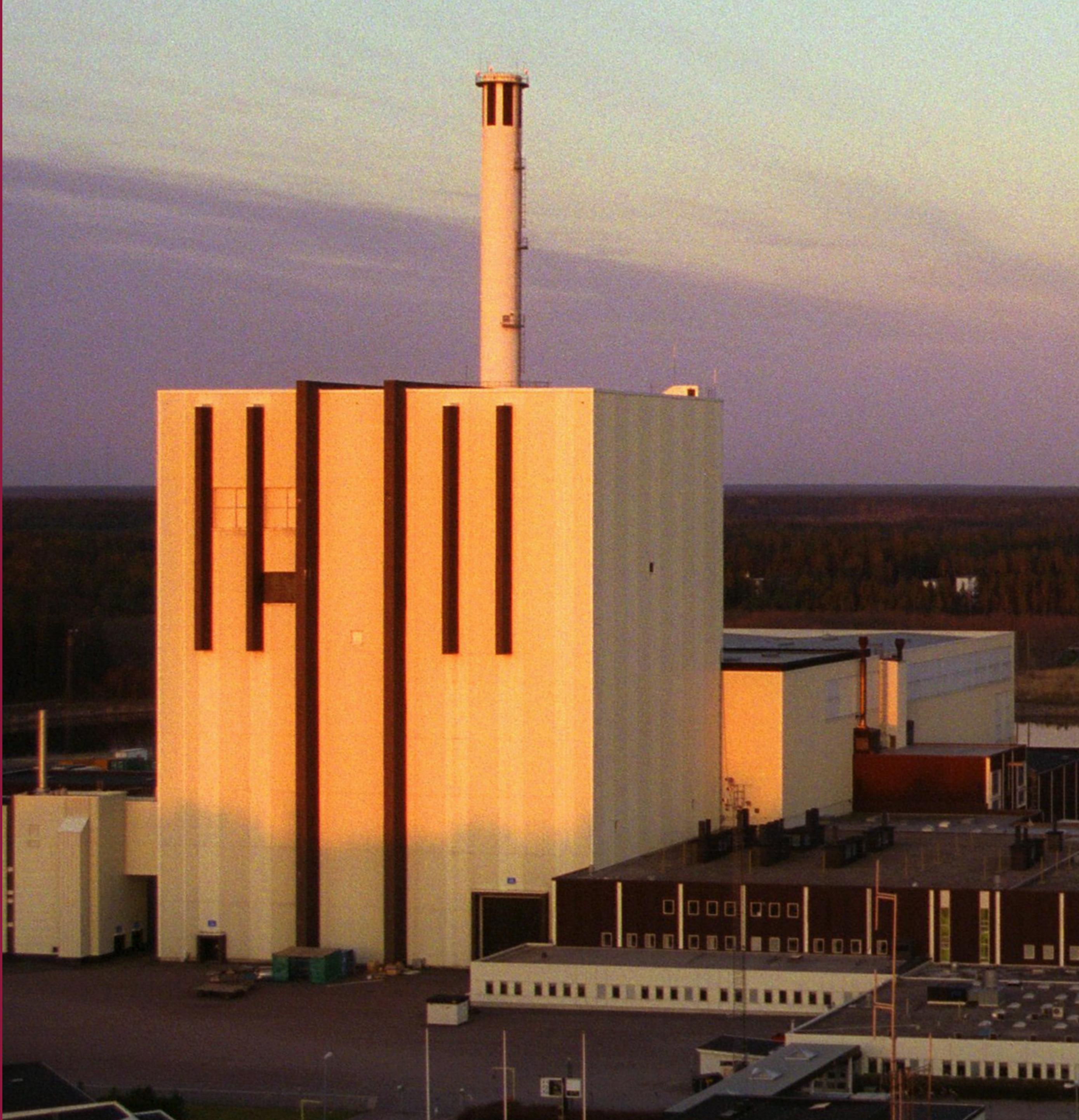
OSPAR COMMISSION

Fourth Periodic Evaluation of Progress Towards the Objective of the OSPAR Radioactive Substances Strategy



2016

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Executive Summary

The Fourth Periodic Evaluation builds on the previous periodic evaluations to assess progress that OSPAR Contracting Parties have made in reducing discharges of radioactive substances to the North-East Atlantic, in order to meet the objective of the OSPAR Radioactive Substances Strategy (RSS

This Fourth Periodic Evaluation focusses on radioactive discharges from the nuclear and non-nuclear sectors. For the nuclear sector, discharges from the chosen assessment period 2007 to 2013 have been compared with data for the baseline period (1995–2001). While environmental concentration data have not been considered in this evaluation, the radiological impacts on man and marine biota of these discharges are expected to be low, as previously concluded in the Third Periodic Evaluation.

Nuclear Sector

There is clear evidence of progress made by Contracting Parties towards the OSPAR RSS objectives for the nuclear sector:

- In 35 out of 53 assessments for individual Contracting Parties across the nuclear sub-sectors, there was evidence that substantial reductions in discharges have taken place compared to the baseline period.
- In another 5 assessments for individual Contracting Parties there was some evidence for a substantial reduction.
- None of the assessments carried out for individual Contracting Parties showed any evidence for any increase in any discharges.

Non-Nuclear Sector

The submission of discharge data for the non-nuclear sector began in 2005 and sufficient data for the derivation of a baseline period (2005 to 2011) for the oil/gas sub-sector have now been collected. However, additional years of data must first be collated before a meaningful comparison of discharges against the agreed baseline can be carried out.

Récapitulatif

La Quatrième Évaluation périodique fait fond sur les évaluations périodiques précédentes pour évaluer les progrès réalisés par les Parties contractantes d'OSPAR en matière de réduction des rejets de substances radioactives dans l'Atlantique du Nord-est, afin de réaliser les objectifs de la Stratégie Substances radioactives (RSS) d'OSPAR.

Cette Quatrième Évaluation périodique porte essentiellement sur les rejets radioactifs des secteurs nucléaire et non nucléaire. Pour le secteur nucléaire, les rejets de la période choisie pour l'évaluation (2007-2013) ont été comparés aux données correspondant à la période de ligne de base (1995-2001). Bien que les données de concentration dans l'environnement n'aient pas été prises en compte dans cette évaluation, on s'attend à voir de faibles incidences radiologiques de ces rejets sur l'homme et sur le biote marin, en accord avec les conclusions tirées précédemment dans la Troisième Évaluation périodique.

Secteur nucléaire

Les progrès des Parties contractantes vers les objectifs de la RSS d'OSPAR pour le secteur nucléaire apparaissent clairement :

- Dans 35 des 53 évaluations conduites pour des Parties contractantes individuelles à travers les sous-secteurs nucléaires, les données indiquent des réductions substantielles des déchets par rapport à la période de ligne de base.
- Cinq autres évaluations réalisées pour des Parties contractantes individuelles apportent des preuves de réduction substantielle.
- Aucune des évaluations conduites pour des Parties contractantes individuelles n'a apporté de preuves établissant une augmentation de rejets quelconques.

Secteur non nucléaire

La présentation de données sur les rejets du secteur non nucléaire a commencé en 2005, et un volume de données suffisant a maintenant été collecté pour la dérivation d'une période de ligne de base (2005-2011) pour le sous-secteur pétrolier et gazier. Il faudra cependant collationner des données correspondant à plusieurs années supplémentaires avant de pouvoir faire une comparaison valable des rejets avec la ligne de base agréée.

1. Introduction and background

Radioactive materials are an essential part of everyday life and have many applications such as the generation of electricity and diagnostic and therapeutic uses in medicine. Radioactivity also occurs naturally. Exposure to natural background radiation results from naturally occurring radioactive materials in the ground, the air, food and from cosmic rays from outer space. For most individuals, exposure to natural background radiation is the largest component of their total radiation exposure[1] (UNSCEAR 2008).

The use of radioactive materials and the disposal and discharge of radioactive waste is subject to stringent internationally agreed regulation. During the course of their use, quantities of radioactive substances may be discharged into the environment, subject to regulatory authorisation, from nuclear installations such as nuclear power stations, and from non-nuclear installations such as hospitals and oil and gas installations. These discharges can lead to additional radiation exposure to humans and other organisms.

OSPAR is the mechanism by which 15 Governments and the European Union co-operate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against sea dumping and was broadened to cover land-based sources and the offshore industry by the Paris Convention of 1974. These two conventions were unified, updated and extended by the 1992 OSPAR Convention.

When the first Ministerial meeting under the 1992 OSPAR Convention was held in 1998 at Sintra, Portugal, agreement was reached on:

- a complete and permanent ban on all dumping of radioactive waste and other matter; and
- a strategy to guide the future work of the OSPAR Commission on protecting the marine environment of the North-East Atlantic against radioactive substances arising from human activities (OSPAR, 2003a).

The OSPAR Radioactive Substances Strategy (the "Strategy" or RSS) provides that "*In accordance with the general objective* [of the OSPAR Convention]*, the objective of the Commission with regard to radioactive substances is to prevent pollution of the maritime area from ionising radiation through progressive and substantial reductions of discharges, emissions and losses of radioactive substances, with the ultimate aim of concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances*. *In achieving this objective, the following issues should, inter alia, be taken into account:*

1. *legitimate uses of the sea;*
2. *technical feasibility;*
3. *radiological impacts on man and biota."*

The Strategy further provides that:

"*This Strategy will be implemented in accordance with the Programme for More Detailed Implementation of the Strategy with regard to Radioactive Substances (the "RSS Implementation Programme") (OSPAR,*

[1] http://www.unscear.org/docs/reports/2008/09-86753_Report_2008_GA_Report_corr2.pdf

2001a). In order to achieve [its objective] *by the year 2020, the Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero."*

The RSS Implementation Programme and the agreements made at the second OSPAR Ministerial meeting in 2003 provide that:

- the Contracting Parties will each prepare a national plan for achieving the objective of the Strategy;
- they will monitor and report on progress in implementing those plans; and
- the OSPAR Commission will periodically evaluate progress against an agreed baseline.

This report is a periodic evaluation of progress and is the fourth such periodic evaluation to be produced by the OSPAR Radioactive Substances Committee (RSC). This Fourth Periodic Evaluation focuses on discharges from the nuclear and non-nuclear sectors and builds upon the data and conclusions of the previous periodic evaluations, in particular the Third Periodic Evaluation published in 2009. For the nuclear sector, it compares discharge data for the assessment period (2007 to-2013) with data for the baseline period (1995 to 2001). Environmental concentrations of radionuclides and doses to man and biota are not included in this evaluation but will be assessed in the next periodic evaluation.

The assessment period in the Third Periodic Evaluation for the nuclear sector was based on data for only five years (2002 to 2006) while discharge data for the non-nuclear sector had only been reported since 2005. As a result it was not possible to draw any general conclusions on whether the objectives of the RSS were being delivered at that time, though there was evidence to suggest that progress was being made for the nuclear sector, in particular through significant reductions in discharges of total beta (excluding tritium (H-3)) and technetium-99 (Tc-99).

Under Annex IV to the OSPAR Convention, OSPAR is required to produce periodic assessments of the quality status of the maritime area covered by the Convention. A general assessment of the whole of the North-East Atlantic was produced in 2000, supported by five sub-regional reports. The Fourth Periodic Evaluation of the Radioactive Substances Strategy will be an important contribution to OSPAR's overall Intermediate Assessment 2017.

2. Radioactive discharges into the North-East Atlantic

2.1 Discharges from the nuclear sector

The discharge data used in this evaluation are taken from the annual OSPAR Reports on Liquid Discharges from Nuclear Installations. The sites considered are shown in Figure 1.1.

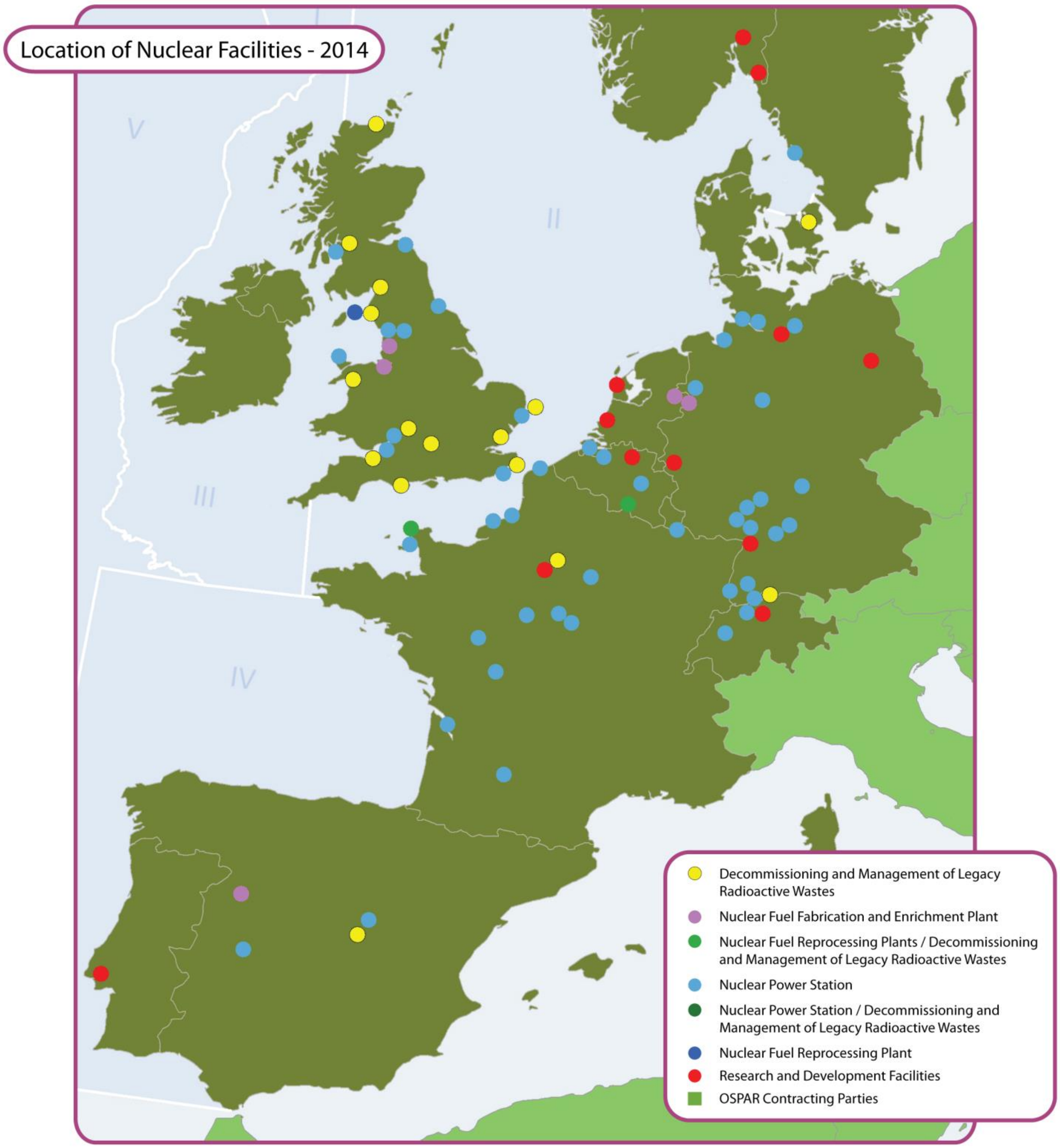

Figure 1.1: Nuclear sites (within Contracting Parties) impacting upon the North-East Atlantic Maritime Area

The following nuclear sub-sectors were considered in this evaluation:

- Nuclear fuel production and enrichment
- Nuclear power
- Nuclear fuel reprocessing
- Research and development

All radioactive discharges from nuclear facilities are subject to regulatory limits and conditions. In particular, national regulatory frameworks for the use of radioactive materials and the discharge of radioactive waste take into account the following general principles of radiation protection:

(a) Justification: The benefits of introducing a practice (a human activity that can increase the exposure of individuals to radiation) must outweigh the health detriment that it may cause.
(b) Optimisation: The radiological risks and doses from a source of radiation exposure should be kept as low as reasonably achievable (ALARA) taking into account social and economic factors.
(c) Dose limitation: In planned exposure situations, the sum of radiation doses to an individual shall not exceed the legal dose limits. This is achieved in the case of radioactive discharges through the application of limits and conditions to control discharges from justified activities to ensure that individuals are not exposed to unacceptable radiation risks.

2.1.1 Nuclear fuel production and enrichment sub-sector

Uranium-235 (U-235), which forms approximately 0.7% of natural uranium by mass, is the principal fissionable isotope used in most nuclear reactors to produce electricity. For light water reactors (LWR), the concentration of U-235 needs to be increased above the level found in natural uranium to 3%-5%, by a process known as uranium enrichment. Two main technologies are available for enrichment: gaseous centrifugation and gaseous diffusion, in both cases employing the chemical intermediate uranium hexafluoride. Gaseous diffusion technology is no longer used by OSPAR Contracting Parties.

The enriched uranium hexafluoride is converted into solid pellets of uranium dioxide which are assembled into nuclear fuel rods used in the core of power reactors. There are currently five installations undertaking uranium enrichment or fuel fabrication in the Contracting Parties with discharges of radionuclides to the OSPAR marine area.
Natural uranium fuel rods for use in certain types of reactor such as the Magnox[2] reactors in the UK, using uranium which had not been enriched in U-235, were also produced at one installation but this process has now ceased.

Liquid discharges from fuel production and enrichment plants largely consist of uranium isotopes and their decay products, as well as other radionuclides such as technetium-99 if certain types of feed material, such as uranium from reprocessing, have been used.

2.1.2 Nuclear power sub-sector

Nuclear power plants use the heat generated by nuclear fission to produce steam to drive electricity-generating turbines. Nuclear power plants are primarily classified according to the coolant systems used to transfer heat from the reactor core to the turbines (e.g. pressurised water, boiling water or gas cooled). Nuclear power stations are the most numerous type of nuclear installation among OSPAR

[2] Magnox is the term used to describe the first generation of gas-cooled reactors named after the magnesium alloy fuel cladding.

Contracting Parties with more than 40 power stations reporting discharge data to the Commission every year.

Radioactive substances in a nuclear power plant are of three broad categories:

- uranium and transuranic (heavier than uranium) elements such as plutonium;
- fission products resulting from the fission process of the uranium-235 or plutonium in the fuel; and
- activation products resulting from the irradiation of non-radioactive substances (such as cobalt) found in the reactor.

Radionuclides present in liquid effluents from nuclear power plants vary depending upon the type of reactor. However, in general, effluents contain quantities of fission products such as caesium-137, and activation products such as cobalt-60 (which are beta/gamma emitters). Sometimes, they also contain very low levels of alpha-emitting radionuclides such as plutonium-239. In addition power stations are also a significant contributor to discharges of tritium (H-3), a weak beta emitter.

The sources of these discharges include the reactor, the coolant and associated systems, and the fuel storage ponds. Effluents are typically routed via treatment plants to reduce the levels of radioactivity before discharge.

2.1.3 Nuclear fuel reprocessing sub-sector

After being used in a nuclear reactor, spent nuclear fuel contains up to 97% of the original fissionable content (consisting of up to 96% uranium and up to 1% plutonium). Reprocessing involves the recovery of these potentially reusable materials and the conditioning of the majority of the remaining 3% of waste (mainly fission products) into a solid form for storage and if chosen as the final management route, eventual disposal.

Among Contracting Parties, France and the United Kingdom operate nuclear fuel reprocessing at two sites. These are:

• Sellafield (UK): two reprocessing facilities: the Magnox reprocessing plant for Magnox reactor fuels; and the oxide fuel reprocessing plant (Thermal Oxide Reprocessing Plant (THORP)), which deals with advanced gas cooled reactor (AGR) and light water reactor (LWR) oxide fuels; and,
• La Hague (France): two operating facilities (UP2-800 and UP3) which deal mainly with pressurised water reactor (PWR) oxide fuels. A third facility (UP2-400) is undergoing decommissioning.

These facilities carry out reprocessing largely for domestic energy utilities but also for international customers.

The Sellafield and La Hague sites also carry out a range of other activities such as spent fuel and waste storage, decommissioning, processing of legacy wastes and research and development. Liquors from the reprocessing plants which contain the highest levels of activity are routed directly to storage and incorporated into a solid glass form through a vitrification process; they are therefore not discharged to the environment. Some medium active waste liquors are also produced which are separated into a number of solid waste streams for storage depending upon their composition and activity.

Reprocessing results in authorised discharges to the environment from a range of sources such as fuel storage ponds, reprocessing plants and associated downstream plants, and legacy waste management and decommissioning. The radionuclides discharged include tritium, carbon-14, beta-gamma emitters such as cobalt-60, strontium-90, technetium-99, ruthenium-106 and caesium-137, and alpha emitters such as plutonium-239, plutonium-240 and americium-241.

Concerns about the level of discharges from reprocessing activities began well before the baseline period considered by OSPAR (1995-2001) and regulatory pressure led to the introduction of a number of significant effluent abatement processes which led to substantial reductions in discharges from reprocessing even before 1995. More details for significant indicator radionuclides are given below.

2.1.4 Caesium-137

Caesium-137 (Cs-137) is an artificial radionuclide and fission product which has a half-life of 30.1 years. Its presence in the marine environment results from three main sources: atmospheric nuclear weapon tests, fallout from the Chernobyl accident and discharges from reprocessing plants. Together with its short-lived decay product (metastable barium-137 or Ba-137m), it is a beta/gamma emitter of particular radiological significance.

At Sellafield, this radionuclide has been the subject of particular attention. Discharge reduction measures began in the late 1970s with the introduction of fuel-pond water treatment, followed in 1986 by the introduction of a large-scale ion-exchange plant designed to remove Cs-137 and other radionuclides from effluents prior to discharge to the sea. Therefore, Cs-137 releases were reduced by a factor of more than 300 from the mid-1970s to the beginning of the OSPAR baseline period in 1995.

At La Hague, this nuclide has also been subject of particular attention and the design and operations of the plants have been optimized to reduce the discharges of this nuclide. Therefore, Cs-137 releases were reduced by a factor of more than 50 from the mid-1970s to the beginning of the OSPAR baseline period in 1995. Discharges of Cs-137 have been further substantially reduced at La Hague since the mid-1990s, due to new effluent management and increased use of evaporation to maximise concentration and the extraction of radionuclides routed to vitrification, storage and ultimately disposal as solid waste. This optimised liquid effluent management strategy has resulted in an almost 8-fold reduction in discharges of Cs-137 since 1995.

Cs-137 remains a significant radionuclide in the context of OSPAR strategy assessments for the reprocessing sector, due principally to the higher discharges made in the past.

2.1.5 Plutonium-239 and Plutonium-240

Plutonium-239 (Pu-239) and plutonium-240 (Pu-240) are long-lived artificial radionuclides (half-lives of 24,100 years and 6,563 years respectively). Their presence in the OSPAR marine environment results mainly from reprocessing activities.

Discharge reductions began at Sellafield in the late 1970s with the storage of effluent, prior to the introduction in the early 1980s of evaporators to reduce the volume of the effluent. The concentrated effluents were then stored until a large-scale actinide-removal plant began operation in 1994. Pu-239 discharges were reduced by a factor of more than 70 between the mid-1970s and the start of the OSPAR baseline period.

At La Hague, Pu-239,240 discharges were reduced by a factor of 97 between 1974 and 1995, primarily due to the optimisation of abatement processes. In 2002 a new facility was introduced which allows the almost total recycling of effluent into the vitrification process and subsequent storage in a solid waste form, which led to a further reduction in discharges by a factor of more than 4.

Despite the success in reducing discharges, Pu-239,240 (and another actinide americium-241) remain among the main contributors to dose to representative persons (persons most highly exposed) in the Irish Sea. Due to the high affinity of Pu-239,240 to attach to sediments, discharged Pu-239,240 has accumulated over time in inter-tidal sediments close to the Sellafield site. The remobilisation of Pu-239,240 from these sediments is now the dominant source of these isotopes in seawater and it is estimated that historic discharges currently account for around 90% of the dose to local representative persons from these radionuclides (Leonard et al., 1999.[3]).

2.1.6 Technetium-99

Technetium-99 (Tc-99) is a long-lived (half-life of 213,000 years), beta-emitting fission product, which is largely present in the environment as a result of reprocessing activities and to a lesser extent of atmospheric nuclear-weapon tests.

Tc-99 is also a decay product of technetium-99m (Tc-99m) used in the medical sector, but discharges of Tc-99m from the medical sector result in a negligible contribution to Tc-99 concentrations in the marine environment.

Tc-99 has a propensity to accumulate in certain marine organisms such as lobsters and certain seaweeds (Mayall, 2005). At the Ministerial meeting in Sintra in 1998, concern about the recent increases in the discharges of Tc-99 from Sellafield was noted and the UK indicated that such concerns would be addressed as part of forthcoming decisions concerning regulatory authorisations for Sellafield.

The principal waste streams at Sellafield containing Tc-99 have been directed to the vitrification process for oxide fuel reprocessing since its start-up in 1994, however this was not the case for the principal technetium bearing waste streams from the reprocessing of Magnox fuel which was the main source of Tc-99 discharges. As a result of regulatory requirements, which took into account the concerns noted at the 1998 Ministerial meeting, modifications were made to the process for managing the principal Tc-99 bearing waste streams from Magnox reprocessing. These process modifications included the diversion of the waste streams to vitrification from 2003 and a new treatment process introduced in 2004 to remove Tc-99 from a stored backlog of Tc-99 bearing waste, which was not suitable for vitrification (Mayall, 2005[4]). Annual discharges of Tc-99 to sea (primarily from treatment of stored wastes from the reprocessing of Magnox fuel) has therefore been reduced by a factor of almost 200 between 1995 and 2013.

Prior to 1995, the discharges of Tc-99 at La Hague had been reduced by a factor of more than 250 by chemical extraction and subsequent storage in a solid glass form (vitrification). Subsequently, a specific

[3] Leonard, K. S., McCubbin, D., Blowers, P., & Taylor, B. R. (1999). Dissolved plutonium and americium in surface waters of the Irish Sea, 1973–1996. Journal of Environmental Radioactivity, 44(2), 129-158

[4] Mayall, A. (2005). A fine balance: multifactorial decision making and the regulation of Tc-99 discharges at Sellafield. Proc. 7th International Symposium of the Society for Radiological Protection.

unit to remove Tc-99 has been developed for the newer facilities UP2-800 and UP3-A to further reduce discharges of this radionuclide.

2.1.7 Research and development sub-sector

Many nuclear installations carry out research and development (R&D). Installations covered under this heading are those where R&D is the sole activity and relate mainly to sites with research nuclear reactors. Where R&D is carried out alongside other activities then discharges relating to R&D are reported with discharges from other activities as a combined total.

There are currently 11 sites reporting discharges for this sub-sector, most of which are associated with research reactors. Liquid discharges from this sub-sector are typically lower than the other sub-sectors. In some cases the range of individual radionuclides reported is relatively large but the principal radionuclides tend to be those found in discharges from the nuclear power sub-sector.

2.2 Discharges from the non-nuclear sector

The discharge data used in this evaluation are taken from the annual OSPAR Reports on Discharges of Radionuclides from the Non-Nuclear sector.

Discharges are reported to the Commission from the following non-nuclear sub-sectors:

- Oil and gas
- Medical
- University and research centres
- Phosphate industry
- Titanium dioxide pigment manufacture
- Primary steel manufacture
- Rare earth mineral production
- Radiochemical production

2.2.1 Oil and gas sub-sector

The main source of discharges of radionuclides to the OSPAR marine environment from the oil and gas sub-sector results from discharges of produced water. Produced water is a by-product of the extraction of oil and gas that can be a mixture of formation water (i.e. water found naturally in the same formation as the oil or gas) and seawater that has been injected into the reservoir to maintain reservoir pressure. The radioactive content of produced water arises from naturally occurring radionuclides contained in the reservoirs, and includes Pb-210, Ra-226 and Ra-228.

Additionally, quantities of discharges of naturally occurring radionuclides arise from descaling operations. As production fluids (oil, gas and water) are extracted, it is common for the temperature and pressure of the fluids to change. This can result in either hard insoluble salts (scale) being deposited inside oil and water processing equipment (separators, process pipework, valves, etc.), or in the formation of a thin film in gas processing equipment. Periodic ‘descaling’ of pipes and tanks is often necessary to prevent such equipment becoming blocked and discharges associated with descaling operations can occur offshore directly from production installations or from onshore treatment facilities.

Other discharges of radionuclides associated with the oil and gas sub-sector results from the use of radiochemical tracers such as tritium.

The activity concentrations of radionuclides in produced water and the total activity discharged can vary between different fields and between installations. This can be due to differences in the local geology and maturity of the reservoirs. Where produced water is normally discharged to sea, the amount of discharged radionuclides from a particular installation can also vary depending on a number of practices such as which wells are being flowed and which target reservoir is being produced as well as the use of scale inhibitors or dissolvers in the process system. Where produced water is routinely re-injected, non-availability of the water injection system can also lead to radioactive discharges.

2.2.2 Medical sub-sector

Discharges from the medical sub-sector are associated with the use of radioactive substances for therapeutic and diagnostic purposes in hospitals. Such hospitals are authorised to discharge such substances which are mainly contained in patient excreta.

OSPAR has gathered data on discharges from the medical sector since 2005. The Radioactive Substances Committee (RSC 2009) took the decision to cease reporting on the short-lived radionuclide Tc-99m from the medical sector, since its contribution to the amount of Tc-99 (through radioactive decay) present in the marine environment from other sources was minor.

The other main discharge reported from the medical sector is for the short-lived (half-life of 8 days) radionuclide iodine-131 (I-131). However, due to uncertainties associated with the reported data and the amount entering the marine environment, OSPAR is not publishing any data or carrying out any assessment of these discharges from this sub-sector at present. RSC is continuing to review the work of individual Contracting Parties on the issues surrounding the discharge of I-131.

2.2.3 Other non-nuclear sub-sectors

Several Contracting Parties report data for a number of other non-nuclear sub-sectors:

- University and research centres: From the data that have been provided it is reasonable to conclude that this sub-sector is not a significant contributor to total beta (excluding tritium) or tritium discharges and there are no alpha discharges.
- Radiochemical production: Radiochemical production is carried out in several Contracting Parties. The discharges from this sub-sector are in some cases included with those from the nuclear research and development sub-sector due to co-location of sites.
- Discharges of naturally occurring radionuclides have been reported by some Contracting Parties for phosphate production, titanium dioxide pigment manufacture, primary steel manufacture and rare earth mineral production. From the data that have been provided it is reasonable to conclude that these sub-sectors are no longer a significant contributor to total alpha and total beta (excluding tritium) discharges.

3. Derivation of discharge data

3.1 Nuclear Sector

Contracting Parties report discharge data for a range of individual radionuclides such as tritium (H-3), Cs-137, Tc-99 and Pu-239,240 (for a summary of the typical radionuclides discharged by the nuclear sector see section 2.1). Discharge data for individual radionuclides are particularly important to assess the radiological impact of the discharges because this is dependent upon the specific characteristics of each radionuclide.

Contracting Parties also report data for groups of radionuclides such as alpha emitting radionuclides (‘total alpha’), beta emitting radionuclides (‘total beta (excluding tritium)’) and in some cases groups of radionuclides not individually listed (‘other radionuclides’). Total alpha and total beta (excluding tritium) discharge data are useful for the RSS as they encompass, together with tritium discharges, all liquid discharges of radioactive substances to the OSPAR marine environment. They are also useful as a regulatory tool, for evaluating trends in discharges, and for comparing discharge data for different periods. The derivation of total alpha and total beta (excluding tritium) activity is not a straightforward process and has varied between Contracting Parties and between sub-sectors.

Two general approaches have been adopted by Contracting Parties to estimate the total alpha and total beta (excluding tritium) activities in the reported discharges:

- The activity concentrations of a certain number of alpha and beta emitting radionuclides are measured separately, and these results are summed. Tritium discharges are reported separately.
- A discharge sample is analysed for ‘gross alpha’ or ‘gross beta’ activity i.e. the total representative amount of alpha or beta activity. Tritium discharges are reported separately

In the latter case, the gross activity can include a contribution from radionuclides which cannot be individually analysed, including some naturally-occurring radionuclides. Measurements of gross activity depend on the mix of radionuclides in the sample, the detection efficiencies for these radionuclides and the energy measurement range of the detector. Hence a figure for total alpha or total beta (excluding tritium) obtained by summing the results of determinations of individual radionuclides is not strictly equal to the gross alpha and gross beta results.

Contracting Parties have employed different approaches when reporting total alpha and total beta (excluding tritium) activities. For example, some Contracting Parties report the gross activity value for one sub-sector and the sum of the individual activity results for another sub-sector. In addition some Contracting Parties have used differing interpretations of ‘other radionuclides’ where this has been included in the calculation of total beta. In general, however, provided that individual Contracting Parties have been consistent in the approach they have taken in the derivation of total alpha and total beta discharges, statistical analyses which compare values for an assessment period with a baseline remain valid.

3.2 Non-nuclear Sector

RSC has agreed that for discharges from the oil and gas sub-sector, data should be reported for the radionuclides Pb-210, Ra-226 and Ra-228. Contracting Parties have reported discharge data on these indicator radionuclides for the oil and gas sub-sector since 2005. Additionally, RSC has agreed to estimate values for total alpha and total beta (excluding tritium) based on reported measured values for Pb-210, Ra-226 and Ra-228 using formulae that take into account contributions from key radioactive daughter products. The formulae take the conservative assumption that these key radioactive daughter products are in radioactive equilibrium in their respective decay chains at the time at which any discharge is released into the marine environment.

The agreed formulae are as follows:

Total alpha (TBq) = (5xRa-228) + (4xRa-226) + (1xPb-210).

Total beta (excluding tritium) (TBq) = (4xRa-228) + (2xRa-226) + (2xPb-210)

4. Assessment methodologies used in the Fourth Periodic Evaluation

4.1 Derivation of data for the baseline and assessment periods

4.1.1 Selection of years for baseline period

RSC has previously agreed that the baseline period for discharges from the nuclear sector would comprise the 7-year period 1995 to 2001. This period was chosen to centre on the "Sintra year" of 1998. RSC has recognised that the industrial scale abatement of tritium in the liquid effluent of nuclear power plants and reprocessing plants is currently not technically feasible. These discharges have not been assessed as part of the Fourth Periodic Evaluation but are available in Annex 7.

RSC has also agreed a baseline period for the non-nuclear oil and gas sub-sector that comprises the 7-year period 2005 to 2011. This period was chosen to ensure a similar approach as for the nuclear sector i.e. a 7 year baseline period and because reporting of discharge data from this sub-sector only commenced in 2005. RSC has not agreed any other baseline periods for other non-nuclear sub-sectors.

4.1.2 Selection of years for the assessment period of the Fourth Periodic Evaluation

For the purposes of the Fourth Periodic Evaluation, RSC has agreed that the assessment period for discharges from the nuclear sector would comprise the 7-year period 2007 to 2013. As currently there are only two years of discharge data for the non-nuclear oil and gas sub-sector available beyond the agreed baseline period for this sector, RSC has agreed that it would be premature to assess these discharges within the context of the Fourth Periodic Evaluation.

4.1.3 Calculation of annual values

For those sub-sectors where baseline periods have been agreed, annual values have been calculated by summing all the discharge data for particular indicators (total alpha, total beta (excluding tritium) and individual radionuclides where applicable), for each Contracting Party, for all installations within a particular sub-sector, for all the years where data have been reported (i.e. 1995 to 2013 for the nuclear sector and 2005 to 2013 for the non-nuclear oil and gas sub-sector). Overall annual values have also been calculated by summing all discharge data for the indicators for all Contracting Parties for all installations.

4.1.4 Calculation of baseline and assessment values

For those sub-sectors where baseline periods have been agreed, baseline values have been calculated as the mean of the available annual values from the baseline period. Assessment values have been calculated as the mean of the available annual values from the assessment period. Baseline and assessment values have been calculated for particular indicators (total alpha, total beta (excluding tritium) and individual radionuclides where applicable) from annual values for individual Contracting Parties and overall values for individual sub-sectors.

4.2 Comparison of baseline and assessment period values

More detailed information on the statistical approach employed in the Fourth Periodic Evaluation is available in Annex 1.

Assessments of discharges from the nuclear sector are based on total discharges (i.e. operational and decommissioning discharges). In some cases since 2007, Contracting Parties have reported discharge data (under the category of exceptional discharges) relating to the decommissioning of nuclear installations and the treatment and/or recovery of old (or 'legacy') radioactive waste in the nuclear sector separately from operational discharges. For the purposes of the assessments carried out in the Fourth Periodic Evaluation, such data have been re-combined with any operational discharges from the corresponding sub-sector.

4.2.1 Simple comparison of the assessment value with the baseline value and baseline bracket

As an initial step, assessment values have been compared with the baseline value and the baseline bracket, where the baseline bracket represents the baseline value ±1.96 times the standard deviation. In this approach, discharge data are assumed to be normally distributed around the mean of the reported values and the 'bracket' is therefore calculated as the interval which should contain 95% of all the values. Simple comparisons of assessment values with the baseline value and baseline bracket cannot be described as giving 'statistically significant' results. Therefore, where these comparisons are made, results can only been described as being either higher than, less than or similar to baseline values and upper and lower baseline bracket values. Where the derivation of the lower baseline bracket value produces a negative value, this value is reported as zero.

4.2.2 Comparison using statistical tests

In addition to the simple comparison outlined in 4.2.1, annual values for the assessment period have been compared against annual values for the baseline period using the Student's t Welch-Aspin test and the Mann-Whitney test. Where the probability (P-value) of less than 0.05 has been determined using these statistical tests, the difference between annual values for the baseline period and assessment period can be said to be 'statistically significant'.

The outcome of the simple comparison and the statistical tests allows for the following conclusions to be made:

- Where both statistical tests give results that are statistically significant it can be concluded that there is evidence of a reduction or increase (as indicated by the simple comparison) in the discharge between the assessment and baseline periods.
- Where only one statistical test gives a result that is statistically significant it can be concluded that there is some evidence of a reduction or increase (as indicated by the simple comparison) in the discharge between the assessment and baseline periods.
- Where neither statistical test gives a result that is statistically significant it can be concluded that there is no evidence of any change in the discharge between the assessment and baseline periods.

4.2.3 Graphical presentation of assessment results

Tables of derived baseline values, baseline brackets, assessment values and results (P values) of the statistical tests are given, where appropriate, in Annex 2 for discharges from the nuclear sector and in Annex 7 for discharges from the non-nuclear sector. Figures for overall discharges for each sub-sector are given in the main results chapters (5 and 6). Figures for discharges from individual Contracting Parties are given in Annexes 3 to 6 for discharges from the nuclear sector and in Annex 8 for discharges from the non-nuclear sector. In this report, where statistical tests show statistically significant results, the simple comparison of the assessment value with the baseline value and bracket is not given in Chapter 5. Where statistical tests do not show any statistically significant results, the simple comparison of the assessment value with the baseline value and bracket is given. In this report, the symbols displayed in table 4.1 are used to indicate the different possible results of the assessment methodology.

Table 4.1: Symbols used to indicate the different possible results of the assessment methodology used in the Fourth Periodic Evaluation.

Result of assessment	Symbol used to indicate assessment result
Evidence of a decrease	↓↓
Some evidence of a decrease	↓
No evidence of any change	↔
Some evidence of an increase	↑
Evidence of an increase	↑↑

5. Evaluation of discharges from the nuclear sector

Tables of derived baseline values, baseline brackets, assessment values and results (P values) of the statistical tests employed for the evaluation of discharges from the nuclear sector are given in Annex 2. An explanation of the symbols used to indicate assessment results in this chapter is given in table 4.1.

5.1 Nuclear fuel production and enrichment sub-sector

5.1.1 Contracting Parties

Discharges have been reported for the nuclear fuel production and enrichment sub-sector by Germany, the Netherlands, Spain and the United Kingdom. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.1. They show that there is evidence of reductions in discharges between the assessment and the baseline periods in 5 out of the 7 cases.

There is no evidence of any change in discharges between the assessment period and baseline period for total alpha for Spain and Tc-99 for the United Kingdom.

The assessment value for total alpha for Spain was lower than the baseline value but not the lower baseline bracket.

The assessment value for Tc-99 for the United Kingdom was higher than the baseline value and upper baseline bracket. It should be noted that the increase in annual discharges of Tc-99 in the period 2009 to 2012 in the nuclear fuel production and enrichment sub-sector by the UK was linked to the processing of recycled uranium, which contained trace levels of Tc-99. The amount of Tc-99 discharged was an order of magnitude lower than the amount of Tc-99 discharged by the nuclear fuel reprocessing sub-sector and has subsequently decreased.

Table 5.1: Assessment results for indicators for the nuclear fuel production and enrichment sub-sector by Contracting Party.

Contracting Party	Indicator	Assessment result
Germany	Total alpha	↓↓
Netherlands	Total alpha	↓↓
	Total beta (excluding tritium)	↓↓
Spain	Total alpha	↔
United Kingdom	Total alpha	↓↓
	Total beta (excluding tritium)	↓↓
	Tc-99	↔

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

5.1.2 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha and total beta (excluding tritium) from the nuclear fuel production and enrichment sub-sector are summarised in Table 5.2 and in Figures 5.1 and 5.2. The assessment results for the sub-sector show that there is evidence of reductions in discharges of total alpha and total beta (excluding tritium) between the assessment and baseline periods.

The overall assessment values for total alpha and total beta (excluding tritium) show a reduction of 8 fold and 30 fold respectively, when compared to the overall baseline values for this sub-sector.

Table 5.2: Overall assessment results for indicators for the nuclear fuel production and enrichment sub-sector.

Indicator	Assessment result
Total alpha	↓↓
Total beta (excluding tritium)	↓↓

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

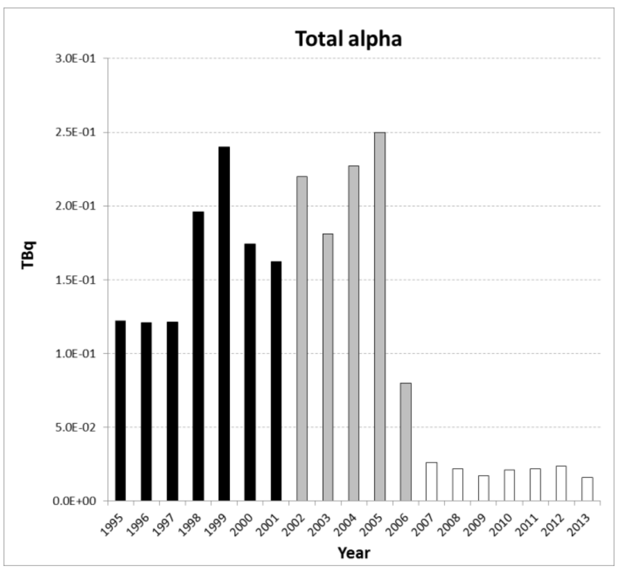

Figure 5.1: Total alpha discharges from the nuclear fuel production and enrichment sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

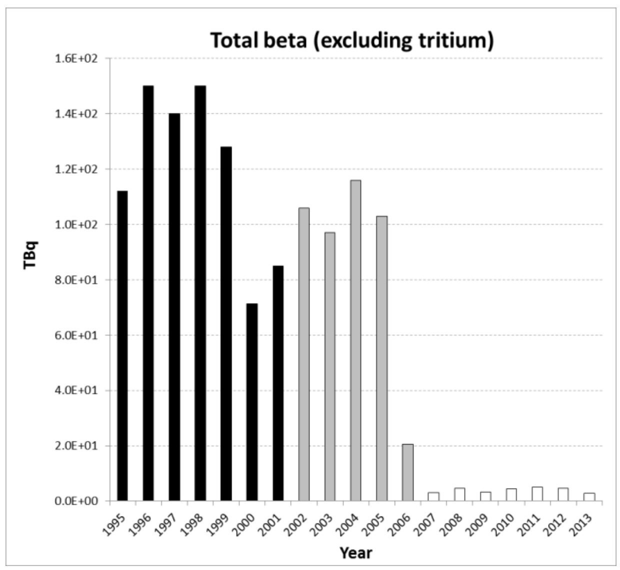

Figure 5.2: Total beta (excluding tritium) discharges from the nuclear fuel production and enrichment sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

5.2 Nuclear power sub-sector

5.2.1 Contracting Parties

Discharges have been reported for the nuclear power sub-sector by Belgium, France, Germany, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.3. They show that there is evidence of reductions in discharges between the assessment and baseline periods in 16 out of the 21 cases, and some evidence of a reduction in discharges in 1 case.

There is no evidence of any change in discharges between the assessment period and baseline period for total alpha for Belgium, Germany, Sweden and Switzerland.

The assessment values for total alpha for Belgium and Switzerland were higher than their respective baseline values but not their upper baseline brackets.

The assessment values for total alpha for Germany and Sweden were lower than their respective baseline values.

Table 5.3: Assessment results for indicators for the nuclear power sub-sector by Contracting Party.

Contracting Party	Indicator	Assessment result
Belgium	Total alpha	↔
	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓
France	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓
Germany	Total alpha	↔
	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓
Netherlands	Total beta (excluding tritium)	↓↓
	Cs-137	↓
Spain	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓
Sweden	Total alpha	↔
	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓

Switzerland	Total alpha	↔
	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓
United Kingdom	Total alpha	↓↓
	Total beta (excluding tritium)	↓↓
	Cs-137	↓↓

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

5.2.2 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha, total beta (excluding tritium) and Cs-137 from the nuclear power sub-sector are summarised in Table 5.4 and in Figures 5.3 to 5.5. The assessment results for the sub-sector show that there is evidence of reductions in discharges of total beta (excluding tritium) and Cs-137 and some evidence of a reduction in discharges of total alpha between the assessment and baseline periods.

The overall assessment values for total alpha and total beta (excluding tritium) show a reduction of 1.5 fold and 8 fold respectively, when compared to the overall baseline values for this sub-sector.

In addition, the overall assessment value for Cs-137 shows a reduction of 30 fold, when compared to the overall baseline value for this sub-sector.

Table 5.4: Overall assessment results for indicators for the nuclear power sub-sector.

Indicator	Assessment result
Total alpha	↓
Total beta (excluding tritium)	↓↓
Cs-137	↓↓

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

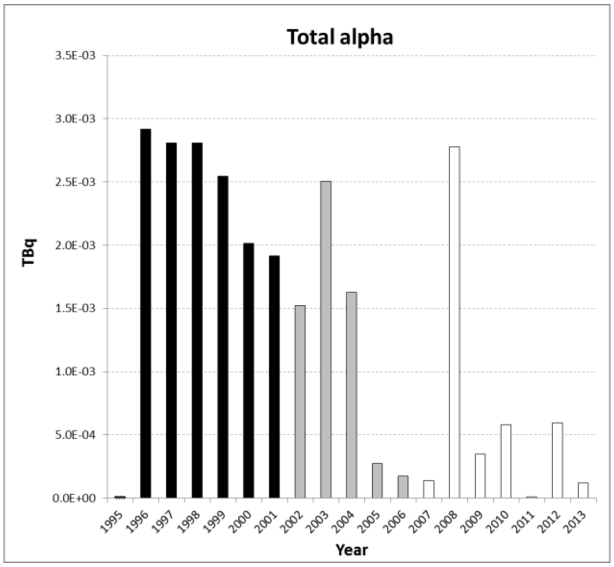

Figure 5.3: Total alpha discharges from the nuclear power sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

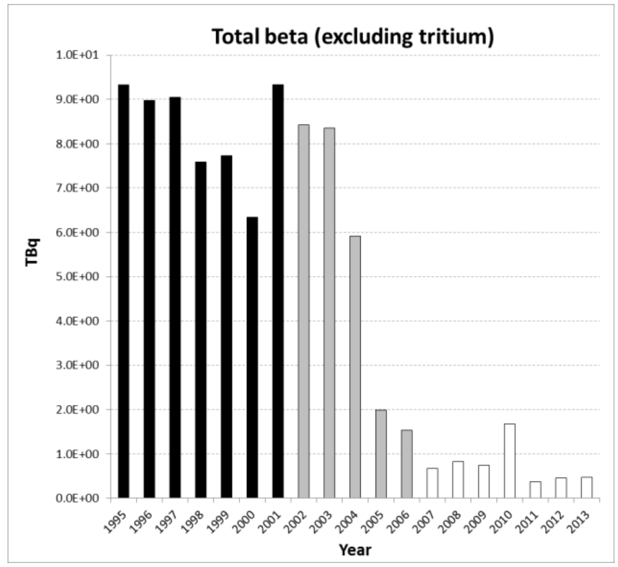

Figure 5.4: Total beta (excluding tritium) discharges from the nuclear power sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

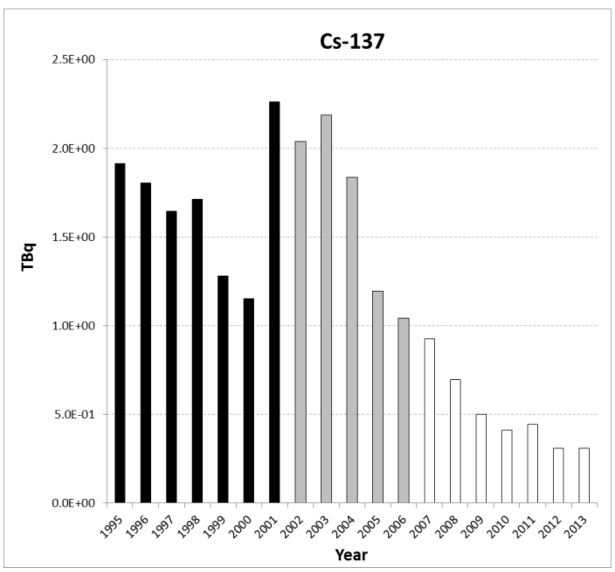

Figure 5.5: Cs-137 discharges from the nuclear power sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

5.3 Nuclear fuel reprocessing sub-sector

5.3.1 Contracting Parties

Discharges have been reported for the nuclear fuel reprocessing sub-sector by France and the United Kingdom. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.5. They show that there is evidence of reductions in discharges between the assessment and baseline periods in 7 out of the 10 cases.

There is no evidence of any change in discharges between the assessment period and baseline period for Tc-99 for France and total alpha and Pu-239,240 for the United Kingdom.

The assessment value for Tc-99 for France was higher than the baseline value but not the upper baseline bracket. It should be noted that the exceptional discharges of Tc-99 in 2010 and 2011 in the nuclear fuel reprocessing sub-sector by France were linked to decommissioning activities and the treatment of previously stored waste.

The assessment values for total alpha and Pu-239,240 for the United Kingdom were lower than their respective baseline values, but not their respective lower baseline brackets.

Table 5.5: Assessment results for indicators for the nuclear fuel reprocessing sub-sector by Contracting Party.

Contracting Party	Indicator	Assessment results
France	Total alpha	↓↓
	Total beta (excluding tritium)	↓↓
	Tc-99	↔
	Cs-137	↓↓
	Pu-239,240	↓↓
United Kingdom	Total alpha	↔
	Total beta (excluding tritium)	↓↓
	Tc-99	↓↓
	Cs-137	↓↓
	Pu-239,240	↔

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

5.3.1 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha, total beta (excluding tritium), Tc-99, Cs-137 and Pu-239,240 from the nuclear fuel reprocessing sub-sector are summarised in Table 5.6 and in Figures 5.6 to 5.10. The assessment results for the sub-sector show that there is evidence of reductions in discharges of total alpha, total beta (excluding tritium), Tc-99 and Cs-137 between the assessment and baseline periods. There was no evidence of any change in discharges of Pu-239,240 between the assessment period and baseline period.

The assessment value for Pu-239,240 for the nuclear fuel reprocessing sub-sector was lower than the baseline value, but not the lower baseline bracket.

The overall assessment values for total alpha and total beta (excluding tritium) show a reduction of 1.6 fold and 8 fold respectively, when compared to the overall baseline values for this sub-sector.

In addition, the overall assessment values for Tc-99 and Cs-137 show a reduction of 39 fold and 2 fold respectively, when compared to the overall baseline values for this sub-sector.

Table 5.6: Overall assessment results for indicators for the nuclear fuel reprocessing sub-sector.

Indicator	Assessment result
Total alpha	↓↓
Total beta (excluding tritium)	↓↓
Tc-99	↓↓
Cs-137	↓↓
Pu-239,240	↔

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

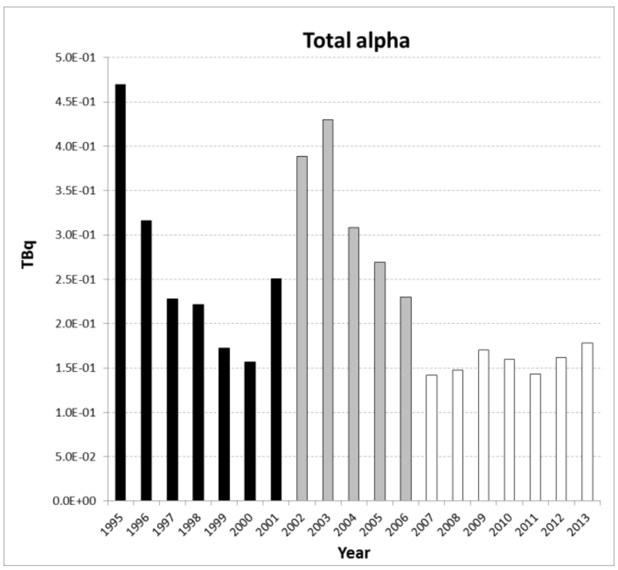

Figure 5.6: Total alpha discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

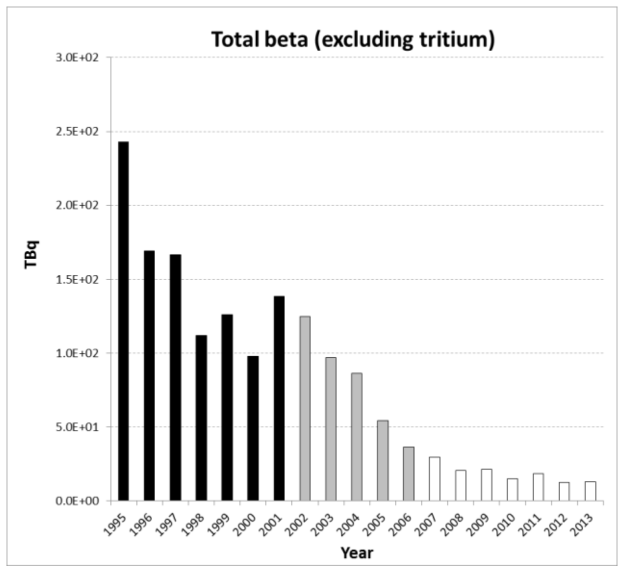

Figure 5.7: Total beta (excluding tritium) discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

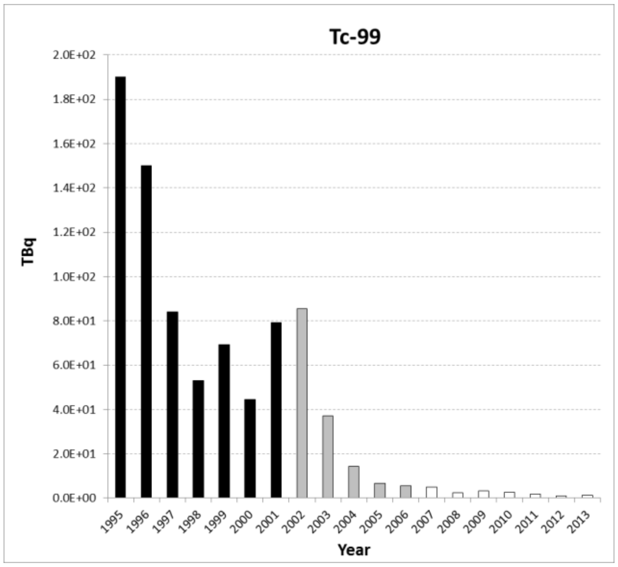

Figure 5.8: Tc-99 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

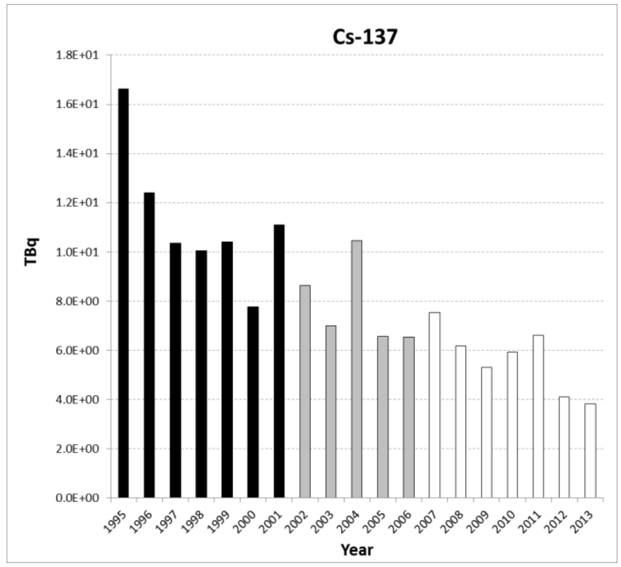

Figure 5.9: Cs-137 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

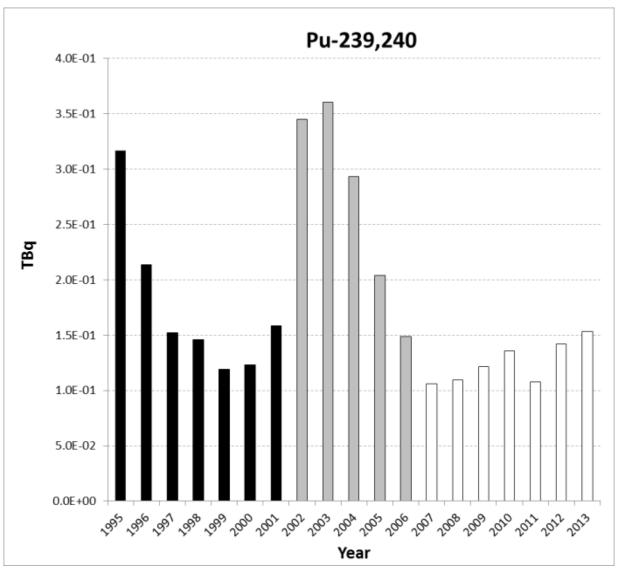

Figure 5.10: Pu-239,240 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

5.4 Nuclear research and development sub-sector

5.4.1 Contracting Parties

Discharges have been reported for the nuclear research and development sub-sector by Belgium, Denmark, France, Germany, the Netherlands, Norway, Portugal, Switzerland and the United Kingdom. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.7. They show that there is evidence of reductions in discharges between the assessment and baseline periods in 7 out of the 15 cases and some evidence of reductions in discharges in 4 cases.

There is no evidence of any change in discharges between the assessment period and baseline period for total alpha for Belgium, the Netherlands and Norway and total beta (excluding tritium) for Denmark.

The assessment value for total alpha for Belgium was lower than the baseline value, while the assessment value for total alpha for the Netherlands was similar to the baseline value. The assessment value for total beta (excluding tritium) for Denmark was similar to the baseline value.

The assessment value for total alpha for Norway was higher than the baseline value, but not the upper baseline bracket. It should be noted that the increase in total alpha discharges from the nuclear research and development sub-sector in Norway are linked to decommissioning activities and the treatment of particular waste solutions. These discharges will continue for a limited period until this work is completed.

Table 5.7: Assessment results for indicators for the nuclear research and development sub-sector by Contracting Party.

Contracting Party	Indicator	Assessment results
Belgium	Total alpha	↔
	Total beta (excluding tritium)	↓↓
Denmark	Total beta (excluding tritium)	↔
France	Total alpha	↓↓
	Total beta (excluding tritium)	↓↓
Germany	Total beta (excluding tritium)	↓↓
Netherlands	Total alpha	↔
	Total beta (excluding tritium)	↓
Norway	Total alpha	↔
	Total beta (excluding tritium)	↓↓

Portugal	Total beta (excluding tritium)	↓↓
Switzerland	Total alpha	↓↓
	Total beta (excluding tritium)	↓
United Kingdom	Total alpha	↓
	Total beta (excluding tritium)	↓

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

5.4.1 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha and total beta (excluding tritium) from the nuclear research and development sub-sector are summarised in Table 5.8 and in Figures 5.11 and 5.12. The assessment results for the sub-sector show that there is some evidence of reductions in discharges of total alpha and total beta (excluding tritium) between the assessment and baseline periods.

The overall assessment values for total alpha and total beta (excluding tritium) show a reduction of 50 fold and 41 fold respectively, when compared to the overall baseline values for this sub-sector.

Table 5.8: Overall assessment results for indicators for the nuclear research and development sub-sector.

Indicator	Assessment results
Total alpha	↓
Total beta (excluding tritium)	↓

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

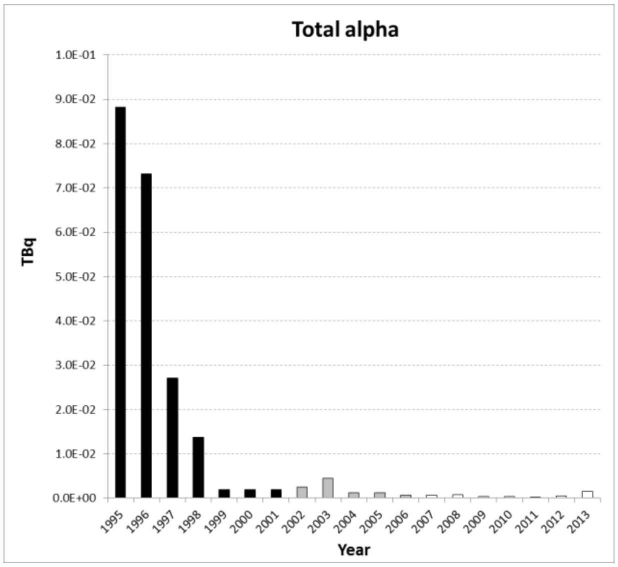

Figure 5.11: Total alpha discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

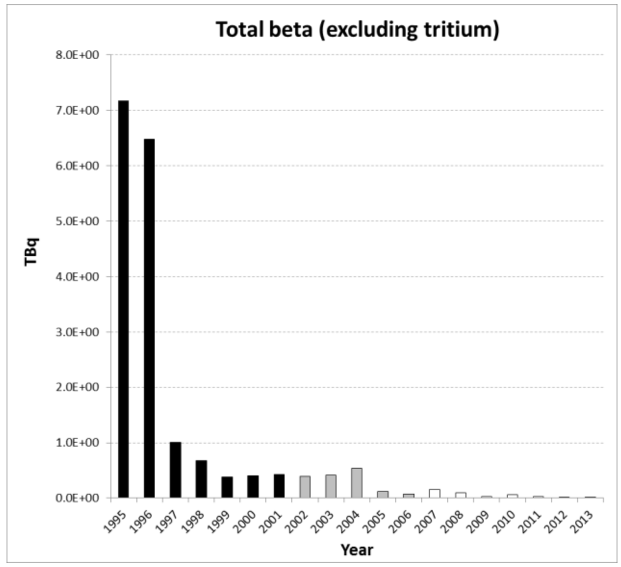

Figure 5.12: Total beta (excluding tritium) discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

5.5 Overall situation for the nuclear sector across all Contracting Parties and sub-sectors

The evaluations of the discharges for each sub-sector are discussed in detail in sections 5.1-5.4. These showed that there is evidence for substantial reductions in discharges in many cases between the baseline and the assessment periods across all four nuclear sub-sectors.

Figures 5.13 and 5.14 compare the baseline and the assessment values (average discharges for the baseline and assessment periods) for total alpha and total beta (excluding tritium) across all sub-sectors and Contracting Parties. This comparison provides a broad indication of the scale of the reductions as well as the relative contributions of the four nuclear sub-sectors. For example, discharges from the nuclear fuel reprocessing sub-sector are much reduced but remain the dominant source of discharges from the nuclear sector, contributing approximately 90% of the average total alpha, and approximately 80% of the average total beta (excluding tritium) discharges over the assessment period. It should be noted that discharges for the nuclear reprocessing sub-sector include contributions from activities such as decommissioning and processing of legacy wastes

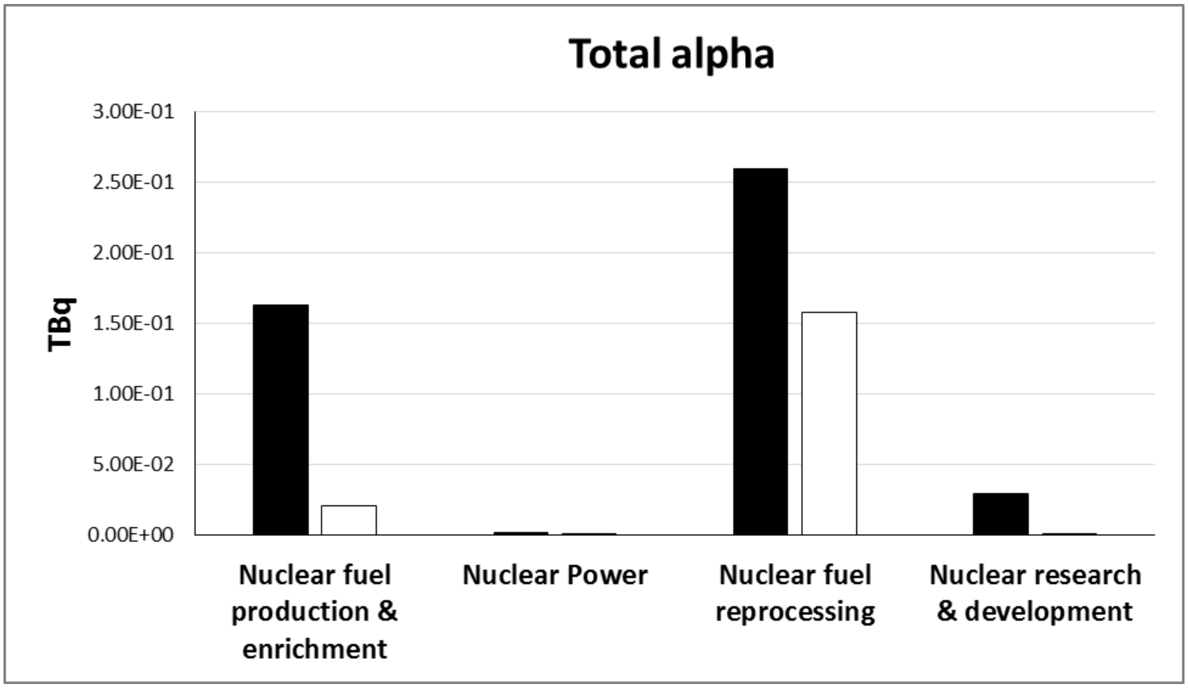

Figure 5.13: Comparison of total alpha overall baseline (black columns) and assessment (white columns) values for the different nuclear sub-sectors.

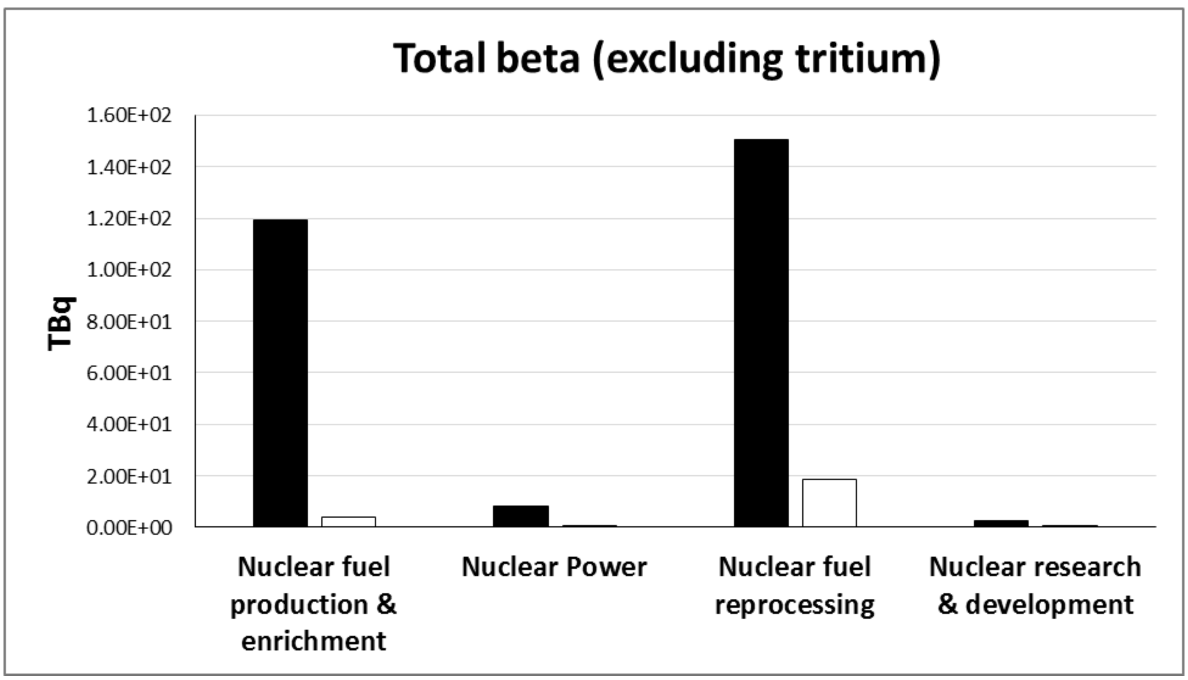

Figure 5.14: Comparison of total beta (excluding tritium) overall baseline (black columns) and assessment (white columns) values for the different nuclear sub-sectors.

The overall situation for discharges of total alpha, total beta (excluding tritium), Tc-99, Cs-137 and Pu-239,240 from the nuclear sector are summarised in Table 5.9. The assessment results for the nuclear sector as a whole show that there is evidence of reductions in discharges of total alpha, total beta (excluding tritium), Tc-99 and Cs-137 between the assessment and baseline periods. The assessment value for Pu-239,240 for the nuclear sector as a whole was lower than the baseline value but not the lower baseline bracket.

The overall assessment values for total alpha and total beta (excluding tritium) show a reduction of 2.5 fold and 12 fold respectively, when compared to the overall baseline values for the nuclear sector as a whole. The overall assessment values for Tc-99 and Cs-137 show a reduction of 38 fold and 2.1 fold respectively, when compared to the overall baseline values for the nuclear sector as a whole.

Table 5.9: Overall assessment results for indicators for the nuclear sector.

Indicator	Assessment results
Total alpha	↓↓
Total beta (excluding tritium)	↓↓
Tc-99	↓↓
Cs-137	↓↓
Pu-239,240	↔

An explanation of the symbols used to indicate the assessment results is given in table 4.1.

6. Evaluation of discharges from the non-nuclear sector

6.1 The oil and gas sub-sector

6.1.1 Produced water

Baseline values and baseline brackets for discharges of indicators in produced water from the oil and gas sub-sector are given in Annex 7. Discharges have been reported for indicators in produced water from the oil and gas sub-sector by Denmark, Germany, Ireland, the Netherlands, Norway and the United Kingdom. As previously stated, RSC has agreed that it is premature to assess these discharges as there are only two additional years of data currently available beyond the baseline period.

The marine environment contains natural background levels of Pb-210, Ra-226 and Ra-228, which can vary depending on the proximity to natural sources of these radionuclides. As a result, it can be difficult to detect the additional concentrations of Pb-210, Ra-226 and Ra-228 resulting from the discharges of these radionuclides in produced water by conventional monitoring. To address this issue, RSC has agreed to undertake modelling approaches to derive the additional concentrations of these radionuclides in seawater close to discharge points as well as further afield. By deriving the additional concentrations, RSC will be able to carry out an assessment of the radiological impact of these radionuclides in the environment.

The overall situation for discharges of total alpha, total beta (excluding tritium), Pb-210, Ra-226 and Ra-228 from the oil and gas sub-sector are summarised in figures 6.1 to 6.5.

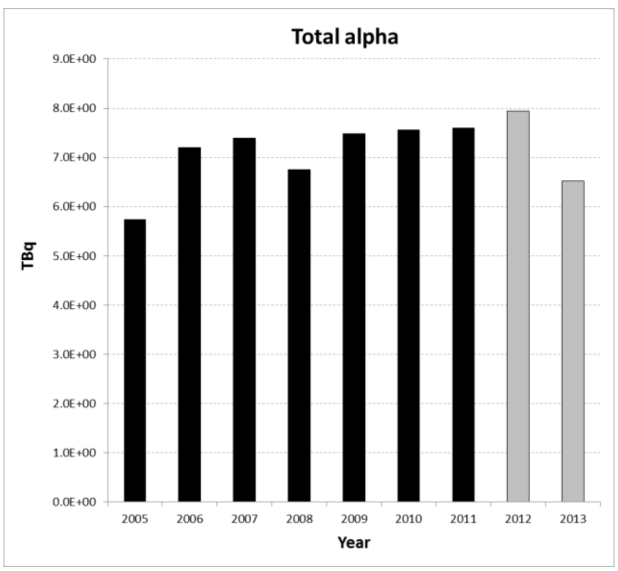

Figure 6.1: Total alpha discharges for produced water from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2013. Time periods indicated are baseline period (black columns), and subsequent years (grey columns).

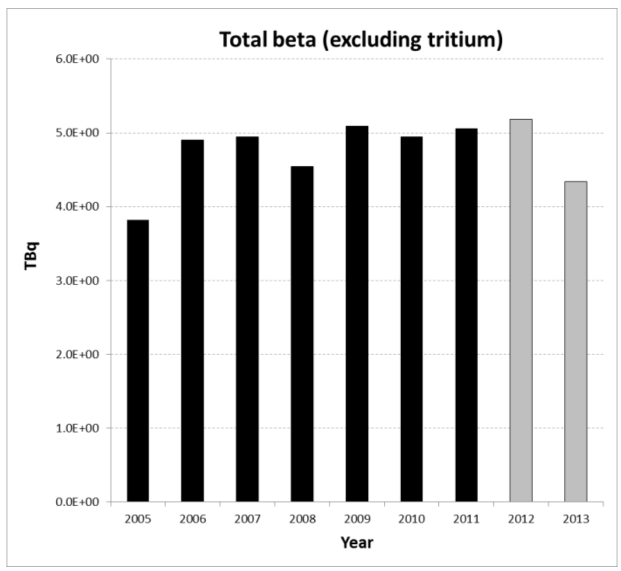

Figure 6.2: Total beta (excluding tritium) for produced water from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2013. Time periods indicated are baseline period (black columns), and subsequent years (grey columns).

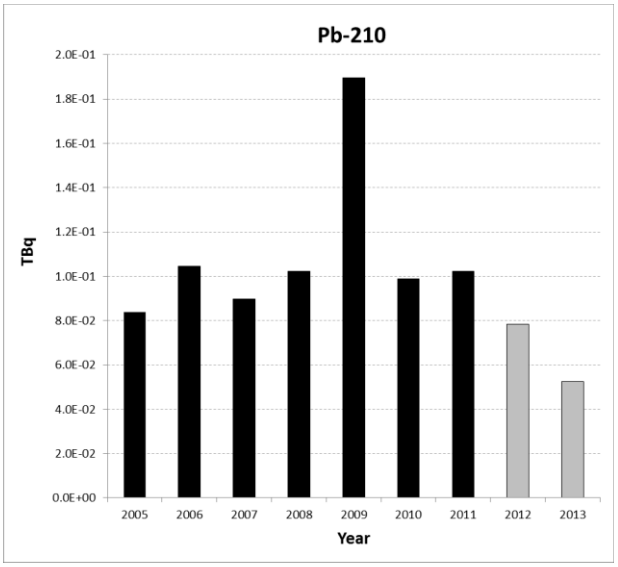

Figure 6.3: Pb-210 discharges for produced water from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2013. Time periods indicated are baseline period (black columns), and subsequent years (grey columns).

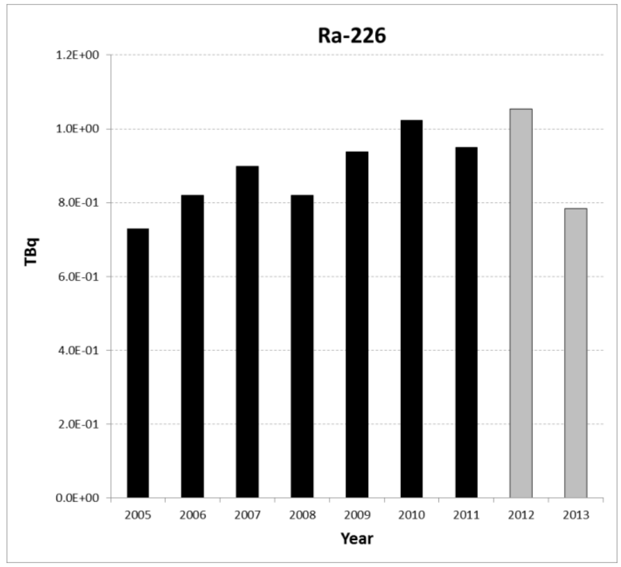

Figure 6.4: Ra-226 discharges for produced water from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2013. Time periods indicated are baseline period (black columns), and subsequent years (grey columns).

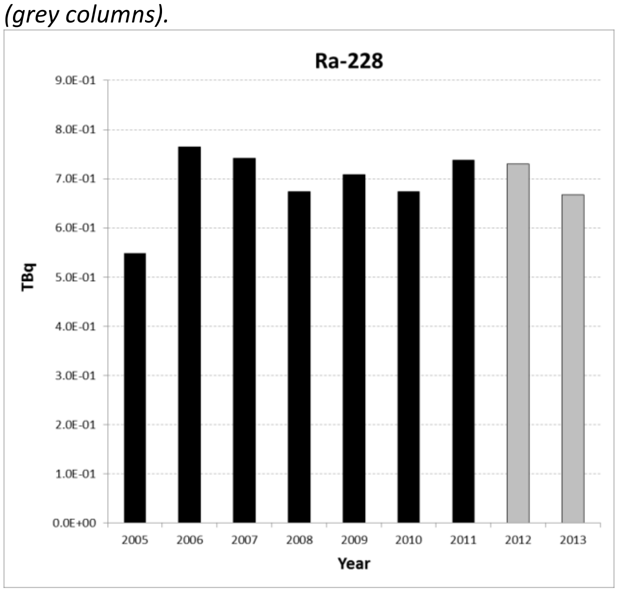

Figure 6.5: Ra-228 discharges for produced water from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2013. Time periods indicated are baseline period (black columns), assessment period (white columns) and intervening years (grey columns).

7. Conclusions of the Fourth Periodic Evaluation

7.1 Background

This Fourth Periodic Evaluation builds on the Third Periodic Evaluation (published 2009) and provides an update on the progress of OSPAR Contracting Parties in meeting the objectives of the OSPAR Radioactive Substances Strategy (RSS). The Fourth Periodic Evaluation focuses on discharges of radioactive substances from the nuclear and non-nuclear sectors.

With regard to discharges, the Third Periodic Evaluation concluded that it was not possible to draw any general conclusions on whether the aims of the OSPAR RSS were being delivered, but that there was evidence to suggest that progress was being made for the nuclear sector. For the non-nuclear sector, insufficient data had been collected at the time to allow any assessment to be carried out.

The Third Periodic Evaluation further concluded that there was evidence to suggest that the effect of the discharges and the resulting concentrations of radioactive substances on the overall quality status of the OSPAR maritime area were low.

The assessment methodology used in the Fourth Periodic Evaluation has allowed Contracting Parties to further assess progress, up to 2013, against the objectives of the OSPAR RSS.

7.1 Conclusions for the nuclear sector by sub-sector

Based on the assessments carried out in the Fourth Periodic Evaluation for discharges from the nuclear sector, there is clear evidence of progress towards the objectives of the OSPAR RSS. Further, it should be noted that none of the assessments carried out for individual Contracting Parties showed evidence of an increase in any discharge.

The evidence of progress includes:

7.1.1 Nuclear fuel production and enrichment sub-sector

i. Evidence for substantial reductions in discharges for 5 out of the 7 assessments for individual Contracting Parties.
ii. Evidence for substantial reductions in discharges for total alpha and total beta (excluding tritium) for the sub-sector as a whole.

7.1.2 Nuclear power sub-sector

i. Evidence for substantial reductions in discharges for 16 out of the 21 assessments for individual Contracting Parties and some evidence of a substantial reduction in a further assessment.
ii. Evidence for substantial reductions in discharges for total beta (excluding tritium) and Cs-137 and some evidence for substantial reductions in discharges for total alpha for the sub-sector as a whole.

7.1.3 Nuclear fuel reprocessing sub-sector

i. Evidence of substantial reductions in discharges in 7 out of 10 assessments for individual Contracting Parties.
ii. Evidence for substantial reductions for total alpha, total beta (excluding tritium), Tc-99 and Cs-137 for the sub-sector as a whole.

7.1.4 Nuclear research and development sub-sector

i. Evidence for substantial reductions in discharges for in 7 out of 15 assessments for individual Contracting Parties and some evidence of substantial reductions in a further 4 assessments.

ii. Some evidence for substantial reductions in discharges for total alpha and total beta (excluding tritium) for the sub-sector as a whole

7.2 Conclusions for the non-nuclear sector

For the non-nuclear sector, RSC has made progress towards the OSPAR RSS by extending the time series of data collected and by agreeing a baseline period for discharges from the oil and gas sub-sector. It was not possible to carry out any assessment of the discharges from the non-nuclear sector for which baseline periods have been agreed as there were insufficient data to identify an assessment period for comparison purposes. Therefore, it is not yet possible to make any conclusions concerning discharges from the non-nuclear sector. RSC expect to be able to make further progress on this issue in the Fifth Periodic Evaluation as more data will be available for consideration.

7.3 Overall conclusions for the nuclear sector

During the baseline period, the main contributors to the total activity discharged from the nuclear sector were the reprocessing and fuel production and enrichment sub-sectors. In the assessment period the discharges from all the sub-sectors have reduced and the relative contributions have changed. For example, the relative reduction in discharges from the fuel fabrication and enrichment sub-sector has been greater than that for the other sub-sectors due to the changes in that sub-sector, as previously reported in the Third Period Evaluation. While discharges from the reprocessing sub-sector are much reduced, it remains the dominant source of discharges from the nuclear sector contributing approximately 90% of the total alpha, and approximately 80% of the total beta (excluding tritium), discharges over the assessment period.

The Third Period Evaluation concluded in relation to discharges from the nuclear sector that:

- There had been a 38% reduction in total beta (excluding H-3) discharges during the assessment period compared with the baseline value and the statistical tests indicated that this change was statistically significant
- There had been a 15% increase in total alpha discharges during the assessment period compared with the baseline value, but the statistical tests indicated that this change was not statistically significant
- Since 2002, reductions had been achieved in discharges of Tc-99, a radionuclide to which both the 1998 and 2003 OSPAR Ministerial Meetings drew special attention, and that discharges of Tc-99 were expected to be reduced further and maintained at low levels.

The Fourth Periodic Evaluation has confirmed that in relation to discharges from the nuclear sector:

- OSPAR Contracting Parties are continuing to make good progress in meeting the objectives of the OSPAR RSS and that
- OSPAR Contracting Parties have achieved substantial reductions in discharges in many cases, as required by the OSPAR RSS.

Furthermore, the overall situation for the nuclear sector has improved since the Third Periodic Evaluation. In particular, the following achievements should be noted:

- There has now been a 2.5 fold reduction in discharges of total alpha since the baseline period
- There has now been a 12 fold reduction in discharges of total beta (excluding tritium) since the baseline period.

- Discharges of Tc-99 have continued to decline with a reduction of 38 fold in the discharges since the baseline period

Exceptional discharges associated with decommissioning and the management of legacy wastes at nuclear sites are reported separately to operational discharges but these were summed to give a total discharge for a site where applicable for the purposes of this evaluation. While relatively low when compared to overall operational discharges, the contribution of exceptional discharges from decommissioning activities is growing and this is expected to continue as essential work to reduce hazards and decommission redundant nuclear installations increases.

Although the focus of the Fourth Periodic Assessment has been on discharges of radioactive substances from the nuclear and non-nuclear sectors, the radiological impacts on man and biota from these discharges are expected to be low, as previously concluded in the Third Periodic Evaluation.

7.4 Steps taken by OSPAR RSC to promote and monitor progress

In order to meet the OSPAR RSS objectives, Contracting Parties have taken important steps since 1998 to promote and monitor progress. These have included:

- The regular reporting on the application by Contracting Parties of Best Available Technology (BAT) to minimise and, as appropriate, eliminate pollution of the marine environment caused by radioactive discharges from nuclear industries (PARCOM Recommendation 91/4) and corresponding guidelines (OSPAR Agreement 2004-3)
- The production by each Contracting Party of a national report setting out how it intends to meet the objectives of the Radioactive Substances Strategy.
- The development of an Agreement (OSPAR Agreement 2005-08) identifying 15 monitoring regions and the radionuclides and environmental compartments for which data are to be collected, as a basis for the reporting and evaluation of environmental concentrations of radioactive substances in the OSPAR maritime area.
- The development of Agreements (REF) for the reporting of discharge data from the nuclear (OSPAR Agreement 2013-10) and non-nuclear sectors (OSPAR Agreement 2013-11).
- The development of baseline values for total alpha, total beta (excluding tritium) and indicator radionuclides for the nuclear sector.
- The development of baseline values for total alpha, total beta (excluding tritium) and indicator radionuclides for the non-nuclear oil and gas sector.
- The adoption of statistical techniques to provide guidance for the treatment of datasets where a relatively large number of values are below the detection limit.
- The adoption of an assessment methodology to measure progress towards the objective of the Radioactive Substances Strategy for discharges of radioactive substances and activity concentrations in the marine environment.
- The identification of a statistical trend detection technique for use with RSC's discharge and environmental concentration data.
- The agreement of a methodology for the derivation of reference levels of activity concentrations in seawater for the assessment of the radiological impact of environmental concentrations of radionuclides (REF).

7.5 Future improvements to OSPAR RSC evaluations

Whilst RSC has made considerable progress in evaluating the extent to which the objectives of the RSS are being met, further work is needed before a future evaluation of progress can be expected to deliver clear overall conclusions. For example, RSC is currently working on, or is developing plans to:

- Develop a standard process for data collection and a rigorous quality control and management system of the OSPAR RSC data for the nuclear and non-nuclear sectors;
- Periodically review the development of industrial abatement techniques of tritium in the liquid effluent of power and reprocessing plants;
- Determine additional activity concentrations in the marine environment resulting from discharges of naturally occurring radionuclides in produced water to the marine environment;
- Review the need to assess the discharges and indicators from the different sub-sectors of the nuclear and non-nuclear sectors;
- Determine a methodology for assessing whether additional concentrations in the marine environment above historic levels are close to zero; and,
- Publish future evaluative reports to analyse progress, including the Fifth Periodic Evaluation which will include radioactive discharge and concentration data.

Previous Periodic Evaluations

OSPAR, 2006. Revised First Periodic Evaluation of Progress Towards the Objective of the OSPAR Radioactive Substances Strategy. Publication 302/2006.

OSPAR, 2007. Second Periodic Evaluation of Progress Towards the Objective of the OSPAR Radioactive Substances Strategy. Publication 338/2007.

OSPAR, 2009. Towards the Radioactive Substances Strategy Objectives. Third Periodic Evaluation. Radioactive Substances Series. Publication 445/2009

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ISBN: 978-1-911458-17-3
Publication Number: 687/2016