74E-02	1,06E-02	1,00E-02	1,51E-02
65 Zn	/	/	4,17E-06	1,68E-04	1,03E-04	1,46E-04
89 Sr	/	/	/	/	/	/
90 SrY	1.60E-01	2,28E-01	3,44E-01	2,13E-01	9,17E-02	2,30E-01
95 ZrNb	/	/	/	/	/	/
99 Tc	2.70E-02	7,73E-02	2,86E-02	2,95E-02	3,13E-02	4,74E-02
103 Ru	/	/	/	/	/	/
106 RuRh	2.40E+00	2,44E+00	2,46E+00	3,04E+00	2,74E+00	4,00E+00
110m Ag	/	/	/	/	/	/
124 Sb	/	/	/	/	/	/
125 Sb	5.40E-01	1,16E+00	3,37E-01	2,85E-01	4,86E-02	1,24E-01
129 I	1.30E+00	1,56E+00	1,53E+00	1,64E+00	1,42E+00	1,26E+00
134 Cs	3.10E-02	2,57E-02	4,26E-02	3,33E-02	5,03E-02	8,29E-02
137 Cs	4.80E-01	4,87E-01	7,96E-01	5,37E-01	6,16E-01	7,62E-01
144 CePr	1.00E-04	2,18E-05	4,58E-05	8,88E-05	1,34E-05	2,46E-03
154 Eu	2.20E-04	2,78E-04	9,45E-05	2,01E-04	3,00E-04	1,58E-03
155 Eu	4.80E-05	2,39E-05	/	1,40E-05	/	4,24E-04
237 Np	6.37E-05	8,46E-05	1,46E-04	1,40E-04	9,37E-05	1,11E-04
239/240 Pu	1.70E-03	1,39E-03	1,97E-03	1,73E-03	1,42E-03	1,31E-03
241 Pu	1.40E-01	1,22E-01	1,42E-01	1,43E-01	1,13E-01	1,02E-01
241 Am	1.70E-03	1,50E-03	2,14E-03	2,15E-03	2,29E-03	2,63E-03
242 Cm	9.20E-06	6,48E-06	5,37E-06	5,44E-06	9,11E-06	1,17E-05
244 Cm	7.50E-04	1,07E-03	1,10E-03	1,53E-03	1,32E-03	2,52E-03
Alpha total	1.80E-02	1,85E-02	1,98E-02	2,14E-02	2,18E-02	1,75E-02
Beta total	2.30E00	2,99E+00	3,38E+00	4,56E+00	2,84E+00	3,99E+00

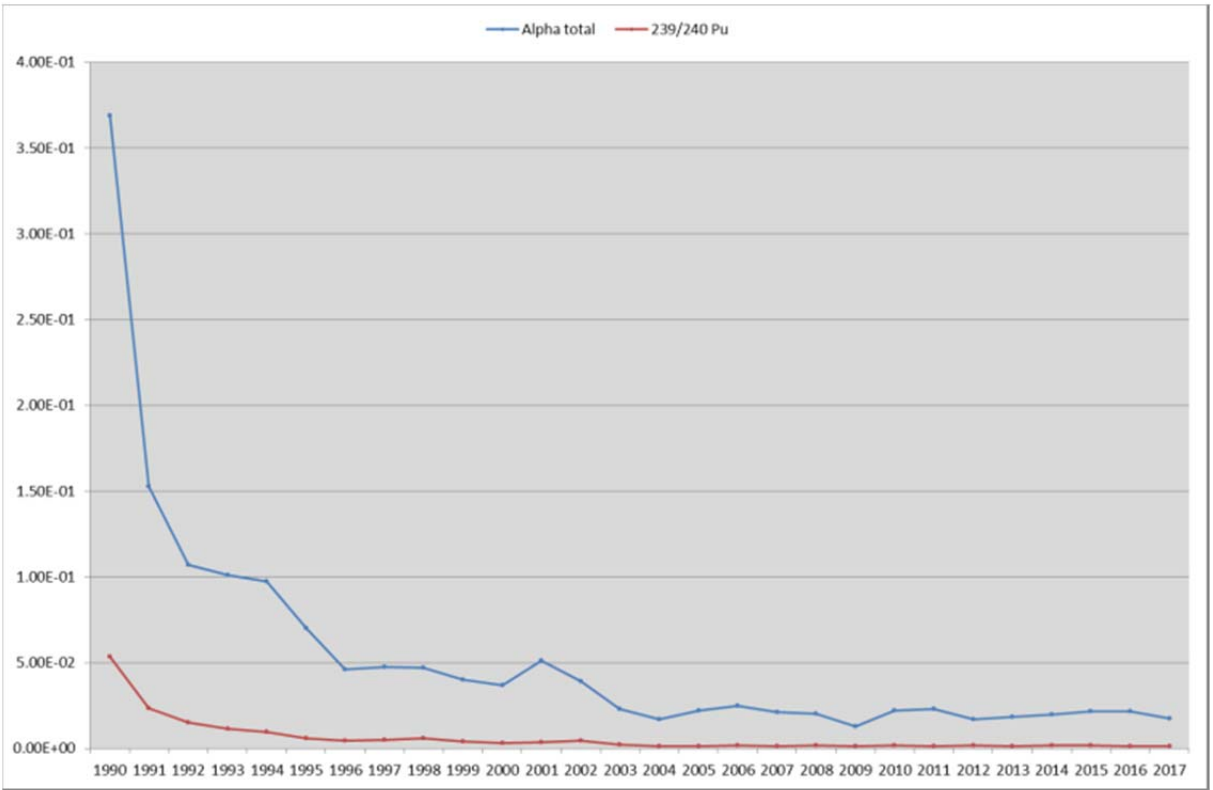
'/' means result below measure threshold

Detail of routine marine discharges over 2012-2017


137 Cs
1.40E+01
1.20E+01
1.00E+01
8.00E+00
6.00E+00
4.00E+00
2.00E+00
0.00E+00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017


Tc 99
6.00E+00
5.00E+00
4.00E+00
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017





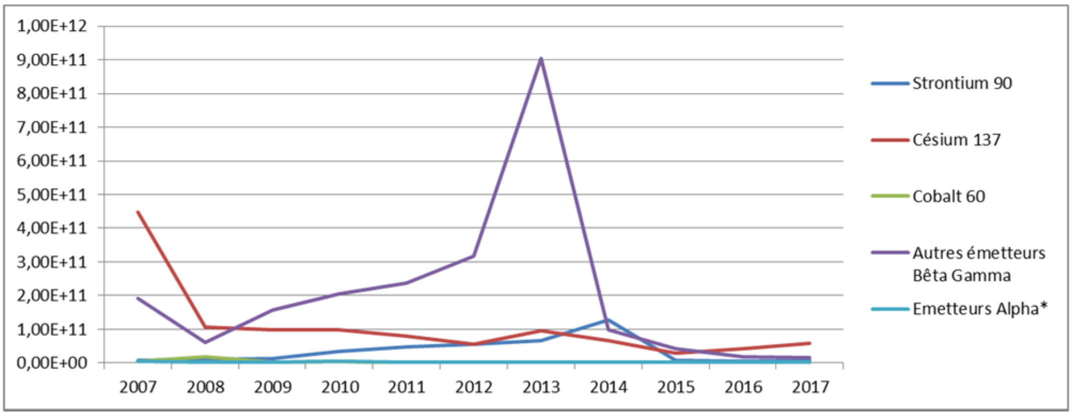
Evolution of the routine discharges of some nuclides between 1990 and 2017(TBq)

2.3.2. Exceptional discharges

These discharges are caused by the so-called “exceptional operations”, related to decommissioning or retrieval and conditioning of legacy waste. They are reported every year to OSPAR in the table “Decommissioning” of the annual report. The scheme generally followed by the exceptional discharges starts when the operation that generates them begins, they reach a maximum, and come back to zero when the operation has come to an end. Several successive operations may appear.

During the period 2012-2017, the main decommissioning or retrieval and conditioning of legacy waste’s operations that have generated marine discharges are operations of rinse, decontamination and equipment’s emptying. The strategy of these discharge’s management is to favor the evaporation and vitrification’s procedure. It minimizes the decommissioning or retrieval and conditioning of legacy waste’s discharges. To put this strategy in place, the discharges’ compatibility with the vitrification is checked at each stage of the operation (from the studies to the implementation of the operation).

This strategy allowed to limit, in an important way, the impact of the decommissioning or retrieval and conditioning of legacy waste on the marine discharges. It has been shown by a decrease of the discharges’ limits coming from the specific 2015 discharge’s allowance. The discharges observed on the period stay below the authorized limits.



Evolution of the exceptional discharges between 2012 and 2017 (TBq)

2.4. Systems for quality assurance in relation to discharges

The Établissement ORANO CYCLE de La Hague has an environmental management system that complies with the ISO 14001:2015 standard. This means that the environmental impact of the activities is systematically assessed and that there is a general commitment, including at the highest management level, to reduce the impact on the environment (See Appendix 4 for more details about the environmental management system).

The ORANO CYCLE La Hague plants renewed in 2016 (first obtained in 2005) the tri-certification for their activities of storage and nuclear fuel reprocessing, waste and recyclable product treatment and conditioning, flasks maintenance: ISO 9001, ISO 14001 and OHSAS 18001.

That is to say that, amongst other activities, the ones relative to the discharges are subject to a documented quality system ensuring a high degree of confidence in their results.

Certifications are subject to regular recertification processes and regulatory orders are under permanent inspection.

Besides, the laboratory which realises the environmental monitoring analysis is agreed by ASN in accordance with the ASN Resolution 2008-DC-0099 of 29th April 2008, as amended in 2015, which specifies the organization of the national network and sets the approval arrangements for the environmental radioactivity measurements laboratories and accredited ISO17025 by COFRAC. The other laboratories which realise the radiological analysis on discharges have an equivalent system to the ISO17025 standard.

Furthermore, in accordance with the articles 3.1.9 et 3.1.10 of the ASN Resolution 2013-DC-0360, modified in 2016, by the Resolution 2016-DC-0569, crossed controls on radiological analysis are done both on gaseous discharges and on liquid discharges. The results of the comparison between Orano's measurements and cross controlled ones (the independent laboratory chosen is IRSN laboratory) taking into account the uncertainties are transmitted each year to the ASN.

2.5. Site specific limit discharges values

The official authorisation limit values apply to the whole site. They are shown in the table below for the 2003 and 2007 orders and for the ASN Resolution 2015-DC-0536.

Discharges to the sea TBq/y		**2003 Ministerial Order**	**2007 Ministerial Order**	**ASN Resolution 2015-DC-0536**
Tritium ^{3}H		18 500	18 500	18500
Iodines		2.6	2.6	2.6
14 Carbon	(1)	42	42	42
90 Strontium	(1)	12	11	11
137 Caesium	(1)	8	8	6
134 Caesium		2	0.5	0.5
106 Ruthenium		15	15	15
60 Cobalt	(1)	1.5	1.4	1.4
Other beta-gamma emitters	(1)	60	60	55
Alpha emitters	(1)	0.17	0.14	0.14

(1) Specific limits are prescribed for the discharges from the so-called exceptional operations – those caused by final cessation of operation and dismantling (MAD/DEM) and reconditioning of legacy waste (RCD). Displayed values include routine and exceptional discharges, split as follows in the ASN Resolution 2015-DC-0536:

- 14 Carbon: total limit including liquid and gaseous discharges for the site,
- 90 Strontium: 1.2 TBq/y for routine discharges, 9.8 TBq/y for exceptional operations,
- 137 Caesium: 2 TBq/y for routine discharges, 4 TBq/y for exceptional operations,
- 60 Cobalt: 0.9 TBq/y for routine discharges, 0.5 TBq/y for exceptional operations,
- Other beta-gamma emitters: 30 TBq/y for routine discharges, 25 TBq/y for exceptional operations,
- Alpha emitters: 0.07 TBq/y for routine discharges, 0.07 TBq/y for exceptional operations.

Authorisation limits of marine discharges

The 2007 ministerial Order features reductions for routine discharges of 40 % for 90 Strontium, 75 % for 134 Caesium, 10 % for 60 Cobalt and 30 % for alpha emitters.

The ASN Resolution 2015-DC-0536 features reductions for exceptional discharges of about 33% for 137 Caesium, of about 16% for others beta-gamma emitters

2.6. Description of on-going or planned activities

Regarding exceptional operations, the ministerial order of January 10th 2003, completed by the January 8th 2007 order and the ASN Resolutions 2015-DC-0535 and 2015-DC-0536, set separate bounds for routine discharges from exceptional operations namely final cessation of operation and dismantling of former facilities or retrieval and conditioning of legacy waste.

Nowadays, regarding waste treatment, the best practice is to promote direct waste conditioning in-line with the treatment. This allows the sorting out at the source, an easier traceability, the transfer of surface storage compatible waste towards the existing disposal facilities and the local safe storage of other wastes.

Historically, conditioning of waste generated by the first spent fuel reprocessing operations has been delayed, considering the technologies unavailability and the required time to develop conditioning processes, set up storing systems and lay out investments.

These wastes have been stored safely in silos or pits, waiting to be retrieved and definitively conditioned.

Some operations have generated specific by-products in the period. They are as much as possible applied to the same abatement techniques as those used for the routine discharges. This is the case for practically all the rinsing operations of the equipment performed in the MAU, MAPu, HA and PF workshop prior to their MAD/DEM quoted in § 1.3, as well as the MAD/DEM operations of the HAO workshop since 2009. Taking into account the efficiency of these techniques, most of these operations generated practically no discharges. Only those by-products that could not, because of their physical or chemical composition, be sent to distillation have been treated by the co-precipitation process in STE3 and generated discharges.

The operations that generated most of the discharges in the period are:

- the retrieval and conditioning of the solvent used in the UP2 plant before 1990 and stored in vessels of the PF workshop, accounting for the greatest part of the discharges, particularly Tc 99 discharges;
- the draining and cleaning of the HAO working pools, accounting for the major part of Co 60 discharges.

These operations have generated discharges representing a detectable but relatively small part of the authorization pertaining to these operations.

2.7. Summary evaluation for discharges

The table below summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on discharges from the ORANO CYCLE La Hague site.

Criteria	Evaluation
The BAT/BEP indicators	
Relevant systems in place	Yes, Management and technical systems [illegible]
Abatement factor	High factors
Downward trend in discharges	Constant or downwards
Downward trend in normalized discharges	Mainly downwards
Comparison with UNSCEAR data	No available comparative UNSCEAR data
Relevant and reliable quality assurance	Yes
Relevant site specific discharge values	Yes
Data completeness	Complete
Causes for deviations from indicators	None
Uncertainties	No influence on the conclusions
Other information	R&D for other improvements in progress

Summary Evaluation for Discharges

3. Environmental impact

3.1. Concentration of radionuclides of concern in environmental samples

A pluralistic committee of international experts, the GRNC (Groupe Radioécologie Nord-Cotentin), comprising stakeholders such as local associations or non-governmental organisations, has been created in 1997 by the ministers in charge of the environment and health with the mission to assess the total impact of the nuclear facilities of the North-Cotentin on the potentially most exposed populations as well as the associated risks.

Sampling of grass

The GRNC has grounded its work on the results of some 80,000 analyses a year carried out from around 25,000 samples, taken in different places and media. The GRNC analysed more than 500,000 results and its Report [1] gives many detailed figures on this subject.

The reported elements come from the regulatory registers, sent monthly to the ASN. Monthly regulatory registers indicate the activities asked for in the order, for various bio-indicators such as ground, grass, vegetation, milk, fruits, vegetables, meat for terrestrial compartment and coastal and deep sea water, sand, sediments, seaweeds, limpets and fishes for the marine compartment. The summary of these measurements can be found in the annual report of environment monitoring which is required by BNI order and by the ASN Resolution 2013-DC-0360, modified in 2016 by the Resolution 2016-DC-0569.

Annual mean concentrations in coastal waters, fucus, limpets and fishes are given in Appendix 3, for 1995 and 2004 to 2017.

Sampling of seawater

A comprehensive assessment of marine biota doses [2] was conducted in 2003 by an environmental-expert consulting firm, SENES, managed by recognized Canadian experts. Key results show that the radiation dose rates to marine biota arising from the ORANO CYCLE La Hague facilities were at that time at least 2-3 orders of magnitude lower than the lowest guidance values for the protection of the populations of marine biota (UNSCEAR, IAEA) and at least 1-2 orders of magnitude lower than those from the background radiation in the region.

The consensus appraisal of this study by a group of international experts came to the major conclusion that “the predicted dose rates to marine biota attributable to the radioactive discharges to the sea from the ORANO CYCLE La Hague facilities are small, and in general, well below the comparison guidance levels at which deleterious and observable effects to populations of marine biota might, according to current knowledge, be expected”.

Besides this so-called “SENES study”, since 2015 a specific assessment of the environmental risk associated with radionuclides is realised in each Environmental Impact Assessment, with the ERICA method (ERICA meaning Environmental Risk for Ionising Contaminants: Assessment and Management). The risk indicators which are calculated are all below than one. It leads to the conclusion that the radiological risk linked both to gaseous and liquid discharges for the environment is acceptable. For example, the maximal risk indicator near the La Hague Cape due to liquid discharges, for the reference organism (that is to say polychaetes), is equal to $2{,}33.10^{-1}$ for discharges equal to the limits.

3.2. Environmental monitoring program

The detailed environmental monitoring program is established every year and communicated to the ASN in consistency with the ASN Resolutions 2015-DC-0535 and 2015-DC-0536. Types of measurements, frequencies and associated sampling and analysis methods are defined in these Resolutions.

Delayed monitoring is performed in different environmental compartments. About 20,000 samples are taken every year, leading to nearly 50,000 analyses every year. Samples are taken in every compartment of the environment participating in the potential pathways of the radionuclides to man: marine, terrestrial and hydrogeological compartments. Feedback from experience helps to choose the place and number of measurement points guaranteeing that the whole process is thoroughly mastered.

The results of the program allow the permanent assessment of the real impact of the ORANO CYCLE La Hague site on the environment:

- Marine monitoring is an important part of the monitoring. It is performed through discontinued measurements with time-shifted analysis. It ranges from Granville to the Bay of river Seine (near Le Havre). The sampling in the marine component comprises coastal samples (sand, seaweeds and limpets), deep sea samples (water, sediments), flat and round fishes, scallop shells, crabs, oysters, mussels, lobsters.
- Terrestrial monitoring is performed on rainwater, vegetation, milk and other foods, which are regularly sampled and analysed.
- Hydrologic monitoring includes drinking waters, small streams and the ground waters, to verify hydrologic and hydrogeologic dispersion.

Sampling is performed by ORANO CYCLE employees, except for the off-shore sampling in the high sea, which is performed by a contractor.

Sampling of seaweed

Some independent complementary samplings are performed by the IRSN's LRC (Cherbourg-Octeville Radioecological Laboratory) that has extensively studied the water movements in the North Sea, using 125 Sb discharged by the ORANO CYCLE La Hague site as a quite perfectly conservative tracer during sampling campaigns in 1986 and 1994. Conversely, the result of these studies is used to determine the dispersion of the ORANO CYCLE La Hague site effluents in the sea, in view of the impact assessments.

The sampling and measurements performed by the LRC for R&D purpose complement those performed by the IRSN on behalf of the ASN.

The North Cotentin Radio-Ecology Group has also made an important use of the LRC results in its independent first assessment of the ORANO CYCLE La Hague site impact.

COGEMA's then AREVA NC and now ORANO CYCLE's monitoring results have been compared with the LRC measurements every year until 2006 within the context of the GRNC impact assessment required by the January 10t[h] 2003 ministerial order. The advice resulting from this assessment for 2006, last year considered by this request that has not been kept in the 2007 ministerial order, has been presented in the 2010 edition of the present report [3] that is available on the OSPAR web site.

3.3. Systems for quality assurance of environmental monitoring

The Environmental Laboratory activity, as part of the activities of the ORANO CYCLE Établissement de La Hague, complies with the ISO 14001 environmental standard, as included in the jointed certifications ISO 14001, ISO 9001 and OHSAS 18001 obtained in 2005 and renewed in 2016. Concerning the analyses and measures of fresh and waste waters for alpha, beta, gamma, tritium and 90 strontium, and sea water for beta and gamma, the COFRAC accreditation (French national accreditation organism) has been renewed in 2013 (first obtained in 1996), as meeting the requirements of the ISO 17025 (2005) standard. This accreditation, delivered by an independent organism, results from the assessment of the quality system and of the management of analysis methods in term of adequacy of materials, equipments used and staff qualification.

This involves regular calibration of detectors with secondary standards traceable to primary standards and intercomparison exercises with other laboratories, both national and international, such as the one of the IAEA. (In addition to the regulatory intercomparisons with IRSN). The intercomparison tests consist in the measurement of a sample by about fifty laboratories and the comparison of the results by the test organizer.

The ORANO CYCLE laboratory participates to ISO standards working-out.

The laboratory has been granted the ministerial agreement for the measurement of a certain number of radionuclides in the environment, in accordance with articles R. 1333-25 and R. 1333-26 of the public health regulations. Most of these agreements, for those related to the marine environment, can be seen for instance in the marine environment monitoring program presented in the Appendix 5 of the 2010 edition of the present report [3].

The ASN requires that the operators follow a program of cross measurements, aimed at guarantying the quality of the results of the analysis performed by the operators. The operator has to provide samples of the discharged effluents to a laboratory which is considered as independent in accordance with ASN. Some of these samples are analysed according to a program defined by the ASN. The operator has to check the consistency of the results of these measurements with those that he has himself obtained. The ORANO CYCLE La Hague has selected for this cross measurements the laboratories of the environment and intervention directorate of the IRSN.

3.4. Summary evaluation for environmental impact

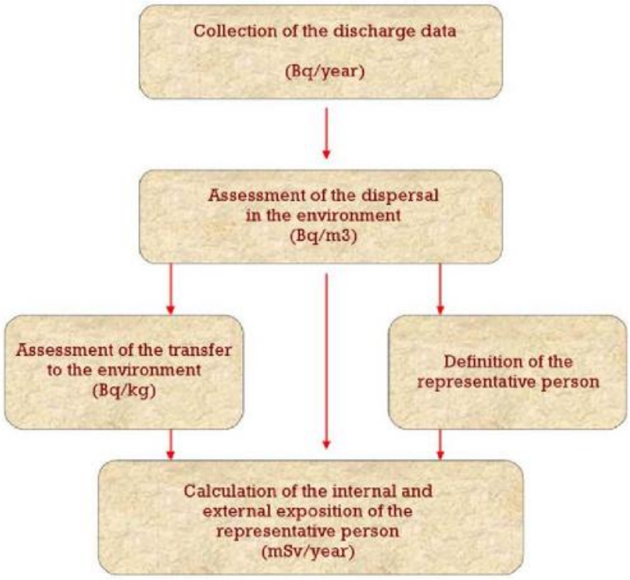
The table below summarizes the evaluation concerning BAT/BEP indicators of the site-specific information on Environmental Impact from the ORANO CYCLE La Hague site.

Criteria	Evaluation
The BAT/BEP indicators	
Downward trends in concentrations	Yes
Relevant environmental programme	Yes
Relevant quality assurance programme	Yes
Data completeness	Yes
Causes for deviations from indicators	No deviations
Uncertainties	Low because many samples
Other information	None

Summary Evaluation for the Environmental Impact

4. Radiation doses to the public

4.1. Average annual effective doses assessment methodology



The principle of the impact assessment

An impact assessment method has been derived from the GRNC method, and a software named ACADIE (Internal and External Dose Calculation Application) has been developed jointly by the IRSN, the ASN and ORANO CYCLE, based on the work of the GRNC and agreed by this committee.

Operator discharge values have been used in the impact assessment. La Hague area specific parameters for dietary and living habits, derived from inquiries or specific studies performed within the context of the 1998 impact study, have been implemented in the ACADIE software. ACADIE is used to assess the impact of annual discharges. This assessment has been until 2006 submitted to the GRNC appraisal, through the 32nd article of the January 10th 2003 ministerial order.

ESTIMATING THE DOSIMETRIC IMPACTS

A radiological or dosimetric impact is a local impact on members of the resident population likely to be the most exposed to radioactive releases. It is expressed as the added effective dose in millisieverts per year (mSv/yr.) and represents a health impact indicator. This population constitutes a "reference group" and may for example represent residents of a downwind village. Impacts are assessed annually by characterizing monitored and measured liquid and gaseous effluent releases as well as actual local conditions (meteorology, dispersion factors, etc.).

The dosimetric impacts of radioactive releases are estimated using a computer model that factors in the environmental dispersion of the releases (by sea, river, air or soil deposition, based on meteorological conditions); transfers to the food chain via agriculture and cattle farming; and external and internal exposures (inhalation and ingestion) based on knowledge of the lifestyles and food habits (through food surveys) of the reference group(s). In this way, the different exposure paths were factored in as realistically as possible. The estimate may be subject to sensitivity analyses to take into account the variability of data and computing assumptions. Particular attention was paid to the qualification of the computing software used to ensure overall control of the impact assessment. The software programs are documented and developed according to a quality assurance process. These models are usually the result of national and international efforts and benefit from long years of experience. This includes in particular work by French and international experts and associations that began in 1997 as part of the multidisciplinary North Cotentin Radioecology Group (CRNC, Groupe radioécologie Nord-Cotentin) (see the website, www.gep-nucleaire.org).

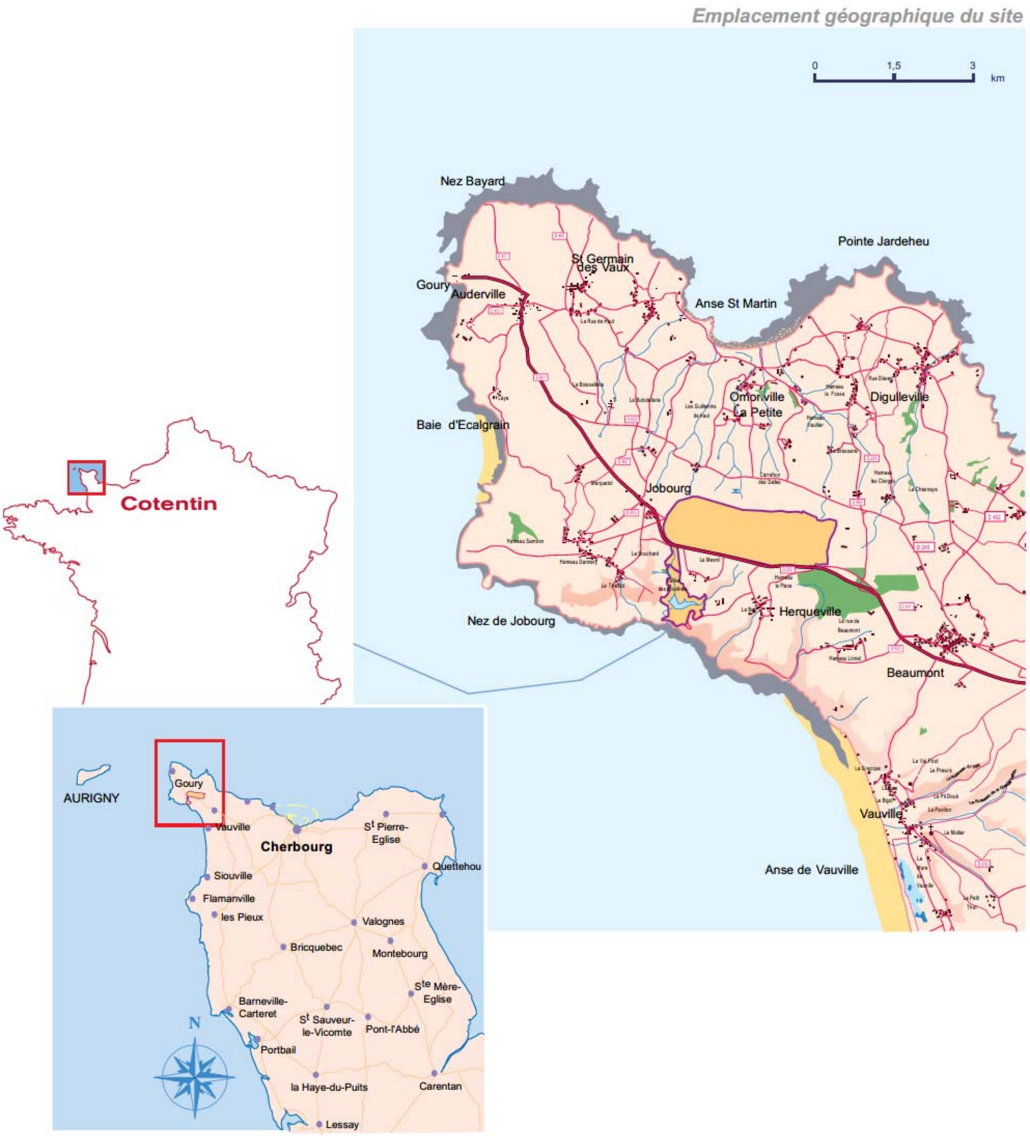
4.2. *The definition of the representative person*

The term representative person, introduced by ICRP Recommendation 101 of 2006 and ICRP Recommendation 103 of 2007 and taken up in EURATOM Directive 2013/59 is the equivalent of, and replaces, the average person of the reference group described in EURATOM Directive 96/29. The representative person is defined in the French Health Public Code in the article R. 1333-23 as a person receiving a dose, which is representative of people most exposed within the population, with the exception of the people having extreme or rare habits.

The representative person relative to the marine pathway is a member of the Goury fishermen group.

Fishermen have the longest lasting contact with the sea and its sprays and their consumption of seafood is proved to be above the average one. The small village of Goury, almost at the tip of the Cap de la Hague, has been identified as the coastal point where radionuclides concentrations are the highest (two times lower at Barfleur, east of Goury on the north coast, three times lower at Blainville, south of Goury on the west coast).

It is assumed, in a conservative way, that the whole seafood with a local origin is ingested by the representative person used to live around Goury.

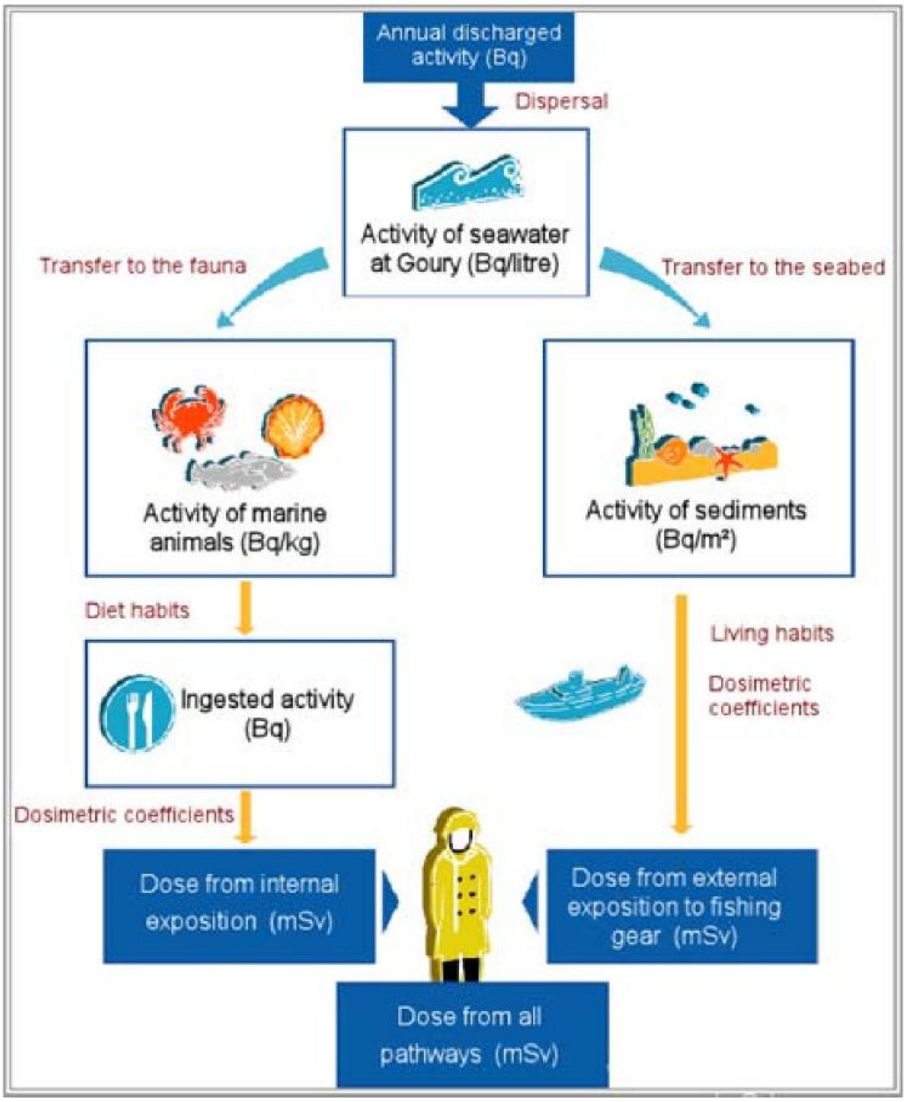


4.3. *The information on exposure pathways considered*

The discharged effluents disperse into the environment. Transfer to man comes through two compartments of the biosphere, the terrestrial compartment (through atmospheric discharges), and the marine compartment. In the marine compartment, most of the nuclides are released in a soluble form, but some of them can form colloids, polymers, or be adsorbed on solid particles. Nuclides are more or less assimilated by marine species, function of the metabolism of the species itself, and of the chemical and physical properties of the nuclide.

Pathways to man from radioactive elements in the marine environment include the ingestion of seafood and external exposure, which depends on the local habits. For the general population, only leisure activities on the beaches have to be considered. The contamination of soil and shore vegetation resulting from the spray of seawater, which can be observed in bioindicators such as gorse is light and does not constitute a significant pathway to man.

The contribution of external exposure, whatever the activity, is much lower than the contribution of the ingestion of seafood.



The exposure pathways for liquid discharges

4.4. Basis for methodology to estimate doses

Since 2003, methodology (modelling) is that of the GRNC, defined during its first mission about the 'Estimation of exposure levels to ionizing radiation and associated risks of leukaemia for populations in the Nord Cotentin' (July 2000 report) [1], later finalised as the ACADIE software.

Specific parameters entered in the model are drawn from dedicated studies, such as local diet and living habits inquiries or concentrations monitoring campaigns.

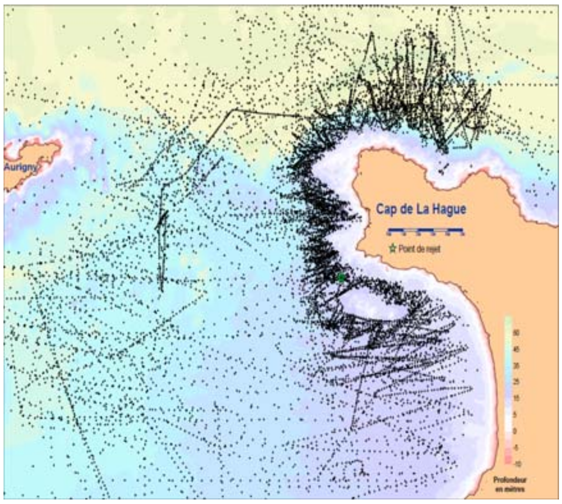
Dispersion factors in the sea are derived from initial experiments with buoys and tracers, and from many measures performed during nearly 50 years, in particular by the IRSN, interpreted and validated by the work of the GRNC.

Dispersion factor has been confirmed from a very important program of qualification following GRNC recommendation. This qualification consisted of a study with IRSN from a 2 D Model developed by IFREMER (French institute of research for the exploitation of the sea). It is a hydrodynamic model with knowledge of uncertainties. A 2D validation from tritium measurements has been realized with DISPRO program:

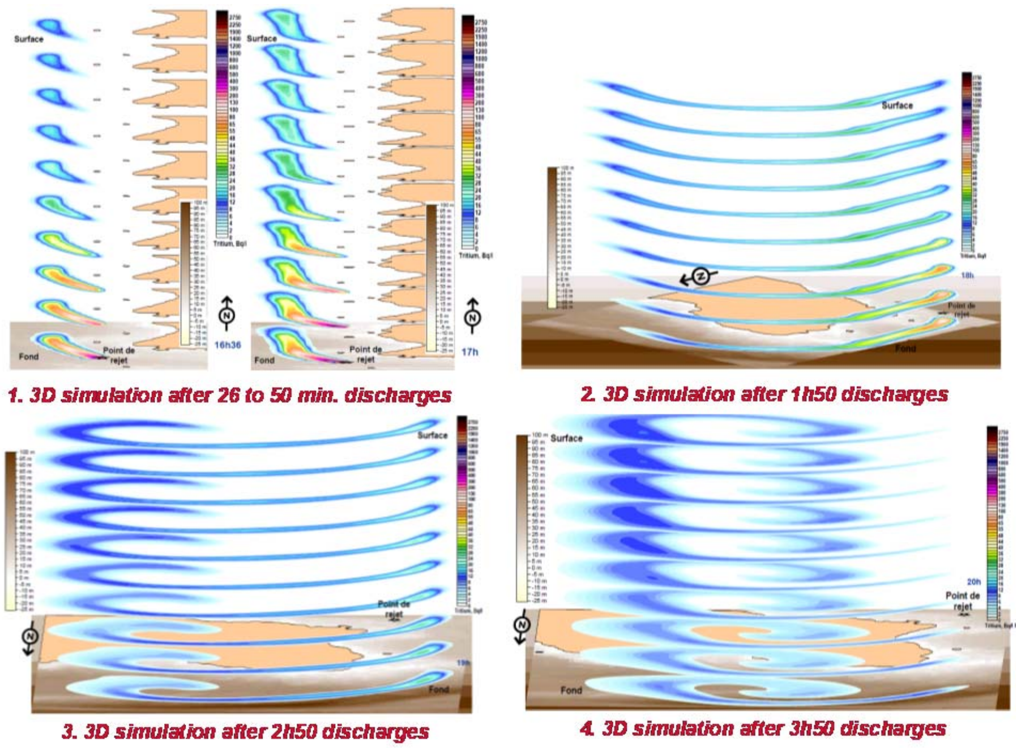
- Validation in the field close to the discharges of La Hague from 1000 m to 30 km (and for the short-term from hour to week);
- From measurements of tritium at sea during an episode of discharges: more than 18 000 measurements between 2002 and 2005.

Then, a 3D validation in progress with DISVER Vertical Dispersion program from tritium measurements also has been operated:

- From 2008, perfecting a sampling system for the validation in three dimensions by IRSN/LRC: taking away from surface with 50 meters of depth;
- Series of measurements: 20 000 measurements in 2010 and 2011.



Localization of the samples taken during programs DISPRO



Model for Marine Dispersion studied with IRSN

Concerning the external exposure of fishermen, exposure time has been conservatively taken at 7 hours a day, 365 days a year [4].

The diet has been defined from the enquiry made by the CREDOC, in April-May 1998, in four zones over Cap de La Hague, Cherbourg city area, West and North coast, Centre, and East coast [4]. Seafood diet of the marine representative person is conservatively taken as the one of the 95th percentile, that is to say the one of the 5 % of people having the highest consumption of seafood. Total annual sea food consumption is taken at about 127 kg, of which more than 70 kg are from local origin (supposed to live precisely in Goury waters); the rest of the food represents about 236 kg of which more than 67 kg are from local origin. This diet was compared with more recent studies (INCA study or ANSES study realized by food agency), of environment and of work. This comparison shows that the home consumption rates supplied by CREDOC are majorants with regard to food evolutions.

Concentration factors in fauna and sediments are taken from measurement results (IRSN/LRC experimental campaigns) interpreted by the GRNC [1] to define the coefficients, when measurable and from EU publication (1979) for others, 14 C for instance.

Corrective factors have been affected to the transfer factors to the marine compartment by the GRNC experts in order to take into account the actual results of measurement in the environment (more than 500,000 results used).

External exposure factors are taken from the September 1st 2003 ministerial order for krypton, and Federal Guidance 12 from US-EPA for other radionuclides.

The whole body dose coefficients for inhalation and ingestion are also taken from this same order, which was the transposition to French law of EURATOM Directive 96/29.

More details on ACADIE are given in Appendix 5.

4.5. Site specific factors for significant nuclides

Site-specific factors are presented above.

4.6. Site specific target annual effective dose

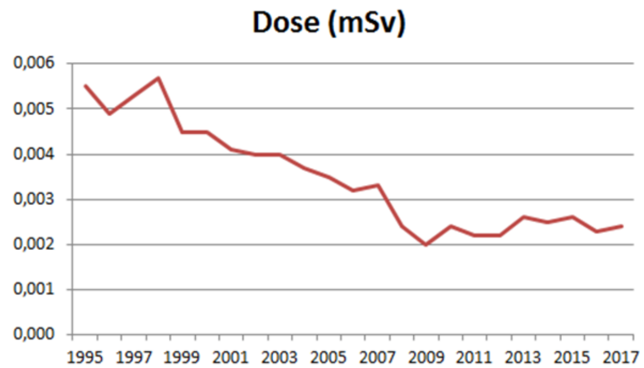
French regulations do not consider targets for the annual effective dose. The limits apply only to the discharges. Nevertheless, the effective doses to the representative persons are assessed every year.

4.7. Results of added annual effective dose or radiological impact

Annual effective doses computed with the latest version of ACADIE on the representative person for marine discharges are shown in the table below.

Year	Dose (mSv)
2012	0.0022
2013	0.0026
2014	0.0025
2015	0.0026
2016	0.0023
2017	0.0024

Evaluation performed with the ACADIE software of the doses to the representative person of the Goury fishermen related to marine discharges during the 2012-2017 period



Evolution of the annual dose to the representative person of the Goury fishermen from 1995 to 2017

For the marine pathway related impact to the Goury fishermen representative person, it can be seen that the doses resulting from the total actual discharges since 1995 have significantly decreased and have always stayed more than two orders of magnitude below the dose limit of 1 mSv set by the French regulations (article R. 1333-11 of the Public Health Code setting the limit of dose added by nuclear activity for the public).

Analysis confirms that the dose caused by tritium is negligible besides the one resulting from the other radionuclides (< 1 %).

4.8. *Total exposures*

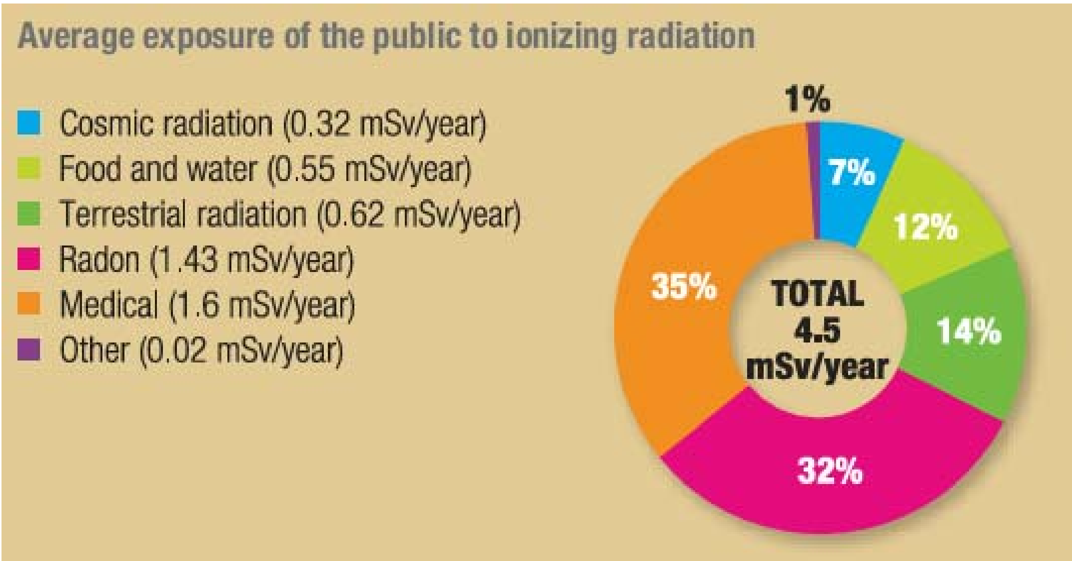
The other sources of exposure can be found in publications [5].

The annual assessment of radiological or dose impacts aims to verify compliance with article R. 1333-11 of the Public Health Code, which sets a limit of 1 mSv per year for the added effective dose due to nuclear operations.

To verify compliance with that limit, all local nuclear operations which could contribute to the dose impacts to a representative person must be considered. This is an exhaustive approach, even though some of the operations could in principle be considered to make a negligible contribution because of the very low releases from them to the same river basin. In many cases, the impacts are so low that the exercise presents real difficulties, for a lot of data has to be collected (impacts of the facilities of other operators, etc.) and their overall consistency must be verified. Adding up the different contributions is thus not a simple administrative formality.

The resulting impacts are commonly compared with France's average naturally occurring radioactivity, but **what exactly goes into that natural radioactivity?** We are all exposed to natural radioactivity, which is everywhere in our environment, but we aren't all exposed in the same way. Depending on the geographic location (geology, altitude), our food habits and our lifestyles (airplane travel, winter sports, etc.), exposure to "natural" radioactivity can range from 1.6 mSv per year to more than 10 mSv per year. The higher number customarily includes the contribution from the so-called "routine" medical exposure of the French population, but not doses delivered for therapeutic purposes.

The chart below (Repères journal of IRSN, no. 29, April 2016) presents the different sources of average exposure in France. In 2015, IRSN re-estimated the average annual exposure to naturally occurring



radioactivity in France at 2.9 mSv instead of 2.4 mSv, excluding the contribution from medical exposure. With the increase in the dose conversion coefficient for radon contemplated by the ICRP, which could more than double, average annual exposure to natural radioactivity in France could be re-estimated at approximately 4.4 mSv (excluding medical exposure).

4.9. Systems for quality assurance of processes involved in dose estimates

As any other activity of the Établissement, the processes involved in dose assessment comply with the ISO 9001 quality standards, as part of the jointed certification of integrated management ISO 14001, ISO 9001 and OHSAS 18001. That is to say, in particular, that they are traceable and subject to verifications. Independent verifications are performed by the technical support of the ASN, the IRSN. The initial work of the GRNC [1], as ordered by the government, constitutes also a very extensive verification of all the work performed relative to the discharges, including the dose assessment.

DEMONSTRATING THE ABSENCE OF IMPACTS

The system as a whole helps demonstrate the absence of environmental impacts from nuclear operations. The quality and reliability of the measurements performed are ensured by compliance with the NF/EN ISO/CEI 17025 standard, certification of environmental laboratories, commitment to and participation in the National Environmental Radioactivity Measurement Network (RNM), successful cross-checks, the surveillance carried out by the regulators (ASN, ASND), and the verification visits carried out by the European Commission under article 35 of the Euratom Treaty.

Additional proof of the absence of impacts from the operations conducted at the INBs was provided by the exercise carried out based on radiological data from the RNM for 2011-2014: the exercise sought to provide more information on public exposure to radioactivity present in the environment, in particular by comparing the operators' assessments based on facility releases. The report concluded that "the doses likely to have been received by the public living near French nuclear facilities, estimated based on the measurement results of the different environmental monitoring programs, are low, 100 to 10,000 times lower than the set exposure limit for the public of 1 mSv/year. […] **These doses agree with the calculated estimates of the nuclear site operators** (modeling of dispersion and transfers), based on actual activity releases." This finding constitutes a major step forward in the approach to monitoring and dose impact assessment. It leads to the conclusion that the monitoring system as a whole is coherent, thereby validating the impact estimate models and the results of annual release reports based on data from the monitoring of environmental radioactivity.

Demonstrating the absence of impacts requires very substantial means and efforts. Paradoxically, the lower the levels, the greater the analytical performance must be and the higher the cost of the measured becquerel. This race to technology would not appear to be totally justified today in view of known information, nor is it necessary to demonstrate the absence of impacts.

4.10. Summary evaluation for radiation doses to the public

Table below summarizes the evaluation concerning the BAT/BEP indicators of the site-specific information on radiation doses to the public from the ORANO CYCLE La Hague site.

The methods for estimating the doses, agreed by the GRNC and the IRSN, are relevant to judge the exposure of the population and to check the compliance with the dose limits and constraints. The doses are decreasing due to managerial and technical improvements continuously implemented on the ORANO CYCLE La Hague site.

Criteria	Evaluation
The BAT/BEP indicators	
Downward trend in radiation dose	Yes
Relevant critical group	Yes
Reliable dose estimates	Yes
Relevance of target dose	No target dose for the site
Relevant quality assurance systems	Yes
Data completeness	Data are complete
Causes for deviations from indicators	No deviations
Uncertainties	Low
Other information	Assessment method based on the work of the GRNC, pluralistic expert group

Summary Evaluation for Radiation Doses to the Public

5. Summary – BAT

From the evaluations of the BAT/BEP indicators for discharges, environmental impact and radiation doses to the public it is concluded that the BAT have been applied at the ORANO CYCLE La Hague site during the time period covered by this report as well as before.

6. Additional information

One of the main goals of the ORANO CYCLE La Hague plants operators has always been to control the discharges and their impact, aiming at an industrial activity without any harm, neither for the workers nor for the population. Since the creation of the site, the operators keep continuously investing in the evolution of the industrial units, in order to integrate progress achieved in processes, technologies and impacts knowledge. This is clearly apparent in the evolution of the doses to the workers, of the waste volume production and of the discharges that have been continuously decreasing since the beginning of the operations and are still decreasing. The impact to the representative person is low and the efforts are nevertheless still going on.

It should not be forgotten, however, that as new improvements are implemented, the expected impact gains will get lower and lower and the corresponding expenses will have to be evaluated in regard to the prevention costs usually accepted against all the domestic, industrial, technological and dietary risks to which the population is exposed, in a consistent way with the ICRP statement: ("If the next step of reducing the detriment can be achieved only with a deployment of resources that is seriously out of line with the consequent reduction, it is not in the society's interest to take that step, provided that individuals have been adequately protected." according to ICRP Publication 21 - 1973).

This point being recalled, several directions of progress are envisaged. Those concerning liquid effluents are exposed hereafter.

In addition to the process improvements already in use in UP3-A and UP2-800 (including the R4 workshop), the preferred orientation of liquid effluents towards vitrification, by concentrating them, will continue to be extended in the following years to the effluents resulting from the shutdown and the decommissioning programs of the UP2-400 plant, in consistency with the constant research of the Best Available Techniques for these operations.

6.1. R&D

In the framework of the prescription [AREVA-LH-83] of the ASN Resolution 2015-DC-0535, about forty options effectively leading to a reduction of the impact[7] of the radioactive discharges to the sea have been examined (these options are not necessarily exclusive from one another, their effects cannot be added up)[8].

The option that leads to the greatest reduction of the impact (near to 30 % mainly by reducing simultaneously ^{129}I and ^{14}C discharges) is based on the Voloxydation/Oreox process. It would require for

[7] The total impact and the relative reductions are determined for a reference industrial scenario of 1,400 tons heavy metal processed by year, with an initial enrichment of 3.9 % in ^{235}U, a burn-up of 46 GW.d/tU and an average cooling time of 8 years before processing. The corresponding reference impact from the total discharges to the representative person that is more particularly subjected to the impact of the discharges to the sea (Goury fisherman) is 8.5 µSv/year.

[8] Details about some of these options have been given in the preceding edition of this report.

each of the two La Hague plants the installation of a whole workshop between the shearing and the dissolution units when these units are closely interlocked inside the same high activity contaminated cell. Each new workshop would comprise two 10 meters long calcinators, working at 400-500 °C that would represent a major safety threat. Moreover, there are absolutely no safe and qualified conditioning and disposal processes for the by-products of this process, neither for ^{129}I nor for ^{14}C, knowing that:

- This process needs more R&D before being industrially implemented;
- There is practically no room around the head-ends of the La Hague plants to build such workshops;
- The energy consumption of these workshops would increase the energy balance of the site by 7 %; it is clear that the implementation of this option cannot be envisaged on the La Hague site.

The three next options relate to a reduction of ^{14}C discharges and would lead to a 15-16 % (each, non-cumulative) reduction of the impact. They are more or less easy to implement, but they suffer the major drawback that there is absolutely no safe and qualified conditioning and disposal process for their by-products.

The problem is the same for the next two ones, very similar but for ^{129}I, that would lead to a nearly 11 % (each, non-cumulative) reduction of the impact, with the same drawback of the lack of a qualified conditioning and disposal process.

Only these 8 options lead to a reduction of impact that is higher than 5 %.

The two next options (7th and 8th) relate to the treatment of the alkaline effluents concentrates (CEB), that could lead to a 8 % (each, non-cumulative) reduction of the impact.

It has to be noted that the anticipated gain relies mainly on the reduction of ^{106}Ru discharges (99.55 %). The gain does not take into account the practical operating dispositions that already allow a reduction of the ^{106}Ru discharges, simply by using the available buffer storages as decay storages, leading to a ^{106}Ru cooling time before discharge of much more than the nominal 8 years before processing. The anticipated 4.5 % value is then more theoretical than realistic.

The first of these two options has been dealt with in the preceding report. It consists in the vitrification of the CEB in their entirety. The process has needed extensive R&D to prevent foaming of the solutions and clogging of the equipment. This process was implemented within an existent plant. It industrially works and allows the treatment of 40 m^3 of CEB produced. It frees up space into the tank for the rest of CEB to favour an additional decay of ^{106}Ru. However the limit of this process is now reached due to the fact that the priority for the vitrification is given to fission product solutions, noble metal particle-rich solutions (issue from clarification) and equipment rinsing solutions.

The second one is the grouting of the entirety of the CEB. This option would require the installation of a new grouting unit of relatively high capacity (400 m^3/year), of a buffer storage unit for this production that would increase the site production of grouted waste by 33 %. This option is not consistent with the first point of the definition of BAT in the OSPAR Convention, which says that “In seeking the best available techniques, emphasis is placed on the use of technologies that do not produce wastes, if such are available.” The constraints and cost of this option lead to make it less favorable than the preceding one.

The next option (9th) relates to the discharges of ^{60}Co and would lead to a nearly 4 % reduction of the impact. It consists in the evaporation of the effluents of the transportation casks maintenance workshop (AEC) and of the water treatment of NPH and T0 storage ponds. Cobalt comes from the oxidised surface of the fuel elements, is deposited in the transportation casks and in the storage ponds. Regarding the preceding edition of this report, improvements were led to lower the radiological activities of the effluents. Especially to favour the decantation of the ^{60}Co in form of particles, some effluents are stored as long as possible before their disposal. The option would require the installation of new evaporation capacities and buffer storage tanks in very irradiating areas. This would lead to high exposures for the setting up and increased exposure for the operation. This puts at a disadvantage this option that would otherwise be acceptable.

The next option (10th) relates to the discharges of alpha emitters and would lead to a 1 % reduction of the impact. It consists in an ionic exchange on the effluents of STE V (very low activity) and in the vitrification of the elution by-product. The ionic exchanger has to be periodically changed and the used one has to be grouted. The size of the equipment must be adapted to the high flow, and its removal and disposal would be a serious safety constraint.

The next option (11t^h) which consisted in improving the process of the liquid effluents treatment unit STE3 (low at medium activity) is implemented. It has been dealt with in the preceding report. It cannot lead anymore to an additional reduction of the impact. Its drawbacks are the cost of the increased reagent consumption and the increase in solid waste volume.

All other options have a potential gain in impact reduction lower than 3 % (for 6 of them) and lower than 1 % (for the remaining ones). The gain for these options can be considered lower than the variability of the discharges and prevents further examination.

The result of this extensive R&D work strengthens the conclusion that the present processes and implementation represent the Best Available Techniques for the discharges to the sea of the ORANO CYCLE La Hague site.

6.2. Tritium discharges

Regarding tritium, in accordance with the BAT philosophy, a periodic review of the processes that could be used to reduce the tritium discharges to the sea is performed. Their nominal impact is already only 0.23 % of the total nominal impact in 2017. To complement the option that was quoted in the preceding report, 8 options have been examined, with a maximal potential gain of 0.1 % on the impact, except for the use of the Voloxydation/Oreox process that would lead to a 0.16 % gain. But it has been seen concerning ^{129}I and ^{14}C that this option was not practicable on the La Hague site.

Three options are based on the grouting of the tritiated effluents, one on the raw effluents, one after concentration by the TRILEX process and one after concentration by isotopic separation of the tritium. These three options, that are not consistent with the first BAT principle of no increase in solid waste, have to be discarded because of the lack of a qualified conditioning and disposal process of the grouted waste.

The four remaining ones are based on discharge after a 12 years decay of the tritium, preceded by more or less concentration that requires more equipment, but less decay storage. These four options create a very strong safety constraint: the smallest atmospheric leak from the storage would generate an impact much more important than the anticipated gain, all the more than the concentration is higher.

The first option does not require any process equipment but stores the raw by-products in 220,000 m^3 storage, quite unrealistic by the surface it would need and its cost.

The second one relies on the TRILEX patents and concentrates the by-product in such a way that the storage would be reduced to a nevertheless hardly realistic 130,000 m^3, with the complementary constraint of more equipment and a subsequent much larger tritiated zone in the plant.

The third one uses a costly complex isotopic separation process to concentrate the effluents so that the necessary storage is reduced to about 870 m^3, which is nevertheless difficult to install and it keeps the drawbacks of the second one.

The fourth one is an improvement of the third one, where the isotopic separation process treats the by-product of a new fission products concentration unit and a new tritiated acid recovery unit, both more efficient, so that the storage volume could be reduced to 500 m^3. The size and complexity, hence the cost, of the two complementary new units make this option more unrealistic than the preceding one.

This survey shows that the physical dispersion and isotopic dilution to the sea of the tritiated effluents of the ORANO CYCLE La Hague site is still today the Best Available Technique.

In parallel, questions about what becomes of tritium in the environment and its impacts on humans led ASN to create two multidisciplinary taskforces in 2008. Their deliberations gave rise to a July 2010 white paper on tritium, which is posted on the ASN website, and an action plan. ASN set up a multidisciplinary committee to follow up on the action plan. The committee meets once a year in early July.

At the July 4, 2012 meeting, a summary of ORANO's studies on the LA HAGUE site was presented and approved by the committee. The work further developed the characterization of the physico-chemical forms of tritium in the releases and in the environment. What emerged was that:

- Measurements of organically bound tritium (OBT) in tributyl-phosphate (TBP) solvent, the main organic precursor in the liquid releases, show very low potential amounts of OBT in the liquid releases, at most 100 Bq/g of solvent, which in the worst case scenario would be a dose of less than one picoSv/year for the benchmark population in question;
- The studies on gaseous releases revealed no form of organically bound tritium whatsoever;
- The ORANO Cycle LA HAGUE laboratory conducted an additional search for OBT in local marine biological species and a comparison was made with the IRSN/ LRC laboratory. Results obtained by both laboratories were consistent and confirmed the white paper's results, i.e. that measurements of free tritium and OBT were the same. This showed that there was no bioaccumulation of organically bound tritium in the marine wildlife around the LA HAGUE headland.

Taken together, these studies provide answers to the questions put to ORANO in the ASN action plan on managing releases and monitoring the environment, and will be turned over to ASN in 2013. ASN has been reporting annually in detail on the dosimetric impacts of radionuclides for all age categories in the benchmark groups since 2007. The reports have now been extended to include a detailed inventory of tritium emissions.

6.3. Conclusion

The impact to the marine pathway representative person is already at levels considered by the radiological protection specialists as being insignificant from the radiological aspect. Considering that the objective of an industrial activity is to perform without any harm, neither to the workers nor to the population, we consider it as reached for the ORANO CYCLE La Hague Facility. Then we make allowance for the principle of the ICRP publication 21 (as already quoted above in § 6: "If the next step of reducing the detriment can be achieved only with a deployment of resources that is seriously out of line with the consequent reduction, it is not in the society's interest to take that step, provided that individuals have been adequately protected.") before envisaging any new progress of the process.

7. Bibliography

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Appendix 1: System(s) in place to reduce, prevent or eliminate discharges and their efficiency

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
	Existing	**Planned**	**Decontamination Factor DF or purification factor FE[9]**	**Other measure of efficiency**	
Recycling:					
Acidic washing of hulls and end-pieces	1990			100 %	After distillation
Water washing of hulls and end-pieces	1990			100 %	After distillation
Water washing of vitrified waste canisters				100 %	After distillation
Water washing of compacted waste canisters				Around 50 %	Function of operating conditions
Condensates from vacuum generation				100 %	After distillation
Recovered tritiated acid	1990			100 %	After distillation
Recovered non-tritiated acid	1990			100 %	After distillation
Recovered solvent	1990			100 %	After distillation, liquid concentrate is grouted
Distillation:					
Acidic effluents	1996		FE=10^3 à 10^5		Distillates discharged to the sea,
Alkaline effluents	1996		FE=10^4		Distillates discharged to the sea, chemical precipitation of concentrates before discharge
Recovered tritiated acid	1990		FE=10^3 à 10^5		
Recovered non-tritiated acid	1990		FE=10^3 à 10^5		
Oxalic mother liquors	1990		FE=10^6 à 10^7		
Process improvements:					
Continuous monitoring of the pH of precipitation process	1987		FD for =400 =4 ^{125}Sb=1,1 106		STE3 with separate reactors
Separate reactors for the introduction of each reagent	1987				STE3
Use of stoichiometric reagent concentrations in the chemical effluent	2008				STE3

9 Decontamination factor FD= Activity flow of the feed divided by activity flow of the distillate Purification factor FE= Specific activity of the concentrate divided by specific activity of the distillate.

Abatement system/ Management	Into operation (Year)		Efficiency of abatement system		Comments
Use of pulsed columns in place of mixers-settlers	1990				UP3-A first and second separation cycles
Use of centrifugal extractors in place of mixers-settlers	2002				R4 plutonium purification
Optimisation of the solvent path in the whole process	1990				UP3-A
Reinforcement of 99 Tc washing	1998			FD increased 4 to 5 times	UP3-A
Change of analysis methods	2000				Laboratory, with no reagent preventing the distillation
Replacement of laboratory analysis by on-line continuous measurement requiring no sampling	2000			100 %	UP3-A, UP2-800
Installation of a Pu recovery unit on the laboratory	2000				UP3-A, UP2-800
Finer adjustment of STE3 process regarding 137Cs removal	2003				
ultrafiltration	1990		=600 =1.5		Laboratory effluents
vitrification		2009-2010	^{106}Ru=2		Integration of alkaline effluent concentrates in vitrified waste
Use of over stoichiometric concentrations of reagents in the chemical decontamination process of STE 3	2009		Increased decontamination factor		Eliminates most of the discharges of type A effluents at the cost of a few more solid waste
Radioactive decay:					
Fuel elements are "cooled" in storage pools during an average period of 5 years after extraction from reactor core before	1990			Radioactive decay of ^{106}Ru	DF=32 for 5 years delay
Fission products solution cannot be processed for vitrification before 6 years after extraction from	1990			Radioactive decay of ^{106}Ru	DF=64 for 6 year delay (does not cumulate with preceding one)

Appendix 2: Annual mean concentrations of nuclides in the marine environment over the 2012-2017 period

Coastal waters (Bq/l)		**2012**		**2013**		**2014**		**2015**		**2016**		**2017**
125 Sb	<	0,46	<	0,45	<	0,4	<	0,4	<	0,4	<	0,43
106 Ru	<	3,3	<	3,2	<	3,0	<	3,0	<	3,0	<	3,03
137 Cs	<	0,2	<	0,16	<	0,18	<	0,18	<	0,18	<	0,18
60 Co	<	0,24	<	0,24	<	0,22	<	0,22	<	0,22	<	0,22
239/40 Pu	<	2,80E-05	<	4,00E-05	<	2,00E-05	<	2,00E-05	<	2,00E-05	<	2,00E-05
238 Pu	<	2,50E-05	<	5,00E-05	<	3,00E-05	<	2,00E-05	<	2,00E-05	<	2,00E-05
Potassium 40		12		12		12		13,2		14		16
Beta activity		13		13		13		13		13		13
3 H	<	9,9	<	12	<	9	<	14	<	14	<	10,1

Fucus (Bq/kg fresh)		**2012**		**2013**		**2014**		**2015**		**2016**		**2017**
125 Sb	<	0,13	<	0,13	<	0,13	<	0,14	<	0,14	<	0,16
137 Cs	<	0,07	<	0,07	<	0,05	<	0,07	<	0,06	<	0,08
129 I		7,5		8		7,24		7,46		7,09		6,1
131 I		-		-		-		-		-		-
60 Co	<	0,14	<	0,13		0,13	<	0,11	<	0,24	<	0,13
106 Ru	<	1,1	<	1,02	<	1,07	<	1,14	<	0,99	<	1,63
241 Am	<	6,80E-02	<	7,50E-02	<	6,00E-02	<	7,00E-02	<	7,00E-02	<	7,00E-02
239/40 Pu	<	3,70E-02	<	4,10E-02	<	3,50E-02	<	3,00E-02	<	3,00E-02	<	3,00E-02
238 Pu	<	2,80E-02	<	3,50E-02	<	3,00E-02	<	3,00E-02	<	3,00E-02	<	5,00E-02
Potassium 40		270		247		225		264		277		280
14 C*		34		32		41		33		34		34

* Natural and artificial

- result of analysis not available

< result below measurement threshold

Limpets (Bq/kg fresh)		2012		2013		2014		2015		2016		2017
125 Sb	<	0,2	<	0,2	<	0,2	<	0,26	<	0,25	<	0,23
110 mAg		-		-		-		-		-		-
137 Cs	<	0,09	<	0,12	<	0,08	<	0,09	<	0,11	<	0,10
129 I	<	0,47	<	0,36	<	0,36	<	0,43	<	0,42	<	0,44
60 Co	<	0,12	<	0,13	<	0,11	<	0,15	<	0,14	<	0,13
106 Ru	<	1,5	<	1,6	<	1,5	<	1,66	<	1,7	<	2,6
241 Am	<	8,00E-02	<	8,00E-02	<	6,80E-02	<	8,00E-02	<	9,00E-02	<	9,00E-02
239/40 Pu		1,40E-02		2,20E-02	<	2,00E-02	<	4,20E-02	<	4,20E-02	<	4,20E-02
238 Pu	<	7,80E-03	<	1,40E-02	<	1,10E-02	<	2,00E-02	<	1,30E-02		2,50E-02
Potassium 40		92		93		91		101		114		113
14 C*		56		53		53		51		55		58

Fishes (Bq/kg fresh)		2012		2013		2014		2015		2016		2017
125 Sb	<	0,15	<	0,16	<	0,14	<	0,12	<	0,14	<	0,15
137 Cs	<	0,14	<	0,100	<	0,08	<	0,08	<	0,12	<	0,09
129 I	<	0,06	<	0,11	<	0,075	<	0,14	<	0,07	<	0,06
60 Co	<	0,09	<	0,10	<	0,08	<	0,08	<	0,07	<	0,08
106 Ru	<	1,1	<	1,22	<	1,11	<	1,00	<	0,98	<	1,03
241 Am	<	5,50E-02	<	5,60E-02	<	0,05	<	0,05	<	0,05	<	0,05
239/40 Pu	<	5,35E-03	<	5,60E-03	<	3,28E-03	<	3,00E-03	<	3,00E-03	<	3,00E-03
238 Pu	<	4,40E-03	<	5,80E-03	<	3,28E-03	<	3,00E-03	<	2,65E-03	<	4,00E-03
Potassium 40		115		112		109		130		132		132
14 C*		34,5		36		36		33		31		31

* Natural and artificial

- result of analysis not available

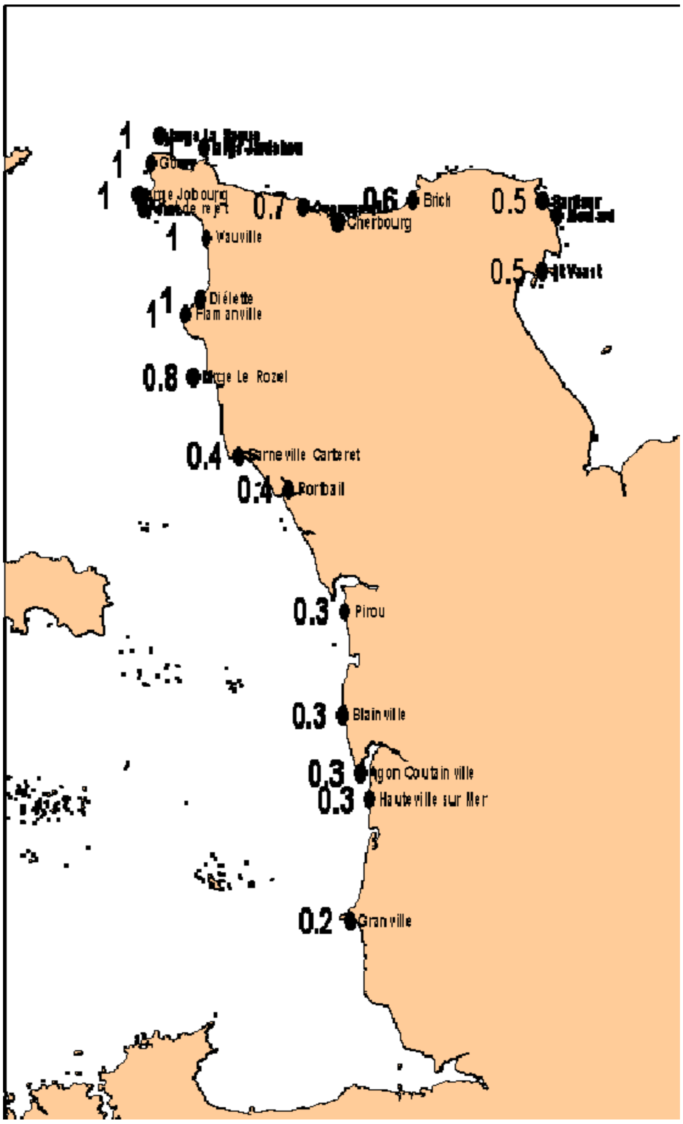
< result below measurement threshold

Appendix 3: ACADIE impact assessment model

I - Dispersion

Dispersion of liquid effluents discharged to the sea can be modelled by dilution factors. These dilution factors are ratios averaged on the year scale of the measured activity of the sea water, from which the background level is derived, to the flow of radioactivity discharged by the considered facility. The GRNC has assessed dilution factors from activity measurement results that have been obtained on a large time scale and for different sampling points. A hydrodynamic model of residual currents has also been used.

The selected dilution factors are indicated on the map below. They are expressed in relative value to the dilution factor assessed by the IRSN for Goury (selected representative person for the impact of the discharges to the sea of the ORANO CYCLE La Hague facility).



Dilution factors of the discharges of the ORANO CYCLE La Hague reprocessing plants
Reference value (unit at Goury) correspond to 0.76 $Bq.m^{-3}$ for 1 TBq discharged per year.

II - The transfer in the various compartments of the marine environment

The activity of the sea water in the different coastal sectors of the North-Cotentin is computed from the dilution factors as defined above and the activities of the various radionuclides annually discharged under liquid form by the reprocessing plant of ORANO CYCLE La Hague, following formula below:

$$A\ sea\ water = Fd \times Q$$

With:

A sea water: activity of the sea water ($Bq.m^{-3}$)

Fd: dilution factor ($Bq.m^{-3}$/Bq discharged.y^{-1})

Q: discharge rate (Bq discharged.y^{-1})

It is possible to estimate the activity content of marine species (algae, fishes, shellfishes and molluscs) and sediments on the basis of a steady state at year's scale. In a steady state, the mass specific activity of living species and sediments is supposed to be proportional to the volumetric activity of the sea water at the place where they are sampled.

Corresponding proportionality factors are named concentration factors (FC) for marine species and distribution factors (Kd) for the sediments. The assumption of proportionality implies that a balance is obtained between the different compartments of the medium (algae, marine species and sediments). When this condition is not reached, the measured radioactivity of marine species is different from the one computed using the FCs and Kds. The GRNC has compared the model and the measurement results for the indicators and the radionuclides for which measures were available spread over a long time. In some cases, corrective factors have been integrated into the model of the transfer to the environment.

The values of the corrective factors are shown in Appendix 3-I to this document, those of the concentration factors in Appendix 3-II and those of the distribution coefficients in Appendix 3-III.

III – Marine species

Six indicators have been selected:

> Algae (a);

> Fishes (f);

> Crustaceans (c);

> Filtering molluscs (m1);

> Non-filtering molluscs (m2);

> Sediments.

The activity of marine species is calculated from the following formula:

$$A\ (a,f,c,m1,m2) = A\ sea\ water \times FC\ (a,f,c,m1,m2) \times 0.001 \times F\ correct.$$

With:

A (a,f,c,m1,m2): activity in the algae, fishes, crustaceans and molluscs ($Bq.kg^{-1}$ fresh),

A sea water: activity in the sea water ($Bq.m^{-3}$),

FC (a,f,c,m1,m2): concentration factor for algae, fishes, crustaceans and molluscs ($l.kg^{-1}$ fresh),

0.001: conversion factor,

Fcorrect.: corrective factor (dimensionless).

The GRNC has selected the concentration factors recommended by the IRSN for living species, because they reflect more particularly the behaviour of the radionuclides in the species living in the English Channel. When there was no IRSN value, the GRNC has selected the IAEA values.

For some radionuclides, there is no concentration factor value available. The concentration factors of the chemical analogs have been selected. Thus beryllium has been taken as cobalt, rubidium as caesium, rhodium as ruthenium and praseodymium as cerium.

IV – Sediments

The activity of the sediments is calculated from the following formula:

$$A\ sed = A\ seawater \times Kd \times 0.001 \times Fcorrect$$

With:

A sed: activity in the sediments ($Bq.kg^{-1}$ dry)

A seawater: activity in seawater ($Bq.m^{-3}$)

Kd: distribution coefficient ($l.kg^{-1}$ dry)

0.001: conversion factor

Fcorrect: corrective factor (dimensionless)

For 244 Cm, the Kd value selected by the GRNC was the value set forth by the IAEA, i.e. 2,000,000 l/kg dry [2]. In February 2002, IRSN has published the results of a study on the behaviour of radionuclides in the environment [3]. One of the conclusions of this study is that the Kd of 244 Cm in the considered sediments is lower than the one selected by the GRNC (by a factor of 100); adequate value is around 20,000 l/kg dry. GRNC has selected this new value and an assessment of the hazards associated to 244 Cm has been performed [4].

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Appendix 3-I.-. Corrective factors

	Algae		Fishes		Crustaceans		Filtering molluscs		Non-filtering molluscs		Sediments	
	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->
3H	1	1	1	1	1	1	1	1	1	1	1	1
10Be	0.6	1.1	0.8	2	0.5	1.3	0.5	2	0.5	1.2	0.04	0.04
14C	1	1	1	1	1	1	1	1	1	1	1	1
36Cl	1	1	1	1	1	1	1	1	1	1	1	1
41Ca	1	1	1	1	1	1	1	1	1	1	1	1
54Mn	1.1	1.1	1	1	1	1	1	1	1	1	1	1
55Fe	1	1	1	1	1	1	1	1	1	1	1	1
57Co	1	1	0.8	2	0.5	1.3	0.5	2	1	1	0.04	0.04
58Co	0.7	0.7	0.8	2	0.5	1.3	0.5	2	0.5	0.5	0.04	0.04
60Co	0.6	1.1	0.8	2	0.5	1.3	0.5	2	0.5	1.2	0.04	0.04
59Ni	1	1	1	1	1	1	1	1	1	1	1	1
63Ni	1	1	1	1	1	1	1	1	1	1	1	1
65Zn	9	9	1	1	1	1	1	1	0.35	0.35	1	1
75Se	1	1	1	1	1	1	1	1	1	1	1	1
79Se	1	1	1	1	1	1	1	1	1	1	1	1
87Rb	0.7	0.7	0.2	0.2	0.4	0.4	0.5	0.5	0.6	0.6	0.2	0.2
89Sr	0.4	0.4	0.6	1.2	1.3	1.3	1	1	0.4	0.4	3	3
90Sr	0.4	0.4	0.6	1.2	1.3	1.3	1	1	0.4	0.4	3	3
91Y	1	1	1	1	1	1	1	1	1	1	1	1
93Zr	1	1	1	1	1	1	1	1	1	1	1	1
95Zr+Nb	1	1	1	1	1	1	1	1	1	1	1	1
94Nb	1	1	1	1	1	1	1	1	1	1	1	1
93Mo	1	1	1	1	1	1	1	1	1	1	1	1
99Tc	1.9	1.9	1	1	1	1	1	1	1	1	1	1
103Ru	0.7	0.7	3.9	3.9	0.5	0.5	0.2	1	0.4	0.4	0.05	0.2
106Ru	0.7	0.7	3.9	3.9	0.5	0.5	0.2	1	0.4	0.4	0.05	0.2
107Pd	1	1	1	1	1	1	1	1	1	1	1	1
110mAg	1	1	1	1	1	1	1	1	1	1	1	1
113mCd	1	1	1	1	1	1	1	1	1	1	1	1

	Algae		Fishes		Crustaceans		Filtering molluscs		Non-filtering molluscs		Sediments	
	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->
121Sn	1	1	1	1	1	1	1	1	1	1	1	1
121mSn	1	1	1	1	1	1	1	1	1	1	1	1
126Sn	1	1	1	1	1	1	1	1	1	1	1	1
124Sb	0.9	0.9	3.8	3.8	1.4	1.4	0.5	0.5	1.2	1.2	0.2	0.6
125Sb	0.9	0.9	3.8	3.8	1.4	1.4	0.5	0.5	1.2	1.2	0.2	0.6
126Sb	0.9	0.9	3.8	3.8	1.4	1.4	0.5	0.5	1.2	1.2	0.2	0.6
127Te	1	1	1	1	1	1	1	1	1	1	1	1
127mTe	1	1	1	1	1	1	1	1	1	1	1	1
129I	1	1	1	1	1	1	1	1	1	1	1	1
131I	1	1	1	1	1	1	1	1	1	1	1	1
134Cs	0.7	0.7	0.2	0.2	0.4	0.4	0.5	0.5	3.4	3.4	0.2	0.2
135Cs	0.7	0.7	0.2	0.2	0.4	0.4	0.5	0.5	1	1	0.2	0.2
137Cs	0.7	0.7	0.2	0.2	0.4	0.4	0.5	0.5	0.6	0.6	0.2	0.2
144Ce	0.5	0.5	1	1	1	1	1	1	3.1	3.1	1	1
147Pm	1	1	1	1	1	1	1	1	1	1	1	1
151Sm	1	1	1	1	1	1	1	1	1	1	1	1
152Eu	1	1	1	1	1	1	1	1	1	1	1	1
154Eu	1	1	1	1	1	1	1	1	1	1	1	1
155Eu	1	1	1	1	1	1	1	1	1	1	1	1
232U	1	1	1	1	1	1	1	1	1	1	1	1
233U	1	1	1	1	1	1	1	1	1	1	1	1
234U	1	1	1	1	1	1	1	1	1	1	1	1
235U	1	1	1	1	1	1	1	1	1	1	1	1
236U	1	1	1	1	1	1	1	1	1	1	1	1
238U	1	1	1	1	1	1	1	1	1	1	1	1
237Np	1	1	1	1	1	1	1	1	1	1	1	1
236Pu	1	1	1	1	1	1	1	1	0.6	0.6	1	1
238Pu	1	1	1	1	1	1	1	1	0.6	0.6	1	1
239,240Pu	1	1	1	1	1	1	1	1	0.6	0.6	1	1
241Pu	1	1	1	1	1	1	1	1	0	0	1	1
242Pu	1	1	1	1	1	1	1	1	0	0	1	1
241Am	1	1	1	1	1	1	1	1	1	1	1	1

	Algae		Fishes		Crustaceans		Filtering molluscs		Non-filtering molluscs		Sediments	
	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->	FC ->90	FC 91->
242Am	1	1	1	1	1	1	1	1	1	1	1	1
242mAm	1	1	1	1	1	1	1	1	1	1	1	1
243Am	1	1	1	1	1	1	1	1	1	1	1	1
242Cm	1	1	1	1	1	1	1	1	1	1	1	1
243Cm	1	1	1	1	1	1	1	1	1	1	1	1
244Cm	1	1	1	1	1	1	1	1	1	1	1	1
245Cm	1	1	1	1	1	1	1	1	1	1	1	1
246Cm	1	1	1	1	1	1	1	1	1	1	1	1
133I	1	1	1	1	1	1	1	1	1	1	1	1

Appendix 3-II.-. Concentration factors

	Algae	FC ($l.kg^{-1}$ fresh)
H	Tritium	1
C	Carbon	5,000
I	Iodine	10,000
Ru	Ruthenium	300
Sb	Antimony	20
Sr	Strontium	40
Cs	Caesium	50
Co	Cobalt	6,000
Tc	Technetium	30,000
Pu	Plutonium	4,000
Am	Americium	400
Cm	Curium	400
Mn	Manganese	5,000
Ag	Silver	5,000
Fe	Iron	20,000
Mo	Molybdenum	100
Ce	Cerium	5,000
Zn	Zinc	2,000
Zr	Zirconium	2,000
Cl	Chlorine	0.05
Ca	Calcium	6
Ni	Nickel	2,000
Eu	Europium	3,000
Se	Selenium	1,000
Np	Neptunium	50
Y	Yttrium	1,000
Nb	Niobium	3,000
Pa	Palladium	100
Cd	Cadmium	5,000
Sn	Tin	20,000
Te	Tellurium	10,000
Pm	Promethium	3,000
U	Uranium	100
Be	Beryllium	
Rb	Rubidium	
Sa	Samarium	3,000
Pr	Praseodymium	

	Fishes	**FC (l.kg^{-1} fresh)**
H	Tritium	1
C	Carbon	5,000
I	Iodine	15
Ru	Ruthenium	2
Sb	Antimony	20
Sr	Strontium	5
Cs	Caesium	400
Co	Cobalt	200
Tc	Technetium	80
Pu	Plutonium	100
Am	Americium	100
Cm	Curium	100
Mn	Manganese	1,000
Ag	Silver	4,000
Fe	Iron	1,000
Mo	Molybdenum	20
Ce	Cerium	100
Zn	Zinc	5,000
Zr	Zirconium	30
Cl	Chlorine	0.05
Ca	Calcium	2
Ni	Nickel	1,000
Eu	Europium	300
Se	Selenium	6,000
Np	Neptunium	10
Y	Yttrium	20
Nb	Niobium	30
Pa	Palladium	50
Cd	Cadmium	1,000
Sn	Tin	50,000
Te	Tellurium	1,000
Pm	Promethium	500
U	Uranium	1
Be	Beryllium	
Rb	Rubidium	
Sa	Samarium	500
Pr	Praseodymium	

	Crustaceans	FC ($l.kg^{-1}$ fresh)
H	Tritium	1
C	Carbon	5,000
I	Iodine	100
Ru	Ruthenium	300
Sb	Antimony	10
Sr	Strontium	5
Cs	Caesium	100
Co	Cobalt	5,000
Tc	Technetium	1,300
Pu	Plutonium	500
Am	Americium	1,000
Cm	Curium	1,000
Mn	Manganese	5,000
Ag	Silver	3,000
Fe	Iron	5,000
Mo	Molybdenum	100
Ce	Cerium	1,500
Zn	Zinc	4,000
Zr	Zirconium	500
Cl	Chlorine	0.05
Ca	Calcium	5
Ni	Nickel	1,000
Eu	Europium	1,000
Se	Selenium	5,000
Np	Neptunium	100
Y	Yttrium	1,000
Nb	Niobium	200
Pd	Palladium	10
Cd	Cadmium	10,000
Sn	Tin	50,000
Te	Tellurium	1,000
Pm	Promethium	1,000
U	Uranium	10
Be	Beryllium	
Rb	Rubidium	
Sm	Samarium	1,000
Pr	Praseodymium	

	Molluscs	FC ($l.kg^{-1}$ fresh)
H	Tritium	1
C	Carbon	5,000
I	Iodine	100
Ru	Ruthenium	600
Sb	Antimony	20
Sr	Strontium	10
Cs	Caesium	50
Co	Cobalt	2,000
Tc	Technetium	400
Pu	Plutonium	3,000
Am	Americium	1,000
Cm	Curium	1,000
Mn	Manganese	10,000
Ag	Silver	40,000
Fe	Iron	20,000
Mo	Molybdenum	100
Ce	Cerium	1,500
Zn	Zinc	80,000
Zr	Zirconium	1,000
Cl	Chlorine	0,05
Ca	Calcium	1
Ni	Nickel	2,000
Eu	Europium	7,000
Se	Selenium	6,000
Np	Neptunium	400
Y	Yttrium	1,000
Nb	Niobium	1,000
Pa	Palladium	500
Cd	Cadmium	20,000
Sn	Tin	50,000
Te	Tellurium	1,000
Pm	Promethium	5,000
U	Uranium	30
Be	Beryllium	
Rb	Rubidium	
Sa	Samarium	5,000
Pr	Praseodymium	

Appendix 3-III.-. Distribution coefficients

	Sediments	Kd (l.kg^{-1} dry)
H	Tritium	1
C	Carbon	2,000
I	Iodine	500
Ru	Ruthenium	5,000
Sb	Antimony	400
Sr	Strontium	30
Cs	Caesium	1,000
Co	Cobalt	40,000
Tc	Technetium	100
Pu	Plutonium	10,000
Am	Americium	30,000
Cm	Curium	20,000
Mn	Manganese	1,000
Ag	Silver	1,000
Fe	Iron	50,000
Mo	Molybdenum	
Ce	Cerium	20,000
Zn	Zinc	2,000
Zr	Zirconium	3,000
Cl	Chlorine	0.03
Ca	Calcium	500
Ni	Nickel	100,000
Eu	Europium	500,000
Se	Selenium	100,000
Np	Neptunium	1,000
Y	Yttrium	10,000,000
Nb	Niobium	500,000
Pa	Palladium	5,000,000
Cd	Cadmium	2,000
Sn	Tin	1,000
Te	Tellurium	1,000
Pm	Promethium	2,000,000
U	Uranium	1,000
Be	Beryllium	
Rb	Rubidium	
Sa	Samarium	2,000,000
Pr	Praseodymium	

APPLICATION OF BATS TO RADIOACTIVE LIQUID DISCHARGES AND TO ENVIRONMENTAL MONITORING OF FRENCH EDF NUCLEAR SITES

5.3. Implementation of BAT

5.4. Environmental management

6. Radiologic impact of marine and estuarine sites

6.1. Results of environmental monitoring

6.2. Human dose assessment

6.3. Biota dose assessment

EXECUTIVE SUMMARY

APPLICATION OF BATS TO RADIOACTIVE LIQUID DISCHARGES AND TO THE ENVIRONMENTAL MONITORING OF THE FRENCH EDF NUCLEAR SITES

Fifteen of the nineteen EDF NPPs in operation and four of the nine EDF reactors under decommissioning are concerned by an OSPAR area because of their authorized liquid radioactive discharges. All are part of the French EDF nuclear fleet distributed on 20 sites. The renewal of discharges permits of the French NPPs has continued over the last ten years and the French regulator still takes advantage of these renewals to lower the limits concerning radioactive liquid discharges. In addition, and in association with strict effluent management, EDF has continued to implement better operating practices that have allowed to lower radioactive discharges, dividing by a factor of more than one hundred the liquid activity discharges for all radionuclides over 30 years, with the exception of Tritium and Carbon-14. And even though the liquid radioactive discharges has reached an asymptote, the efforts are still kept constant to maintain this low level of discharges.

Concerning Tritium and Carbon-14, and given the large volumes of water to be processed and the corresponding low volumic activity, there is still no industrial method for trapping them. However, an active watch is carried out and the potentially interested methods are studied.

As for NPPs in operation, the discharges of effluents of NPPs under decommissioning have been reduced as far as reasonably possible and at an acceptable cost. It has to be noted that the contribution of NPPs under decommissioning to the amount of liquid radioactive discharges is negligible in accordance with strict discharges permits whose limits are regularly optimized, based on the implementation of BAT approach in association with operating experience.

For NPPs in operation and those under decommissioning, measurements in the effluents must comply with regulatory requirements. They must also be consistent with the ISO/IEC 17025 standard or equivalent (BAT). They are performed using procedures approved by the operator and the French ASN (cross-check analysis, inter laboratory tests, internal audits and inspections by the Authorities). Because the results of the controls are used to assess the impact of discharges on the environment and public health, the quality of the measurements is of major importance and no effluent likely to be radioactive can be discharged prior to controlling that all the regulatory requirements are met.

Radioactivity controls and measurements are also performed in the environment of the NPPs in operation or under decommissioning within the framework of their monitoring program and radioecological survey. They show very low levels of artificial radioactivity in the environment, which for a major part comes from other sources. Consequently and as mentioned above, the radiological impact of a site on the public or the environment cannot be assessed from those measurements. It is therefore calculated on the basis of the total amount of radioactivity discharged taking into account the transfer mechanisms from the environment to humans. It allows to assess the level of exposure which is attributable to the radioactive discharges from one site and to compare it to the regulatory limit of public exposure as defined in the article R1333-11 of the French Public Health Code. The annual effective dose calculation takes into account site specific data such as weather conditions or dilution conditions in the receiving water compartment. The calculated dose (e.g.: for all radioactive liquid and gaseous discharges) are below 0.01 millisievert per year (< 0.01 mSv/y). These values can be compared with the exposure limit set to 1 mSv/y for a member of the public by the article R1333-11 of the French Public Health Code. This dose is also well below natural fluctuations of radioactivity in France and is below the average natural exposure level of around 2.9 mSv/y.

1. Characteristics of French EDF nuclear sites in OSPAR areas

1.1. NPPs in operation and under decommissioning in OSPAR areas

Fifteen EDF NPPs are concerned by an OSPAR area (Cf. Table 1). They are part of the EDF French nuclear fleet distributed on 19 sites for 58 PWRs in operation (Cf. Figure 1):

There are 3 standardized plant series in operation in France, all are pressurized water reactors (PWR):

- 900 MW (3 loops) – 34 units ;
- 1300 MW (4 loops) – 20 units ;
- 1450 MW (N4, 4 loops) – 4 units.

Table 1 - EDF NPPs concerned by an OSPAR area.

Map reference	**NPP**	**Destination of discharges**	**Number and type of units**	**Installed capacity** (MWe)	**Date of first divergence**
F1	Belleville-sur-Loire	Loire	2 PWR	2600	1987
F2	Le Blayais	Gironde Estuary	4 PWR	3600	1981
F3	Cattenom	Moselle	4 PWR	5200	1986
F4	Chinon	Loire	4 PWR	3600	1982
F5	Chooz	Meuse	2 PWR	2900	1996
F6	Dampierre-en-Burly	Loire	4 PWR	3600	1980
F7	Fessenheim	Rhin	2 PWR	1800	1977
F8	Flamanville	English Channel	2 PWR	2600	1985
F9	Golfech	Garonne	2 PWR	2600	1990
F10	Gravelines	North Sea	6 PWR	5400	1980
F11	Nogent-sur-Seine	Seine	2 PWR	2600	1987
F12	Paluel	English Channel	4 PWR	5200	1984
F13	Penly	English	2 PWR	2600	1990

		Channel			
F14	Saint Laurent des Eaux	Loire	2 PWR	1800	1981
F15	Civaux	Vienne	2 PWR	2900	1997

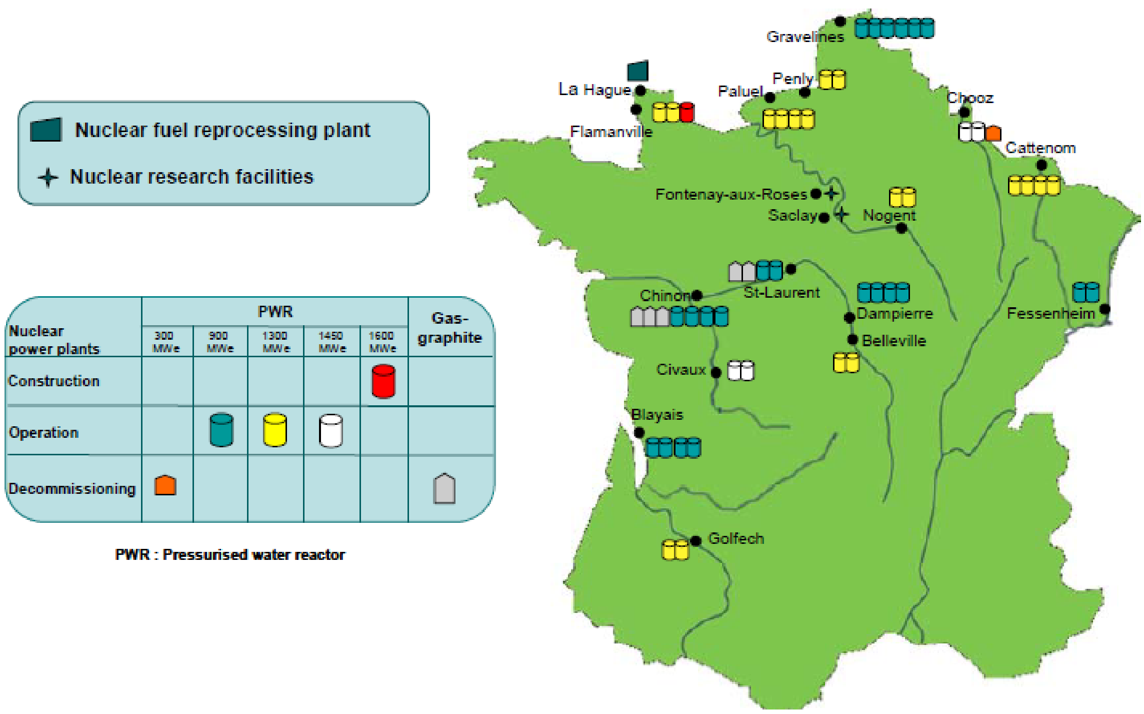

Figure 1 - EDF NPPs and other French facilities concerned by an OSPAR area.

As shown in figure 2, seven of the nine EDF reactors under decommissioning are potentially concerned by an OSPAR area:

- The Heavy Water Reactor (HWR) based in Brennilis along the Ellez River ;
- The three Natural Uranium “Graphite-Gaz” (UNGG) based in Chinon along the Loire River ;
- The two Natural Uranium “Graphite-Gaz” (UNGG) based in Saint-Laurent des Eaux along the Loire River ;
- The Pressurized Water Reactor (PWR) based in Chooz along the Meuse River.

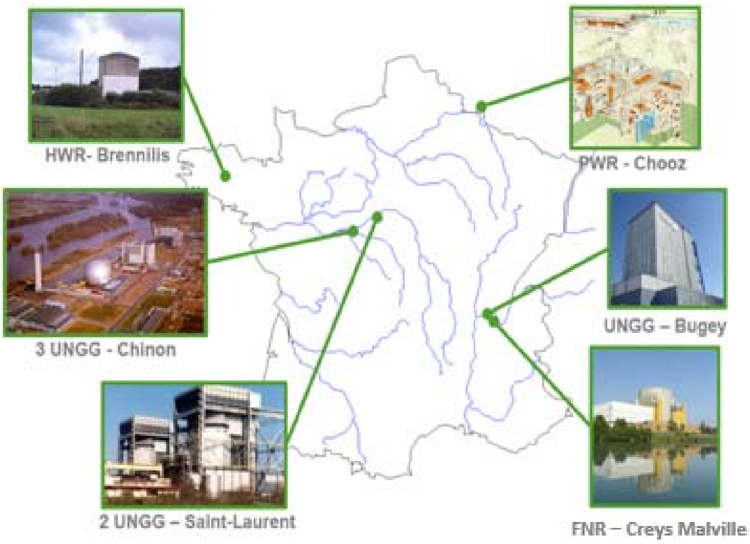

Figure 2 – Nuclear reactors under decommissioning.

But only the PWR in Chooz (called hereafter Chooz A or CHO A) and the three UNGGs reactors in Chinon (called hereafter Chinon A or CHI A) have permits for liquid discharges into the environment.

- CHO A have been in operation between 1967 and 1991 ;
- CHI A have been in operation between 1963 and 1990.

It has to be noted that the HWR based in Brennilis and the UNGGs based in Saint-Laurent des Eaux have no permits for liquid discharges into the environment.

1.2. ....Schedule for renewals of discharges permits for EDF NPPs

Table 2 - Schedule for renewals of discharges permits for EDF NPPs.

Administrative status	**NPP**	**Date of renewal of discharge permits**
Renewed	St-Laurent des Eaux	02/19/2015
Renewed	Flamanville with EPR	07/19/2018
In progress	Paluel	5/11/2000
In progress	Belleville	01/16/2014
Renewed	Chinon B	10/20/2015
In progress	Gravelines	11/07/2003
Renewed	Le Blayais	09/18/2003
Renewed	Cattenom	01/16/2014
Renewed	Nogent	12/29/2004
Renewed	Golfech	09/18/2006
Renewed	Penly	02/15/2008
In progress	Civaux	07/05/2011
Renewed	Chooz B[10]	11/17/2009
Renewed	Fessenheim	07/17/2018
In progress	Dampierre	05/06/2011

[10] *This renewal includes discharges due to the decommissioning of the CHOOZ A NPP.*

Chooz B NPP (2x1300 MW)

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1.3. ....Radioactive liquid discharges limits for EDF NPPs in operation

Table 3 - Annual limits (GBq/y) on radioactive liquid discharges for two 900-MWe units

Example of Saint Laurent-des-Eaux NPP.

PARAMÈTRES	LIMITES ANNUELLES (EN GBQ/AN)
Tritium	45 000
Carbone 14	130
Iodes	0,2
Autres produits de fission ou d'activation émetteurs bêta ou gamma	20

Arrêté du 19 mars 2015 portant homologation de la décision n° 2015-DC-0498 de l'Autorité de sûreté nucléaire du 19 février 2015 fixant les limites de rejets dans l'environnement des effluents liquides et gazeux des installations nucléaires de base n° 46, n° 74 et n° 100 exploitées par Electricité de France - Société Anonyme (EDF-SA) dans la commune de Saint-Laurent-Nouan (département de Loir-et-Cher).

Table 4 - Annual limits (GBq/y) on radioactive liquid discharges for two 1300-MWe units

Example of Belleville NPP.

PARAMÈTRES	LIMITE ANNUELLE (en GBq/an)
Tritium	60 000
Carbone 14	190
Iodes	0,1
Autres produits de fission ou d'activation émetteurs bêta ou gamma	10

Arrêté du 4 mars 2014 portant homologation de la décision n° 2014-DC-0414 de l'Autorité de sûreté nucléaire du 16 janvier 2014 fixant les limites de rejets dans l'environnement des effluents liquides et gazeux des installations nucléaires de base n° 127 et n° 128 exploitées par Electricité de France-Société Anonyme (EDF-SA) dans les communes de Belleville-sur-Loire et Sury-près-Léré (département du Cher).

Table 5 - Annual limits (GBq/y) on radioactive liquid discharges for two 1450-MWe units

Example of Civaux NPP.

Paramètres	Limites annuelles (GBq/an)
Tritium	Valeur maximale par an (1) (2) : 40 000*N1+ 45 000*N2 avec N1 : nombre de réacteurs avec une gestion du combustible autre que à haut taux de combustion. En particulier nombre de réacteurs avec une gestion standard N4 (combustible enrichi à 3,4 %) N2 : nombre de réacteurs avec une gestion du combustible à haut taux de combustion (du type ALCADE) N1 + N2 = 2
Carbone 14	190
Iodes	0,1
Autres produits de fission ou d'activation émetteurs bêta ou gamma	5

N1 & N2 correspond to two different possibilities of fuel management mode.

Arrêté du 2 août 2011 portant homologation de la décision n° 2011-DC-0233 du 5 juillet 2011 de l'Autorité de sûreté nucléaire fixant les limites de rejets dans l'environnement des effluents liquides et gazeux des installations nucléaires de base n° 158 et n° 159 exploitées par Electricité de France (EDF-SA) sur la commune de Civaux (département de la Vienne).

Civaux NPP (2x1450 MW)

1.4. .... Schedule of discharge permits for EDF NPPs under decommissioning

The current permits for radioactive liquid discharges of the three UNGGs of Chinon A have been promulgated in 2015. Previous permits where promulgated in 2005, with no specific limits for NPPs under decommissioning. The current permits cover the preliminary decommissioning operations. New permits are expected after 2020 to cover the reactors core decommissioning operations (one of the three UNGG) and safe enclosure configuration (other UNGGs).

The current permits for radioactive liquid discharges of the Chooz A PWR have been promulgated in 2009. The permits cover all steps of the decommissioning operations, including reactor core and spent fuel pool decommissioning.

1.5. .... Limits for radioactive liquid discharges for EDF NPPs under decommissioning

Limits for radioactive liquid discharges of Chinon A (e.g. Chinon A3D reactor) are given in table 6. They take into account atmospheric and industrial water gathered from the nuclear buildings during preliminary decommissioning operations.

Table 6 – Limits for radioactive liquid discharges of Chinon A.

Radionuclides	**Limit** (GBq/y)
Tritium (^{3}H)	0,93
Carbon-14 (^{14}C)	0,031
Others β and γ emitting radionuclides	0,86
α emitting radionuclides	none

Arrêté du 27 novembre 2015 portant homologation de la décision n° 2015-DC-0527 de l'Autorité de sûreté nucléaire du 20 octobre 2015 fixant les limites de rejet dans l'environnement des effluents des installations nucléaires de base n° 94, n° 99, n° 107, n° 132, n° 133, n° 153 et n° 161 exploitées par Electricité de France-Société anonyme (EDF-SA) dans la commune d'Avoine (département d'Indre-et-Loire).

Limits for radioactive liquid discharges of Chooz A are given in table 7. They take into account atmospheric and industrial water gathered from the “nuclear buildings” during all the decommissioning operations. Specific limits are defined for underwater decommissioning of the reactor core, and other for the monitoring of the effluents after the decommissioning operations of the core.

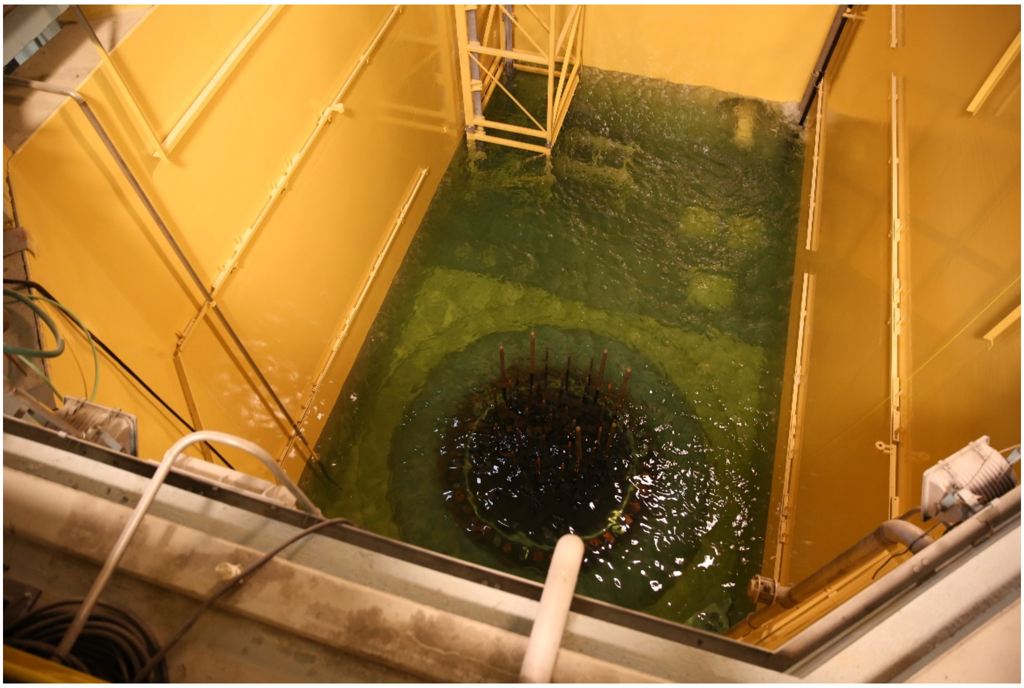
Table 7 - Limits for radioactive liquid discharges of Chooz A.

Radionuclides	**Limit** (GBq/y)	**Limit during core decommissioning** (GBq/y)	**Limit after core decommissioning** (GBq/y)
Tritium (^{3}H)	100	100	3
Carbon 14 (^{14}C)	10	80	none
Others β/γ emitting radionuclides	2	5	0,75
α emitting radionuclides	none	None	None

Arrêté du 30 novembre 2009 portant homologation de la décision n° 2009-DC-0165 de l'Autorité de sûreté nucléaire du 17 novembre 2009 fixant les limites de rejets dans l'environnement des effluents liquides et gazeux des installations nucléaires de base n° 139, n° 144 et n° 163 exploitées par Electricité de France (EDF-SA) sur la commune de Chooz (département des Ardennes).

Chooz A NPP under decommissioning

(©EDF-Cedric HELSLY)



Chooz A NPP reactor vessel decommissioning(

©EDF-Alexandre SIMONET)

2. Inventory of radioactive liquid discharges

2.1. Accounting rules

Accounting rules, based on radionuclide-by-radionuclide analysis rather than on global measurements, have been introduced and used on all EDF NPPs since 2002. These rules made not possible an underestimation of radioactive liquid discharges compared to the previous accounting system by taking into account the uncertainty of the measurement.

They primarily rely on the definition of a reference spectrum. For liquid discharges, this spectrum consists of a list of radionuclides that must be identified by appropriate measurement methods.

The reference spectrum includes the following radionuclides:

- Fission Products & Activation Products such Manganese-54, Cobalt-58 & Cobalt-60, Nickel-63, Silver-110m, Tellure-123 m, Antimony-124, Antimony-125, Cesium 134 & Cesium-137 ;
- Iodine-131 ;
- Tritium ;
- Carbon-14.

The second basic rule consists of a mandatory declaration of the activity discharged by the radionuclides belonging to the reference spectrum. Radionuclides whose measured activity is below the decision threshold of the analytical method are systematically recorded at an activity value equal to this decision threshold. Other radionuclides are taken into account only when their volumic activity is above the decision threshold.

The main objective is to take into account the uncertainty of the measurement to prevent from underestimating the volumic activity of the discharge.

It has to be noted that French NPPs in operation are not allowed to discharge artificial emitter radionuclides. Analyses are performed to strictly verify this regulatory requirement and the analytical performance set by the regulator.

2.2. Inventory of radioactive liquid discharges from NPPs in operation

The liquid activities released by radionuclides monitored for OSPAR are given in the tables below for the years 2012 to 2017. In liquid discharges, the presence of radioactivity is recognized by the measurement of an activity, which corresponds to the number of atomic nuclei transforming spontaneously per second. Resulting from a global or a specific measurement (e.g.: radionuclide by radionuclide), the activity is expressed in Becquerel (Bq). It is an extremely small physical unit, which does not quantify by itself the radiological impact on a person (e.g.: member of the public) nor to the environment. It also does not prejudge in any way the harmfulness of the radiations nor the radionuclide.

Total discharges of NPPs are usually expressed as multiples of Becquerel such as presented below:

The energy produced in a nuclear power reactor comes from the nuclear fission reaction. A wide variety of radionuclides is produced by nuclear fission but also by the activation of materials and substances subject to neutron flux within the facility. These radionuclides are discharged to the environment after checks and controls through liquid (and/or atmospheric) discharges.

Among these radionuclides, we can mention:

- <u>Carbon-14</u>: It is formed by reactions of neutrons on the nitrogen and the oxygen contained in the fuels and in some circuits in different chemical states (oxides, nitrates, etc) ;
- <u>Tritium</u>: It comes mainly from neutron capture by boron and lithium from the primary circuit. It is found mostly in liquid effluents in the form of tritiated water (HTO) ;

- Iodines: They are fission products managed with great attention because they are very volatile. They are accounted separately in accordance with the requirements of the regulations ;
- Fission products (PF) and activation products (AP): The FPs are radionuclides resulting from the fission of the nuclei of Uranium-235 and Plutonium-239 contained in the fuel placed in the reactor core in the fuel assemblies. The vast majority of FPs remain trapped in the fuel. However, the presence of traces of fissile materials on the fuel surface or in case of untightness of the fuel cladding lead to their presence in the effluents. Due to the efficiency of successive effluent treatments, a small proportion of FPs may be found in effluent discharges. APs are derived from the activation of structural materials and impurities contained in the water of the primary circuit.

Among radioactive liquid effluents, two categories can be distinguished:

- Hydrogenated liquid effluents that come from the primary coolant system. They contain dissolved fission gases (Xenon, Iodine, etc.), fission products (Cesium, Tritium, etc.), activation products (Cobalt, Manganese, Tritium, Carbon-14, etc.), but also chemical substances such as boric acid and lithium. These effluents are mainly produced in operating phase due to primary coolant management during power variations or chemical parameters adjustment of the reactor coolant.

- Auxiliary systems effluents also called "used effluents". Those effluents mainly come from maintenance operations which involve circuits draining (filters, demineralizers, exchangers…), spent fuel disposition operations, spent resins conditioning operations, facility cleaning operations (floor and cloth cleaning) and operations performed in the decontamination shops.

Radioactive liquid effluents from the primary circuit and auxiliary circuits are treated before being stored in control tanks prior to discharge. The radionuclides present in the liquid discharges are fission products such as iodine (Iodine-131, Iodine-132, Iodine-133 mainly), Cesium-137 & 134 and activation products such as Cobalt-58 & 60, Manganese 54, Silver-110m, Tellure-123m, Antimony 124 & 125… and of course Tritium and Carbon-14.

Since the commissioning of the nuclear fleet, EDF has endeavored to minimize radioactive discharges by acting on the three levers that are:

- The improvement of effluent collection and treatment circuits (modification of catch basins, installation of additional treatment means, etc) ;
- The introduction of strict effluent management aimed at reducing their production at the source.

Today, the FP-AP activity discharged annually is, on average for the entire fleet and per reactor, below 0.5 GBq/reactor/year. All the actions described above resulted in a significant reduction in the activity discharged (except for Tritium and Carbon-14) by liquid discharges. Thus, the activity discharged has been divided by more than a factor of 100 since 1985 (Cf. 3.1.1).

Tritium discharges, directly related to the quantity of energy produced, have not decreased as it has been demonstrated that, with the lack of effective treatment, discharges with liquid effluent is the best available technique. Tritium discharges are between 10 and 35 TBq per reactor per year (Cf. 3.1.1). It has to be noted that following the works led by the French ASN (Cf. 3.3.2 White paper committee to monitor the action plan), EDF funded a PhD thesis in order to get a better knowledge of Tritium species that may be found in the radioactive liquid discharges from NPPs in operation and to identify if the presence of Tritium linked to organic molecules is likely or not. The thesis led to develop a new method to separate the different organic compounds present in the effluents and to the measurement of Tritium by liquid scintillation. No tritiated organic compounds have been characterized in the liquid discharges, Tritium was found quite exclusively as tritiated water (HTO).

Carbon-14 discharges are between 10 to 20 GBq per reactor per year (Cf. 3.1.1).

In terms of radioactivity discharged, the differences between the three types of reactors (900, 1300 and 1450 MWe) are small, except, as shown above, for the Tritium discharges that depend directly on the way boric acid is managed in the reactor and the amount of energy produced. The distributions of AP-FP in liquid discharges are variable according to reactor generations, but mainly vary as a function of the maintenance work carried out during the year. Control and optimization of radioactive effluents discharges aim at limiting their impact on both the environment and the neighboring populations. Radioactivity controls and measurements are performed in the environment of the sites within the framework of their monitoring program and radioecological survey. They show very low levels of artificial radioactivity in the environment, which for a major part comes from other sources, as detailed in another chapter of this document. Consequently, the radiological impact of a site on the public cannot be assessed from these measurements. It is calculated on the basis of the effective radioactive effluents discharges of the site, which are regulated and controlled. Those assessments are performed each year for each site and are included in the annual environment monitoring report of each site. Effective dose is derived from the activities discharged for all radionuclides, taking into account the transfer mechanisms from the environment to humans. It allows to assess the level of exposure which is due to the radioactive discharges from one site and to compare it to the regulatory limit of public exposure as defined in the article R1333-11 of the French Public Health Code. The annual effective dose calculation takes into account site specific data such as weather conditions or dilution conditions in the receiving water compartment.

The calculated dose (e.g.: for all radioactive liquid & atmospheric discharges) **are below 0.01 mSv/y. These values can be compared to the exposure limit set to 1 mSv/y for a member of the public by the article R1333-11 of the French Public Health Code. This dose is also well below natural fluctuations of radioactivity in France (a few mSv/y) and is below the average natural exposure level of around 2.9 mSv/y** (Cf. Figure 3)**.**

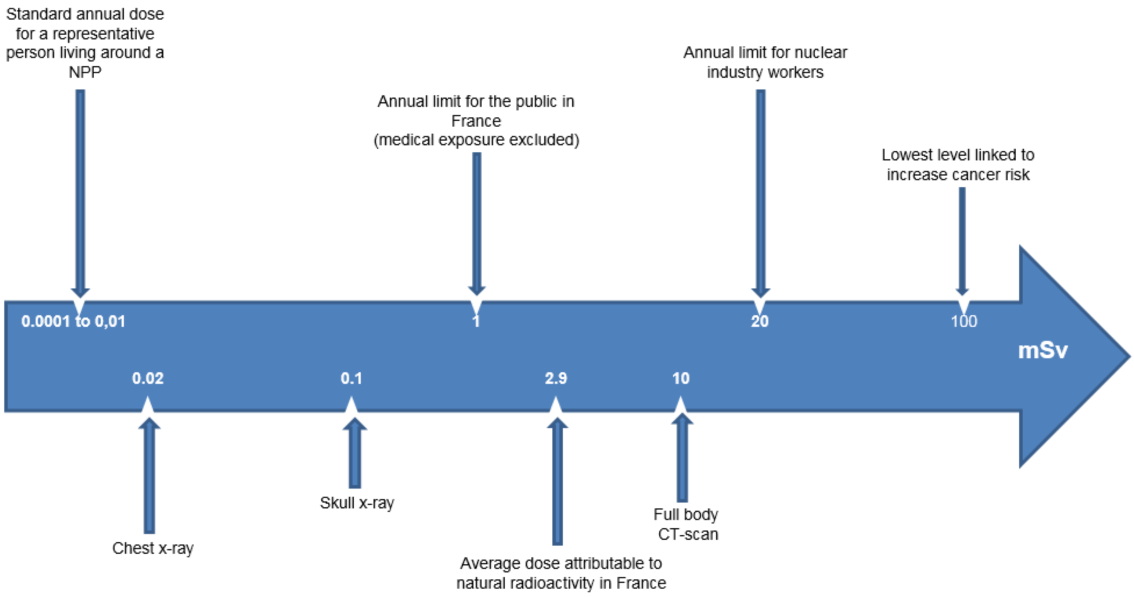


Figure 3 - Order of magnitude of human doses.

Control room - Penly NPP (2x1300 MW)

(©EDF- Marc CARAVEO)

Belleville NPP (2 x 1300 MW)

(©EDF- Pierre MERAT)

Inventory of radioactive liquid discharges from NPPs in operation

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	**3H**	**58Co**	**60Co**	**110mAg**	**125Sb**	**134Cs**	**137Cs**	**GBq**	**GBq**
Belleville sur Loire	2012	6,0E+04	1,1E-01	2,2E-02	1,0E-02	3,1E-02	2,8E-02	3,2E-02	2,7E-01	34,7
	2013	5,9E+04	1,2E-01	8,4E-02	3,5E-02	4,8E-02	3,1E-02	4,1E-02	4,3E-01	28,8
	2014	5,5E+04	1,2E-01	4,5E-02	1,9E-02	4,6E-02	1,5E-02	2,1E-02	3,3E-01	31,9
	2015	5,9E+04	2,1E-01	3,9E-02	1,6E-02	3,8E-02	1,4E-02	1,5E-02	3,8E-01	35,1
	2016	5,5E+04	2,8E-01	7,5E-02	1,7E-02	4,5E-02	1,6E-02	1,8E-02	5,1E-01	29,7
	2017	4,1E+04	9,9E-02	4,1E-02	1,4E-02	3,7E-02	1,3E-02	1,7E-02	2,7E-01	14,2
Le Blayais	2012	3,9E+04	2,6E-01	2,2E-01	2,2E-01	6,8E-02	1,6E-02	3,9E-02	9,1E-01	43,1
	2013	4,5E+04	1,7E-01	9,1E-02	1,6E-01	3,4E-02	1,4E-02	1,7E-02	5,4E-01	42,6
	2014	5,0E+04	1,4E-01	8,0E-02	1,5E-01	4,3E-02	1,5E-02	1,7E-02	5,1E-01	41,3
	2015	3,1E+04	2,1E-01	6,2E-02	2,2E-01	3,9E-02	1,8E-02	1,9E-02	6,3E-01	35,6
	2016	4,3E+04	8,0E-02	4,5E-02	4,5E-02	3,6E-02	1,2E-02	1,4E-02	2,9E-01	43,5
	2017	5,1E+04	1,2E-01	1,1E-01	5,2E-02	3,6E-02	1,2E-02	1,6E-02	4,1E-01	46,1

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	Year	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Cattenom	2012	1,2E+05	2,1E-01	5,2E-01	7,8E-02	7,0E-02	2,6E-02	4,7E-02	1,1E+00	54,6
	2013	1,1E+05	1,4E-01	4,8E-01	8,9E-02	6,2E-02	2,1E-02	3,8E-02	9,5E-01	54,2
	2014	1,1E+05	1,6E-01	2,3E-01	8,4E-02	6,2E-02	2,2E-02	3,1E-02	7,0E-01	64,8
	2015	8,9E+04	1,5E-01	3,4E-01	1,0E-01	6,1E-02	2,2E-02	5,6E-02	8,4E-01	65,2
	2016	1,2E+05	1,2E-01	1,9E-01	3,0E-02	6,7E-02	2,4E-02	3,6E-02	5,8E-01	57,1
	2017	9,7E+04	1,3E-01	1,4E-01	7,7E-02	6,1E-02	2,2E-02	4,3E-02	5,8E-01	33,0
Chinon	2012	5,7E+04	6,3E-02	1,1E-01	1,1E-01	5,5E-02	1,1E-02	1,3E-02	4,2E-01	48,1
	2013	4,5E+04	2,3E-01	1,3E-01	7,6E-02	4,3E-02	1,5E-02	1,9E-02	5,8E-01	38,3
	2014	4,0E+04	7,8E-01	4,4E-01	2,9E-01	6,0E-02	1,5E-02	2,2E-02	1,7E+00	45,2
	2015	5,2E+04	1,3E-01	2,6E-01	1,5E-01	3,4E-02	1,2E-02	1,4E-02	6,6E-01	43,2
	2016	4,4E+04	5,7E-02	2,4E-01	8,5E-02	4,0E-02	1,4E-02	1,9E-02	5,1E-01	41,9
	2017	5,0E+04	4,2E-02	1,2E-01	3,5E-02	3,6E-02	3,4E-02	6,3E-02	3,8E-01	18,8

* *To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Chooz	2012	5,5E+04	1,2E-01	1,2E-01	2,2E-02	2,2E-02	9,0E-03	1,6E-02	5,6E-01	32,5
	2013	6,4E+04	7,2E-02	5,9E-02	5,5E-02	2,6E-02	1,3E-02	1,5E-02	3,0E-01	36,7
	2014	7,0E+04	7,0E-02	2,8E-01	5,2E-02	2,4E-02	2,2E-02	2,5E-02	5,6E-01	37,9
	2015	6,0E+04	3,9E-02	9,8E-02	4,7E-02	2,4E-02	1,1E-02	2,0E-02	2,8E-01	37,0
	2016	6,6E+04	3,2E-02	1,3E-01	3,7E-02	2,7E-02	9,0E-03	1,2E-02	2,9E-01	39,8
	2017	3,7E+04	9,3E-02	4,2E-01	8,3E-02	2,5E-02	8,9E-03	1,2E-02	7,7E-01	26,6
Civaux	2012	6,7E+04	1,7E-02	1,0E-01	6,0E-02	1,4E-02	5,0E-03	6,0E-03	3,1E-01	28,9
	2013	5,3E+04	4,0E-03	5,2E-02	2,1E-02	1,2E-02	7,0E-03	9,0E-03	1,4E-01	32,5
	2014	3,7E+04	2,0E-02	5,1E-01	4,0E-02	1,1E-02	9,6E-03	2,2E-02	8,5E-01	35,0
	2015	4,6E+04	6,8E-03	1,0E-01	3,2E-02	1,3E-02	1,0E-02	1,1E-02	2,1E-01	36,7
	2016	7,0E+04	1,0E-02	1,0E-01	4,9E-02	2,0E-02	1,8E-02	2,4E-02	2,6E-01	32,3
	2017	5,1E+04	4,4E-03	4,1E-02	1,5E-02	6,5E-03	3,2E-02	3,9E-02	1,6E-01	18,7

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Dampierre en Burly	2012	4,3E+04	2,9E-01	2,3E-01	6,7E-02	4,1E-02	1,6E-02	2,4E-02	7,4E-01	41,6
	2013	5,0E+04	1,2E-01	2,7E-01	8,4E-02	4,9E-02	2,3E-02	3,8E-02	7,3E-01	42,1
	2014	4,1E+04	2,0E-01	8,3E-01	2,3E-01	5,8E-02	3,3E-02	6,7E-02	1,6E+00	41,8
	2015	5,6E+04	9,3E-01	9,1E-01	2,9E-01	4,7E-02	1,6E-02	2,4E-02	2,6E+00	46,0
	2016	4,6E+04	2,3E-01	3,7E-01	1,1E-01	4,3E-02	1,5E-02	1,9E-02	9,2E-01	43,5
	2017	4,8E+04	1,3E-01	2,4E-01	8,3E-02	4,4E-02	1,4E-02	1,8E-02	6,5E-01	43,9
Fessenheim	2012	3,1E+04	3,2E-02	3,8E-02	9,3E-02	2,5E-02	4,0E-03	5,0E-03	2,4E-01	22,1
	2013	1,4E+04	1,2E-01	3,1E-02	8,2E-02	2,0E-02	5,0E-03	6,0E-03	3,3E-01	16,5
	2014	2,9E+04	4,9E-02	2,4E-02	1,8E-01	2,3E-02	4,3E-03	5,3E-03	3,6E-01	21,7
	2015	3,0E+04	7,8E-02	6,0E-02	1,6E-01	2,6E-02	4,7E-03	1,2E-02	4,3E-01	22,8
	2016	1,7E+04	2,5E-02	3,9E-02	1,5E-01	2,2E-02	4,0E-03	6,0E-03	3,6E-01	14,9
	2017	1,1E+04	2,9E-03	2,1E-02	6,7E-02	2,0E-02	2,2E-03	2,8E-03	2,1E-01	4,0

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Flamanville	2012	5,9E+04	1,1E-01	9,3E-02	1,8E-02	7,3E-02	1,8E-02	2,1E-02	4,1E-01	30,6
	2013	4,9E+04	2,6E-01	1,2E-01	1,4E-02	3,2E-02	1,0E-02	1,1E-02	5,1E-01	32,1
	2014	5,2E+04	2,9E-01	1,3E-01	1,2E-02	1,8E-02	5,2E-03	5,5E-03	5,0E-01	32,8
	2015	3,9E+04	1,2E-01	1,3E-01	5,5E-03	1,2E-02	3,9E-03	4,4E-03	3,0E-01	28,9
	2016	6,3E+04	8,1E-02	1,0E-01	1,0E-02	1,9E-02	5,0E-03	6,0E-03	2,6E-01	35,4
	2017	5,0E+04	1,2E-01	1,3E-01	1,5E-02	2,2E-02	5,8E-03	6,6E-03	3,2E-01	24,5
Golfech	2012	4,9E+04	1,0E-01	4,5E-02	8,0E-03	2,4E-02	7,0E-03	1,0E-02	2,4E-01	28,2
	2013	6,9E+04	3,0E-02	2,1E-02	9,0E-03	2,6E-02	8,0E-03	1,0E-02	1,4E-01	34,1
	2014	4,8E+04	7,1E-02	5,0E-02	9,8E-03	2,4E-02	8,0E-03	9,3E-03	2,4E-01	26,8
	2015	6,4E+04	2,5E-02	4,0E-02	9,0E-03	2,7E-02	8,7E-03	1,1E-02	1,7E-01	33,4
	2016	6,4E+04	4,7E-02	3,3E-02	1,0E-02	4,5E-02	9,0E-03	1,4E-02	2,2E-01	35,4
	2017	4,0E+04	6,9E-02	6,3E-02	1,3E-02	3,3E-02	1,2E-02	1,5E-02	2,8E-01	20,9

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Gravelines	2012	5,7E+04	3,1E-01	1,1E+00	6,1E-01	8,7E-02	3,7E-02	6,5E-02	2,4E+00	57,2
	2013	6,1E+04	7,1E-01	2,1E+00	8,9E-01	2,0E-01	5,1E-02	9,0E-02	4,6E+00	63,0
	2014	6,9E+04	5,5E-01	1,3E+00	3,2E-01	1,6E-01	6,4E-02	8,1E-02	2,7E+00	62,2
	2015	7,8E+04	1,8E-01	7,0E-01	4,4E-01	1,1E-01	8,4E-02	1,0E-01	1,9E+00	67,3
	2016	5,9E+04	1,2E-01	1,0E+00	5,2E-01	1,8E-01	5,0E-02	6,9E-02	2,2E+00	56,1
	2017	5,9E+04	2,0E-01	1,1E+00	3,0E-01	1,0E-01	2,7E-02	4,1E-02	2,0E+00	31,2
Nogent Sur Seine	2012	3,8E+04	1,8E-01	1,5E-01	4,3E-02	4,4E-02	1,5E-02	1,9E-02	5,8E-01	29,1
	2013	5,9E+04	1,4E-01	1,3E-01	7,2E-02	4,7E-02	1,6E-02	2,0E-02	5,3E-01	33,3
	2014	5,0E+04	4,7E-02	1,0E-01	1,5E-02	4,1E-02	1,5E-02	3,4E-02	3,1E-01	29,8
	2015	4,2E+04	6,2E-02	3,7E-02	1,4E-02	3,8E-02	1,4E-02	1,7E-02	2,4E-01	28,2
	2016	7,3E+04	3,0E-02	2,3E-02	3,4E-02	4,2E-02	1,5E-02	1,9E-02	2,2E-01	36,6
	2017	5,5E+04	3,4E-02	7,2E-02	1,7E-02	3,7E-02	1,6E-02	1,8E-02	2,5E-01	39,3

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	Year	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Paluel	2012	9,6E+04	2,3E-01	2,5E-01	4,3E-02	4,2E-02	1,7E-02	3,1E-02	7,3E-01	60,7
	2013	1,0E+05	4,4E-01	3,4E-01	2,5E-02	1,7E-01	1,3E-02	3,7E-02	1,1E+00	62,1
	2014	1,1E+05	2,5E-01	1,8E-01	2,4E-02	3,0E-02	1,1E-02	1,6E-02	6,0E-01	68,1
	2015	9,0E+04	2,8E-01	2,5E-01	2,4E-02	3,0E-02	1,1E-02	1,4E-02	6,9E-01	54,3
	2016	5,3E+04	2,8E-01	5,2E-01	1,5E-02	6,2E-02	1,2E-02	1,0E-01	1,1E+00	34,8
	2017	5,6E+04	1,6E-01	6,0E-01	2,0E-02	5,4E-02	1,1E-02	1,0E-01	1,0E+00	24,5
Penly	2012	7,0E+04	1,9E-01	2,2E-01	1,1E-02	1,9E-02	7,0E-03	8,0E-03	5,2E-01	31,4
	2013	5,9E+04	1,5E-01	4,0E-01	2,6E-02	1,1E-01	8,0E-03	3,0E-02	7,8E-01	34,3
	2014	4,5E+04	2,1E-01	1,0E-01	7,8E-03	3,0E-02	9,2E-03	1,8E-02	4,4E-01	27,7
	2015	7,0E+04	3,3E-02	4,0E-02	7,5E-03	1,9E-02	6,1E-03	8,5E-03	1,9E-01	34,5
	2016	5,0E+04	8,3E-02	5,1E-02	8,0E-03	1,7E-02	6,0E-03	8,0E-03	2,8E-01	32,3
	2017	5,8E+04	4,7E-02	1,2E-01	2,4E-02	1,7E-02	6,3E-03	8,3E-03	2,9E-01	50,2

** To be consistent with values reported to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

Radioactive Liquid discharges		Radioactivity discharged (GBq)							Other radionuclides	Carbon-14*
NPP	**Year**	3H	58Co	60Co	110mAg	125Sb	134Cs	137Cs	GBq	GBq
Saint Laurent des Eaux	2012	2,3E+04	1,1E-02	3,7E-02	3,0E-02	1,7E-02	6,0E-03	8,0E-03	1,3E-01	23,5
	2013	1,5E+04	1,3E-02	4,3E-02	9,0E-03	1,8E-02	2,0E-02	9,0E-03	1,4E-01	14,7
	2014	2,6E+04	7,9E-03	1,9E-01	6,2E-02	1,7E-02	6,4E-03	8,8E-03	3,3E-01	22,0
	2015	2,3E+04	3,9E-02	1,8E-01	1,5E-01	2,1E-02	1,1E-02	1,5E-02	4,6E-01	19,1
	2016	2,4E+04	2,8E-02	1,0E-01	1,3E-01	2,0E-02	7,0E-03	8,0E-03	3,4E-01	21,9
	2017	2,7E+04	2,0E-02	8,5E-02	6,9E-02	2,0E-02	7,2E-03	8,9E-03	2,4E-01	4,6

* *To be consistent with values transmitted to OSPAR, Carbon-14 liquid discharges data are calculated values until 2016 and measured values since 2017.*

2.3. Inventory of radioactive liquid discharges for NPP under decommissioning

a) Chooz A NPP

Inventory of radioactive liquid discharges are given in figure 4 below. Annual radioactive activities of discharges are proportional to the volume. Highest activities were obtained between 2008 and 2013 while main coolant system components (hot legs, cold legs, steam generators) were dismantled. Highest as usual Carbon-14 activities were declared in 2016: after analysis, an error for a couple of samples was attributed to the laboratory, meaning that the activities declared are not representative. Despite this, Carbon-14 activity in 2016 remained below the permits.

All activities discharged strictly respect and are in accordance with the discharges permit that is specific to each facility.

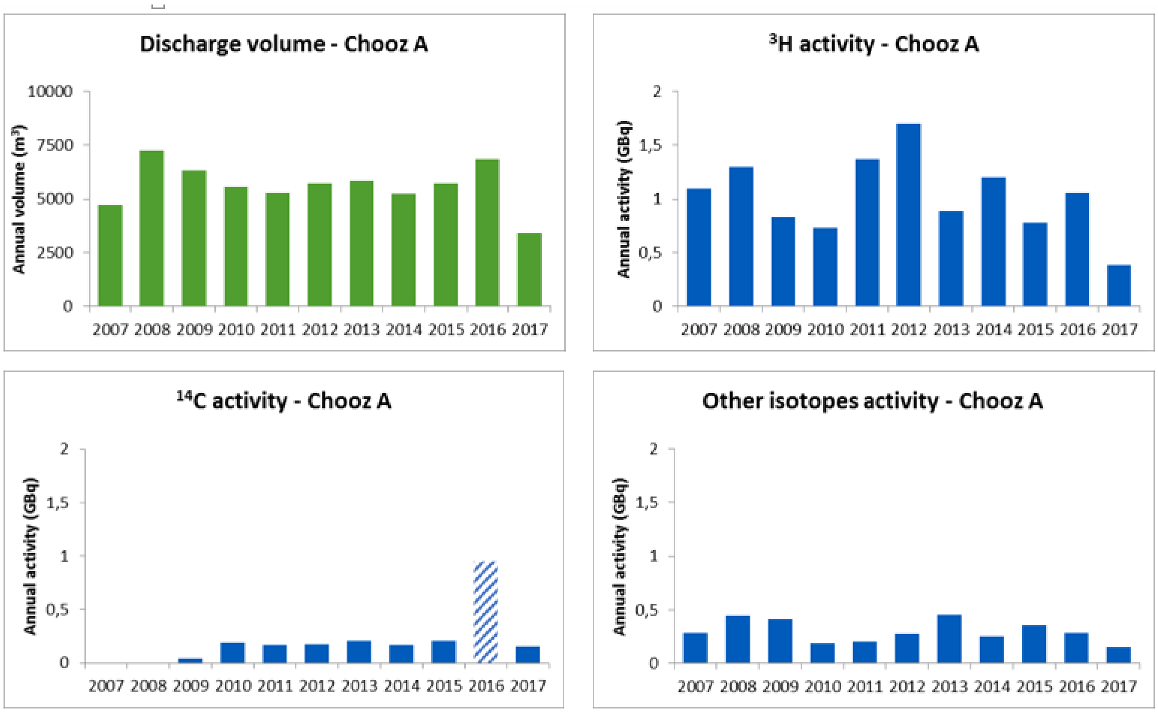


Figure 4 – Inventory of radioactive liquid discharges for Chooz A.

b) Chinon A NPP

Inventory of radioactive liquid discharges are given in figure 5 below. Activities of radioactive discharges are declared since 2012 for Chinon A. All effluents from year 2017 were discharged at the beginning of 2018, therefore there is no volume nor activities declared in 2017. Carbon-14 measurements were declared in 2016 for the first time (after new permits from 2015). Annual radioactive discharges are proportional to the volume. The source of effluent being mainly atmospheric water, volumes and activities are not correlated with decommissioning operations but with pluviometry. Comparing to NPPs in operation, volumes and activities are negligible.

All activities discharged strictly respect and are in accordance with the discharges permit that is specific to each facility.

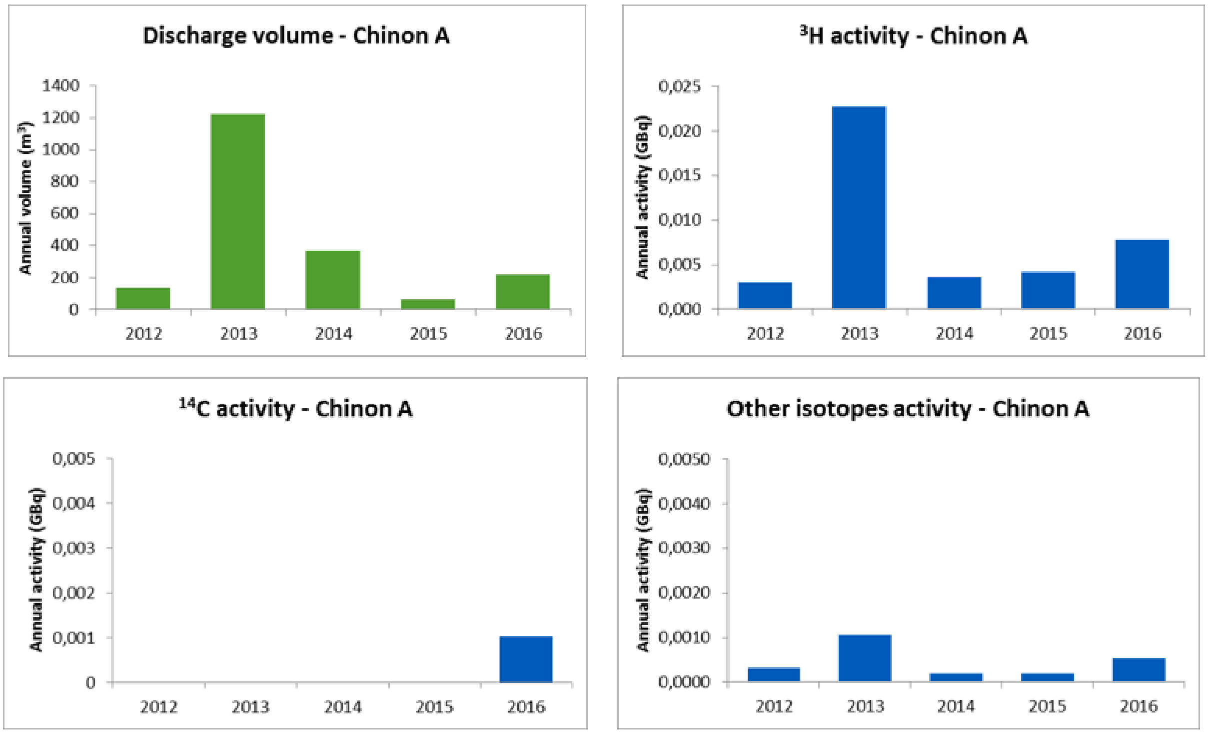


Figure 5 – Inventory of radioactive liquid discharges for Chinon A.

2.4. Quality Assurance/Deviation Management (significant events)

The monitoring of environment-related events within EDF is ensured by a two-level process:

- Local (by the NPP itself) ;
- National (by a special network). This network investigates events that are deemed to be major issues, occurring in French and foreign NPPs.

Depending on their level of importance, these events are the subject of appropriate management either at the national (generic aspect) or local level. Each event is immediately declared to the Regulator. If the event is considered to be significant, a report is prepared and sent to the French Nuclear Safety Authority. Since 2000, no event taking place in a French NPP has led to a significant increase in liquid discharges.

Chinon NPP – Control and Surveillance of the facility

(©EDF- Cyrus CORNUT)

3. Optimization of radioactive liquid discharges on EDF sites

3.1. ....Optimization of radioactive liquid discharges from NPPs in operation

3.1.1. Radioactive liquid effluents management and global performance

The overall regulation of Basic Nuclear Installations (BNI) is based among other things on the so-called optimization principle.

This principle has been integrated in the design of the systems as well as in the operating procedures of all EDF NPPs in operation in order to "reduce as far as reasonably possible and at an acceptable cost" the discharges of effluents.

With this goal in mind, since the commissioning of the first NPPs, EDF have implemented the best operating modes, treatment processes and liquid discharges procedures at an acceptable cost to get to an optimized management of the discharges. These constant efforts to keep radioactive liquid discharges at a minimum level are based on:

- Reducing the generation of liquid wastes from their various sources ;
- Improving the selective collection of the different effluents, their treatment methods and in some cases their recycling while maintaining an adequate proportion between liquid discharges and solid wastes ;
- Monitoring, in order to verify the efficiency of effluent-processing systems and operating practices.

Radioactive liquid discharges (^{3}H and ^{14}C excluded)

Over the last thirty years, the radioactive liquid discharges (Tritium and Carbon-14 excluded) have been reduced by a factor of 100 (Cf. Figure 6).

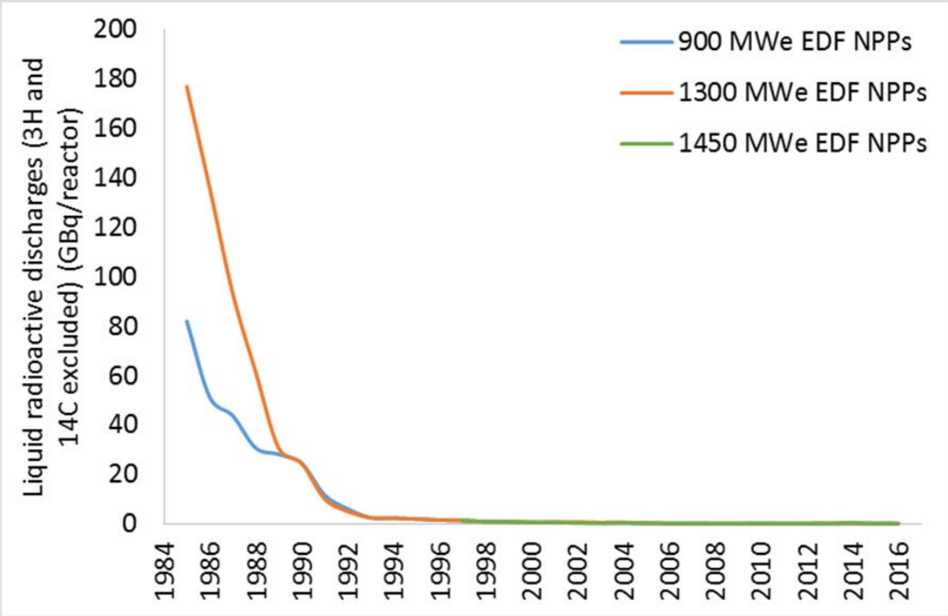


Figure 6 – Radioactive liquid discharges from French NPPs in operation

Since 2005, the discharged activity has reached a very low level, below 0.5 GBq/reactor/year. These results could be obtained thanks to the improvements performed on the collecting and treatment systems as well as to the efforts made to reduce the generation of effluents and wastes at their sources:

- In the years 1980's, improving the equipment led to a significant reduction in the radioactive liquid discharges (e.g. improvement in the fuel cladding) ;
- From the years 1990's, the decrease in liquid radioactive discharges is essentially due to a more systematic treatment of the effluents before release ;
- From the beginning of the 2000's, an asymptotic level in the liquid radioactive discharges is reached thanks to the incentive goals/objectives and indicators set in the NPPs management system.

It is worth noting that the decrease in the radioactive liquid discharges did not lead to an increase in the solid wastes (filters, ion exchange resins, concentrates from evaporation). The volume of solid wastes has also decreased thanks to the reduction in the effluents generation at their sources.

Even though the liquid radioactive discharges has reached an asymptote, the efforts are still kept constant to maintain this low level of discharges, especially by:

- Tracking systems and procedures failures or deviations ;
- Identifying and implementing new good practices ;
- Improving the discharges and wastes management in the under-performing plants.

In this context, EDF NPPs are helped by national engineering entities which analyze the OPEX data and highlight good practices through OPEX sharing meetings, QRs and answers to FAQs, specific advices to help operators solving technical, environmental or regulatory issues.

Good practices guide-books are also edited and regularly updated to help operators improving the management of their discharges and wastes.

Gravelines NPP (6 x 900 MW)

Tritium

Tritium is generated mainly from the activation of Boron-10 and Lithium-6 in the reactor cooling system. Moreover, the French 1300 and 1450 MWe series are equipped with secondary neutron source assemblies producing Tritium during exposition to the neutron flux. Hence, Tritium is present as tritiated water in the liquid effluents. Due to its very low volumic activity, Tritium cannot be industrially removed from liquid effluents and thanks to its low radiotoxicity, Tritium is discharged to the environment and mainly in the aquatic compartment in order to have a smaller dosimetric impact.

The discharges are between 10 and 35 TBq/year/reactor, depending on power output, fuel management and the presence or not of secondary neutron source assemblies (Cf. Figure 7).

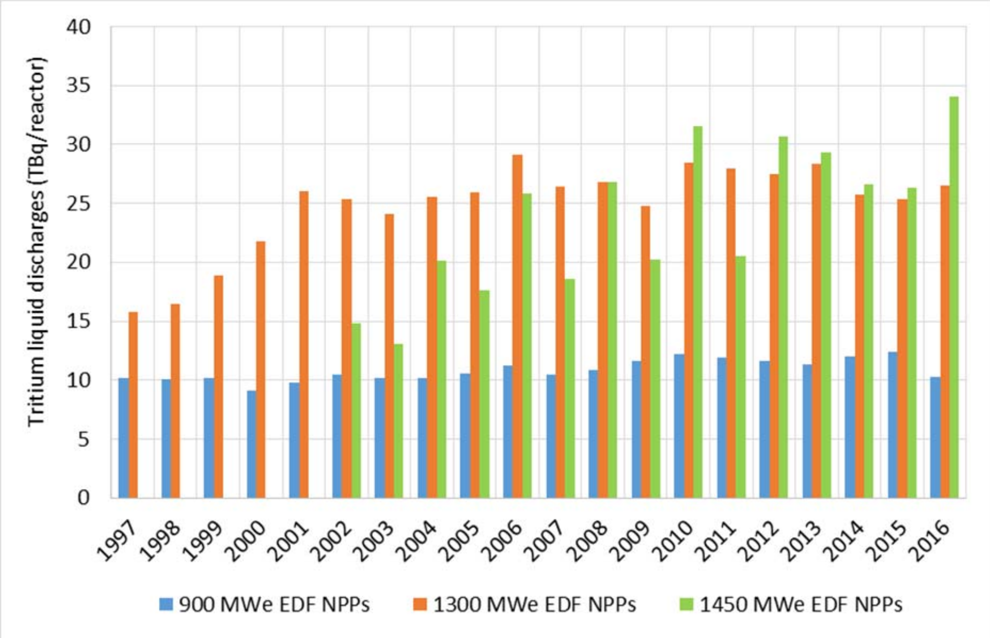


Figure 7 – Tritium liquid discharges from French NPPs.

CI-LWDS [SEK] tanks – Le Blayais NPP (4 x 900 MW)

Carbon-14

Carbon-14 generation is directly driven by power output and is essentially due to the activation of Oxygen-17 from the cooling water, although its isotopic abundance is quite low (0.04%). This is due to the fact that the primary circuit contains between 200 and 400 tons of water depending on the reactor power. As for Tritium, there is no suitable industrial removal technique for Carbon-14 that can be applied in PWRs.

About 5% of the total amount of the carbon-14 produced is discharged to the environment through liquid discharges corresponding to an activity between 10 and 20 GBq/year/reactor (Cf. Figure 8).

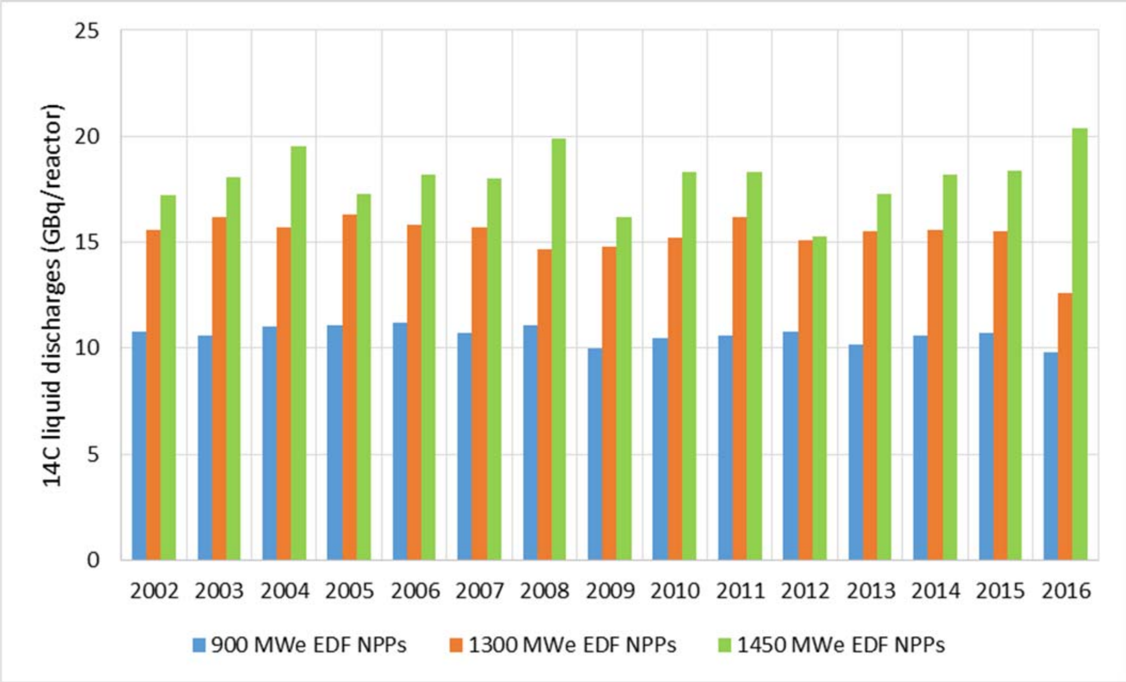


Figure 8 – Carbon-14 liquid discharges from all French NPPs.

Paluel NPP (4 x 1300 MW) – "Hot" Effluent laboratory

(©EDF-Sophie BRANDSTROM)

<u>Iodine</u>

Iodine discharges are very low, less than 0.01 GBq/year/reactor for the last 10 years (Cf. Figure 9). The reasons for these very low levels of discharges are the following:

- Iodines are contained inside the fuel rods. In case of fuel cladding untightness, they can reach the reactor cooling water. However, the radioactivity of the reactor cooling water and especially its iodine activity is limited, based on radiochemical technical specifications, and strictly monitored. Moreover, the reactor cooling water passes through the Chemical and Volumetric Control System (CVCS) [RCV] to be continuously purified and have its activity kept as low as possible ;
- Iodines in the reactor cooling system are trapped in the liquid effluent/wastes treatment process ;
- Iodines have short half-lives (8 days for iodine-131 & 21 hours for iodine-133) - they rapidly decay.

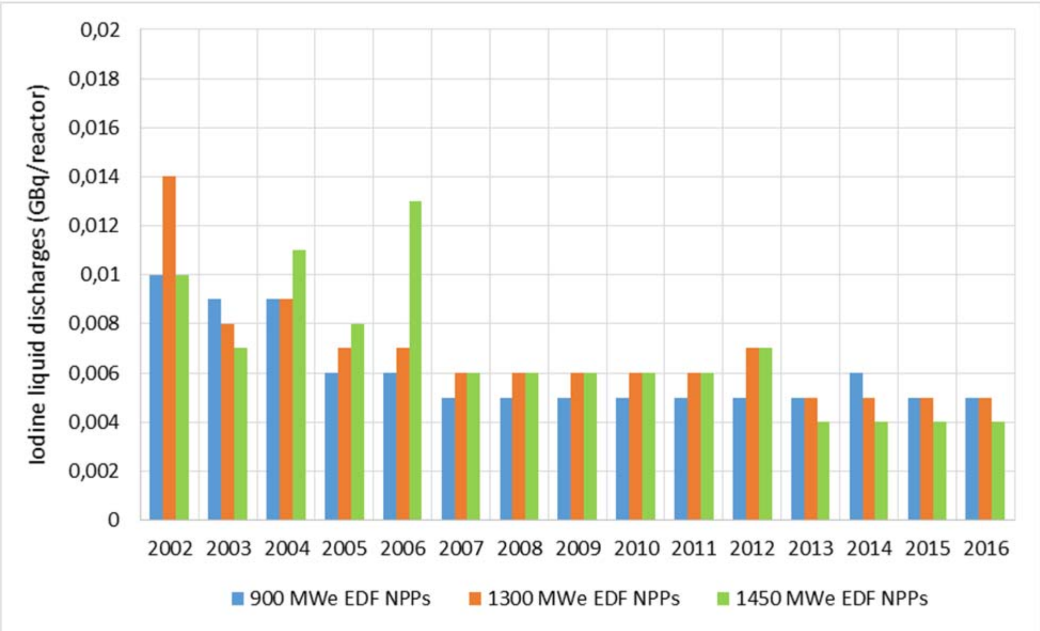


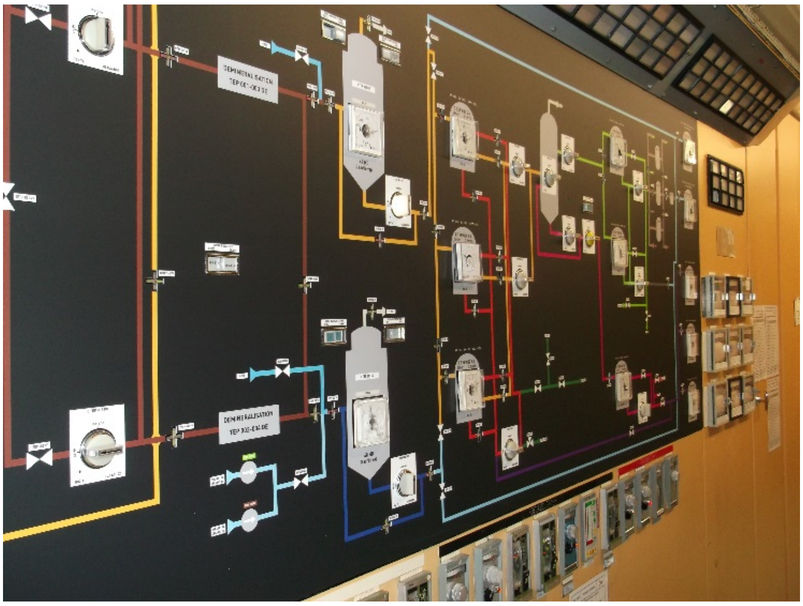
Figure 9 – Iodine liquid discharges from French NPPs.

3.1.2. Radioactive liquid effluents treatment system description

Radioactive liquid effluents are collected depending on their sources. Then, based on their activity and chemical concentration, they pass through the appropriate systems and undergo different treatment methods to remove most of the radioactivity they contain (Figure 10):

- Liquid effluent/wastes coming from the reactor cooling system, also called hydrogenated liquid effluents, contain fission gases (e.g. Xenon, Iodine and Cesium), activated products (e.g. Cobalt, Manganese, Silver, Tellurium, Antimony and of course Tritium and Carbon-14) and chemical compounds (e.g. boric acid, lithium, dissolved hydrogen or nitrogen). They are generated essentially during operation. They are sent to the Boron Recycle System (BRS) [TEP] which is composed of:
    - o Collecting tanks upstream the treatment process. These tanks are kept under a nitrogen blanket because of hydrogen degassing from primary system water, in order to avoid any hydrogen/oxygen explosion risk that would exist in the presence of oxygen ;
    - o Filtration and demineralization equipment to get effluents free of radioactive compounds (Tritium excepted) and of chemical compounds (boric acid excepted) ;

- o A degasser to extract the dissolved gases (i.e. radioactive noble gases, hydrogen, nitrogen) and send them to the gaseous effluents/wastes treatment system ;
- o An evaporator to separate the distillate of the treated effluents from the concentrate. The distillate consists of low activity water that can either be sent to storage tanks before discharge or recycled; the concentrate contains boron which is usually recycled to the reactor cooling system.



Control room of the Boron Recycle System (BRS) on a 900 MW NPP

(©EDF-Christel SASSO)

- Liquid effluents/wastes coming from the auxiliary systems, also called auxiliary system effluents or used effluents, are collected by a specific drainage system. They are sent to the Liquid Waste Treatment System (LWTS) [TEU] and treated according to their physical and chemical properties (cf. Figure 11):
    - o The process drains effluents come from the reactor cooling system or the spent fuel pool. They are radioactive and usually have a low chemical concentration. They are filtered to get them free of suspended solids and they are demineralized (through ion exchange resins) to get them free of dissolved radioactive and chemical compounds (except for Tritium and boric acid). Depending on its chemical concentration, the downstream water can either be partly recycled to the BRS and primary cooling system or sent to storage tanks before discharge. However, due to the risk to increase chemicals that may contribute to corrosion phenomena in the primary system, recycling is not recommended and may be done only if the quality of the downstream water is adequately checked prior to recycling ;
    - o The chemical drains effluents come from various systems inside the nuclear island or decontamination works. They are radioactive and chemically polluted and are sent to the evaporator. The distillate consists of water with low activity and low chemical concentration that can be sent to storage tanks before discharge. The concentrate is sent to the Solid Waste Treatment System (SWTS) [TES] since it is radioactive (beta/gamma activity usually varies from 5 to 15 MBq/L) and contains high quantities of boric acid (boron concentration up to 50 000 mg/L). In order to avoid boric acid crystallizing in the evaporator, sodium hydroxide is added to get sodium borate which is more soluble than boric acid ;

- The floor drains effluents come from different sumps in the nuclear island. They are slightly radioactive but chemically polluted. They are filtered and the downstream water can be sent to storage tanks before discharge ;
- The service effluents come from surfaces and floors cleaning, showers, sinks and laundry washing in the nuclear island. They are slightly radioactive and slightly chemically "polluted". They are filtered and the downstream water can be sent to storage tanks before being discharged.

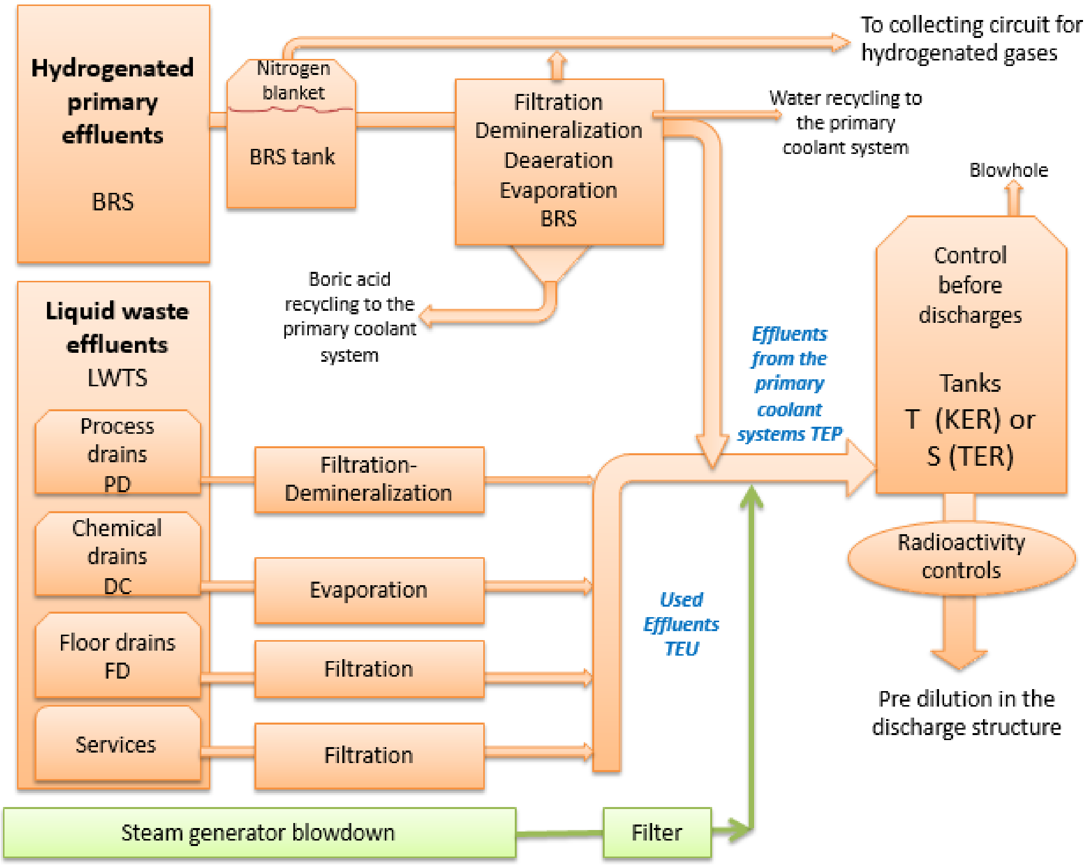


Figure 10 – Collection, treatment and discharge of radioactive liquid wastes/effluents

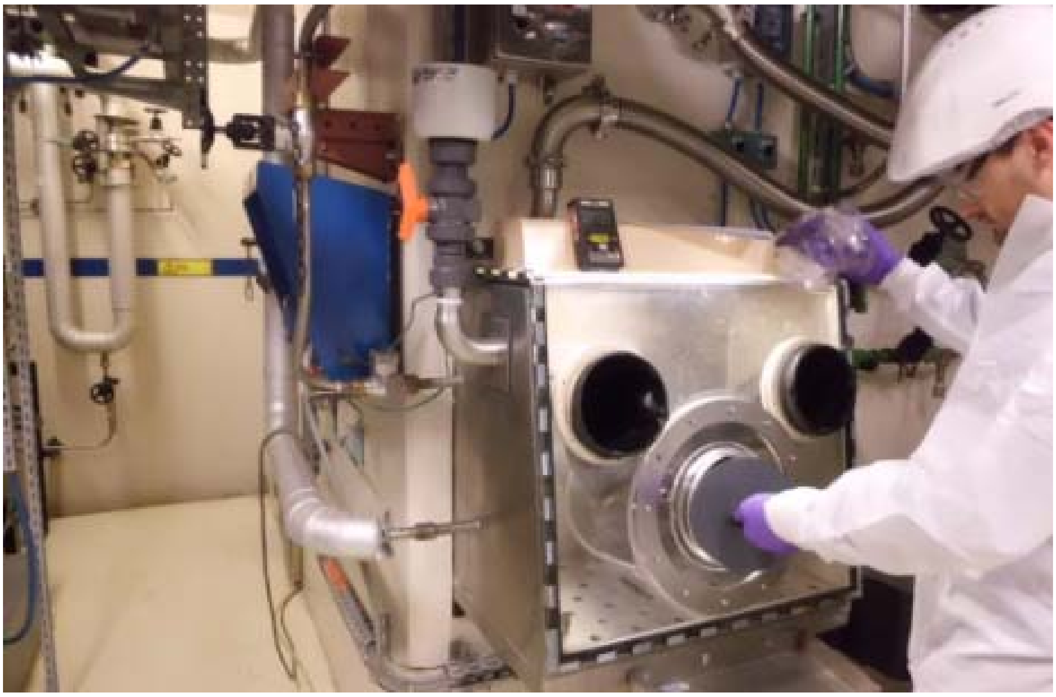


Figure 11: LWTS [TEU] concentrate sampling device on Cattenom NPP.

(©EDF-Cattenom NPP)

Control console in the Effluents Treatment Building

(©EDF-Christel SASSO)

These treatment processes also allow to get effluents free of suspended solids (mesh > 5 µm).

The common features for the (BRS) [TEP] and (LWTS) [TEU] systems are presented in the following table 8:

Table 8- Common features for (BRS) [TEP] and (LWTS) [TEU] systems.

	900 MWe NPPs	1300 MWe NPPs	1450 MWe NPPs
BRS tanks upstream filtration and demineralization	2 x 75 m^3 for 2 units	1 x 145 m^3/unit	2 x 325 m^3/unit
Intermediate BRS tanks downstream evaporation	3 x 350 m^3 for 2 units	2 x 390 m^3/unit	-
Distillate BRS tanks	2 x 70 m^3 for 2 units	2 x 90 m^3/unit	1 x 130 m^3/unit
Concentrate BRS tanks	1 x 10 m^3 for 2 units	1 x 14 m^3/unit	1 x 18 m^3/unit
Floor drains tanks	2 x 20 m^3 for 2 units	2 x 200 m^3 for 2 or 4 units	2 x 75 m^3 for 2 units
Service effluents tanks	2 x 20 m^3 for 2 units	-	-
Process drains tanks	2 x 35 m^3 for 2 units	2 x 60 m^3 for 2 units or 2 x 51 m^3 for 4 units	2 x 75 m^3 for 2 units
Chemical drains tanks	2 x 20 m^3 for 2 units	2 x 300 m^3 for 2 units	2 x 160 m^3 for 2 units
Distillate LWTS tanks	2 x 35 m^3 for 2 units	2 x 8 m^3 for 2 or 4 units	1 x 8 m^3 for 2 units

Before being discharged, the effluents stored in storage tanks are monitored for radioactivity and chemicals and controlled by the plant operators. If necessary, the liquid effluents/wastes can be treated once again. Their discharge may also be postponed if the environmental conditions for discharge are not satisfactory (e.g. for radioactive elements to be sufficiently diluted in rivers during low-water periods). During discharge, the radioactivity in the discharge pipe before reaching the environment is continuously monitored with real-time detection equipment; if an alarm threshold is exceeded (i.e. if too much radioactivity (e.g. > 40 $kBq.L^{-1}$) is detected), the discharge is automatically stopped and new analysis are performed. All the discharges are reported to the French Safety Authority.

3.1.3. Operational efficiency

The performance of NPPs depends not only on the efficiency of their effluent-processing systems but also on their operating practices.

The management of effluents in NPPs is subject to operating instructions aiming at:

- Checking the quality and quantity of radioactive effluents produced ;
- Controlling the activity discharged (before and during).

Hence, actions are implemented to reduce the production of effluents at their sources and optimize the collection and processing of effluents. Moreover, an organization dedicated to effluent management is set, and lastly a results-based management.

a) <u>Reduction at the source</u>

The following arrangements assist in reducing the production of effluents at their sources.

- During operational inspections the main sumps are inspected to detect any significant flow of effluent ;
- Plexiglas covers were installed on the inlet manifolds of some of the sumps in order to see the origin of the effluents ;
- Procedures for tracking leaks were implemented.

b) <u>Collection and processing</u>

Spent liquid effluents are selectively collected under four categories (① drain waters from floors, ② service-drain effluents, ③chemical effluents, and ④ residual drain waters) in order to send them to the treatment that best suits their characteristics (filtration, evaporation, or demineralization).

c) <u>Organization</u>

The organization set up to manage effluents is designed to:

- Prevent pollution ;
- Provide for full control of effluent discharges.

This organization implies the active involvement of all the concerned workers (awareness-raising and training). It relies in particular on making use of the experience acquired on the site and through the entire production fleet, and encourages the implementation of the best practices identified by this experience operating.

This organization is strengthened during periods when the unit is shut down, when more effluents are produced because of the numerous maintenance activities requiring circuits to be drained.

Daily monitoring of effluent production enables discharges to be efficiently reduced during this phase of the operation of the facilities.

3.1.4. Implementation of BAT

Measurements in effluents must comply with regulatory requirements. They must be consistent with the ISO/IEC 17025 standard and be performed using procedures approved by the operator. Hence, the following requisites have to be met by effluents laboratories:

- The measurement procedures must be consistent with standards whenever possible ;
- They must comply with the state of the art, rules and standards concerning metrology ;
- They must carry out inter-laboratory tests to prove the quality of their measurements ;
- The NPPs effluents laboratories must have skilled and trained personnel.

In order to be fully confident in the measurement results, the best available technique for measurement has to be determined based on:

- A benchmark of the standard methods and external laboratories practices ;
- Avoiding the use of reprotoxic, mutagenic and carcinogen chemical products ;
- The NPPs equipment, constraints and OPEX ;
- Technical feasibility studies to make sure that final procedures will reach the required performance.

Once the BAT for measurement is determined, the EDF national laboratory develops and validates the methods that will then be used in every EDF NPP effluents laboratories. The validation is performed according to different standards (e.g. NF EN 90-210 standard "Protocol for initial evaluation of the performances of a method in a laboratory", NF ISO 11352 standard "Water quality - Estimation of measurement uncertainty based on validation and quality control data", ISO 7870-2 standard "Initial evaluation of control chart characteristics").
Once the BAT method is validated, effluents laboratories have to verify its performance on their respective devices (calibration, decision threshold, accuracy, control charts limits) before using it routinely.
In order to check the quality of their measurements, EDF NPP effluents laboratories regularly participate in inter-laboratory tests organized by other reference laboratories such as IRSN, LNHB or IARMA for radiochemical measurements. In addition to the checks and measurements performed by the operator, the French nuclear safety authority ask for the accomplishment of regular checks and controls by an independent laboratory on its behalf. Cross-checks measurements are carried out on effluents duplicating those conducted by the operator with the aim of giving confidence in the results produced and presented by the operator.

Moreover, the operator undergoes regular internal audits by the safety and quality assurance department of the NPP, and regular inspections by EDF "Nuclear Inspection" services and by the French Nuclear Safety Authority (ASN).

Flamanville NPP – French ASN during an inspection

(©EDF- Alexis MORIN)

3.1.5. Performance of the future Flamanville EPR reactor

The environmental performance of the Flamanville 3 EPR is of the most importance for the new reactor to be acknowledged. It was estimated based on:

- The integration of the existing units OPEX from the beginning of the EPR design ;
- Improvements of some EPR operating features compared to the existing units and based on the Best Available Techniques.

Except for Tritium and Carbon-14, the expected radioactive liquid discharges from the Flamanville 3 EPR during normal operation should be as low as those concerning the French existing units, even though the electrical power will be significantly greater. This expected performance is based on aerated liquid wastes recycling, on an optimized sorting of the floor drains effluents, as well as on a reduced source term for Cobalt-58 and Cobalt-60 thanks to primary coolant chemistry regime optimization and use of cobalt-free materials whenever possible.

Tritium generation is directly driven by the electrical power and is essentially due to Boron-10 and Lithium-6 neutron capture. Moreover, there is no suitable industrial removal technique for Tritium that can be applied in PWRs, and given the Tritium half-life (a little more than 12 years) and the great liquid volumes involved, decay before discharge is not relevant. As the Flamanville 3 EPR will operate with significant Boron-10 concentrations, specific design features were set so that its liquid Tritium discharges should be similar to that of the French existing plants:

- Use of gadolinium burnable poison in significant quantities to limit the Boron-10 concentrations;
- Use of Boron-10 enriched boric acid to limit the lithium concentration.

Carbon-14 generation is directly driven by the electrical power and is essentially due to the activation of Oxygen-17 from the cooling water and of Nitrogen-14 dissolved from the CVCS tank blanket gaz. As for Tritium, there is no suitable industrial removal technique for Carbon-14 that can be applied in PWRs. However, as the Flamanville 3 EPR will recycle more effluents as compared to the French existing plants, the Carbon-14 discharges will be mostly gaseous and the Carbon-14 in liquid discharges should be similar to that of the French existing units.

The Flamanville 3 EPR liquid effluents will be sent to the storage tanks used by Flamanville 1 & 2 before being discharged and controlled. However, the activity and volume of the EPR liquid effluents will be monitored before their transfer to the shared storage tanks to provide OPEX data from the new reactor.

Flamanville 3 EPR (1 x 1650 MW)

3.2. ...Optimization of radioactive liquid discharges from NPPs under decommissioning

Decommissioning operations can lead to liquid radioactive discharges depending on the processes used. Significant liquid discharges may come from underwater decommissioning operations. Insignificant discharges may come from other decommissioning operations (cutting with water coolant, tank draining…). Apart from decommissioning operations of the main reactor components, liquid radioactive discharges are composed of atmospheric and industrial water collected in nuclear areas of the plant during normal operations. As CHO A & CHI A share the same geographical sites with NPPs in operation, it has to be noted that the contribution of NPPs under decommissioning to the amount of liquid radioactive discharges is negligible.

3.2.1. <u>Description and performance of systems</u>

As for NPPs in operation, the discharges of effluents is reduced as far as reasonably possible and at an acceptable cost. With this goal in mind, liquid radioactive discharges are reduced to a minimum level. Decommissioning operations employ a variety of systems, most of the time specifically designed for a decommissioning process. Decommissioning operations are designed to increase the overall performance of the process. Performance is assessed thanks to multi-criteria analysis taking into account:

- Nuclear safety ;
- Radiation protection ;
- Hazards and security ;
- Environment ;
- Costs.

Environmental impact assessment takes into account atmospheric and liquid discharges, wastes, resources consumption and pollution (including visual and noise pollutions). If during design a risk of significant impact to the environment is pointed out, workarounds and reductions are defined to reach a residual impact.

During the last years, this strategy has led to a reduction of projected radioactive liquid discharges. Underwater decommissioning operations are substituted to “in air” decommissioning operations when relevant. The dismantling strategy for UNGGs reactors has been adapted in 2017 from an "underwater" to an "in air" process leading to a major reduction of projected radioactive liquid discharges (this new strategy also improve the safety of the process). This leads to almost no liquid discharges to the environment for some decommissioning operations in the OSPAR area (HWR of Brennilis, UNGGs of Saint-Laurent des Eaux). Because water was used as primary coolant, underwater decommissioning is still the best practice for PWR (e.g. CHO A). Water recycling and purification approach are used to reduce radioactive liquid discharges in that case.

Decommissioning operations are designed to improve the overall performance of the process, taking into account environment and all others constraints.

3.2.2. <u>Characterization of radioactive liquid discharges</u>

The characterization of liquid radioactive discharges for NPPs under decommissioning is consistent with the characterization of NPPs in operation.

Liquid radioactive effluents of a single source are characterized before mixing with other sources and before discharge.

Two complementary characterization methods are set-up: real-time characterization and detailed characterization.

- Real-time characterization is based on a global γ-activity assessment along the discharge pipe. The real-time assessment is connected to an alarm and a valve: if the global γ-activity of the fluid is greater than a limit set in permits, the discharge process is automatically stopped. Activation of the alarm would lead to a significant event regarding to the Quality Assurance ;
- Detailed characterization is performed before discharge. Measurements are carried out on a representative sample. All isotopes subject to limits (or subject to a total absence assessment) are characterized thanks to dedicated measurement techniques. Precision of

measurement techniques meets high standard regulatory values. Detailed characterization results are declared to authorities a posteriori. No discharge can be carried out without detailed characterization.

Discharges are characterized by real-time characterization, samples measurements for detailed characterization, and environmental monitoring. All are performed with high standard measurement techniques.

3.2.3. <u>Operational efficiency</u>

NPPs under decommissioning in the OSPAR area are located on the same site than NPPs in operation. Therefore discharge operations are managed by the same qualified and trained teams for all the facilities on the site.
Discharge operations are planned considering all constraints, such as current liquid level in tanks (margin before full level), effluent forecast, weather forecast, river flow rate. Low river flow rates and high river flow rates may lead to an environmental impact, therefore discharges are authorized only for suitable river flow rates. Depending on full level margin in tanks, priority is set between the NPP of the same site.
After a discharge operation has been validated, discharge conditions are assessed. Discharge flow rate is evaluated regarding river flow rate to avoid any environmental impact. Alarms are embedded in discharge flow meters, and connected to valves designed to stop a discharge if needed.
At defined time steps, during and after the discharge, environmental monitoring is carried out at several points in the river upstream and downstream of the NPP to confirm and ensure the compliance of the results with the impact study.

Best discharges conditions are required to avoid any environmental impact.

3.2.4. <u>Implementation of BAT</u>

The strategy followed by NPPs under decommissioning in order to optimize the liquid radioactive discharges is fully consistent with the approach from NPPs in operation. This strategy is based on three main concepts:

- Reduction at the source, in order to reduce the amount and activity of liquid radioactive discharges ;
- Collection and processing (including storage for decay), taking account of the specificities of discharges from NPPs under decommissioning ;
- Monitoring, in order to verify the efficiency of effluent-processing systems and operating practices.

Moreover, NPPs under decommissioning must comply with strict discharges permits, whose limits are regularly optimized, based on the implementation of BAT approach in association with operating experience. As on NPPs in operation, liquid radioactive discharges are optimized, thanks to the following best practices:

- Selecting the best decommissioning processes taking into account environment and other constraints ;
- Filtrating and recycling liquid effluent ;
- Conditioning liquid effluent into waste product as far as reasonable ;
- Requiring the best discharges conditions to avoid any environmental impact ;
- Characterizing effluents and monitoring the environment with high standard measurement techniques.

4. Control of radioactive liquid discharges on EDF sites

4.1. Objectives of discharges controls

Several thousands of measurements are performed each year by EDF operators to control the effluents. Among these measurements, the radioactivity is checked, based on regulatory requirements and discharge permits that have to be complied with at all time. For example:

- The measurements on effluents have to be performed in a dedicated on-site laboratory by skilled personnel ;
- Laboratory equipment has to be regularly controlled and maintained in order to comply with standard ISO 17025 or equivalent provisions ;
- Some sampling and real-time devices have to be backed-up and equipped with an emergency power supply.

Controlling the discharges from a NPP is essential to ensure that they comply with the discharge permit in terms of:

- Annual limits for Tritium, Carbon-14, Iodines, other FP-AP (in GBq or TBq/y) ;
- Emission rate limit (in Bq/s) ;
- Volumic activity limits downstream the discharge location (in Bq/L).

The results of the controls are also used to assess the impact of the discharges on the environment and public health and ensure that it is always below the assessment presented to the French Safety Authority in the regulatory files.

Sampling and measurement quality is of major importance to be confident in the analytical results and is ensured by the implementation of standardized methods whenever possible. It is also based on the personnel skills, trained to operate on-line monitors and laboratory equipment. In this context, the analytical results obtained on one NPP are reliable and can be confidently compared with results from other NPPs, Safety Authority or other independent services.

Procedures and control sheets covering sampling, analysis and discharge conditions are edited to ensure that discharge flow rates, concentrations and activities requirements are fully met.

4.2. Description of sampling and analysis program

Specific wastes sampling nozzles had been integrated into the initial design of the NPPs. From these nozzles, pipes transfer the fluids towards different sampling rooms and their length is optimized so that samples are the most representative of the effluents. Before sampling, the lines are purged as long as needed.

Liquid wastes are sampled (1 or 2 liters) from the storage tanks after several hours stirring so that the effluents in the tanks are homogeneous.

Radioactivity measurements in the radioactive liquid wastes are as follows:

- ⍰ and ⍰/⍰ emitting radionuclides ;
- Control of the absence of any artificial alpha emitter nuclide.

The following techniques or devices are used to perform the measurements:

- Proportional counter for gross ⍰ activity and gross ⍰ activity ;
- NaI (Tl) type counter at room temperature or proportional counter for global ⍰ activity ;
- Liquid scintillation for Tritium activity and Carbon-14 activity ;

- Spectroscopy with a high purity germanium detector for isotopic characterization.

No effluent likely to be radioactive can be discharged prior controlling that the regulatory requirements are met.

No effluent from the Nuclear Island Liquid Radwaste Monitoring and Discharge System (NI-LRMDS) [KER] nor from the Conventional Island Liquid Waste Discharge System (CI-LWDS) [SEK] can be released before the control results in Tritium, gross activity, gross activity, global activity and isotopic composition are checked. If gross activity exceeds 20 $kBq.L^{-1}$, the effluents cannot be discharged and have to be treated again. However, effluents can be released prior checking Carbon-14 and Nickel-63 activities, since their analysis is complex and takes a long time.

Discharge flow rate has to be determined so that the effluent pre-dilution in the cooling water before discharge to the environment is enough and meets the regulatory requirements (1/500).

Concerning river-side NPPs, discharges are allowed only if the river flow rate meets the regulatory requirements: in case of low-water or flood period, discharges are forbidden (unless specific authorization and conditions from the French Nuclear Safety Authority).

During discharge to the environment, a real-time monitoring of global activity is performed on the discharge pipe. The analytical device is backed-up and equipped with an emergency power supply. In case the global activity exceeds 40 $kBq.L^{-1}$, the discharge is automatically stopped. As long as the discharge goes on, the operator checks the discharge flow rate and the water level in the storage tank and adjusts the discharge flow rate to the river flow rate in order to ensure the regulatory requirements are met. During low-water periods, discharges are coordinated among all the sites located on the same drainage basin in order to ensure that their environmental impacts are minimized.

5. Management and monitoring of the environment

5.1. Objectives of Environmental monitoring

Concerning the environmental monitoring strategy of French NPPs, two types of observations are necessary and complementary:

The regulatory program of radiological monitoring of the environment is prescribed by the French Nuclear Safety Authority (ASN).

It aims at fulfilling the three following functions:

- Alert function: Alert in case of any atypical evolution of one or more parameters related to the environment monitoring, in order to trigger complementary investigations and, if necessary, preventive actions ;
- Control function: Verify the compliance with the regulatory limits and verify the safe functioning of the facilities. The results of the measurements are compared, either with the authorized limits, or with reference values (decision threshold, radioactive background, etc) ;
- Environmental study function: Assess the potential influence of discharges on the environment. This is the purpose of radioecological campaigns.

The regulatory program is strictly applied and carried out by EDF or its partners, certified by French agencies, which follow the French or European standards for environmental radioactivity measurements.

This program is completed, under EDF's initiative, by radioecological studies. It has to be noted that these studies (expertise) need more sensitive observation devices and techniques in order to:

- Understand the transfer mechanisms of artificial radionuclides in the environment ;
- Evaluate to what extent the operating (and/or the decommissioning) of nuclear facilities contribute to the input of artificial radionuclides to the environment (long term low-level monitoring).

The results of these radioecological studies establish the spatial and temporal distribution of radionuclides in the environment, from the first fuel load to the end of decommissioning operations. These studies are carried out by external specialized laboratories and experts in the field of radioecology.
The three historical functions described above meet the objectives mentioned in a regulatory order (e.g. BNI ministerial order) which states that environmental monitoring tends to:

- Contribute to the knowledge of the radiological and radioecological state of the environment of the facility, and its evolution with time ;
- Contribute to verify that the impact of the facility on health and the environment, in particular food products, is consistent with the impact assessment [...];
- Detect as early as possible an abnormal rise in radioactivity ;
- Make sure there is no malfunction of the facility.

5.2. Description of sampling and analysis program

Environmental monitoring of French NPPs is performed through radiological analyses on selected environmental matrixes and samples important in order to understand and explain the transfer of radionuclides within the environment and in the exposure of the population (e.g.: notion of representativity of the selected species). Of course, it takes into account the operating experience acquired since the commissioning of the site. These measurements, combined with the strict control of radioactive effluent discharges, allow to ensure the absence of impact on man and biota as demonstrated in the impact assessment.

5.2.1. Regulatory program of radiological monitoring of the environment

Concerning the regulatory measurements, the minimal monitoring required is prescribed in a French regulatory order named « Environment Resolution »[11] described in a previous chapter and applicable to all the French nuclear facilities (e.g. not only NPPs). On this basis, the regulatory measurements are specified in dedicated resolutions specific to each site.

[11] *French Decree no 2016-DC-0569 dated 29th of September 2016*

The table 9 below presents the parameters to be monitored on different types of samples according to the Environment Resolution. The type of analysis and the frequency are also prescribed.

Table 9 – Parameters, samples and analyses required by the Environment Resolution[2].

SAMPLE	**CONDITIONS ON RADIOACTIVE DISCHARGES**	**MONITORED PARAMETER**	**FREQUENCY**	**ANALYSIS** (for all nuclear facilities)	**ANALYSIS** (for facilities emitting □ emitters radionuclides)
Air at ground level	In case of atmospheric discharges	Volumic activity in air	Weekly to monthly	According to the discharges	
		Airborne dusts	Daily	Determination of gross □ activity □ spectrometry if the gross □ activity exceeds 2 mBq/m^3	Determination of gross □ activity □ spectrometry if the gross □ activity exceeds 2 mBq/m^3
			Monthly	□ spectrometry compiling all daily filters from the same sampling station	□ spectrometry compiling all daily filters from the same sampling station
Ambient radioactivity		Ambient radioactivity in a 10 km radius around the facility	Continuous recording	Ambient □ dose rate	
Rainfall	In case of atmospheric discharges	Continuous collecting of rainwater	Every 2 weeks	Determination of gross □ activity Tritium (HTO) Potassium concentration (for seaside sites)	Determination of gross □ activity
Surface water	In case of liquid discharges	Activity in surface water	Hourly to monthly	Determination of gross □ activity Tritium (HTO) Potassium concentration	Determination of gross □ activity
Groundwater		Activity in groundwater	Monthly to annually	Determination of gross □ activity Tritium (HTO) Potassium concentration	Determination of gross □ activity
Terrestrial plants	In case of atmospheric discharges	Activity in plants sampled downwind from the facility, close to the facility	Monthly to annually	□ spectrometry Tritium (HTO & OBT) Carbon 14	□ spectrometry

		(about 1 km)			
Milk	In case of atmospheric discharges	Activity in milk produced in the vicinity of the plant (0-10 km)	Monthly to annually	⍰ spectrometry Tritium Carbon 14 Strontium 90	
Soil	In case of atmospheric discharges	Activity in superficial layers of soil	Annually	⍰ spectrometry	
Aquatic flora	In case of liquid discharges	Activity in aquatic flora sampled near the discharge point	Annually	⍰ spectrometry	
Aquatic fauna	In case of liquid discharges	Activity in aquatic fauna sampled near the discharge point	Annually	Freshwater : ⍰ spectrometry, OBT & ^{14}C on fishes Seawater: ⍰ spectrometry and OBT on crustaceans, molluscs and fishes, ^{14}C on fishes or molluscs	
Sediments	In case of liquid discharges		Annually	⍰ spectrometry	⍰ spectrometry
Agricultural productions	In case of atmospheric discharges	Activity in main agricultural productions, especially downwind	Annually	Tritium (HTO & OBT) ⍰ spectrometry	

Le Blayais NPP – Environmental monitoring

(©EDF- Philippe ERANIAN)

Each NPP is responsible for implementing this program and is equipped with a laboratory dedicated to environmental measurements, strictly separated from the effluent laboratory. Laboratories are equipped with specific equipment allowing the analysis of samples collected in the environment, and the staff is qualified for chemical and radiochemical analysis. Some specific analyses may be outsourced but only to ISO 17025 certified laboratories. Thus, each site carries out annually, under the control of the ASN, several tens of thousands of measurements. The associated results ought to be transmitted to the Regulator and are also used in documents or supports intended/accessible to the public. The results of environmental monitoring around each NPP are also published by EDF on its website and in a dedicated annual environmental report (e.g. one for each NPP).

Furthermore, all environmental radioactivity measurements are also communicated and accessible to the public via the National Network for Environmental radioactivity as describe in a previous chapter.

5.2.2. Radioecological studies

In addition to the regulatory monitoring program, EDF has also developed its own strategy to assess as accurately as possible the long term impact of NPPs operation in terms of artificial radionuclides input to the environment and their fate. Radioecological studies notably make it possible to evaluate the contribution of one NPP to the traces of radioactivity detected in the environment over the long term, and to distinguish it from various origins and sources (fallout from nuclear tests, Chernobyl accident, etc.). The results of radioecological studies are compared with radioecological data collected before the commissioning of the facility (“zero point or reference point”) to estimate the long-term impact (e.g. from a NPP under normal operating conditions to the end of the decommissioning period). Thus, since 1992, an annual monitoring of the gamma activity by low-level measurements of terrestrial environmental matrixes (soil, plant, milk) and continental aquatic or marine matrixes (sediments, plants, fish, etc.) has been set up for all the French NPPs. This annual monitoring has been completed in 2000 by the characterization of free water Tritium (HTO) activity and in 2011 by the measurement of organically bound Tritium (OBT) and Carbon-14.

The sampling stations and the nature of the collected samples are chosen in order to allow the comparison of the results with those obtained during previous studies. It is also taken into account the main economic activities of the region and the local meteorological conditions, particularly the wind rose. Thus, the sampling stations are located under and outside the influence of radioactive discharges, in the terrestrial (out & under prevailing winds) and in the aquatic compartments (downstream and upstream or equivalent for sea sided NPPs). The samples chosen are representative of direct or indirect ways of transfer of the radioactivity towards human and the environment. Depending on the radionuclides monitored, samples can be:

- Bio indicators, which make the detection of trace elements easier, with reaction times and variable capacities of integration (mosses, lichens, tree leaves, etc.) ;
- Located in accumulation compartments (soils, sediments) ;
- Direct vectors of radioactivity (superficial waters, groundwater, airborne dusts, etc) ;
- Eatable products for humans and/or animals (herbs, cereals, vegetables, milk, fishes, etc).

In the OSPAR context, samples are mainly composed of: sea water, algae, mollusks, crustaceans, fishes and sediments.

Every ten years, a complementary radioecological assessment is carried out in order to complete the annual survey. Organically bound Tritium (OBT) is characterized, as well as Carbon-14, emitters radionuclides (such as Plutonium-238, Plutonium-239 and 240, Americium-241), and other -emitting radionuclides like Strontium-90, Technetium-99, Nickel-63. To carry out the analysis, a larger number and a greater diversity of samples are collected and compared with the results of previous studies. These studies require excellent scientific knowledge in biology and also concerning the behavior of chemical and radioactive substances in the ecosystems. They also use complex sampling and analysis techniques, very different from those used for daily industrial monitoring also called "routine monitoring". Impossible to be done by the operator (that's not its role and then he would be judge and part) they are therefore entrusted to qualified laboratories that are recognized for their expertise in that field.

Radioecological studies enable to precisely characterize the levels of natural and artificial radioactivity in various environmental compartments around each French NPPs, and to specify the influence of the radioactive discharges during operating and decommissioning periods. Data collected over several decades showed that NPPs discharges did not modify the biological and radiological characteristics of the receiving environment in accordance with the conclusions of the impact assessments. They showed that natural radioactivity is the main component of the radioactivity in the environment of each NPP, and that the artificial radioactivity is mostly attributable to global fallouts from atmospheric nuclear tests and also to the Chernobyl accident. Due to the elapsed time from these old events and the efforts made by EDF to reduce all the discharges, the level of radioactivity in the environment around NPPs has been decreasing over the past thirty years.

5.3. Implementation of BAT

Daily environmental monitoring

In late 2009, actions to improve the reliability and availability of information transmitted by the Environmental Monitoring System (KRS) were started. The first actions undertaken in 2010 focused mainly on the renovation of multi-parameter physicochemical measurement stations, the securing of radiametric data (in particular by replacing the probes of the fence networks, 5 km and 10 km by Genitron probes, and the network 1 km by SBN 91), the reliability of meteorological measurements as well as the reliability of the transmission of collected data. An upgrade of preventive maintenance and spare parts management was also carried out.

These renovations carried out on the sites between 2010 and 2013 represent a total cost of 4.5 million €.

Since 2010, the follow-up of the declarations of Events Concerning the Environment (EIE) shows an improvement of the reliability of the transmitted information thanks in particular to the progressive commissioning of the new Genitron probes on the fence networks, 5 km and 10 km. No further actions are planned.

Metrological robustness of EDF laboratories in charge of monitoring the environment of the sites

The regulation, and in particular the Environment Resolution (ASN resolution 2013-DC-360 dated 16th July 2013 amended), requires that environmental radioactivity measurements have to be made by nuclear facilities operators in laboratories approved by the ASN (for each type of measurement) and that the results have to be transmitted to the RNM to be published on a free website that is accessible to the public.

Laboratory certifications for environmental radioactivity measurements are given by a Nuclear Safety Authority resolution. These certifications are released by a commission chaired by the ASN on the basis of two prerequisites:

- Compliance of sampling practices (since 2010) and measurement with the requirements of standard NF EN ISO / IEC 17025 ;
- Success in an Inter-Laboratory Test organized by ASN.

EDF's laboratories have the certifications required to carry out the measures performed on their own and subcontract the others to certified laboratories.

A national action plan for the normative compliance of environmental sampling participating in the RNM was set on all sites from 2010 to 2014, including materials, organizations and procedures. This involved a total investment of nearly 6 million €. The RNM certifications, incorporating the sampling activity, were all successfully acquired during this process.

In addition, to facilitate the obtaining and renewal of these certifications, EDF has been involved in an accreditation process by the COFRAC (French Accreditation Committee) for its activities since 2009. To date, all accreditation demands and renewals have been obtained.

Internal and COFRAC audits are also regularly carried out in EDF Environment laboratories. For its contribution to the RNM, each laboratory has implemented a local organization compliant with the requirements of the NF EN ISO / IEC 17025 standard. The steering of the approach, particularly with regard to strategy, pooling and technical support, is carried out by the EDF national engineering entities.

5.4. Environmental management

All EDF NPPs have a management system, linked to an integrated policy, in which the environmental domain is ISO 14001" certified since 2002. Environmental management of nuclear sites is part of a process called "Improving and monitoring environmental performance". This process aims at identifying, preventing and controlling the environmental impact and contributing to continuous improvement of performance in compliance with environmental regulations. All the environmental aspects of the sites are covered, namely, water withdrawals and consumption, effluents management, waste management and environmental monitoring. All the actions taken from the commissioning of the NPPs within the framework of a continuous improvement of industrial and environmental achievements led to a better understanding of interactions between the facilities and their environment and to a better control over the impacts associated to inconveniences.

The top management of each site is in charge of the strategic leadership of the management system and each profession contributes at its level to the control of inconveniences.

Environment process reviews and/or Management reviews, held at least on an annual basis, allow to analyze results and to define choices for the year to come with a pluri-annual vision if necessary. These reviews allow to assess results, risks and opportunities and to decide on further actions. Those actions are taken into account by the departments.

The environment process includes the operating experience regarding events related to the environment, controls before discharge, discharges and environment monitoring, conventional and radioactive waste management and control over regulatory compliance.

The integrated organization allows to ensure that environmental stakes are taken into account in all nuclear sites activities. Noteworthy interactions with other processes are numerous, for example:

- Producing process: the Chemistry section is in charge of the monitoring of radiochemical and chemical conditions of circuits and advises the Operations department on the orientation of effluents during operations on circuits ;
- Maintenance process: the Maintenance section contributes to operational conditions upkeep of effluents collection, treatment and control systems and of environmental monitoring systems.

In addition, each profession contributes at its level to the control of inconveniences, notably through the environmental analyses that cover all the activities of a site.

National engineering services also offer some support to the sites. They have different missions, among which:

- Operation reference documents release ;
- Support in particular or specific situations ;
- Second level analyses of operating experience ;
- Studies on changes applied to the sites ;
- Performance assessment of the effluents/waste domain by EDF Nuclear Inspection.

The human resources department of each entity is responsible for the leadership of the competence management process (acquisition, upkeep and development). Needs for training are identified each year through surveys performed by the management of each department. Each member of the staff attends a training session to raise awareness on environmental stakes, relevant regulations and continuous improvement process. These awareness sessions allow to acquire knowledge on the integrated general policy, to identify key actors, their roles and responsibilities, as well as instructions and best practices to be applied (selective sorting of waste, resources preservation).

Contract partners' staff is trained by its own company according to operations requirements defined in the contracts. The assessment of the respect of environmental requirements is performed through a monitoring program defined on each nuclear site. Each "newcomer" contract partner on site is physically hosted and receives awareness in a relevant environment.

6. Radiologic impact of marine and estuarine sites

6.1. Results of environmental Monitoring

a) NPPs located on the English Channel and the North Sea

Environmental monitoring and radioecological studies carried out on sea sided NPPs (Flamanville, Paluel, Penly and Gravelines (Cf. Charts 1 to 6)) over the last decades showed that the radioactivity detected in the environment is mainly composed of natural radionuclides. However, artificial radionuclides are also detected in sediments and some biological samples taken from the marine environment. These radionuclides have different origins among which we can mention:

- Waters from the Atlantic Ocean, marked by the global fallout attributable to atmospheric nuclear tests and effluent discharges from the Sellafield reprocessing plant (United Kingdom). Those two sources contribute in particular to the input of Cesium-137 and Tritium. In addition, in 2011, a fleeting marking of the marine environment by radioactive plume fallout from the Fukushima Daiichi NPP accident in Japan has been observed ;
- Rivers, in particular the Seine, which drains a strongly industrialized watershed, notably with the presence of Nogent-sur-Seine NPP and many hospitals and research centers using radionuclides ;
- Liquid discharges from Flamanville, Paluel, Penly and Gravelines NPPs ;
- Liquid discharges from the Orano La Hague reprocessing plant.

Among these different sources, liquid discharges from Orano La Hague reprocessing plant are the major contributor to radionuclides input in French coastal waters of the English Channel and the North Sea. Some emitting radionuclides such as Cesium-137, Cobalt-60, Maganese-54, and Silver-110m, as well as free Tritium, are present in liquid effluent discharges from NPPs and from the Orano La Hague reprocessing plant. However, levels of activity in artificial radionuclides in liquid effluents discharged into the sea by the Orano La Hague plant are several orders of magnitude higher than those of the NPPs, especially for Tritium (HTO). However, we can observe a decreasing gradient of the activities of these different radionuclides between the peninsula of Cotentin and the Strait of Pas-de-Calais.

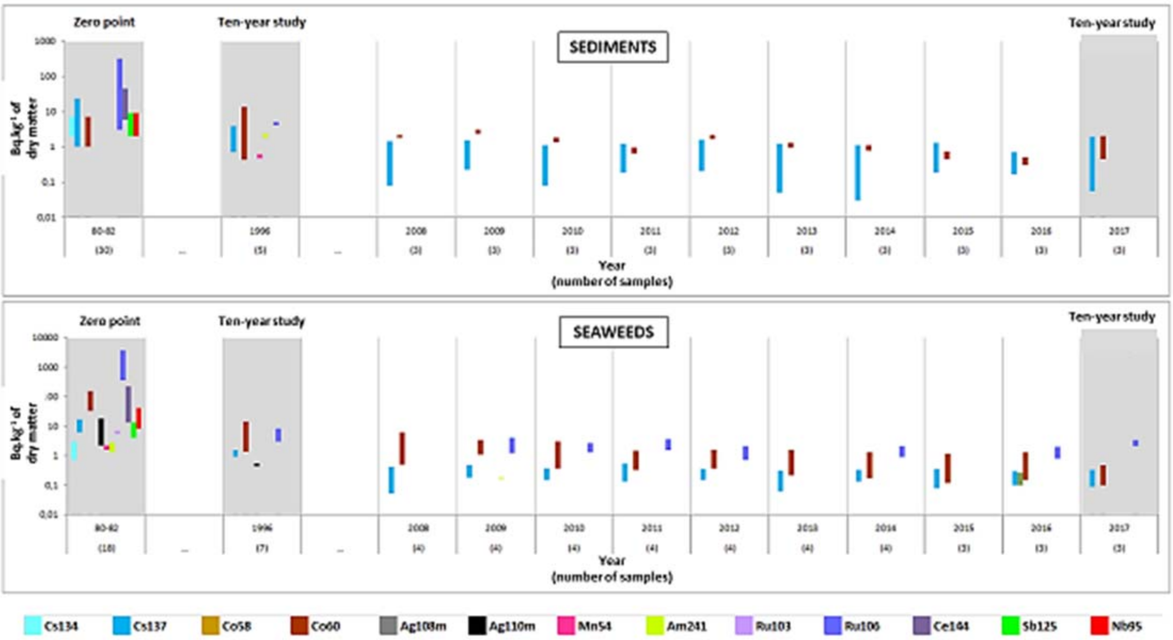
Cesium-137 is the most frequently detected artificial radionuclide in the different collected samples and matrixes (almost systematically). Cesium-137 activities are relatively homogeneous throughout the Eastern Channel. Mollusks are the organisms in which the greatest diversity of artificial radionuclides is detected and that can be easily explained by the way of life of these organisms. Qualitatively, grazing gastropods (e.g.: limpets) are excellent bio indicators of the artificial gamma radioactivity present in the marine environment. Nevertheless, quantitatively, the levels of activity in artificial gamma emitters within these organisms remain very low, in the order of a few tens to a few hundred mBq per kg of fresh material.

Tissue free water Tritium (HTO) activities in mollusks sampled in the near field and in the far field from the effluent discharge point of NPPs are globally consistent with the expected values in the Channel seawater (in the order of 5 $Bq.L^{-1}$ of tissue free water) and mainly attributable to the dispersion of liquid effluents from the Orano La Hague reprocessing plant. However, there is a slight HTO footprint on mussels sampled in the close vicinity of NPPs. In addition, activities of organically bound Tritium (OBT) in mollusks, arthropods and fishes sampled close to the NPPs are also consistent with the expected values, while showing a slight OBT marking for some samples but excluding any bio accumulative process (e.g. OBT/HTO < 1).

Carbon-14 activities quantified in mollusks and fishes sampled in NPPs marine environment are, for the most part, higher than background activity without industrial influence (e.g. 240 ± 2 $Bq.kg^{-1}$ of Carbon), but consistent with the average values recorded by the past due to the overall influence of the Channel's nuclear plants, and in particular the Orano La Hague plant. According to the year and the site, Carbon-14 activity can slightly increase in the close vicinity of the liquid effluent discharge points of NPPs for mollusks and fishes in relation with a smaller dilution capability.

The main results are illustrated in the charts thereafter.

Flamanville NPP



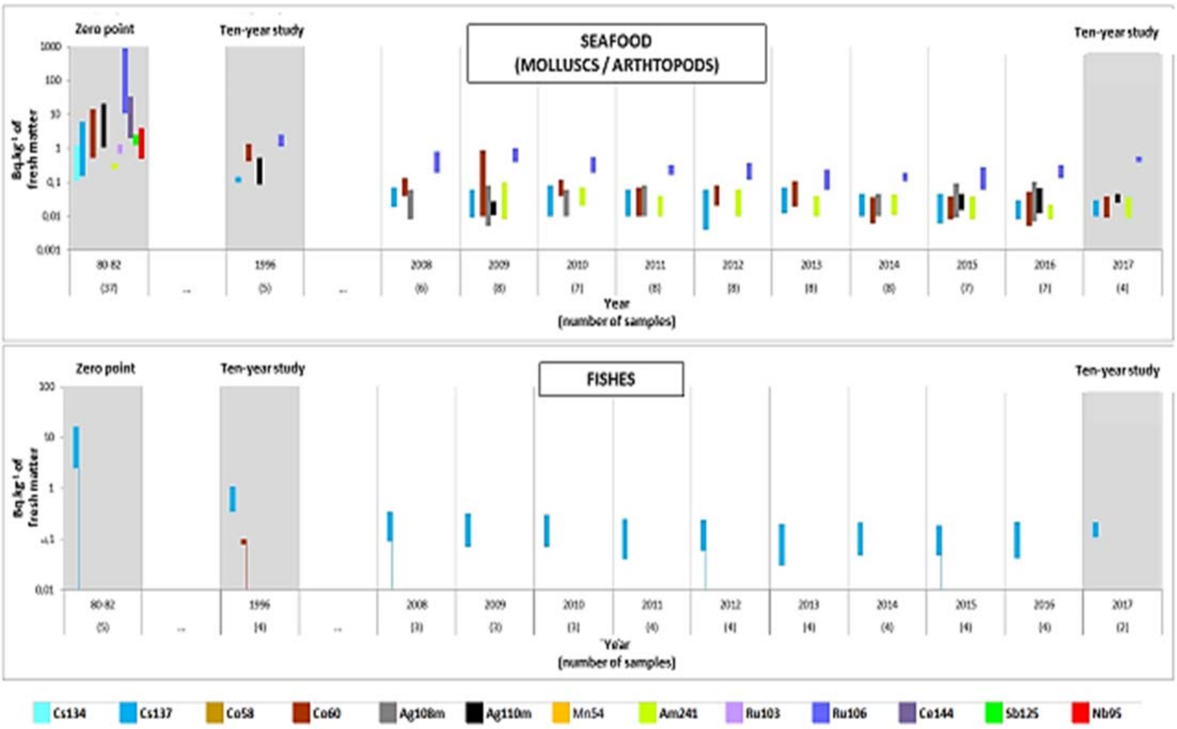


Chart 1 – Temporal variation of activities (minimal and maximal values) of main artificial gamma-emitters radionuclides in sediments, seaweeds, seafood (mollusks and arthropods) and fishes collected in the local marine environment of Flamanville NPP.

Paluel NPP

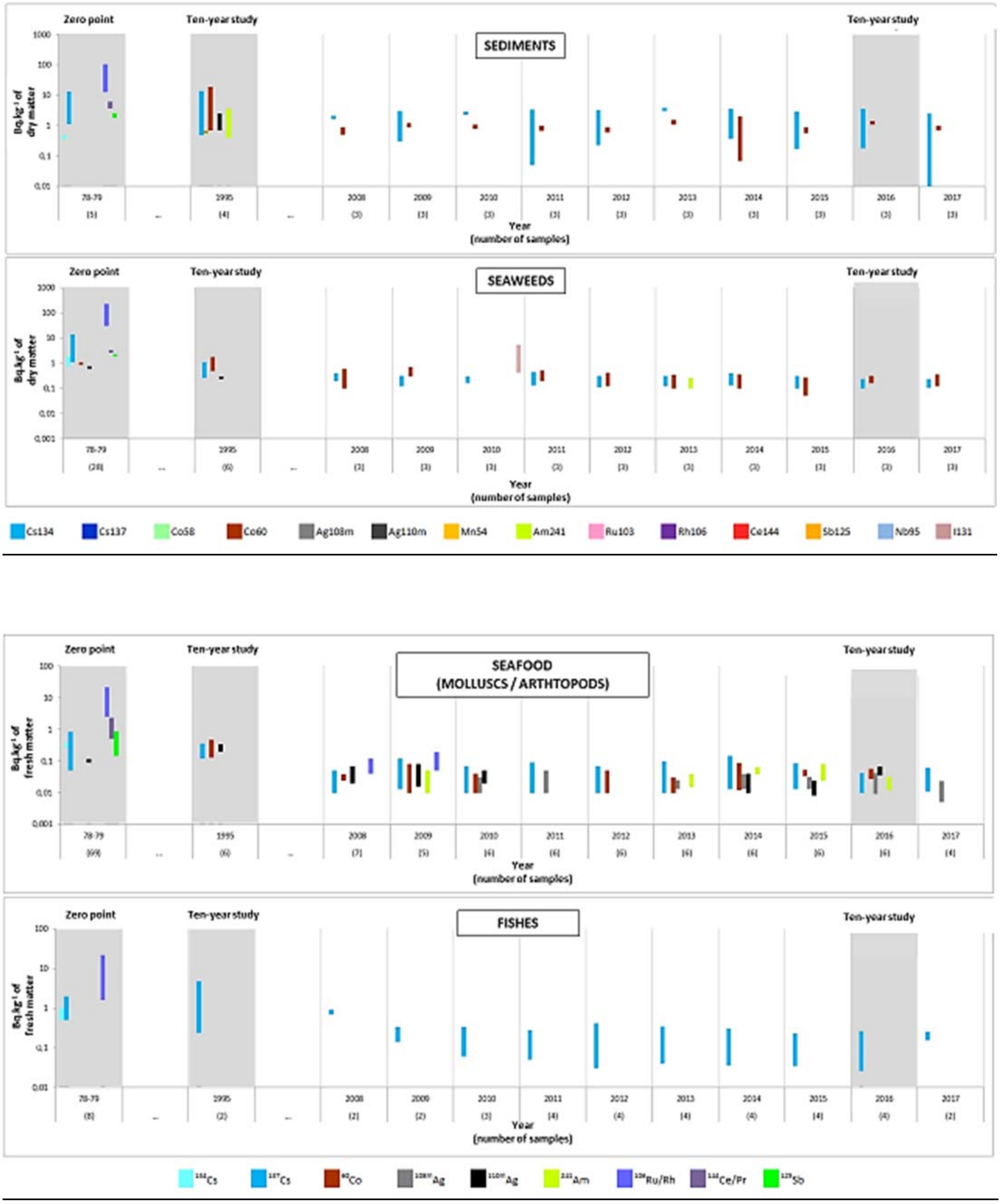


Chart 2 –Temporal variation of activities (minimal and maximal values) of main artificial gamma-emitters radionuclides in sediments, seaweeds, seafood (mollusks and arthropods) and fishes collected in the local marine environment of Paluel NPP.

Penly NPP

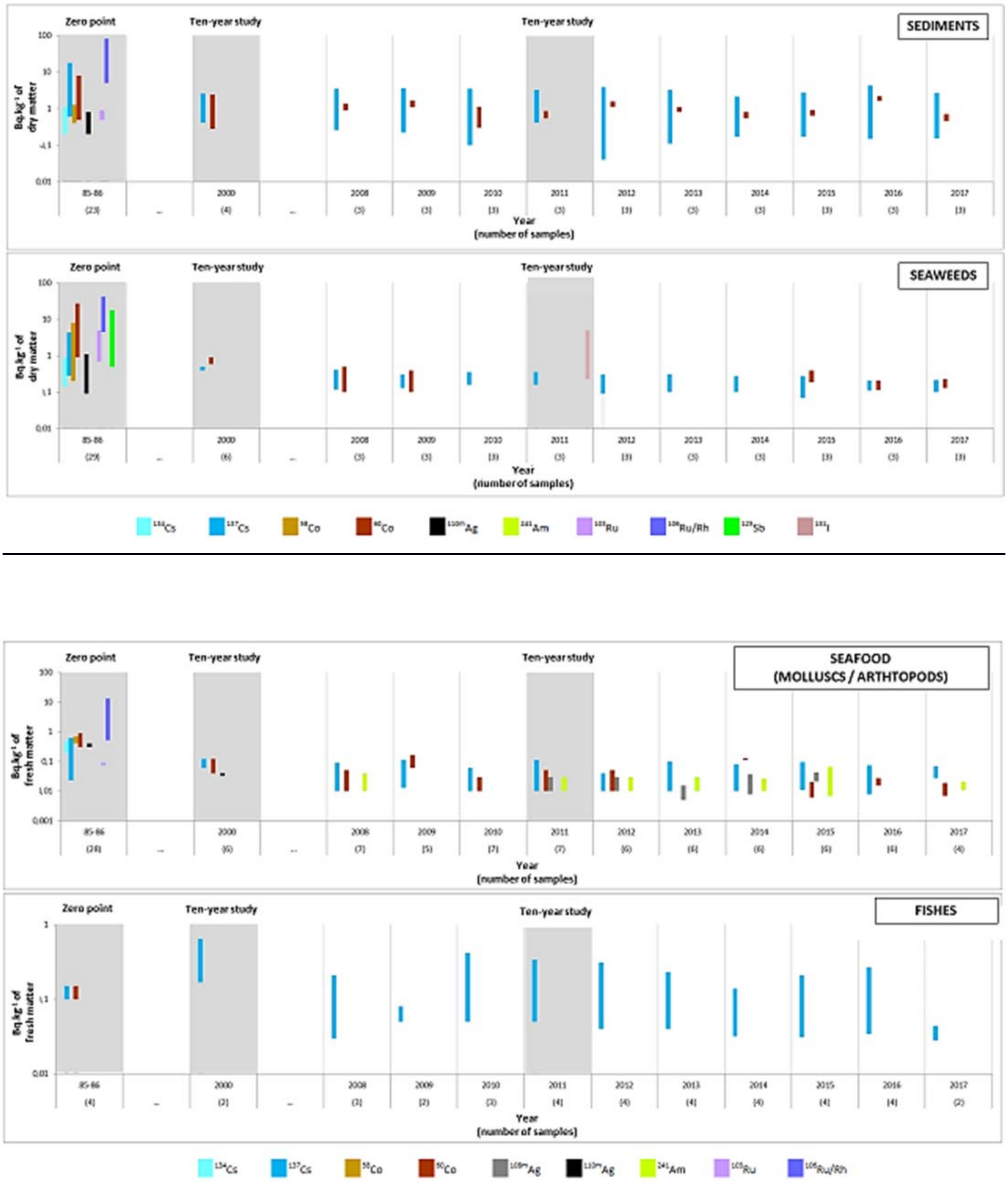
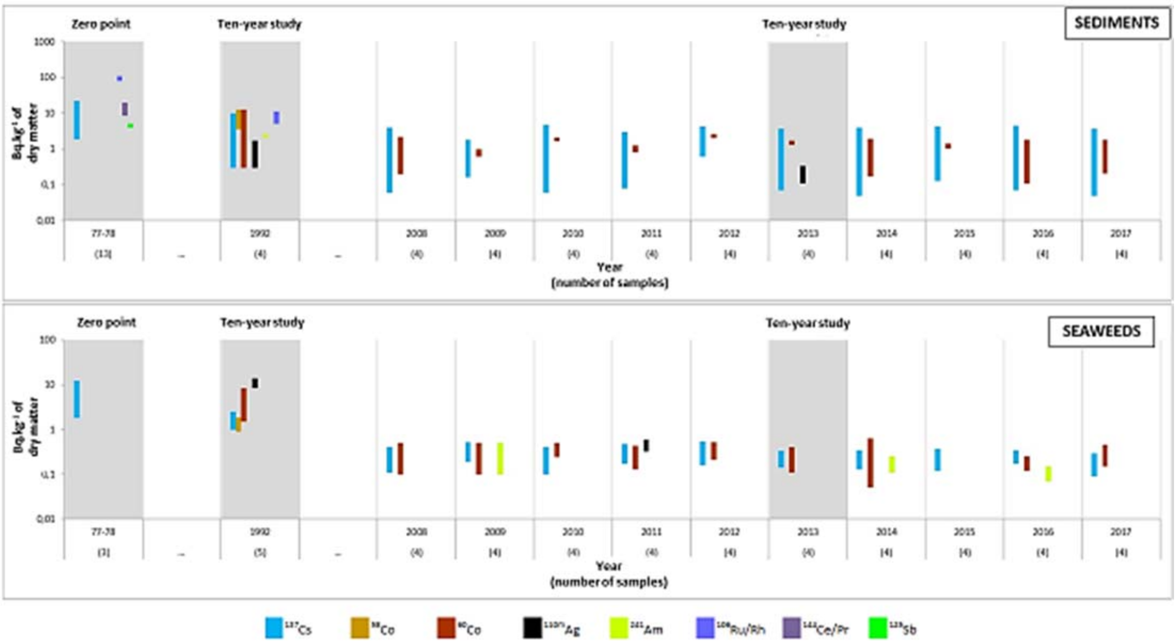


Chart 3 –Temporal variation of activities (minimal and maximal values) of main artificial gamma-emitters radionuclides in sediments, seaweeds, seafood (mollusks and arthropods) and fishes collected in the local marine environment of Penly NPP.

Gravelines NPP



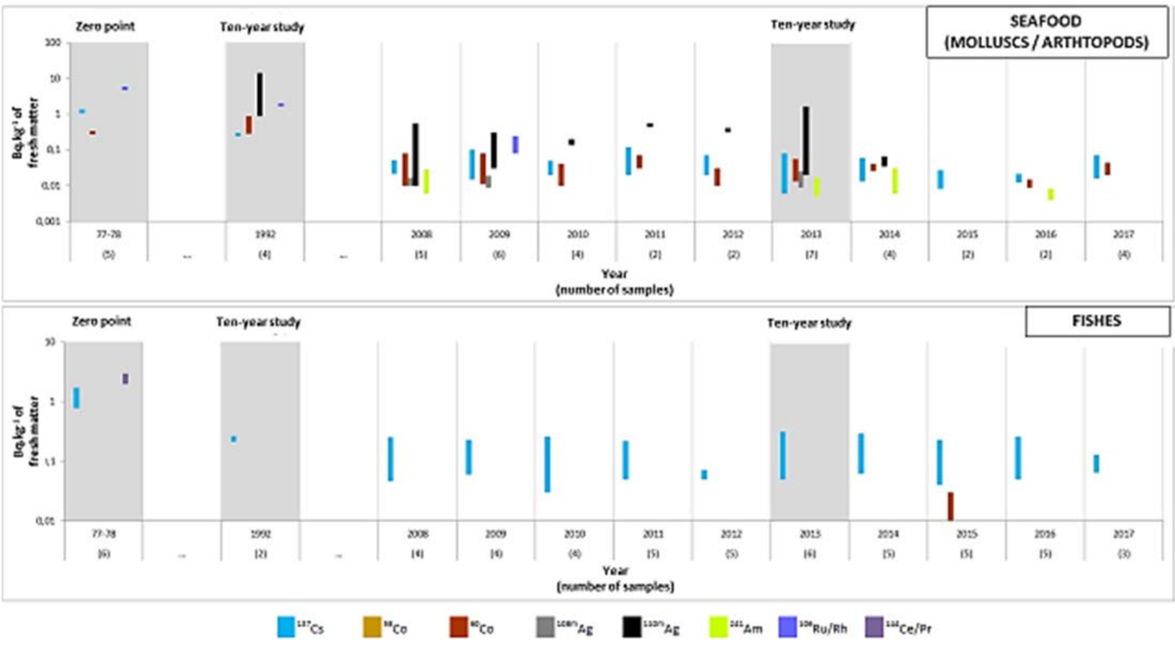


Chart 4 – Temporal variation of activities (minimal and maximal values) of main artificial gamma-emitters radionuclides in sediments, seaweeds, seafood (mollusks and arthropods) and fishes collected in the local marine environment of Gravelines NPP.

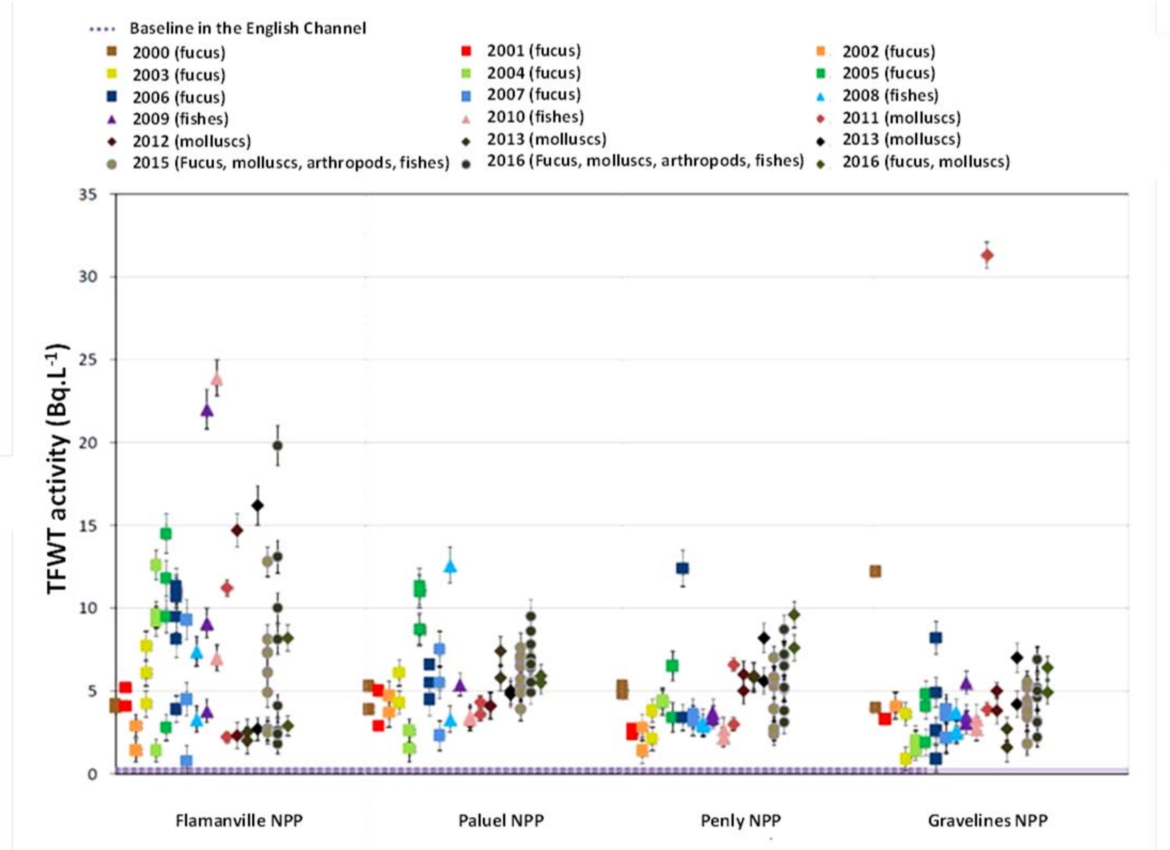


Chart 5 - Temporal variation of Tissue Free Water Tritium (TFWT) activities in seaweeds, seafood (mollusks and arthropods) and fishes collected

in the near field marine environment of French NPPs.

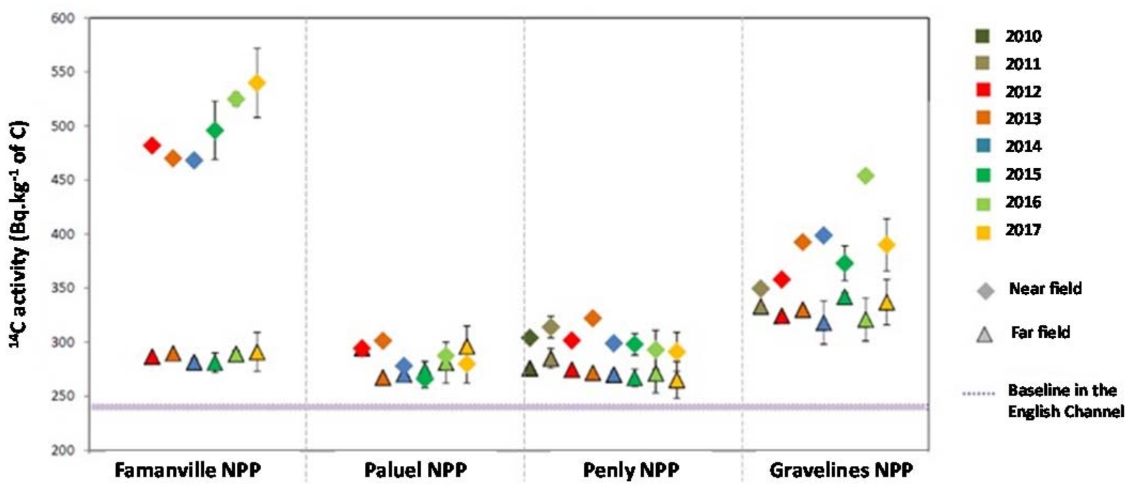


Chart 6 - Temporal variation of Carbon-14 activities in mollusks collected since 2010

in the marine environment of French NPPs.

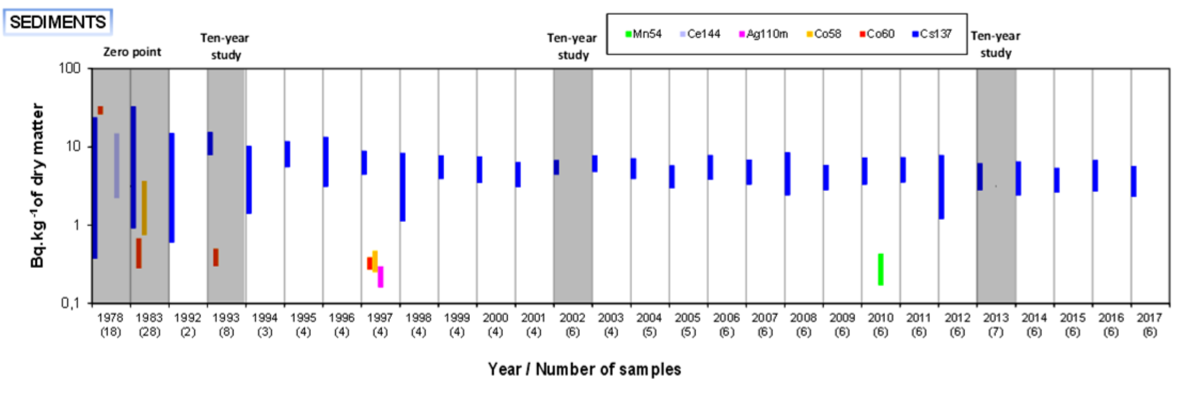
b) Results for NPP located in the Gironde Estuary

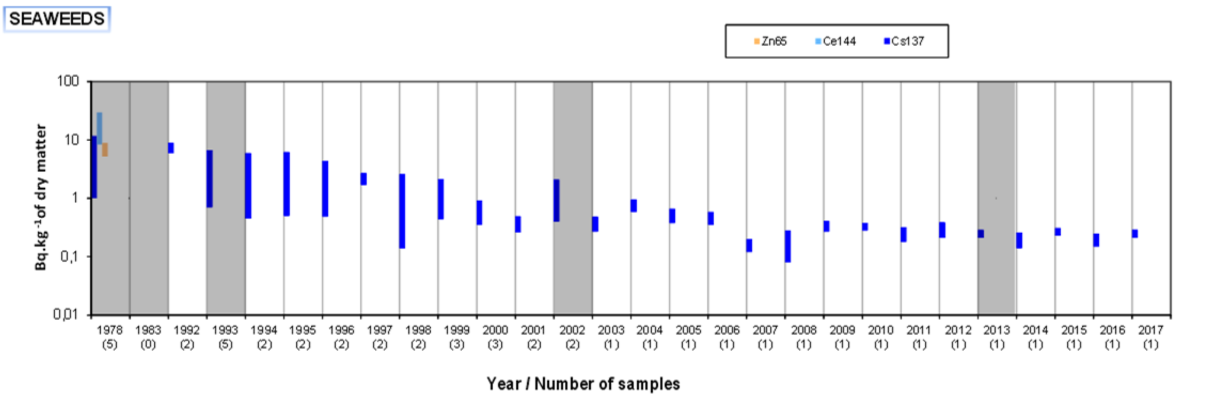
The radioecological monitoring carried out for Le Blayais NPP (Cf. Charts 7) in recent years shows that the radioactivity present in the environment is mainly from a natural origin and that the level of natural radioactivity remains similar to that recorded before the commissioning of the facilities.

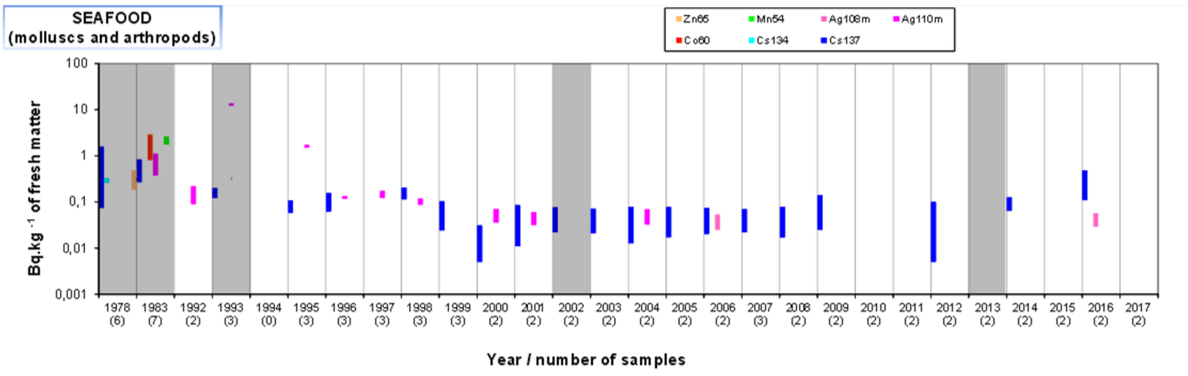
With the exception of traces of Iodine-131 and Cesium-134 detected in mosses in 2011 following the fallout attributable to the Fukushima accident, Cesium-137 is currently the only artificial radionuclide detected in the terrestrial environment over the last decade. It comes mainly from the fallouts of the old atmospheric nuclear tests and the Chernobyl accident. Carbon-14 analysis in samples taken in areas outside and under prevailing winds relative to the atmospheric NPPs discharges reveal activities consistent with ambient background outside industrial influence. Tritium activities (tissue free water Tritium and organically bound Tritium) are consistent with those expected in an environment under no industrial influence.

In the aquatic ecosystem, traces of Cesium-137 are almost systematically present in sediments, plants and fishes, but the activity levels are similar from the fluvial estuary to the lower estuary of Gironde and they do not show any link with a NPP in operation. Its presence is therefore mainly related to the atmospheric fallouts of old nuclear atmospheric tests and the Chernobyl accident fallouts. From time to time, on some samples, other radionuclides like Maganese-54 and Silver-108m have been detected over the last decade. Carbon-14 measurements results are consistent with liquid effluent discharges of Le Blayais' NPP, and potentially those of Golfech NPP, located upstream on the Garonne River. For Tritium (HTO and OBT), activity levels detected are globally in the same order of magnitude than the background excluding local anthropogenic contribution.

The main results are presented in the following tables:







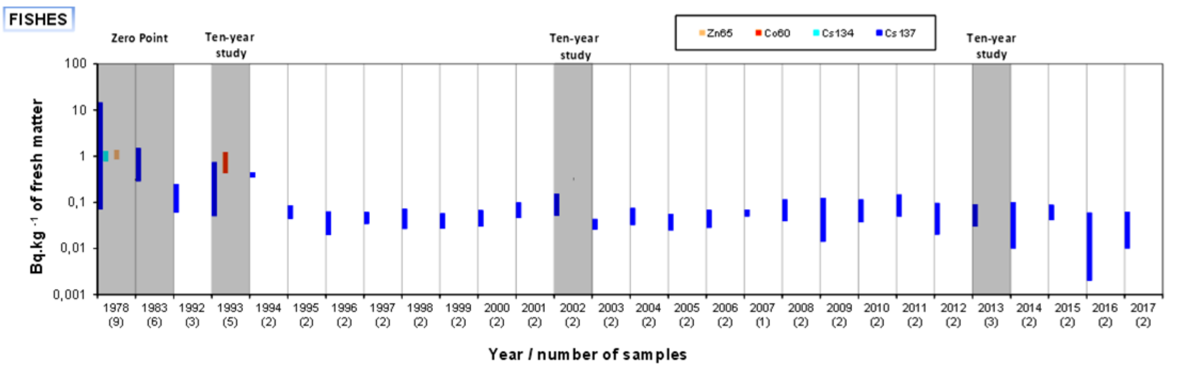


Chart 7 - Temporal variation of activities (minimal and maximal values) of main artificial

γ-emitters radionuclides in sediments, seaweeds, seafood (mollusks and arthropods) and fishes collected in the local marine environment of Blayais NPP.

6.2. *Human dose assessment*

The dosimetric impact assessments of French NPPs radioactive discharges are carried out in accordance with the following steps:

- Step 1: Radioactive discharges characterization and accounting in accordance with the regulation ;
- Step 2: Monitoring and characterization of the environment around the NPP ;

- Step 3: Evaluation of the transfers of the radionuclides discharged to the different environmental compartments (atmospheric, terrestrial, aquatic, agricultural (plants and animals)) to humans ;
- Step 4: Dosimetric impact assessment ;
- Step 5: Results presentation and comparison with the regulatory annual dose limit for the public (1mSv/year as set in the French public Health code).

In Step 1, the annual limits for authorized discharges are considered. In the regulatory orders, the authorizations of discharges are given for families of radionuclides, separately for liquid and atmospheric discharges. There are 4 families of radionuclides for liquid discharges (e.g. Tritium, Carbon-14, FP-AP and Iodine) and five for atmospheric discharges (e.g. Tritium, Carbon-14, FP-AP (others emitters radionuclides), noble gases, Iodine). Nevertheless, the assessment of the dosimetric impact requires more detailed input: it is for example necessary to separate the activity discharged by families of radionuclides, radionuclides by radionuclides, in order to take into account the specific properties of each of them. For this purpose, a reference spectra based on the operating experience of analysis performed on radioactive discharges of all our NPPs is considered.

Steps 2, 3 and 4 involve the use of a specific tool, SYMBIOSE, co-developed by EDF and the French Institute of Radiological protection and Nuclear Safety (IRSN).

Step 2 aims at characterizing the environment around the NPP. The landscape is a representation of the territory which makes it possible to take into account the specificity and the spatial heterogeneity of the local environment.

The landscape is described including the following components:

- The nuclear site, characterized by its points of discharges in marine and atmospheric environments ;
- Terrestrial environment: agricultural areas dedicated to farming, arable crops, grasslands, breeding sites, bare surfaces, villages ;
- The marine environment, in particular to locate the areas of use of the sea by humans (for the beach or swimming for example) closest to the site.

In Step 3, radionuclides transfers into the environment are calculated with a tri-hourly step over a period of 5 years. This duration allows the stabilization of the equations solving the transfer models. Transfer models are common to all radionuclides with the exception of Carbon-14 and Tritium, which are modelled specifically for their particular behavior in the environment. Focusing on the marine environment transfer model, the activity in the seawater, in the bottom sediments and in the sand beach is estimated at some points where humans use to go for bathing activities and/or fishing. The seawater volumic activity is a function of site-specific dilution conditions. The effluents are first diluted in the cooling water from the NPP (1/500 dilution minimum), and then discharged to the sea. This dilution is taken into account via a dilution factor resulting from tracer experiments or evaluations of the thermal plume dispersion in the marine environment. The dilution coefficient in the environment may vary according to the zone considered (fishing zone, bathing area). The calculation also takes into account the exchanges between seawater, sediments and sand. The activity in the edible parts of seafood (fish, crustaceans, shellfishes) is evaluated on the assumption that they are in equilibrium with the marine environment.

In Step 4 and 5, different ways of exposure and three human ages are taken into account. In particular, internal exposure, for which radionuclides enter the body from the surrounding environment, and external exposure, are considered.

The exposure pathways taken into account are:

- For atmospheric discharges:
  - ✓ External exposure to the plume of atmospheric discharges,
  - ✓ External exposure to atmospheric deposition on soils,
  - ✓ Internal exposure by inhalation,
  - ✓ Internal exposure by ingestion of foodstuffs.
- For liquid discharges:
  - ✓ External exposure (swimming, exposure on the beaches),
  - ✓ Internal exposure through ingestion of food (seafood) and of sand or seawater inadvertently.
- Three human ages are considered:
  - ✓ 1-year-old child,
  - ✓ 10-year-old child,
  - ✓ Adult.

The dosimetric impact assessment requires the definition of exposure scenario that are representative of the main population behaviors. This defines a set of human exposure variables, including:

- The food ration, which defines the type and quantity of food ingested by the population. It is accompanied by a self-consumption rate to specify the proportion of locally sourced foods. These data are important and necessary to estimate the dose attributable to ingestion ;
- Respiratory flows, which are defined according to the type of activity practiced (rest, physical activity). These data are needed to evaluate the dose attributable to inhalation ;
- Time budgets, corresponding to the time spent daily by the population to do activities. These data are necessary to evaluate the external and internal exposure of the population by inhalation.

Usually made on a reference group, 2017 exposures have been made on the representative person. According to the COUNCIL DIRECTIVE 2013/59/EURATOM dated 5 December 2013 setting basic safety standards for protection against the hazards arising from exposure to ionizing radiation, the representative person chosen is the person receiving a dose, which is representative of the most exposed persons in the population, excluding people with extreme or rare habits:

- 1-year-old child, 10-year-old child or adult individuals ;
- Residing in a 5 km radius around the site (it is assumed here that the representative person stays all year at home) ;
- Staying on the beaches closest to the discharge points ;
- Practicing swimming at sea near the bathing places closest to the discharge points ;
- Inadvertently ingesting seawater during a swim or sand while staying on the beach ;
- Ingesting local seafood such as fishes, shellfishes and crustaceans caught close to the discharge points, either in a moderate way (average consumption rate) or more significantly (consumption rate associated to the value of the percentile 95).

An exposure scenario corresponding to high consumption of seafood is also considered because of dietary habits specific to seaside NPPs ("large seafood consumer").

For example, the results obtained for the 2017's radioactive liquid discharges for the different sea sided French NPPs concerned by an OSPAR area are presented in the table 10 below:

Table 10 – Doses due to radioactive liquid discharges in 2017.

NPP	Total radioactive liquid discharges (Bq) in 2017	Adult (Sv)		10-year-old Child (Sv)		1-year-old Child (Sv)	
		External exposure	Internal exposure	External exposure	Internal exposure	External exposure	Internal exposure
Flamanville	5,00E+13	4,76E-11	7,82E-08	1,59E-10	4,18E-08	5,91E-11	2,11E-08
Paluel	5,62E+13	2,12E-10	1,94E-07	7,06E-10	1,06E-07	2,63E-10	2,21E-08
Penly	5,81E+13	6,38E-11	3,53E-07	2,13E-10	1,69E-07	7,92E-11	5,05E-08
Gravelines	5,87E+13	1,09E-09	4,16E-07	1,68E-09	2,43E-07	6,27E-10	2,62E-08
Blayais	5,05E+13	8,04E-10	3,41E-07	1,59E-09	1,65E-07	5,93E-10	1,02E-07
Golfech	4,03E+13	2,14E-10	9,16E-08	0,00E+00	7,69E-08	0,00E+00	9,38E-08
Fessenheim	1,13E+13	1,11E-10	8,84E-09	0,00E+00	9,20E-09	0,00E+00	1,38E-08
Cattenom	9,65E+13	2,78E-08	5,18E-06	0,00E+00	6,22E-06	0,00E+00	7,67E-06
Chooz	5,48E+13	1,19E-09	3,34E-07	0,00E+00	3,92E-07	0,00E+00	4,78E-07
Nogent	3,71E+13	6,03E-09	2,36E-07	0,00E+00	2,40E-07	0,00E+00	3,10E-07
Belleville	4,12E+13	1,62E-09	1,93E-07	0,00E+00	2,15E-07	0,00E+00	2,64E-07
Dampierre	4,75E+13	6,32E-09	3,18E-07	0,00E+00	3,44E-07	0,00E+00	4,04E-07
Chinon	4,95E+13	1,69E-09	1,20E-07	0,00E+00	1,06E-07	0,00E+00	1,32E-07
Saint Laurent	2,69E+13	3,07E-09	6,35E-08	0,00E+00	6,63E-08	0,00E+00	9,07E-08
Civaux	5,13E+13	1,78E-09	4,97E-07	0,00E+00	5,12E-07	0,00E+00	7,60E-07

6.3. Biota dose assessment

In addition to the retrospective approach based on the analysis of radioecological monitoring results, an environmental risk assessment is carried out to assess the potential impact of radioactive effluents discharges. The methodology used by EDF is based on the ERICA tool, developed as part of a European research program (ERICA 2004-2007[12]).The ERICA Tool is a software system that has a structure based on the tiered ERICA Integrated Approach to assess the radiological risk to the environment (e.g.: terrestrial, freshwater and marine biota). The Tool guides the user through the assessment process, recording information and decisions and allowing the necessary calculations to be performed to estimate risks to some selected animals and plants.

In the framework of the impact studies for French NPPs, the ERICA tool is used to assess the impact on the aquatic and terrestrial ecosystems of the liquid and atmospheric radioactive discharges. In order to

[12] *The ERICA project (Environmental Risks from Ionizing Contaminants: Assessment and Management) is the result of the joint effort of 15 institutions (including the IRSN) of 7 European countries under the 6th Framework Program for Research and Development funded by the European Union - http://www.erica-tool.com/erica/.*

consider the most disadvantageous scenario, the impact assessment is carried out by considering the annual limits for effluent discharges authorized for one NPP.

The ERICA method relies on three steps based on assumptions with a decreasing degree of conservatism. The more the user progresses in the steps, the more it is possible to include specific ecosystem parameters to make the risk evaluation. The impact assessments for the French NPPs are generally carried out with step 2 of the tool, allowing a calculation of dose per reference organism (RAP) and allowing the addition of radionuclides not basically included in the tool. The method is based on a simplified conceptual model of the receiving ecosystem: The external or internal exposure of each reference organism is established according to its environment (air/soil, air/water and air/sediment). External exposure for the marine ecosystem will be evaluated differently depending on whether the organisms live totally in the sediment (e.g. insect larvae), on the surface of the sediment (e.g. gastropod, crustacean, bivalve shellfishes, etc.), or in the water (e.g. fish, mammal, phytoplankton, etc.). Internal exposure pathways are different according to the organism way of life: for example, the direct and root pathways are considered for plants living in water while inhalation, watering and/or ingestion of living organisms in the same receiving environment (like insect larvae) are considered for animals.

For each risk assessment, the list of species present in the NPP terrestrial and marine environments is consulted to determine whether the generic organisms referenced in the ERICA tool are suitable for assessing the environmental risk of the site. Thus, the morphological, biological and behavioral characteristics of the species present are examined in order to determine if it is possible to associate them with one of the generic organisms integrated in the tool.

The list of radionuclides taken into account for the assessment of the environmental risk is the same that the one used for the assessment of the human dosimetric impact of radioactive liquid discharges. Radionuclides activities in seawater and sediments are calculated by the SYMBIOSE tool (Cf. § 6.2). They correspond to averaged activities (chronic approach). They are determined by considering the annual limits of discharges authorized for each NPP. Thus, the activities calculated from these limits represent the most disadvantageous scenario because they correspond to the maximum amount of radionuclides discharges that can be emitted simultaneously by a NPP.

For all the impact studies carried out to date with the ERICA tool, the environmental impact assessment associated to radioactive liquid discharges into the marine environment, gives risk indices < 1 in all the cases, allowing to conclude that the impact on its environment of the considered NPP under normal operating conditions is negligible.

All impact assessments carried out with the ERICA tool by EDF have received the approval of the Regulator and the public, without questioning the method.

The landscape around Penly NPP (2x1300 MW)

(©EDF- Didier MARC)

The landscape around Civaux NPP (2x1450 MW)

(©EDF- Gilles HUGUET)

PART IV: APPLICATION OF THE B.A.T. TO THE RADIOACTIVE DISCHARGES OF THE CEA PARIS-SACLAY CENTER

SUMMARY

Even if the CEA's discharges cannot be detectable in the marine environment, due to the distance and to the fact they have been already diluted before arriving in the Seine, France is very attentive to the application of the BAT to deal with these discharges.

The program of denuclearization of the site of Fontenay-aux-Roses, which is still currently in progress, includes the cleanup and complete dismantling of the nuclear installations. This process is accompanied by smaller liquid effluent than during the operational phase and will fluctuate around the current level.

Radioactive liquid discharges to the environment have very low radiological activity and their characteristics are within authorized limits. Prior to the discharge, this effluent is treated to reduce its radioactivity. The most active liquid effluents coming from the installations are always in dedicated tanks specific to their nature and activity (truck transport). They are then transferred towards one of three treatment stations of the CEA; two of the three treatment stations being outside the OSPAR region i.e Cadarache and Marcoule and the third one is on Saclay site, which discharges are inside the OSPAR zone. Their subsequent treatment in a dedicated treatment station concentrates a large part of radioactive material into solid waste.

In the site of Saclay, the radioactive liquid effluent treatment station has benefited from a major renovation program during the last decade, which allows the treatment of approximately 1500 m^3 of effluent per year. This installation benefits from best available technologies. It is equipped with a new evaporator benefiting from the latest technical progress and from feedback gained after many years. It benefits also from the new process of solidification of the evaporation concentrats by concreting, to guarantee a better safety towards the risk sets on fire. This new facility has improved the factors of decontamination of the radioactive effluents (more than 10 000 for the main alpha, beta or gamma radionuclide emitters, except the tritium and the carbon 14).

Since the start of the 1990s, there has been also a net reduction in liquid discharges of the site of Saclay, which varies from a factor 5 to 30 depending on the radionuclide or groups of radionuclides considered.

The remaining activity, which is below the authorized limits, can be ultimately discharged to the environment; after numerous controls being performed before and during the discharge and completed by monitoring of the environment. The continuous improvement of the performance of the installations and processes has led to the reduction of discharges into the environment over a number of years.

The exposure of population (defined as reference group in each site) due to annual liquid discharges is estimated for several scenarios every year. This evaluation ends with a value significantly lower than the "trivial" effective dose of 10 micro-Sievert per year and would be ever less when reaching the English Channel.

1 GENERAL INFORMATION REGARDING PARIS-SACLAY CENTER

1.1 New organization of the Paris-Saclay center

Since February 2017, the two French Alternative Energies and Atomic Energy Commission (CEA) former centers of Saclay and Fontenay-aux-Roses have become a unique center called CEA Paris-Saclay. Both sites have been merged together to develop their programs more effectively and to increase their visibility within Paris-Saclay University. This dynamic is based on a common environmental policy aimed at taking a proactive approach to achieve convincing results in terms of prevention, energy saving and reducing the environmental marking of its activities on each site.

1.2 Common features regarding discharges

The CEA Paris-Saclay center ensures compliance with each of the Fontenay-aux-Roses and Saclay sites with their ministerial orders and resolution, that define prescriptions relative to discharge limits and their control, as well as environmental monitoring. This monitoring is based on continuous and delayed measurements of several radiological parameters in the various compartments of the environment, particularly surface water.

The measures are performed by qualified technicians in the laboratories of SPRE (Radiation Protection and Environmental Monitoring Service).

The results of the radiological analyzes carried out on the environmental samples are put on line on the website of the RNM (The national network for environmental radioactivity measurement).

Note: for the Fontenay-aux-Roses site, traces of tritium measured in the liquid effluents come mainly from the tritium background in the drinking water network (Seine water) delivered to the site. This tritium concertation activity is also observable at the Saclay site.

1.3 Quality assurance systems for data retention and management

The Paris-Saclay center has been certified in 2018 for quality according to ISO 9001/2015-AFAQ n°2013/55750.3 for the following activities:

- Technical and safety support by the center's support units: maintenance, information and telecommunication system management, conventional waste management, technical and scientific information, radioprotection and environmental monitoring, on-site service in case of accident, logistics, security, reception and medical supervision, and
- Administrative support: procurement, training and employee management, accounting and financial management for units and facilities of the center.

It should be noted that before merging the two sites, Saclay was certified ISO 9001 since 2004 and Fontenay-aux-Roses since 2010.

1.4 Quality assurance systems for the environmental monitoring

The Paris-Saclay center has been certified in 2018 for its environmental management system according to ISO 14001/2015-AFAQ n° 2013/55751.3 for the following activities :

- Research and development in nuclear energy,
- Operation of facilities,
- Clean up and dismantling of nuclear facilities,
- Research in climate and materials sciences,
- Research in life sciences (Saclay site only) and technological research,
- Teaching,
- Security,
- Administrative and technical support,

PART IV: APPLICATION OF THE B.A.T. TO THE RADIOACTIVE DISCHARGES OF THE CEA PARIS-SACLAY CENTER

SUMMARY

Even if the CEA's discharges cannot be detectable in the marine environment, due to the distance and to the fact they have been already diluted before arriving in the Seine, France is very attentive to the application of the BAT to deal with these discharges.

The program of denuclearization of the site of Fontenay-aux-Roses, which is still currently in progress, includes the cleanup and complete dismantling of the nuclear installations. This process is accompanied by smaller liquid effluent than during the operational phase and will fluctuate around the current level.

Radioactive liquid discharges to the environment have very low radiological activity and their characteristics are within authorized limits. Prior to the discharge, this effluent is treated to reduce its radioactivity. The most active liquid effluents coming from the installations are always in dedicated tanks specific to their nature and activity (truck transport). They are then transferred towards one of three treatment stations of the CEA; two of the three treatment stations being outside the OSPAR region i.e Cadarache and Marcoule and the third one is on Saclay site, which discharges are inside the OSPAR zone. Their subsequent treatment in a dedicated treatment station concentrates a large part of radioactive material into solid waste.

In the site of Saclay, the radioactive liquid effluent treatment station has benefited from a major renovation program during the last decade, which allows the treatment of approximately 1500 m^3 of effluent per year. This installation benefits from best available technologies. It is equipped with a new evaporator benefiting from the latest technical progress and from feedback gained after many years. It benefits also from the new process of solidification of the evaporation concentrats by concreting, to guarantee a better safety towards the risk sets on fire. This new facility has improved the factors of decontamination of the radioactive effluents (more than 10 000 for the main alpha, beta or gamma radionuclide emitters, except the tritium and the carbon 14).

Since the start of the 1990s, there has been also a net reduction in liquid discharges of the site of Saclay, which varies from a factor 5 to 30 depending on the radionuclide or groups of radionuclides considered.

The remaining activity, which is below the authorized limits, can be ultimately discharged to the environment; after numerous controls being performed before and during the discharge and completed by monitoring of the environment. The continuous improvement of the performance of the installations and processes has led to the reduction of discharges into the environment over a number of years.

The exposure of population (defined as reference group in each site) due to annual liquid discharges is estimated for several scenarios every year. This evaluation ends with a value significantly lower than the "trivial" effective dose of 10 micro-Sievert per year and would be ever less when reaching the English Channel.

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- Teaching,
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- Administrative and technical support,

- Environmental monitoring,
- Clean up of former facilities.

The testing laboratories are COFRAC (French committee of accreditation) accredited according to standard NF EN ISO/IEC 17025 and the other technical standards in force. The environmental monitoring laboratories has approvals delivered by the French Nuclear Safety Authority to provide environmental radioactivity measurements which are performed as part of the national measurement network (Ministerial order of July 8, 2008).

1.5 Quality assurance systems for dose estimates

For radiological impact calculations, the CEA uses expertise developed by it center of expertise, within its Analysis, Surveillance and Environment Department (DASE), located on the Bruyères-le-Châtel site.

Doses are estimated using the "ABRICOT" code, employing a source term which corresponds to the effective discharges.

1.6 Relevant information not covered by the following headings

The CEA Paris-Saclay center compiles an annual public report (one for each site of Fontenay-aux-Roses and Saclay) containing in particular the provisions for safety and radiological protection in the BNI, as well as the results of measurements of discharges and their impact on the environment. The publication of these annual reports called "transparency and nuclear safety” reports is established in accordance with article L.125-15 of the Environmental Code for its BNIs.

Local information commission (CLI), an authority for information, dialogue and follow-up, is chaired by the President of the Essonne General Council for the Saclay site and by the President of the Hauts-de-Seine General Council for the Fontenay-aux-Roses site.

CEA participates to the work undertaken by the Tritium White Paper. In particular, CEA Saclay undertook a characterization of releases based on specific measurements to identify physicochemical forms of tritium in effluents. CEA contributes also to this work through development of methods through its Analysis method establishment Committee (CETAMA).

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2 FONTENAY-AUX-ROSES SITE

2.1 SITE CHARACTERISTICS

2.1.1 Type of facility

The Fontenay-aux-Roses site is the first historical site of CEA, established since 1946. It hosted a wide range of research and development activities in the nuclear field, whether for safety, security, radioprotection, robotics and finally biomedical research. Today, its activities are mainly devoted to life sciences around themes placed at the heart of societal concerns such as radiobiology, toxicology, neurovirology and neurodegenerative diseases. With nearly 300 researchers, the scientific production of the three institutes devoted to biomedical research gives the site a scientific influence of international scale. The Fontenay-aux-Roses site is currently heavily involved with two major projects for the fight against infectious diseases and neuroscience.

2.1.2 Start of operations and decommissioning

Since 1946, several generations of nuclear facility have been constructed in the site of Fontenay-aux-Roses. They were in operation until their gradual decommissioning occurred between 1982 and 1995. Up until 2006, there were 4 Basic Nuclear Installations (BNI) on the site. Since then, only 2 BNI remain:

- BNI 165 known as "BNI procédé" (Process-BNI),
- BNI 166 known as "BNI support" (Support-BNI).

Figure 1 : Dismantling of building (BNI 165) © CEA

2.1.3 Location

The CEA Fontenay-aux-Roses site is located several kilometers south from Paris and about 150 kilometers from the Manche (English Channel), with average coordinates of latitude 48°78’ North and longitude 2°28’ East. The site is located in the district of Fontenay-aux-Roses (Department 92).

2.1.4 Receiving waters and catchment area

All of the radioactive effluents are stored and then evacuated following processes which depend on the specific nuclear sector concerned.

Liquid effluents which are likely to contain traces of radioactivity are stored in the laboratory's tanks. These effluents are inspected before authorization for discharge.

Note that effluents from the Fontenay-aux-Roses site are not directly discharged into the environment, but are transferred to public sewage network and end at the waste water treatment is granted. For simplicity of reading, the term of discharge is used, even if it is a transfer.

These discharge are realized in accordance with the ministerial order of March 30, 1988 relating to the authorizations for the discharge of liquid radioactive effluents by the nuclear industry research site of Fontenay-aux-Roses. This authorization is being currently under review.

Monitoring programs for liquid effluent discharges, put in place for CEA Fontenay-aux-Roses site, also comply with the regulation on authorization of discharges of non-domestic wastewater from this site into the public sewage network of the Department of Hauts-de-Seine. This prefectoral order, dated March 1st, 2011, was established by the Hauts-de-Seine General Council.

The characteristics of the effluents are conform to the prescriptions defined in these ministerial orders. The discharge is made directly into the communal and departmental sewerage systems, following the methods defined in the effluent instructions of the site; these internal specifications define the procedures that must be followed in order that the prescriptions are adhered to. The waters are then transferred to the purification plant at Achères (30 km from the site), which then discharges the treated effluent into the Seine.

2.1.5 Production

The site is dedicated to research. There are no research reactors active on the site.

2.2 DISCHARGES

2.2.1 Systems in place to reduce, prevent or eliminate discharges and emissions

Both the methodology applied for cleanup, waste management procedures as specified in waste studies and the waste directives of the site contribute to the overall reduction of discharges and emissions.

With regard to liquid discharges:

- The SABINE facility (Station d’Assainissement des Boues Issues du Nettoyage des Egouts – Sewage plant for the cleansing of slurry resulting from the cleaning of sewers), created in 1993, is used to treat slurry resulting from cleaning of the sewer network at the site, from the bottom of the tanks and the underground technical galleries. The slurry effluents are collected by hydro-cleaning and then treated by settling filtration. The dehydrated slurries and clarified effluents are then directed towards the appropriate waste management processes.
- The retention tanks were created in 2003 and 2004 in order to recover any water used for extinguishing a fire in one of the BNI (the retention tanks are sized to be able to recover water used in the most serious extinguishing scenario conceivable).

Figure 2 : The SABINE facility at Fontenay-aux-Roses site © CEA

The program of denuclearization of the site, which is currently in progress, will include the cleanup and complete dismantling of the BNI. This process will be accompanied by smaller liquid discharges discharge than during the operational phase and will fluctuate around the current level.

2.2.2 Efficiency of the abatement systems

Annually, the SABINE facility produces on average around 5 m^3 of very low level activity waste (dehydrated slurries) and 100 m^3 of liquid effluents which are discharged into the public sewage network (after control according to the waste directives of the site).

2.2.3 Target values for releases from the site

The CEA site of Fontenay-aux-Roses has authorization for its liquid discharges, which is currently under review.

2.2.4 Annual liquid discharges

The annual liquid discharge activities are summarized in the table below. Note that Fontenay-aux-Roses site is declared to OSPAR among historical or legacy wastes (exceptional discharges).

Discharges in GBq	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Total alpha	1,00E-03	1,50E-04	1,30E-04	4,50E-04	1,80E-04	1,90E-04
Total bêta *	4,00E-03	2,50E-04	3,00E-04	3,40E-04	2,00E-04	2,70E-04
Tritium	8,00E-03	6,00E-03	5,00E-03	5,30E-03	3,40E-03	5,20E-03
^{14}C	< 0,0028	< 0,0024	< 0,0024	< 0,0024	< 0,0015	< 0,0019

*The variations observed result from the diversity of cleanup and dismantling works for the facilities.

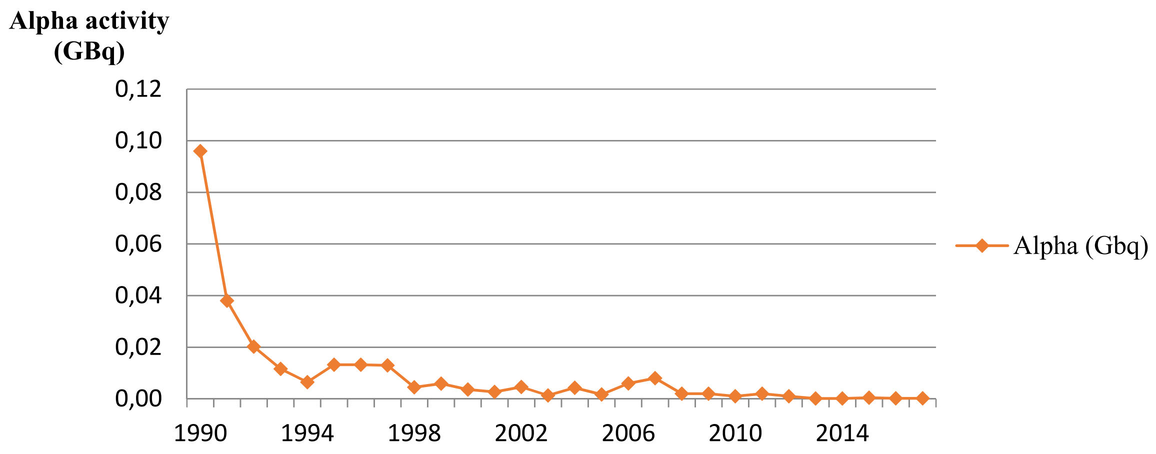

Figure 3 : Temporal variation of alpha activity at Fontenay-aux-Roses site

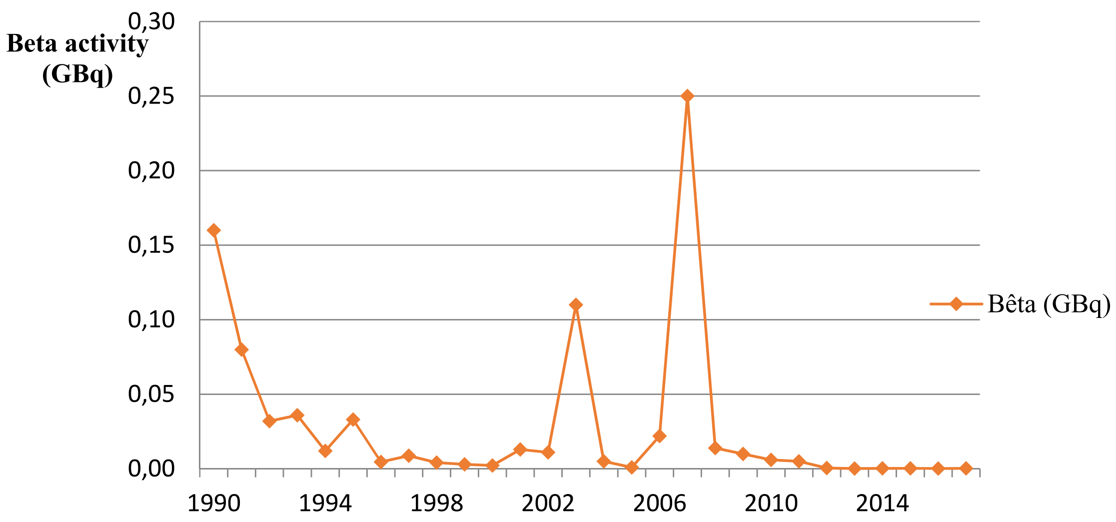

Figure 4 : Temporal variation of beta activity at Fontenay-aux-Roses

The peaks recorded in 2003 (in August) and 2007 (in June and September) are linked to exceptional releases of beta-radionuclides from a vessel in Building 18 of INB 165. These released are exceptional releases during the dismantling operations.

These discharges were carried out in accordance with the requirements of the ministerial order of March 30, 1988 relating to the discharge of liquid effluents on the site of Fontenay-aux-Roses. The annual beta activity released in 2003 and 2007 remains well below the limit values imposed.

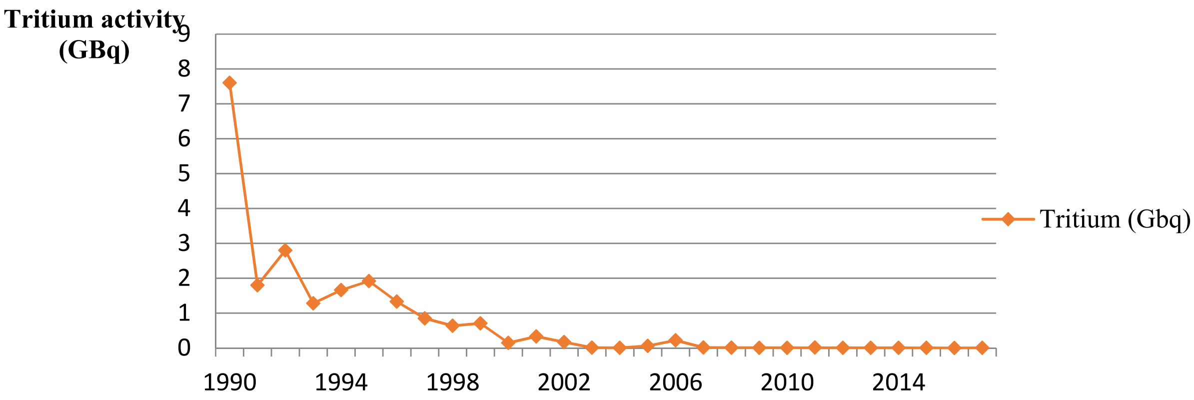

Figure 5 : Temporal variation of tritium activity at Fontenay-aux-Roses

2.2.5 *Summary evaluation*

Criterion	Evaluation
MTD/MPE indicators:	
Relevant systems put in place	Relevant systems
Decontamination or abatement factor	Effective systems
Downward trend in discharges	The downward trend has been significant for more than 10 years. There are no more BNI in operation.
Comparison with values recorded by similar facilities	Not applicable
Relevance and reliability of the quality assurance systems	Relevant quality assurance systems
Relevance of the target	Yes
Comprehensive nature of the data communicated	Yes
Reasons for variation compared to the indicators	Not applicable
Uncertainties	Determined
Other information	Not applicable

2.3 *ENVIRONMENTAL IMPACT*

2.3.1 Concentration of radionuclides in environmental samples

The CEA site of Fontenay-aux-Roses does not discharge directly into the marine environment, but rather into the Seine after passing through the purification plant at Achères, via the water sewerage network.

The large dilution which occurs, *by a factor of order 50,000*, between the transfer into the urban sewage water network (20 m^3/h or 5.5 E-03 $m^3.s^{-1}$ on average) and discharge into the Seine (mean flow of 1.00 E+06 m^3/h or 278 $m^3.s^{-1}$) should be noted. If the mean flow at the mouth of the seine (1.0 E+07 m^3/h or 2780 m^3/s) is also considered, then *the dilution factor increased to 500,000*.

By considering the values measured during the last years, from 2013 to 2017, the concentration of radionuclides added to the urban sewage water network, downstream of the site, is seen to be on average of order 1,5 $Bq.m^{-3}$ for alpha and 2 $Bq.m^{-3}$ for beta emitters, and 30 $Bq.m^{-3}$ for Tritium. The ^{14}C is not take in consideration for beta emitters because it is always under detection limit.

At the mouth of the Seine, taking account of the dilution factor, the concentrations will have been of order 3,0 E-06 $Bq.m^{-3}$ for alpha emitters, 4,0 E-06 $Bq.m^{-3}$ for beta emitters and 6,0 E-05 $Bq.m^{-3}$ for tritium.

2.3.2 Environmental monitoring program

The environmental monitoring program is described in the monitoring plan which defined the requirements of the ministerial order of March 30, 1988.

For liquid discharges, continuous monitoring is performed on effluents passing into the site's two drainage channels and from these into the urban sewage downstream from all the outflow points at the site. There are similar checks on the groundwater, re-emergence points and lakes.

Sampling frequencies are varied and range from daily sampling to annual sampling.

The number of annual samplings is around 1000; these are taken from the urban sewers, water mains, drainage channels, groundwater, re-emergence points, surface water and rainwater. The measurements performed on the samples amounted to a total of around 4100 analyses per year; these are mainly for analysis of the total alpha and beta counts as well as tritium and carbon-14 analyses.

2.3.3 Summary evaluation

Criterion	**Evaluation**
MTD/MPE indicators:	
Downward trends in the concentrations	Effective downward trends since the shutdown of the BNI
Relevance of the environmental monitoring programme	Relevant programme
Relevance and reliability of the quality assurance systems	Appropriate and reliable systems
Comprehensive nature of the data communicated	Yes
Reasons for variation compared to the indicators	Not applicable
Uncertainties	Determined
Other information	Not applicable

2.4 IONISING RADIATION DOSES RECEIVED BY THE PUBLIC

2.4.1 Mean annual doses for individuals from the reference group

For the period considered, the estimate of the annual dose due to liquid discharges for each local reference group remains, for each site of the CEA, well below the "trivial" (according to publications 10[3] and 10[4] of the International Commission on Radiological Protection) effective dose of 10 micro-Sievert per year. This estimate decreases by several orders of magnitude, if one takes into account the dilution of radionuclides into the Seine at the mouth of the English Channel.

2.4.2 Definition of the reference group

The reference group is made up of individuals working eight hours per day in the fields fertilized with slurries from the purification plant at Achères and irrigated with water from the Seine.

2.4.3 Exposure routes considered

It is assumed that all radioactivity discharged by the CEA site at Fontenay-aux-Roses reaches the Achères purification plant. The individuals in the reference group:

- Exclusively consume products cultivated in these fields,
- Consume fish caught in the Seine downstream from Achères,
- Drink reprocessed water from the Seine.

Note: no allowance is made for any radioactivity in the Seine due to natural radioactive elements or due to radioisotopes coming from other facilities.

3 SACLAY SITE

3.1 SITE CHARACTERISTICS

The CEA Saclay site, with 5000 researchers, is the largest of the CEA sites. Located on an area of around 150 hectares, it houses research and innovation of the highest quality on the national and European scales. It is characterised by a wide diversity of activities, ranging from fundamental research to applied research in very varied areas and disciplines, such as astrophysics, nuclear physics, particle physics, metallurgy, electronics, biology, nuclear medicine, pharmacology, climatology, numerical simulation, chemistry and the environment.

Five primary research directions are pursued there: research in physical sciences, nuclear applications research, health research, technological research and studies of the environment. The CEA Saclay site also houses the National Institute for Nuclear Science and Technology (INSTN) whose mission is focused on higher education and training.

3.1.1 Type of facility

The CEA Saclay site has eight basic nuclear installations (BNI) and around 80 facilities, mostly classified for environmental protection (ICPE); these are the research laboratories. The eight BNI are the following :

- Two open pool-type research reactors of which one is now in the dismantling phase and one teaching reactor, the latter being permanently shut down,
- One reactor for training, being dismantled,
- Two high-level activity laboratories for the study of irradiated materials, of which one is now in the dismantling phase,
- Two reprocessing facilities for radioactive liquid effluent and solid radioactive waste,
- One irradiation facility with a mission to study radiosterilisation of products intended for medical use.

The company CURIUM/CIS Bio International is situated on the edge of the site. It manufactures and sells radiopharmaceutical products for medical use and contains an BNI.

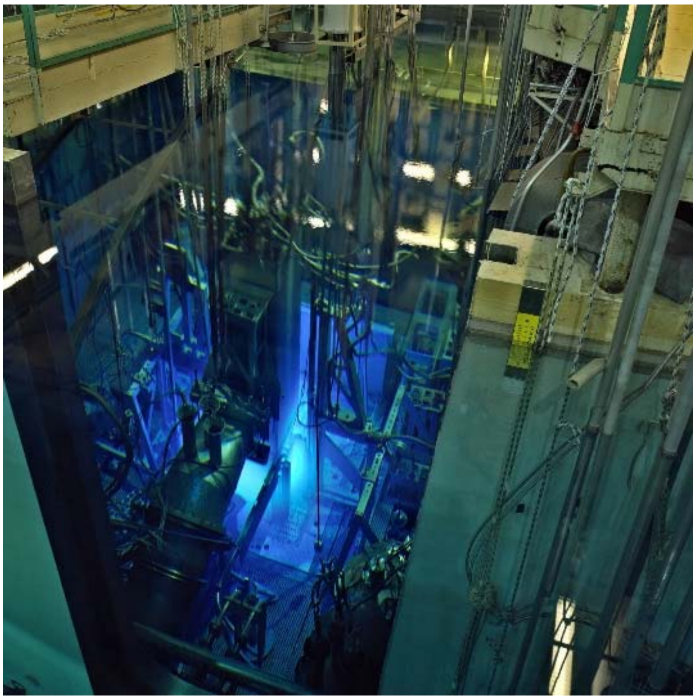

Figure 6: The CEA's OSIRIS and ORPHEE reactors © CEA

3.1.2 *Start of operations and decommissioning*

Research was first performed at CEA Saclay site at the start of the 1950s. The key dates for the 8 BNI at the site are the following:

BNI	Type of installation	Authorization of commissioning	Shut down	Decree of final shutdown and dismantling
40 - OSIRIS	Research reactor	8th June 1966	16th December 2015	-
101 – ORPHEE	Research reactor	21th March 1978	End of 2019	-
18 - ULYSSE	Teaching research reactor	23th July 1961*	9th February 2007	18th August 2014**
49 - LHA	High-level activity laboratory	1954*	February 1996	18th September 2008
50 - LECI	Irradiated fuel research laboratory	November 1959*	-	-
35 - STELLA	Radioactive liquid effluent reprocessing and management area	1958*	-	-
72 – Zone de gestion de déchets radioactifs solides (ZGDS)	Solid radioactive waste management area	14th June 1971	-	-
77 - POSEIDON	Irradiation facility	7th August 1972	-	-

* Date of achievment

** Implementation within 5 years

3.1.3 *Location*

The CEA Saclay site is located around 20 km south-west of Paris, with average coordinates of latitude °43’ North and longitude 2°09’ East.

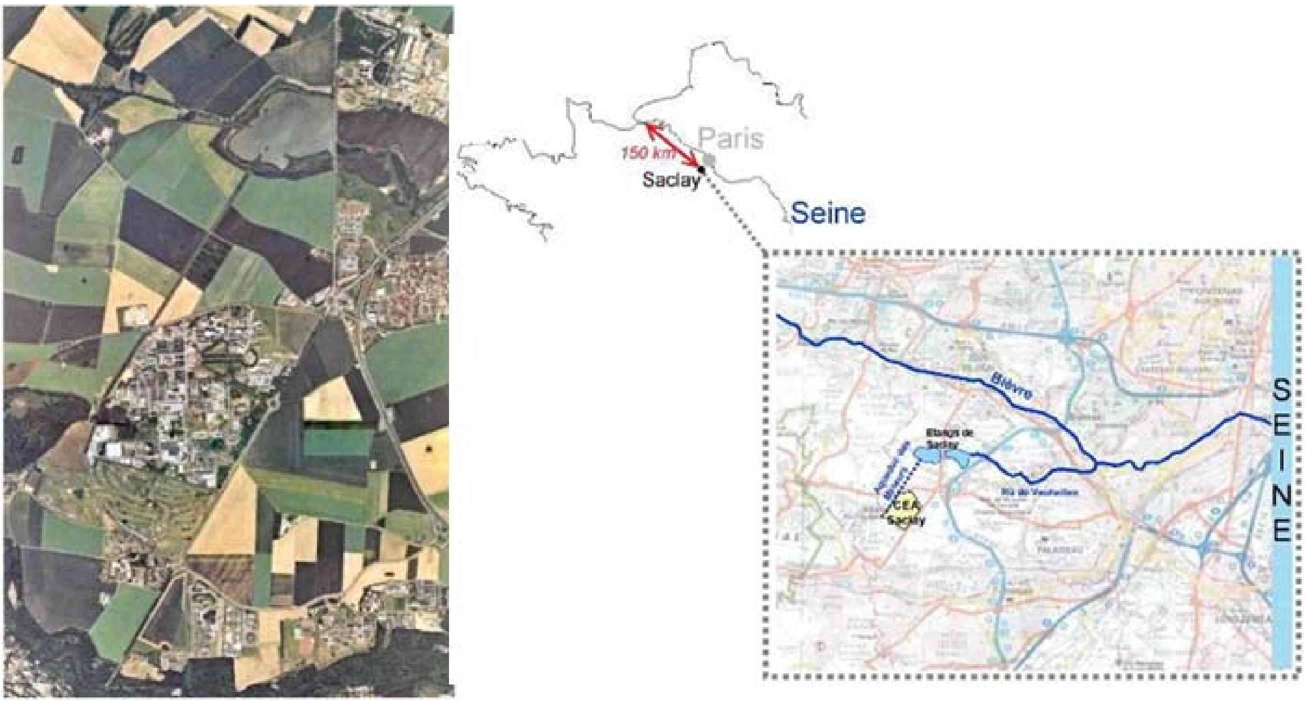

Figure 7: Aerial view and geolocation of Saclay site © CEA

3.1.4 Receiving waters and catchment area

The industrial waste water produced by the CEA Saclay site is sent, after treatment, into the Saclay ponds, from where the waters flow on into the ru de Vauhallan and then into the Bièvre and the Seine before finally reaching the English Channel. The dilution factor at the mouth of the Seine, when compared to the mean flow of industrial water produced, is around 50,000.

Figure 8: Aerial view of the Saclay site and the ponds © CEA

3.1.5 Production

The ORPHEE reactor has a power of 14 MW (th). No energy production (heat or electricity) is coming from this reactor.

3.1.6 <u>Other relevant information</u>

Radioactive liquid effluents, produced by the various facilities at CEA's Saclay site, are collected exclusively in dedicated tanks, or drums in the case of small producers. For this type of effluent, there is no network of channels on the site which could carry it to a direct or indirect discharge point. Rather, these effluents are transported in special road tankers to the radioactive liquid effluent treatment station, which is part of BNI 35 known as STELLA, and are treated there, most of the time. After a very major renovation program including, in particular, the commissioning of a new evaporator and a new cementation workshop, the facility has started in 2011 for radioactive effluent treatment. The volumes treated could range between 0 and 1000 m^3 per year.

Figure 9: View of the STELLA facility© CEA

Figure 10: Evaporator at the STELLA facility © CEA

3.2 DISCHARGES

3.2.1 <u>Systems in place to reduce, prevent or eliminate discharges and emissions</u>

Apart from the radioactive liquid effluent treatment station referred above, which has units for distillation of effluents and cementation of salts which concentrate the radioactivity (figured in orange below), the CEA Saclay site also possesses:

- A facility which includes processes of neutralisation, settling, pre-chlorination, coagulation, filtration through sand, neutralisation by sodium hydroxide and post chlorination. It treats industrial effluents coming from the various laboratories and for produces recycled water starting with the majority of these processed effluents, which is intended to reduce consumption of drinking water by supplying the cooling circuits of the research reactors and the various facilities;
- A sewage plant (settlement, digestion, biological treatment, clarification) which has been replaced in 2012 by a new one (membrane filter type). This sewage plant treats only the sanitary effluents of the site.

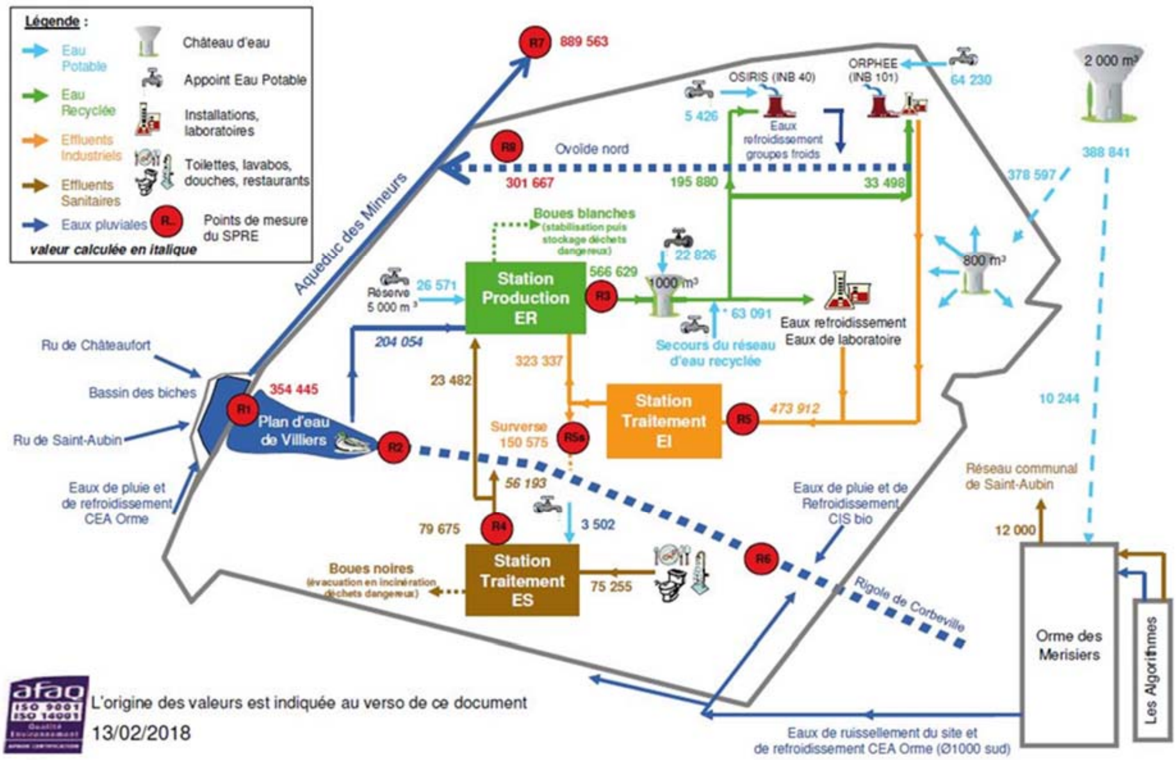

Figure 11: Water cycle at Saclay site (2017 data) © CEA

3.2.2 *Efficiency of the abatement systems*

The decontamination factor for radioactive liquid effluent is around 1.0 E+04, except for tritium and carbon-14. Tritiated and/or carbon effluents, separately collected, can be added to the cement after distillation. The cement fixes the radioactive concentrates.

3.2.3 *Target values for releases from the site*

The CEA Saclay site requires authorisation for its liquid discharges, which was modified in 2009. The table below shows the annual authorised liquid discharges in force since 25 September 2009.

Depending on the category of radionuclides, the reduction factor of the new prescriptions on discharges, compared to those previously in force, lies between 4 and 30.

	Radionuclides	**Annual authorisations**
Liquid releases	H-3	250 GBq
	Alpha emitters	0.2 GBq
	C-14	2 GBq
	Other beta-gamma emitters	0.5 GBq

3.2.4 *Annual liquid discharges*

The total annual liquid discharges from the CEA Saclay site (including those from CURIUM/CIS Bio International) are presented in the table below for the period 2012-2017. Note that Saclay site is declared to OSPAR among research and development facilities (operational discharges).

Discharges in GBq	2012	2013	2014	2015	2016	2017
H-3	10	12	17	13	16	8.3
Total alpha *	< 0.040	< 0.049	< 0.049	<0.046	<0.041	<0.040
C-14	0.045	0.074	0.066	0.070	0.11	0.081
Other radionuclides (Beta gamma emitters without H-3 and C-14)	0.004	0.011	0.011	0.010	0.016	0.012

* The actual discharges of α-emitters are very low: total activity of Pu-238+239+240 + Am-241 is less than 1.0 E-03 GBq in 2017.

Pure beta emitters essentially consist of carbon-14 (> 95%). Since 2010 a new C-14 measurement method with a lower detection limit has been implemented.

As demonstrated by the plots showing the monitored changes in discharges over time of tritium, gamma emitters and pure beta emitters, it can be seen that since the start of the 1990s there has been a net reduction in liquid discharges which varies from a factor of 5 to 30 depending on the radionuclide, or groups of radionuclides, considered.

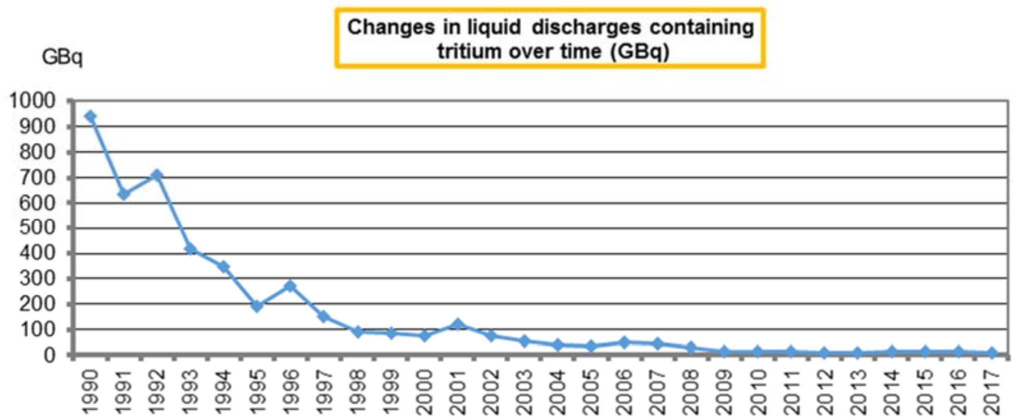

Figure 12: Temporal variation of tritium at Saclay site

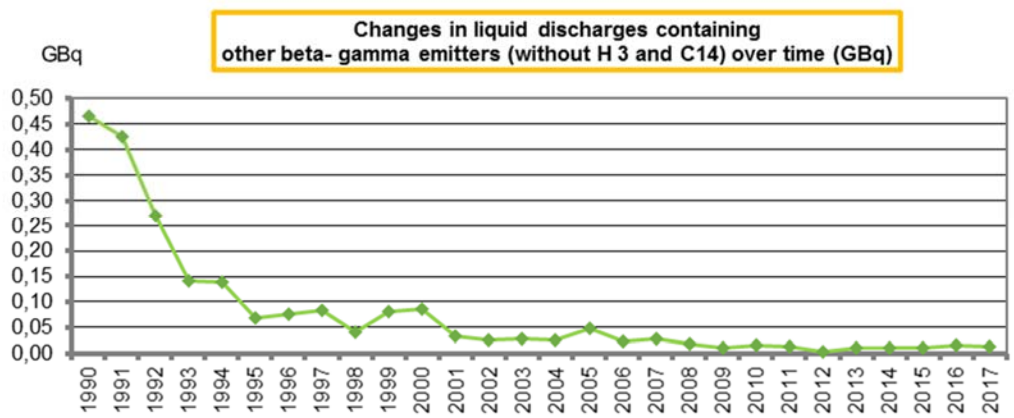

Figure 13: Temporal variation of other beta-gamma emitters (without H^3 and C^{14}) at Saclay site

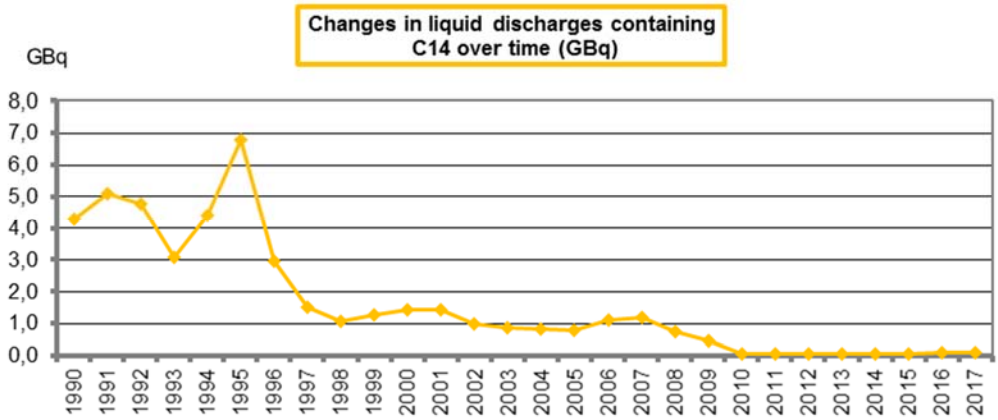

Figure 14: Temporal variation of C^{14} at Saclay site

3.2.5 *Summary evaluation*

Criterion	Evaluation
MTD/MPE indicators	
Relevant systems put in place	Relevant systems
Decontamination or abatement factor	Effective systems
Downward trend in discharges	The downward trend is significant: depending on the radionuclide, reductions by a factor of between 10 and 100 over 30 years, and between 5 and 30 since 1990.
Comparison with values recorded by	Not applicable
Relevance and reliability of the quality assurance systems	Relevant quality assurance systems
Relevance of the target	Yes
Comprehensive nature of the data communicated	Yes
Reasons for variation compared to the indicators	Not applicable
Uncertainties	Determined
Other information	Not applicable

3.3 ENVIRONMENTAL IMPACT

3.3.1 Concentration of radionuclides in environmental samples

The water from CEA Saclay site discharged into the natural environment after treatment, flows into the Etang vieux and the Etang neuf at Saclay, and then along the ru de Vauhallan into the Bièvre, before flowing into the Seine.

Their radionuclide concentration is very low, as shown in the following table. The levels of Cs-137 are comparable, moreover, to those observed in the North Atlantic.

Concentrations in Bq/l	**H-3**	**Sr-90**	**Cs-137**	**Pu-239+240**
Water flowing into the Etang neuf at Saclay (annual average 2016)	6.5	0.002	< 0.8.E-03	< 2.9 E-06

3.3.2 Environmental monitoring program

Environmental monitoring is considered locally through samples taken from physical environment and local biotope (surface water, deep water, sediment, aquatic flora, fish) and is carried out over a radius of around 5 km.

This monitoring produces around 9000 samples annually requiring more than 24,000 radiological measurements.

Over all the results, only a light tritium effect is perceptible locally in the environment.

3.3.3 Summary evaluation

Criterion	**Evaluation**
MTD/MPE indicators :	
Downward trends in the concentrations	Effective downward trend
Relevance of the environmental monitoring programme	Relevant programme redefined by a prefectural order of 25/09/09
Relevance and reliability of the quality assurance systems	Appropriate and reliable systems
Comprehensive nature of the data communicated	Yes
Reasons for variation compared to the indicators	Not applicable
Uncertainties	Determined
Other information	Not applicable

3.4 IONISING RADIATION DOSES RECEIVED BY THE PUBLIC

3.4.1 Mean annual doses for individuals from the reference group

The local impact of liquid discharges is very low. For the period considered, the estimate of the annual dose due to liquid discharges for each local reference group remains, for each site of the CEA, is well below the "trivial" effective dose of 10 microsievert / year. This estimate decreases by several orders of magnitude, if one takes into account the dilution of radionuclides into the Seine at the mouth of the English Channel.

Given that the mean flow entering the ponds at Saclay is order 0.05 m3/s and that the mean flow at the mouth of the Seine is around 2500 m^3/s, it can be deduced that there is a dilution factor of order 50,000. The effect on concentrations of radionuclides discharged by the CEA Saclay site is therefore very low compared to the concentrations of the same radionuclides already present in the waters of the North Atlantic, which come from the fallout of worldwide airborne nuclear tests.

3.4.2 Definition of the reference group

The group consists of fishermen who consume 8 kg of fish per year from the pond, 2 liters of water per day from groundwater of the ponds and the agricultural products irrigated by the groundwater of the ponds.

3.4.3 Exposure routes considered

There are two categories of transfer modes:

- The first results from the exploitation of the local hydrological environment for the production of drinking water and the consumption of fish,
- The second results from the watering of ponds with agricultural products that are intended for human or animal consumption.

These transfer routes essentially lead to internal exposure by ingestion. However, watering can also lead to external exposure due to deposits and internal inhalation exposure related to re-suspension of deposits.

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