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COMMISSION

Fifth periodic evaluation of progress towards the objective of the OSPAR Radioactive Substances Strategy

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OSPAR's Radioactive Substances Committee undertakes periodic evaluations to analyse the progress that Contracting Parties to the OSPAR Convention make towards the objective of the Radioactive Substances Strategy in reducing discharges of radioactive substances to the North-East Atlantic. The fifth periodic evaluation also contributes to OSPAR's Quality Status Report 2023.

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

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998.

The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998.

Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union européenne.

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Executive summary

The Fifth Periodic Evaluation is the culmination of more than two decades of cooperation and work by Contracting Parties on the issue of Radioactive Substances under OSPAR.

The Fifth Periodic Evaluation builds on the previous periodic evaluations to assess whether OSPAR Contracting Parties have made progressive and substantial reductions in discharges of radioactive substances and whether additional concentrations of radioactive substances in the environment are close to historic levels in the OSPAR Maritime Area, by 2020, in order to meet the objectives of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy (NEAES) 2010-2020.

OSPAR's Radioactive Substances Committee (RSC) successfully established the necessary monitoring and data reporting programmes and developed the necessary assessment methodologies to determine whether the objectives of the RSS 2010-2020 were fulfilled. The measures developed by OSPAR RSC, as well as action by national authorities, ensured that progress could be made against these objectives. The assessments carried out in the Fifth Periodic Evaluation show that Contracting Parties have successfully fulfilled the objectives of the RSS for 2020 and have made significant progress towards fulfilling 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 doing so, Contracting Parties have prevented pollution of the OSPAR maritime area by ionising radiation.

This is evidenced by:

- Discharges from the nuclear sector have shown progressive and substantial reductions.
- Discharges from the non-nuclear oil and gas sub-sector have mostly remained unchanged but are not as yet amenable to reduction where the option of re-injection is not possible.
- Environmental concentrations of indicator radionuclides for the nuclear sector are close to or lower than historic levels.
- Environmental concentrations of indicator radionuclides for the nuclear sector and modelled additional concentrations of indicator radionuclides for the non-nuclear oil and gas sub-sector would not result in a significant radiological impact to humans or the marine environment.

Delivering the aims of the OSPAR Convention, including preventing pollution of the maritime area is an ongoing task. To this end, new strategic and operational objectives for radioactive substances have been agreed by OSPAR and the Ministerial Meeting 2021 in Cascais, Portugal under the North-East Atlantic Environment Strategy 2030.

Récapitulatif

La cinquième Evaluation périodique est l'aboutissement de plus de deux décennies de coopération et de travail des Parties contractantes sur la question des substances radioactives dans le cadre d'OSPAR.

La cinquième Évaluation périodique fait fond sur les évaluations périodiques précédentes pour déterminer si les Parties contractantes d'OSPAR ont réalisé des réductions progressives et substantielles des rejets de substances radioactives, et si les concentrations additionnelles de

substances radioactives dans l'environnement sont proches des niveaux historiques dans la zone maritime d'OSPAR, d'ici 2020. Ceci afin d'atteindre les objectifs de la Stratégie substances radioactives (RSS) d'OSPAR dans le cadre de la Stratégie pour le milieu marin de l'Atlantique du Nord-Est (NEAES) 2010-2020.

Le Comité substances radioactives (RSC) d'OSPAR a réussi à établir les programmes nécessaires de surveillance et de notification des données et à développer les méthodologies d'évaluation nécessaires pour déterminer si les objectifs de la RSS 2010-2020 ont été atteints. Les mesures développées par le RSC, ainsi que l'action des autorités nationales, ont permis de progresser par rapport à ces objectifs. Les évaluations effectuées dans le cadre de la cinquième Evaluation périodique montrent que les Parties contractantes ont réussi à atteindre les objectifs de la RSS 2010-2020 et ont réalisé des progrès significatifs pour atteindre son but ultime, à savoir, de parvenir à des concentrations, dans l'environnement proches des valeurs ambiantes dans le cas des substances radioactives présentes à l'état naturel et proches de zéro dans celui des substances radioactives de synthèse. Ce faisant, les Parties contractantes ont empêché la pollution de la zone maritime d'OSPAR par les rayonnements ionisants.

Les conclusions suivantes en témoignent :

- Les rejets du secteur nucléaire ont connu des réductions progressives et substantielles.
- Les rejets du sous-secteur non nucléaire pétrolier et gazier sont restés pour la plupart inchangés mais ne peuvent pas encore être réduits lorsque la réinjection n'est pas possible.
- Les concentrations environnementales de radionucléides indicateurs pour le secteur nucléaire sont proches ou inférieures aux niveaux historiques.
- Les concentrations environnementales de radionucléides indicateurs pour le secteur nucléaire et les concentrations additionnelles modélisées de radionucléides indicateurs pour le sous-secteur non nucléaire pétrolier et gazier n'entraîneraient pas d'impact radiologique significatif pour l'homme ou le milieu marin.

La réalisation des objectifs de la Convention OSPAR, y compris la prévention de la pollution de la zone maritime, est une tâche permanente. À cette fin, de nouveaux objectifs stratégiques et opérationnels pour les substances radioactives ont été convenus par OSPAR et la réunion ministérielle de 2021 à Cascais, au Portugal, dans le cadre de la Stratégie pour le milieu marin de l'Atlantique du Nord-Est 2030.

1. Introduction

The OSPAR Convention is the mechanism by which 15 Governments and the European Union (the OSPAR Contracting Parties) co-operate to protect the marine environment of the North-East Atlantic. OSPAR has its origins in the 1972 Oslo Convention against sea dumping. International cooperation was then broadened to cover land-based sources and the offshore industry by the 1974 Paris Convention. These two conventions were unified, updated and extended to form the 1992 OSPAR Convention.

Delivery of the requirement of the OSPAR Convention is taken forward by the OSPAR Commission. To assist in delivering the aims of the Convention, the wide range of issues that may impact on the OSPAR Maritime Area have been allocated to a number of work areas:

- Biological Diversity and Ecosystems
- Hazardous Substances and Eutrophication
- Human Activities
- Offshore industry
- Radioactive substances
- Cross Cutting issues

The first five work areas are overseen by a specific committee, while all committees are asked to contribute to any identified cross cutting issue. The OSPAR Radioactive Substances Committee (RSC) is the committee assigned to work on the issues of radioactive substances. Figure 1.1 illustrates the organisation of OSPAR.

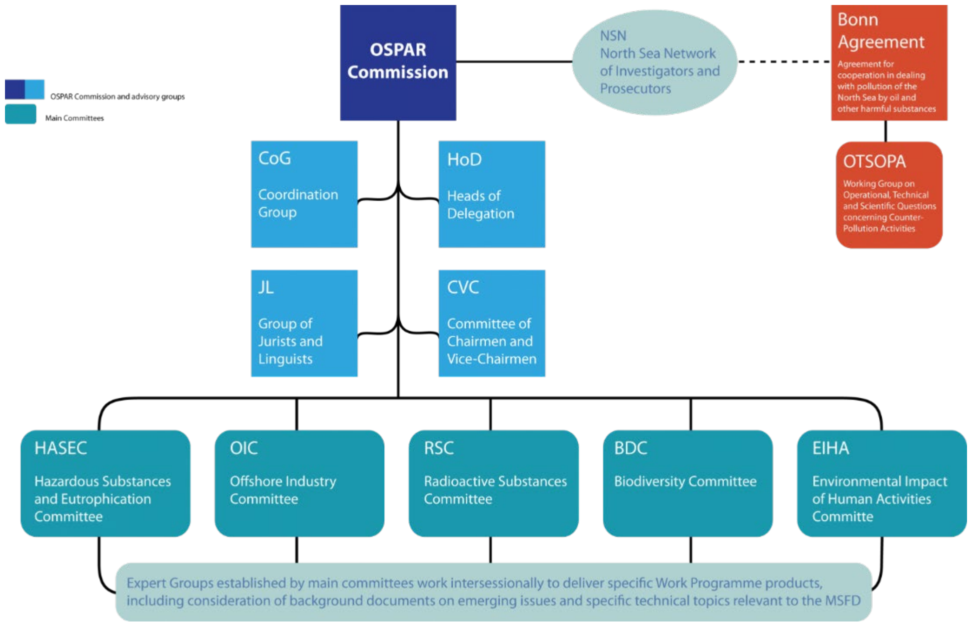

Figure 1.1: The organisation of the five work area committees under the OSPAR Commission.

1.1 OSPAR and radioactive substances

The OSPAR Convention, and its predecessors, acknowledged that radioactive substances are a form of pollution to be addressed. The OSPAR convention commits the Contracting Parties to promote measures to protect the marine environment from pollution by ionising radiation.

At the first Ministerial Meeting of the OSPAR Commission, held in 1998 at Sintra, Portugal[1], a complete and permanent ban on all dumping of radioactive waste and other matter was agreed. Agreement

[1] Ministerial Meeting of the OSPAR Commission, Sintra, 22 - 23 July 1998. (https://www.ospar.org/site/assets/files/36552/98_sintra_statement_english.pdf)

was also reached on objectives to protect the marine environment of the North-East Atlantic against radioactive substances arising from human activities. These objectives were reaffirmed at subsequent Ministerial Meetings of the OSPAR Commission (Bremen 2003[2], Bergen 2010[3]), and continued as the objectives of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy (NEAES) 2010-2020. These objectives state that:

1.1 The OSPAR Commission's strategic objective with regard to radioactive substances is to prevent pollution of the OSPAR 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:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

1.2 The Radioactive Substances Strategy will be implemented progressively by making every endeavour, through appropriate actions and measures to ensure that by the year 2020 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.

New strategic and operational objectives for radioactive substances have been agreed by the Ministerial Meeting of the OSPAR Commission 2021 in Cascais, Portugal under the NEAES 2030[4].

1.2 OSPAR reporting

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. Quality Status Reports (QSR) are prepared approximately every 10 years, with Intermediate Assessments being produced in between.

The QSRs are underpinned by indicator reports for specific OSPAR indicators and thematic assessments for broader work areas, as in the case of radioactive substances. Thematic assessments are in turn underpinned by more detailed scientific assessments, such as the periodic assessments produced in the past by OSPAR RSC.

1.3 This report

This report, the Fifth Periodic Evaluation, is a comprehensive evaluation that assesses authorised discharges from the nuclear and non-nuclear sectors, environmental concentrations of radionuclides in the OSPAR Maritime Area and the radiological consequences of those concentrations. It builds upon the data and conclusions of the previous four periodic evaluations. This Fifth Periodic Evaluation will provide the necessary scientific assessments to underpin the thematic assessment on radioactive substances for the QSR 2023.

[2] Ministerial Meeting of the OSPAR Commission, Bremen, 25 June, 2003. (https://www.ospar.org/site/assets/files/36552/03_bremen_statement_english.pdf)
[3] Ministerial Meeting of the OSPAR Commission, Bergen, 20-24 September 2010. (https://www.ospar.org/site/assets/files/36552/bergen_statement.pdf)
[4] Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2030 (Agreement 2021-01). (https://www.ospar.org/documents?v=46337)

Whilst the OSPAR RSS objectives refers to discharges, emissions and losses, this report does not assess the magnitude or trends in emissions or losses. Emissions (authorized gaseous releases) are not assessed because evidence suggests that they have a minimal impact on the OSPAR Maritime Area[5]. Losses have not been specifically addressed by OSPAR RSC as in many cases losses are addressed by other conventions (e.g. the Convention on Nuclear Safety, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter). However, as part of the work planned under the NEAES 2030, OSPAR RSC have agreed to identify the different types of loss of radioactive substances that may contribute to pollution of the marine environment and determine if any additional measures are required to prevent such pollution, to the extent that such pollution is not already the subject of effective measures agreed by other international organisations or prescribed by other international conventions.

This report is based on assessment of data reported over the period 1995 to 2018. As such it represents an assessment of over 20 years of the collective efforts of Contracting Parties in delivering the objectives of the OSPAR RSS. Although the report does not include data up to the year 2020 it provides a clear indication of whether the 2020 target included in the second objective of the OSPAR RSS, originally agreed in 1998, has been or is likely to be achieved. Where appropriate this report also refers to earlier data to illustrate longer term trends in radioactive substances discharges and environmental concentrations.

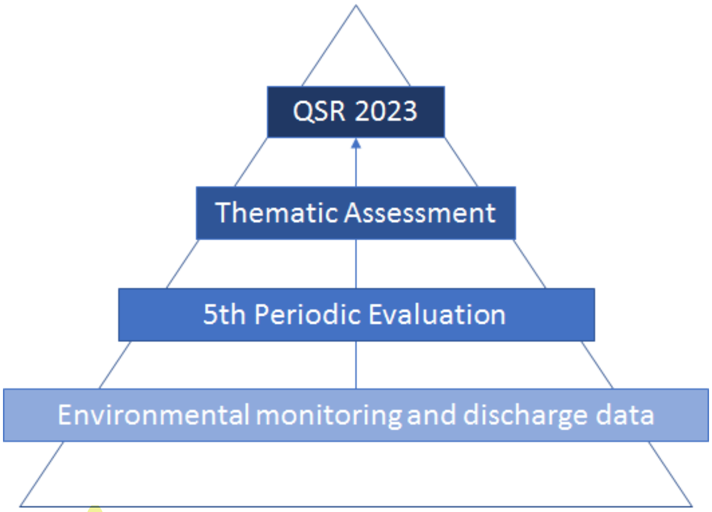

Figure 1.2: Schematic showing relationship between the data reported over the period 1995 to 2018, the Fifth Periodic Evaluation and the QSR2023.

1.4 OSPAR and its relationship to other international organisations

OSPAR is a regional convention that sits within a wider framework of other international conventions at the regional and global scale (e.g. the London Convention). Recognising this, the OSPAR Convention contains provisions designed to minimise duplication of effort and promote complimentary and joint scientific research. International engagement and partnership are an important part of the current NEAES and the strategies that preceded it. To this end, the OSPAR Commission has entered into various memoranda of understanding and co-operation agreements with other organisations.

Considering radioactive substances, there are a number of international bodies that provide authoritative advice on this topic such as the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP). The importance of such advice is recognised in the OSPAR Convention, which requires that Contracting Parties shall take account of the

[5] DEFRA, 2004. Contribution of aerial radioactive discharges to radionuclide concentrations in the marine environment Final report April 2004. DEFRA/RAS/04.002, Department for Environment, Food and Rural Affairs, UK.

recommendations of appropriate international organisations and agencies when adopting any programmes or measures for radioactive substances. With this in mind, OSPAR notes its appreciation to the IAEA as an observer organisation that actively contributes to the work of OSPAR RSC including the preparation of this Periodic Evaluation and the underlying assessment methodologies.

The IAEA have noted the importance that the OSPAR strategic objective to prevent pollution by radioactive substances is consistent with international safety standards for radiological protection of the public and environment. The IAEA also acknowledged that the practical implementation of the OSPAR RSS, as reported in this Periodic Evaluation, is compatible with the application of the international system for radiation protection reflected in national, regional (EU) and international safety standards.

1.5 Approach and structure of this evaluation

In order to assess whether the objectives of the OSPAR RSS have been delivered, it is necessary to examine the different elements of the objectives.

1.5.1 Discharges

Section 2 describes the main sources of discharges of radioactive substances from both the nuclear and non-nuclear sectors and how information on such discharges is collected. It also describes the measures that Contracting Parties have implemented to reduce discharges. Section 4 explains how discharge data is assessed to determine if there have been progressive and substantial reductions. Section 5 (nuclear sector) and Section 6 (non-nuclear sector) present the results of these assessments.

1.5.2 Environmental Concentrations

Section 3 describes the environmental concentration data collected and reported by Contracting Parties to OSPAR along with its limitations. Section 4 explains how the environmental concentration data is assessed to determine if additional concentrations in the marine environment are close to historic levels. Section 7 presents the result of that assessment.

1.5.3 Radiological assessment

Section 4 describes how the radiological impact on humans and non-human biota from environmental concentrations and additional concentrations of naturally occurring radionuclides arising from discharges of produced water from the oil and gas sub-sector are assessed. Section 8 presents the results of these assessments.

1.5.4 Overall Conclusions

Section 9 draws together the assessment of discharges, environmental concentrations and their radiological impact to provide an overall statement on the achievement of Contracting Parties against the OSPAR RSS under the NEAES 2010-2020.

2. Radioactive discharges into the North-East Atlantic

The OSPAR Convention requires Contracting Parties to apply Best Available Techniques (BAT) and Best Environmental Practice (BEP) including, where appropriate, clean technology, in their efforts to prevent and eliminate marine pollution including radioactive discharges. In addition, 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 general principles of radiation protection: justification, optimisation and dose limitation[6] [7] [8].

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. Contracting Parties have agreed which individual radionuclides or groups of radionuclides are required to be annually reported for each sector, using an agreed reporting format. The sites for which discharges have been reported by Contracting Parties to OSPAR in the period 1995 to 2018 are shown in Figure 2.1.

[6] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).

[7] EU BSS, 2014. European Union Basic Safety Standards. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Official Journal L-13 of 17 January 2014.

[8] IAEA, 2014. International Atomic Energy Agency IAEA Safety Standards Series No. GSR Part 3. Publication No. 1578, Vienna.

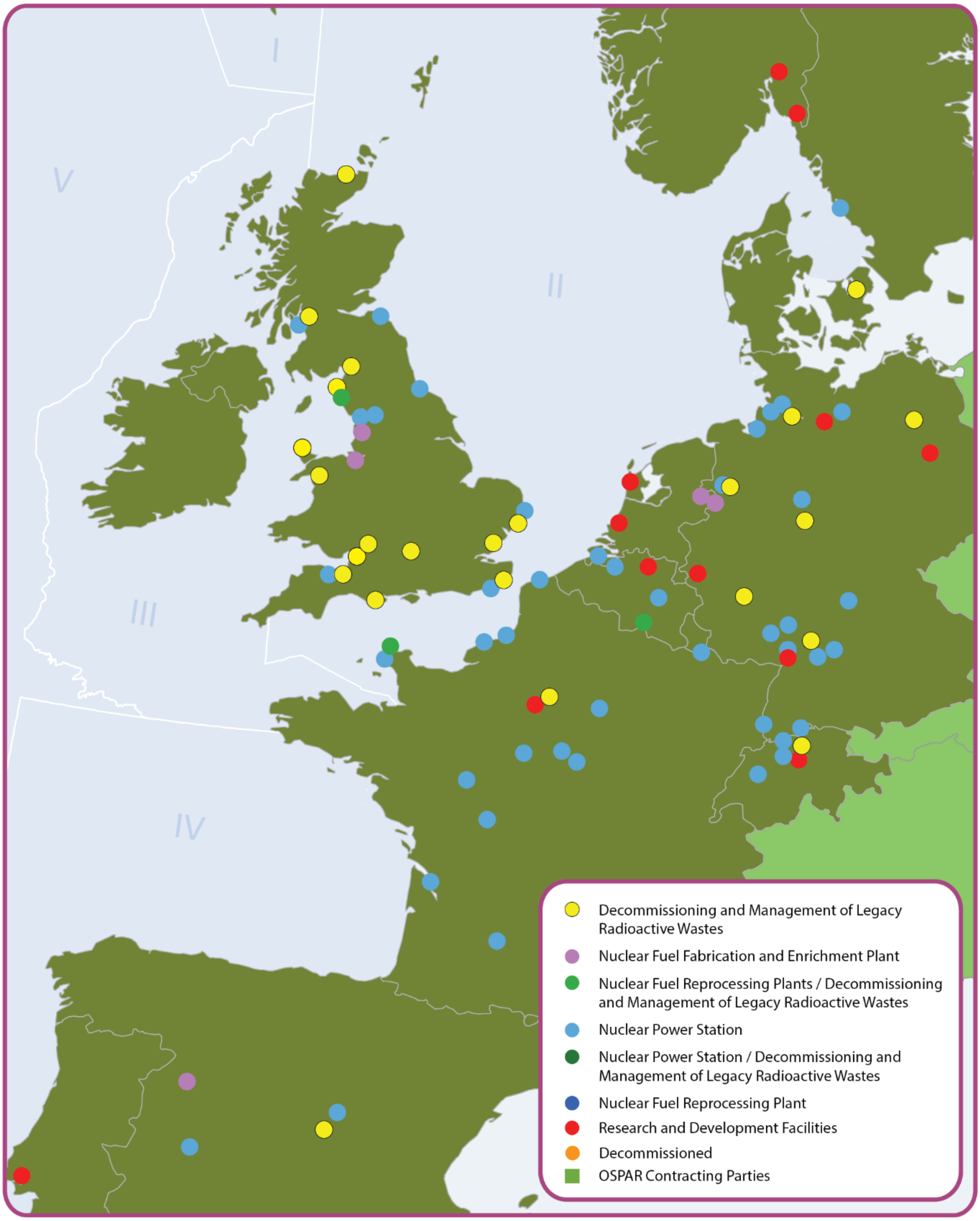

Figure 2.1: Nuclear sites for which discharges have been reported by Contracting Parties to OSPAR in the period 1995 to 2018. The status of the above sites may have changed from operational to decommissioning during the reporting period. The nuclear sites for which discharges are reported to OSPAR are given in OSPAR Agreement 2013-10 (2021 update).

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

- Nuclear power station
- Nuclear fuel reprocessing

- Nuclear fuel fabrication and enrichment
- Nuclear research and development

An increasing number of facilities have reached a decommissioning phase and their dismantling may generate discharges; also, some Contracting Parties have developed programs to recover historical or legacy waste. Since 2005, exceptional discharges associated with the recovery of historical or legacy waste and decommissioning are reported separately for some sites. Such differentiation is becoming particularly important as, in recent years, the contribution of 'exceptional' discharges has increased to become one of the main contributors of discharges from nuclear installations. However, for the evaluation of the discharges of the nuclear sub-sectors, the contribution of 'exceptional' discharges has been added to the subsector relevant to the facility being decommissioned or to the sub-sector which has generated the historical or legacy waste.

2.1.1 Nuclear power station sub-sector

Nuclear power stations (NPS) use the heat generated by nuclear fission to produce steam to drive electricity-generating turbines. Nuclear power stations 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 types of nuclear installation among OSPAR Contracting Parties with more than 60 power stations (in operation or in decommissioning) reporting discharge data to the Commission every year.

Radioactive substances that can be discharged by a nuclear power station fall into three broad categories:

- Uranium and transuranic (heavier than uranium) elements such as plutonium.
- Fission products (such as caesium-137 and technetium-99) resulting from the fission process of the uranium-235 or plutonium-239 in the fuel.
- 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 stations 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 or plutonium-240. In addition, nuclear 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.

2.1.2 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), which can be reprocessed in nuclear fuel reprocessing plants and then recycled in nuclear reactors. Reprocessing involves the recovery of these potentially reusable materials and the conditioning of the majority of the remaining 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 facilities at two sites. These are:

- Sellafield (UK) is the site of two reprocessing facilities: the Magnox reprocessing plant for Magnox reactor fuels which is nearing completion and is expected to finish reprocessing by the end of 2022; and the Thermal Oxide Reprocessing Plant (THORP), which dealt with advanced gas cooled reactor (AGR) and light water reactor (LWR) oxide fuels and was in operation until 2018.
- La Hague (France) which has 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, 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 discharge data was first collected by OSPAR in 1995 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. This trend has been pursued through the use of BAT.

2.1.3 Nuclear fuel fabrication 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 Maritime Area. Liquid discharges from nuclear fuel fabrication 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.

2.1.4 Nuclear 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. In some facilities there is also radiochemical production (production of radionuclides for medical or industrial purposes) in addition to R&D activities. Where R&D is carried out alongside other activities, discharges relating to R&D are reported with discharges from other activities as a combined total.

There are currently 12 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 Indicators for discharges from the nuclear sector

2.2.1 Total alpha and total beta (excluding tritium)

Contracting Parties 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'). The discharges of tritium are reported separately because they are the overall dominating beta emitting radionuclide in the discharges from the nuclear sector. Total alpha and total beta (excluding tritium) are useful as indicators as they encompass, together with tritium discharges, all liquid discharges of radioactive substances to the OSPAR Maritime Area. 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 total alpha and total beta (excluding tritium) activities in the reported discharges:

- Either the activity concentrations of a certain number of alpha and beta emitting radionuclides are measured separately, and these results are then summed with tritium discharges reported separately.
- Or a discharge sample is analysed for 'gross alpha' or 'gross beta' activity i.e., the total representative amount of alpha or beta activity with tritium discharges 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 for individual radionuclides is not strictly equal to the gross alpha and gross beta results.

Contracting Parties have used these different approaches when reporting total alpha and total beta (excluding tritium) activities across the different nuclear sub-sectors. For example, some Contracting Parties use the gross activity value for one sub-sector and the sum of the individual activity results for another sub-sector. In addition, where some Contracting Parties have used the data reported under 'other radionuclides' in the calculation of total beta (excluding tritium), the interpretation of what radionuclides are included in this broad group has varied between Contracting Parties. However, in general and provided that individual Contracting Parties have been consistent in the approach they have taken in the derivation of total alpha and total beta (excluding tritium) discharges, statistical analyses which compare values for an assessment period with a baseline remain valid. When assessing discharges from the nuclear sector, discharges from operational and decommissioning activities are reported separately to OSPAR but are combined for assessment purposes.

The indicators total alpha and total beta (excluding tritium) have also been used to assess the total discharges from each nuclear sub-sector and the sector as a whole. In each case, the values for these indicators from each Contracting Party have been summed.

2.2.2 Individual radionuclides

Contracting Parties report discharge data for a range of individual radionuclides such as tritium (H-3), caesium-137 (Cs-137), technetium-99 (Tc-99) and plutonium-239,240 (Pu-239,240) which can vary across the different sub-sectors. 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. For each sub-sector certain individual radionuclides have been selected for assessment purposes in addition to the indicators for total alpha and total beta (excluding tritium). The OSPAR Radioactive Substances Committee (RSC) has recognised that the industrial scale abatement of tritium in the liquid effluent of nuclear power stations and nuclear reprocessing facilities is currently not technically feasible. Therefore, discharges of tritium have not been assessed as part of the Fifth Periodic Evaluation but the discharge data for tritium that has been reported to OSPAR are stated in Annex 2.

The following individual indicator radionuclides are assessed for each nuclear sub-sector, but not necessarily for each Contracting Party:

- For the nuclear power station sub-sector - Cs-137.
- For the nuclear fuel reprocessing sub-sector - Tc-99, Cs-137 and Pu-239,240.
- For the nuclear fuel fabrication and enrichment sub-sector - Tc-99.
- For the nuclear research and development sub-sector - Cs-137 and Pu-239,240.

The individual indicator radionuclides have also been used to assess the total discharges from each nuclear sub-sector and the sector as a whole. In each case, the values for these indicators from each Contracting Party have been summed.

2.2.3 Tritium (H-3)

Tritium (half-life 12.3 years) is a natural product produced by cosmic rays, accounting for approximately 20 - 30% of the radionuclide measured in the North Sea; tritium is also an activation product discharged by nuclear power stations and a fission product mainly discharged by reprocessing plants. Discharges of tritium are predominantly in the form of tritiated water, which does not become concentrated in biota (i.e., low bioaccumulation) although some organically bound tritium has been discharged in the past by some facilities. It is a weak pure beta emitter with the lowest radiotoxicity among all nuclides discharged by nuclear facilities (tritium has a very low dose coefficient)).

However, it is by far the most discharged beta emitter from nuclear facilities. This is the reason, together with the fact that its radiotoxicity is much lower than for the other beta emitters, for which the discharges of tritium are reported separately and not included with other beta emitters in the "total beta" category.

There is currently no 'technical feasibility' for the industrial scale abatement of tritium in the liquid effluent of LWR NPS (including PWR NPS) and reprocessing plants, as shown for example by the BAT reports following PARCOM Recommendation 91/4, OSPAR Recommendation 2018/01 (as amended) and periodic review of the potential development of such techniques. Discharges of tritium from the reprocessing plants fluctuates in accordance with spent fuel reprocessing rates and from LWR NPS with the generated power.

2.2.4 Technetium-99 (Tc-99)

Technetium-99 is a long-lived (half-life of 213,000 years), beta-emitting artificial fission product, which is largely present in the environment as a result of reprocessing activities and to a lesser extent from 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[9].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 OSPAR 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[10]. As a result, annual discharges of Tc-99 to sea (primarily from treatment of stored wastes from the reprocessing of Magnox fuel) were reduced by a factor of 174 between 1995 and 2013. The Magnox reprocessing facility is expected to finish reprocessing by the end of 2022.

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 unit to remove Tc-99 has been developed for the newer facilities UP2-800 and UP3-A and has been operated since 1998 to further reduce discharges of this radionuclide (decontamination factor has increased 4 to 5 times).

2.2.5 Caesium-137 (Cs-137)

Caesium-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

[9] Brown, J.E., Kolstad, A.K., Brungot, A.L., Lind, B., Rudjord, A.L., Strand, P. and Føyn, L., 1999. Levels of 99Tc in seawater and biota samples from Norwegian coastal waters and adjacent seas. Marine Pollution Bulletin, 38(7), pp.560-571.

[10] Mayall, A., 2005. The regulation of technetium-99 discharges at Sellafield. International conference on issues and trends in radioactive waste management; Vienna (Austria); 9-13 Dec 2002.

weapon tests, fallout from the Chernobyl accident and discharges from reprocessing plants and in small amounts from nuclear power plants. Together with its short-lived decay product (metastable barium-137 or Ba-137m), it is a radiological significant beta/gamma emitter. That Cs-137 remains a significant radionuclide in the context of current environmental concentration assessments, is due principally to higher discharges made in the past.

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 1995, when data was first collected to OSPAR.

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 when discharge data was first collected by OSPAR 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, as described in the BAT reports submitted by France. This optimised liquid effluent management strategy has resulted in an almost 8-fold reduction in discharges of Cs-137 since 1995.

2.2.6 Plutonium-239 and plutonium-240 (Pu-239,240)

Plutonium-239 and 240 are long-lived artificial radionuclides (half-lives of 24,100 years and 6,563 years respectively). Their presence in the OSPAR Maritime Area results mainly from reprocessing activities and to a lesser extent from atmospheric nuclear weapon tests.

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-239,240 discharges were reduced by a factor of more than 70 between the mid-1970s and 1995, when data was first collected by OSPAR.

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 as described in the BAT reports submitted by France.

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[11].

2.3 Discharges from the non-nuclear sector

Contracting Parties report discharge data for a number of non-nuclear sub-sectors to OSPAR, but RSC has agreed that only discharges of naturally occurring radionuclides from the oil and gas sub-sector should be assessed using the agreed assessment methodologies. Discharge data from the following non-nuclear sub-sectors are reported to OSPAR:

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

2.3.1 Oil and gas sub-sector

The main source of discharges of radionuclides to the OSPAR Maritime Area from the oil and gas sub-sector results from discharges of produced water. Figure 2.2 shows the location of installations under the oil and gas sub-sector for which discharges of produced water have been reported by Contracting Parties to OSPAR in the period 2005 to 2018. 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 lead-210, radium-226 and radium-228. The activity concentrations of naturally occurring radionuclides in produced water and the total activity discharged can vary between different oil and gas 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 production platform can also vary depending on a number of practices such as which target reservoir is being produced at any given time, as well as the use of scale inhibitors or dissolvers in the process system.

The previous PARCOM Recommendation 91/4 and the current OSPAR Recommendation 2018/01 (as amended) do not cover the implementation of BAT in the non-nuclear sector. BAT is applied for the treatment and discharge of produced water by Contracting Parties under OSPAR Recommendation 2001/1 (as amended), but this is not specific to radioactive discharges. Re-injection as an option depends on a number of variables such as having a suitable sub-surface formation; a dedicated disposal well to re-inject produced water; having the necessary infrastructure on the installation to re-inject produced water or the possibility to retrofit re-injection equipment on existing Installations. Not all production fields have sub-surface geology that would allow or accommodate the re-injection of produced water. Where

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

produced water is routinely re-injected, the availability of the injection system can also result in periodic discharges of produced water.

OSPAR Offshore Industry Committee Expert Assessment Panel concluded in 2018 that there were currently no suitable techniques that could selectively reduce levels of radionuclides in produced water as it was being extracted and discharged[12]. Any future implementation of such techniques, should they be developed, would depend on several factors including efficiency and cost compared to discharging to the sea.

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.

[12] RSC 2019 Summary Record

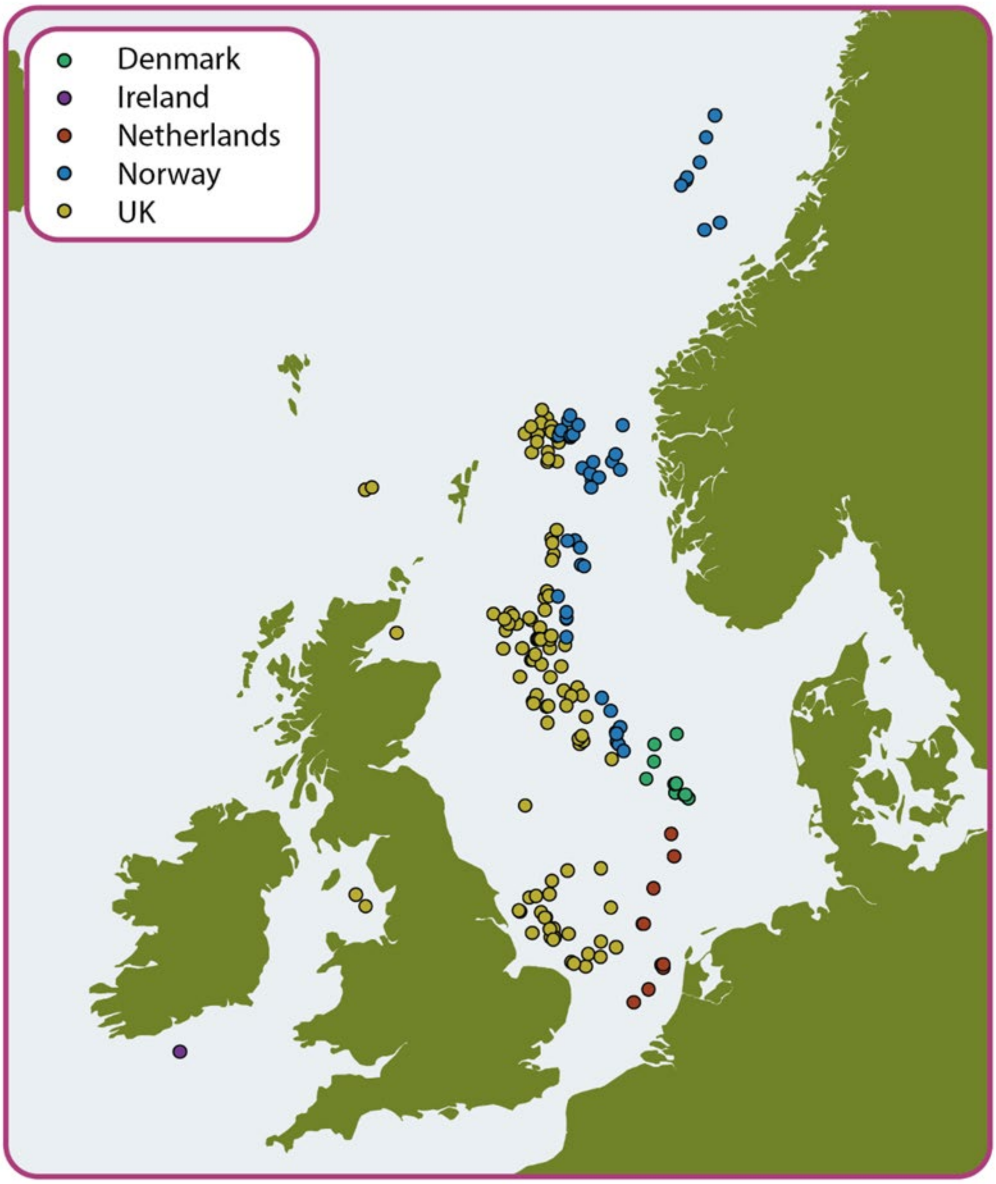

Figure 2.2: Location of installations under the oil and gas sub-sector for which discharges of produced water have been reported by Contracting Parties to OSPAR in the period 2005 to 2018.

2.3.2 Medical sub-sector

Discharges from the medical sub-sector are associated with the use of short-lived radioactive substances for therapeutic and diagnostic purposes in hospitals. Such hospitals are authorised to discharge these substances which are mainly contained in patient excreta. OSPAR has collected data on discharges from the medical sector since 2005. OSPAR RSC took the decision to cease reporting on the short-lived radionuclide Tc-99m from the medical sector, since its contribution to the amount of technetium-99 (through radioactive decay) present in the marine environment was minor compared to other sources.

The other main discharge reported from the medical sector is for the short-lived (half-life of 8 days) radionuclide iodine-131 (I-131). In a number of countries, the use of decay tanks has notably reduced the discharge of iodine-131 from the medical sector. Due to uncertainties associated with the reported data and the amount entering the marine environment, OSPAR publishes reported data, but OSPAR RSC has agreed not to carry out any assessments of the discharges from this sub-sector at present. However, OSPAR RSC is continuing to review the work of individual Contracting Parties on the issues surrounding the discharge of I-131.

2.3.3 Other non-nuclear sub-sectors

Several Contracting Parties report data to OSPAR for a number of other non-nuclear sub-sectors. From the data that have been reported for the university and research centre sub-sector, 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 is carried out in several Contracting Parties, but 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 reported to OSPAR, it is reasonable to conclude that these sub-sectors are no longer a significant contributor to total alpha and total beta (excluding tritium) discharges.

2.4 Indicators for discharges from the oil and gas sub-sector

2.4.1 Total alpha and total beta (excluding tritium) and individual radionuclides

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

The agreed formulae are as follows:

- Produced water
  Total alpha (TBq) = (5xRa-228) + (4xRa-226) + (1xPb-210).
  Total beta (excluding tritium) (TBq) = (4xRa-228) + (2xRa-226) + (2xPb-210)

- Descaling activites
  Total alpha (TBq) = (5xTh-228) + (4xRa-226) + (1xPb-210).
  Total beta (excluding tritium) (TBq) = (2xTh-228) + (2xRa-228) + (2xRa-226) + (2xPb-210)

When assessing discharges from the oil and gas sub-sector, discharges reported for produced water and descaling activities have been combined (discharges of radiotracers are not assessed). This is in keeping with the approach adopted for the nuclear sector, where discharges from operational and decommissioning activities are reported separately but are combined for assessment purposes. However, total annual discharged activities are dominated by the contribution of indicator radionuclides from the discharges of produced water as annual activities discharged in produced water are many orders of magnitude greater than from discharges associated with descaling activities.

2.4.2 Lead–210 (Pb-210)

Lead-210 is a naturally occurring isotope and one of the last elements created by the radioactive decay of the isotope uranium-238. It is a beta emitter with a half-life of about 22 years. Pb-210 is also a decay product of radon gas (Rn-222).

2.4.3 Radium-226 and radium 228 (Ra-226 and Ra-228)

Radium-226 and 228 are naturally occurring decay products of uranium and thorium isotopes that are present in subsurface formations from which hydrocarbons are produced. While uranium and thorium are largely immobile, radium is slightly more soluble. Dissolved Ra-226 and Ra-228 either remains in solution or coprecipitates with other elements in the scales or carbonate sludges generated during oil and gas production.

2.4.4 Thorium-228 (Th-228)

Thorium-228 is a naturally occurring decay product of thorium-232 with a half-life of about 1.9 years. Thorium is found at low levels in soil, rocks, water, plants, and animals. Almost all naturally occurring thorium exists in the form of either radioactive isotope thorium-232, thorium-230, or thorium-228.

3. Environmental concentrations in the North-East Atlantic

Contracting Parties report data on environmental concentrations of radionuclides to OSPAR, and this data is used to assess against the objectives of the OSPAR Radioactive Substances Strategy (RSS). This section describes the rationale behind the agreed monitoring programme, the choice of indicator radionuclides and environmental compartments monitored as well as the limitations of the data that has been reported.

It is important to note that not all radionuclides present in the environment are the result of authorized discharges from the nuclear and non-nuclear sectors. There have been a number of accidents and events, such as the Chernobyl accident in 1986 and fallout from atmospheric nuclear weapons testing in the 1950s and 1960s, which have resulted in the introduction of radionuclides to the marine environment. Other industrial activities have also released radionuclides into the marine environment as a consequence of their processes. In many cases, the additional sources of radionuclides from these historical accidents and events are still detectable today and will generally be indistinguishable from past and contemporary discharges of radionuclides. For this reason, monitoring data for environmental concentrations is a reflection of the sum of contributions from historical accidents and events and also from past and contemporary discharges of radionuclides. In addition, environmental concentrations of naturally occurring radionuclides by definition will also contain natural background levels of these radionuclides.

3.1 Monitoring of environmental concentrations

Contracting Parties agreed a monitoring programme for environmental concentrations of radionuclides (OSPAR agreement 2005-08) in 2005 which was reviewed and revised in 2018. This agreement sets out what each Contracting Parties will monitor throughout the OSPAR Maritime Area. The contribution of each Contracting Party to the monitoring programme is based on the existing national monitoring programmes within each Contracting Party.

This agreement underpins all data collection for environmental concentrations used for evaluation purposes. Specific sampling and analytical methodologies are not prescribed by OSPAR, but determination of these methods is for the individual Contracting Party based on national and international best practice and national capability. However, all participating laboratories have reported on quality assurance and quality control procedures to the OSPAR Radioactive Substances Committee (RSC) and all laboratories routinely participate in International Atomic Energy Agency (IAEA) proficiency tests, which have taken place since the early 2000s. The results of these proficiency tests are reported by the IAEA to OSPAR RSC.

3.1.1 Geographical regions monitored

OSPAR RSC agreed to split the OSPAR Maritime Area into 15 sub-regions, taking into account specific sources, prevailing currents and the areas used in the MARINA II study[13]. These 15 OSPAR RSC sub-regions generally represent subdivisions of the five main regions of the OSPAR Maritime Area, although some of the boundaries do not coincide exactly (see Table 3.1 and Figure 3.1).

Table 3.1: Comparison of established OSPAR RSC sub-regions and the five main regions of the OSPAR Maritime Area

OSPAR RSC sub-region	OSPAR Region
1. Wider Atlantic	Regions III, IV, V
2. Cap de la Hague Channel	Region II
3. Channel East	Region II
4. Irish Sea (Rep. of Ireland)	Region III
5. Irish Sea (Northern Ireland)	Region III
6. Irish Sea	Region III
7. Scottish waters	Regions II, III, V
8. North Sea South (Belgian and Dutch Coast)	Region II
9. German Bight	Region II
10. North Sea (NW, SE, and Central)	Regions I, II
11. North Sea (Skagerrak)	Region II
12. Kattegat	Region II
13. Norwegian Coastal Current	Region I

[13] MARINA II. European Commission (2003). Update of the MARINA Project on the radiological exposure of the European Community from radioactivity in North European marine waters.

14. Barents Sea	Region I
15. Norwegian, Greenland Seas and Icelandic Waters	Region I

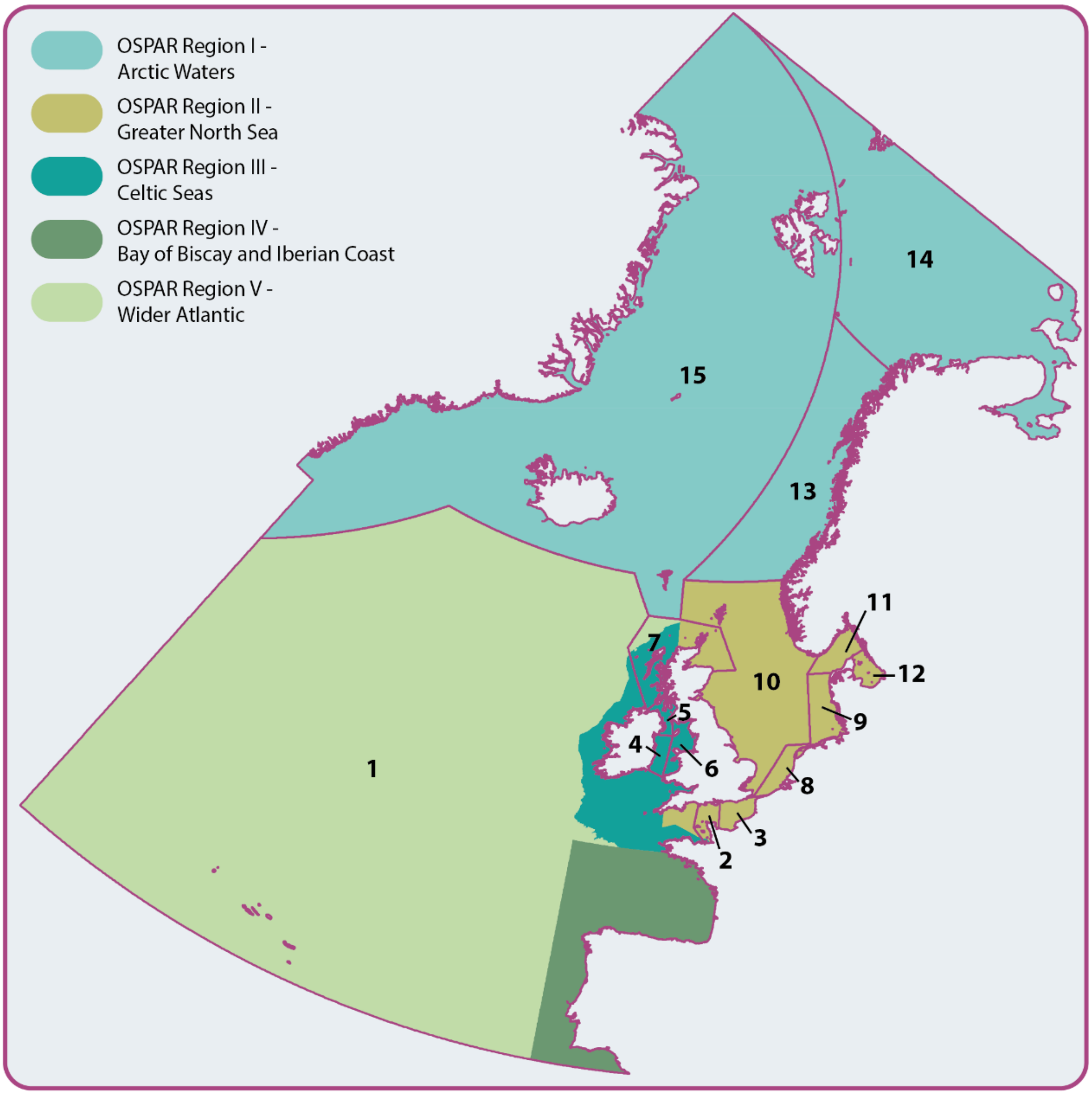

Figure 3.1: Comparison of established OSPAR RSC sub-regions and the five main regions of the OSPAR Maritime Area. The 15 OSPAR RSC sub regions are: 1. Wider Atlantic, 2. Cap de la Hague Channel, 3. Channel East, 4. Irish Sea (Rep. of Ireland), 5. Irish Sea (Northern Ireland), 6. Irish Sea, 7. Scottish waters, 8. North Sea South (Belgian and Dutch Coast), 9. German Bight, 10. North Sea (NW, SE, and Central), 11. North Sea (Skagerrak), 12. Kattegat, 13. Norwegian Coastal Current, 14. Barents Sea and 15. Norwegian, Greenland Seas and Icelandic Waters.

3.1.2 Radionuclides monitored

OSPAR RSC agreed to report monitoring data for the radionuclides tritium (H-3), technetium-99 (Tc-99), caesium-137 (Cs-137) and plutonium-239 and 240 (Pu-239,240) as indicators for the nuclear sector. OSPAR RSC also agreed to report monitoring data for the naturally occurring radionuclides polonium-210 (Po-210), lead-210 (Pb-210), radium-226 (Ra-226) and radium-228 (Ra-228) to provide information on the magnitude and range in background levels of these radionuclides.

3.1.3 Environmental compartments monitored

OSPAR RSC agreed to report monitoring data for the indicator radionuclides in seawater and marine biota (seaweed, molluscs and fish), although monitoring data for tritium is only reported for seawater. OSPAR RSC agreed not to report monitoring data for sediments as it is difficult to make comparisons over such wide spatial areas covered by the OSPAR RSC sub-regions and over long-time scales. Sediments can exhibit a wide range in variation of chemical composition and particle sizes and are exposed to a range of physical (e.g. wave action, dredging and bottom trawling), biological (e.g bioturbation) and chemical (e.g. diagenesis) processes that can impact on the levels of any radionuclides in the sediments. In addition, the process by which radionuclides bind to sediments is often reversible, and the rate at which radionuclides bind to and are released from sediments can be affected by the aforementioned physical, chemical and biological processes. The complexity of these issues makes it difficult to draw any conclusions about radionuclides concentrations in sediment in the OSPAR Maritime Area.

Tritium is not considered relevant for marine biota because there is no evidence for any bioaccumulation of tritium by marine biota (with the exception of organic tritium compounds). All marine biota activity concentration data are reported as wet weight. Where concentration data has been measured as dry weight, a conversion factor of 5 has been used to convert these data to wet weight. The specific species of marine biota monitored within the categories of seaweed, molluscs and fish is decided by the individual Contracting Parties and is based on local availability and significance.

3.2 Limitations and considerations of the monitoring data reported to OSPAR

There are a number of limitations to the monitoring programme established by OSPAR RSC and the subsequent use of the monitoring data reported with regard to the agreed methodologies that are used to assess environmental concentrations in the Fifth Periodic Evaluation. It must be remembered that national monitoring programmes are designed to meet the regulatory requirements of each Contracting Party. In addition, there is a need to consider the impact of past discharges on current environmental concentrations.

3.2.1 Spatial and temporal nature of monitoring data

Monitoring data reported to OSPAR can be based on long-term regular monitoring programmes, while in other cases monitoring data has been derived from short-term, or single, monitoring-campaigns (e.g. research cruises). For seawater, monitoring data is typically reported for coastal and open sea stations, though this can vary from year to year and across the different OSPAR RSC sub-regions. For marine biota, data generally relate to coastal measurements with the exception of certain monitoring for fish. Some monitoring data reported to OSPAR has been based on individual samples taken over the course of a year, whereas other data has been based on average annual values that may have been derived from several samples in a year.

3.2.2 Insufficient or no data available
There is only limited or no monitoring data available for some combinations of environmental compartments, indicator radionuclides and OSPAR RSC sub-regions, as monitoring of all these combinations is not viable or practical.

3.2.3 Data reported below detection limits
In many cases, environmental concentration data has been reported to OSPAR as below a stated detection limit. This can be due to the type of analytical methodology employed and or because the levels of the radionuclides in the marine environment are low.

3.2.4 Impact of past discharges
Radionuclides that are soluble in seawater are typically dispersed away from their discharge points by tidal and prevailing ocean currents. Radionuclides that are less soluble typically bind to sediments in the areas around their discharge points, where they can accumulate over time. The process by which such radionuclides bind to sediments can be dynamic, meaning that these radionuclides can be released or remobilised back into the overlying seawater. Through such processes, radionuclides that have accumulated in sediments as the result of previous higher discharge levels, can act as a significant source of these radionuclides over time, particularly where discharge levels have subsequently been reduced.

4. Assessment and other methodologies used in the Fifth Periodic Evaluation

The Fifth Periodic Evaluation undertakes assessments of discharge data reported for the nuclear and non-nuclear sectors as described in Section 2 and data reported for environmental concentrations as described in Section 3. In addition, the Fifth Periodic Evaluation assesses the radiological impact of environmental concentrations of artificial radionuclides and additional concentrations of naturally occurring radionuclides from the discharge of produced water from the non-nuclear oil and gas sub-sector. The following section describes the assessment methodologies employed in the Fifth Periodic Evaluation. These assessment methodologies have been developed by the OSPAR Radioactive Substances Committee (RSC) over a number of years. The detailed background and justification for the choice of statistical methods used in the assessment methodologies are given in the First and Third Periodic Evaluations as well as the peer reviewed scientific publication by Fiévet & Della Vedova (2010)[14].

4.1 Assessment methodologies for discharge data

4.1.1 Scope of assessment

Assessments of discharge data are based on data reported to OSPAR by Contracting Parties under the reporting agreements for nuclear discharge data (OSPAR Agreement 2013-10, 2021 update) and non-nuclear discharge data (OSPAR Agreement 2013-11, 2021 update).

[14] Fiévet, B., & Della Vedova, C. (2010). Dealing with non-detect values in time-series measurements of radionuclide concentration in the marine environment. Journal of environmental radioactivity, 101(1), 1-7.

Assessments of discharges from the nuclear sector are based on total discharges (i.e. operational and decommissioning discharges). Since 2005, Contracting Parties have in some cases reported discharge data 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 Fifth Periodic Evaluation, such data have been re-combined with any operational discharges from the corresponding sub-sector.

OSPAR recognised in previous Periodic Evaluations that the industrial scale abatement of tritium in the liquid effluent from nuclear power stations and nuclear reprocessing facilities is currently not technically feasible. These discharges have not been assessed as part of the Fifth Periodic Evaluation but are reported in Annex 2.

Assessments of discharges from the non-nuclear oil and gas sub-sector are based on the total of the following different discharges of naturally occurring radionuclides reported under this sub-sector:

a. Produced water.

b. Descaling operations, both offshore and onshore, from normal production that leads to discharges of:

i Radioactivity in suspended solids arising from water-jet descaling;

ii Radioactivity in solution as a result of descaling using acids or scale dissolvers.

c. Descaling operations, both offshore and onshore, from decommissioning of oil and gas installations that leads to discharges of:

i Radioactivity in suspended solids arising from water-jet descaling;

ii Radioactivity in solution as a result of descaling using acids or scale dissolvers.

Discharges of naturally occurring radionuclides in produced water are far greater than the other discharges assessed for the non-nuclear oil and gas sub-sector and typically account for at least 95% of the total discharge for each Contracting Party for each year. Discharges of radiotracers (such as tritium) are also reported for the non-nuclear oil and gas sub-sector, but these are not included in the totals that are assessed. The discharges of tritium when used as a radiotracer under the oil and gas sub-sector are orders of magnitude lower than the activity of tritium discharged from the nuclear sector. OSPAR RSC agreed that it is not currently necessary to assess the discharges under any other non-nuclear sub-sectors for which data is reported to OSPAR (see Section 2 for further information). Such data is not reported in the Fifth Periodic Evaluation but is available from the OSPAR online database for non-nuclear discharges.[15]

4.1.2 Aim of assessment

The stated aim of the first OSPAR Radioactive Substances Strategy (RSS) objective (2010 to 2020) is to prevent pollution of the OSPAR 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

[15] https://oap.ospar.org/en/ospar-assessments/committee-assessments/radioactive-substances/discharges-non-nuclear/

substances. In achieving this objective, the following issues should, inter alia, be taken into account:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

The assessments of discharge data used in the Fifth Periodic Evaluation test the progressive and substantial nature of any reductions in discharges from the nuclear and the non-nuclear oil and gas sub-sector. In situations where the statistical assessments indicate that progressive and substantial reductions in discharges have not occurred, it is important to consider the context to those situations.

4.1.3 Selection of years for baseline period

OSPAR RSC 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.

OSPAR RSC 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.

4.1.4 Selection of years for the assessment period of the Fifth Periodic Evaluation

For the purposes of the Fifth Periodic Evaluation, OSPAR RSC has agreed that the assessment period for discharges from the nuclear sector and discharges for the non-nuclear oil and gas sub-sector would comprise the 7-year period 2012 to 2018.

4.1.5 Calculation of annual values

For the nuclear sub-sectors and the non-nuclear oil and gas sub-sector, in each case annual values have been calculated by summing all the discharge data for the indicators total alpha and total beta (excluding tritium) as well as 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 2018 for the nuclear sector and 2005 to 2018 for the non-nuclear oil and gas sub-sector). Annual values for each sub-sector were also calculated by summing all discharge data for the indicators for all Contracting Parties for all installations. For the nuclear sector as a whole, annual values for the sector were calculated by summing all discharge for the indicators across all nuclear sub-sectors.

4.1.6 Calculation of baseline and assessment values

For the nuclear sub-sectors and the non-nuclear oil and gas sub-sector, in each case baseline values were calculated as the mean of the available annual values from the baseline period and assessment values were calculated as the mean of the available annual values from the assessment period. Baseline and assessment values were calculated for the indicators total alpha and total beta (excluding tritium) as well as individual radionuclides where applicable from annual values for individual Contracting Parties, overall values for individual sub-sectors and for the nuclear sector as a whole. In previous Periodic Evaluations, baseline brackets representing the baseline value ±1.96 times the standard deviation were derived for an initial simple comparison with the assessment value. Due to the development of more robust statistical assessments, the baseline bracket is not used in the Fifth Periodic Evaluation.

4.1.7 Statistical assessment of discharges

In order to test whether any reductions (or increases) in discharges were substantial annual values for the assessment period were compared against annual values for the baseline period using the Welch-Aspin's t test and the Mann-Whitney test. Where a probability (P-value) of less than 0.05 is 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 these 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 substantial 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 substantial 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.

In order to test whether there were progressive reductions (or increases) of discharges the Kendall Tau Coefficient test was used to assess the overall trend in annual values of discharges across the entire reporting period for the Fifth Periodic Evaluation (i.e. 1995 to 2018 for nuclear discharges and 2005 to 2018 for the non-nuclear oil and gas sub-sector). Where a probability (P-value) of less than 0.05 is determined using this statistical test, it can be said that there is a 'statistically significant' trend, with the direction of the trend (positive or negative) indicated by the coefficient value.

4.1.8 Graphical presentation of assessment results

Tables of derived baseline values, assessment values and results (P values and coefficient values) of the statistical tests are given, where appropriate, in Annex 1 for discharges from the nuclear sector and in Annex 3 for discharges from the non-nuclear oil and gas sub-sector. Figures for overall discharges for each sub-sector are given in the main results sections (5 and 6). Figures for annual discharges from individual Contracting Parties for the nuclear sector are given in Annex 2 and for the non-nuclear oil and gas sub-sector in Annex 4. In this report, the symbols displayed in Table 4.1 are used to indicate the different possible results of the statistical tests used in the assessment methodology for discharges.

Table 4.1. Symbols used to indicate the different possible results for the statistical assessment of discharges from the nuclear sector and non-nuclear oil and gas sub-sector.

Result of the Kendall's Tau Coefficient*	Symbol	Result of the two simple statistical tests**	Symbol
Evidence of a downward trend	↘	Evidence of a reduction	↓↓
Evidence that there has been no overall trend	→	Some evidence of a reduction	↓
Evidence of an upward trend	↗	No evidence of any change	↔

	Some evidence of an increase	↑
	Evidence of an increase	↑↑

* Kendall's Tau Coefficient is used to test whether any changes in discharges have been progressive.
** The two simple statistical tests are used to test whether any changes in discharges have been substantial.

4.2 Assessment methodologies for environmental concentrations

4.2.1 Scope of assessment

Assessments were carried out for environmental concentration data of the agreed indicator radionuclides for the nuclear sector that was reported to OSPAR by Contracting Parties under the monitoring agreement for environmental concentrations (OSPAR Agreement 2005-8, 2018 update). OSPAR RSC agreed previously that there was no merit in agreeing baseline values and carrying out statistical assessments for environmental concentrations of naturally occurring radionuclides

4.2.2 Aim of the assessment

The stated aim of the second OSPAR Radioactive Substances Strategy (RSS) objective (2010 to 2020) is to ensure that by the year 2020 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 assessments of environmental concentrations used in the Fifth Periodic Evaluation test whether additional concentrations in the marine environment above historic levels are close to zero. In situations where the statistical assessments indicate that additional concentrations in the marine environment above historic levels are not close to zero, it is important to consider the context to those situations.

4.2.3 Selection of years for baseline period

OSPAR RSC agreed that the baseline period for environmental concentrations would comprise the 7-year period 1995 to 2001. This period was chosen to centre on the "Sintra year" of 1998. OSPAR RSC also agreed that the baseline period of 1995 to 2001 is representative of historic levels of the individual indicator radionuclides.

4.2.4 Selection of years for the assessment period of the Fifth Periodic Evaluation

For the purposes of the Fifth Periodic Evaluation, OSPAR RSC agreed that the assessment period environmental concentrations would comprise the 7-year period 2012 to 2018.

4.2.5 Calculation of annual values

For environmental concentrations, annual datasets for individual indicators for each sub-region fall into three categories as described in Table 4.2.

Table 4.2. Approach to determining annual values for indicators of environmental concentrations.

Description of annual dataset	Approach to determine annual value
All values above detection limits	Arithmetic mean

Less than 80% of values below detection limits	Helsel recommended methods[16]
More than 80% of values below detection limits	Not possible to derive annual mean

For annual datasets where all radionuclide concentrations were above detections limits, annual values were derived by calculating the arithmetic mean of all reported activity concentrations for that year for each indicator in each sub-region (where data was available). For annual datasets that included less than 80% of values below detection limits, the statistical methods recommended by Helsel (2005) in Table 4.3 below were used to derive annual values.

Table 4.3. Statistical methods used for determining annual values in datasets with less than 80% of values below *detection limits.*

% of detection limits in dataset	Method for determining annual value	
	Dataset n<50	Dataset n>50
<50%	Kaplan-Meier	Kaplan-Meier
50% - 80%	Regression on order statistics	Maximum likelihood estimation

Due to the nature of the statistical assessments in Table 4.3, there are two cases where additional approaches must be employed. In situations where an annual dataset contains only 1 or 2 data points and one of these values is not a detection limit, this value is used as the annual value. In situations where the dataset contains less than 50% of detection limits, but only one data point is not a detection limit, it is not possible to derive a mean value. For annual datasets that contained more than 80% of values below detection limits, it is not possible to determine an annual value in such cases.

4.2.6 Calculation of baseline and assessment values

For environmental concentrations, baseline values were calculated as the mean of the available annual values from the baseline period and assessment values were calculated as the mean of the available annual values from the assessment period, where in each case the number of annual values in these periods is at least n=2. This is the minimum value required for the mathematics of the statistical tests used and ensures that it is possible to carry out as many assessments as possible, albeit with a reduced degree of robustness in those situations where the number of annual means in either the baseline or assessment period is only 2. In cases where no or only one annual value for the baseline period and/or assessment period can be derived, it is not possible to derive a reciprocal baseline or assessment value. In previous Periodic Evaluations, baseline brackets representing the baseline value ±1.96 times the standard deviation were derived for an initial simple comparison with the assessment value. Due to the development of more robust statistical assessments, the baseline bracket is not used in the Fifth Periodic Evaluation.

4.2.7 Comparison using statistical tests

In order to test whether additional concentrations in the assessment period were close to historic levels (i.e. levels in the baseline period) annual values for the assessment period were

[16] Helsel, D.R., 2005. Nondetects and Data Analysis: Statistics for Censored Environmental Data. John Wiley and Sons, New York.

compared against annual values for the baseline period using the Welch-Aspin's t test and the Mann-Whitney test. Where a probability (P-value) of less than 0.05 is 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 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 that environmental concentrations in the assessment period are lower or higher than (as indicated by the simple comparison) historic levels.
- Where only one statistical test gives a result that is statistically significant it can be concluded that there is some evidence that environmental concentrations in the assessment period are lower or higher than (as indicated by the simple comparison) historic levels.
- Where neither statistical test gives a result that is statistically significant it can be concluded that environmental concentrations in the assessment period are close to historic levels.

For environmental concentrations, no trend detection assessment was performed in the Fifth Periodic Evaluation as progressive reductions are only associated with discharges in the Radioactive Substances Strategy.

4.2.8 Graphical presentation of assessment results

Tables of derived baseline values, assessment values and results (P values) of the statistical tests are given, where appropriate, in Annexes 5 and 7 for environmental concentrations in seawater and marine biota, respectively. Examples of figures of annual means for environmental concentrations of individual indicators are given in Section 7. Figures of annual means for all indicator radionuclides in the 15 OSPAR RSC sub-regions (where data is available) for seawater and marine biota are given in Annexes 6 and 8, respectively. In this report, the symbols displayed in Table 4.4 are used to indicate the different possible results of the statistical tests used in the assessment methodology for environmental concentrations.

Table 4.4. Symbols used to indicate the different possible results of the statistical assessment of environmental concentrations and conclusions against historic levels

Result of the two simple statistical tests	Symbol	Compared to historic levels
Evidence of a decrease	↓↓	Lower
Some evidence of a decrease	↓	Lower
No statistically significant difference	↔	Close
Some evidence of an increase	↑	Higher
Evidence of an increase	↑↑	Higher
No statistics possible	NS	-

4.3. Derivation of the radiological impact of environmental concentrations of indicator radionuclides in seawater

4.3.1 Derivation of reference activity concentrations in seawater

OSPAR Agreement 2016-07 (2022 update) presents a methodology for deriving Environmental Assessment Criteria (EAC) for activity concentrations of radioactive substances in the marine environment of the OSPAR Maritime Area. The methodology is based on the methodology developed by the International Atomic Energy Agency (IAEA) to assess the radiological impact on humans and non-humans in an integrated manner (IAEA, 2015[17]). The EAC are in the form of reference activity concentrations in filtered seawater (Cref) which equate to whichever is the lower of the concentrations that would give rise to an annual dose of 1 millisievert (mSv) to humans or a dose rate at the lower bound of the relevant Derived Consideration Reference Level (DCRL), as defined by the International Commission on Radiological Protection for key marine Reference Animals and Plants. The scheme for deriving the reference concentrations (Cref) of the indicator radionuclides is summarised in Figure 4.1.

[17] IAEA (2015) Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure. IAEA TECDOC No. 1759.

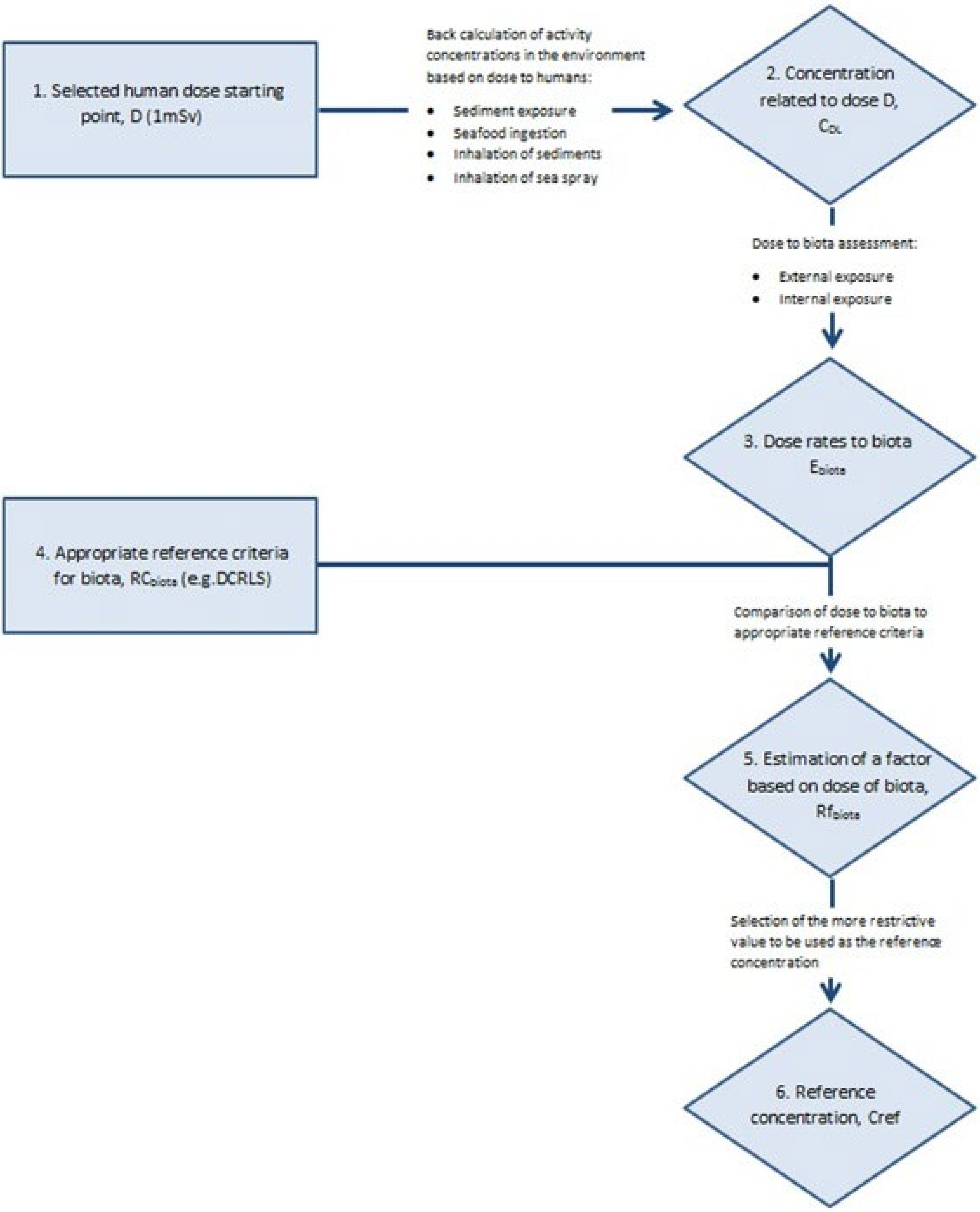

Figure 4.1: Scheme to derive reference concentrations for indicator radionuclides according to OSPAR Agreement 2016-07 (2022 update).

The Cref values for the OSPAR indicator radionuclides are given in Table 4.5. These values are intended for screening purposes and are therefore also applicable for assessing additional concentrations due to discharges.

Table 4.5. Environmental Assessment Criteria for OSPAR Indicator Radionuclides

OSPAR Indicator Radionuclide	Cref values (Bq/l, filtered seawater)

H-3	5.60E+05
Tc-99	1.80E+01
Cs-137	4.50E+00
Pu-239/240	2.80E-02
Ra-226	2.60E-02
Ra-228	6.70E-02
Po-210	1.10E-04
Pb-210	8.80E-04

4.3.2 Comparison of environmental concentrations against reference activity concentrations

In the Fifth Periodic Evaluation, derived environmental concentration assessment values in seawater were compared against values of Cref/100 which is considered to be representative of a trivial risk (10 µSv/yr) for humans and non-human biota and provides a margin for the possible combined impact of each indicator with other radionuclides. In order to assess the radiological impact of the indicator radionuclides in seawater in situations where environmental concentration data was reported for the assessment period, but it was not possible to derive an assessment value (i.e. where $n<2$ for annual values in the assessment period) due to the number of detection limits in annual datasets and/or the limited data available, a slightly different approach was used. In such situations, an assessment period mean was derived by taking the arithmetic mean of all data reported for the assessment period, using the full value of any data reported as a detection limit. This seawater assessment period mean was then compared against values of Cref/100 as was the case for seawater assessment values.

4.4 Derivation of additional concentrations of naturally occurring radionuclides from discharges of produced water from the non-nuclear oil and gas sub-sector

It is not possible to measure by any analytical means the additional concentrations of naturally occurring radionuclides in seawater resulting from discharges of produced water from the non-nuclear oil and gas sub-sector separate from environmental background concentrations, particularly at a distance (far-field) from any discharging production platform. Monitoring of seawater in the immediate vicinity around installations (near-field) is not routinely carried out by all Contracting Parties. In order to assess their radiological impact, additional concentrations of these naturally occurring radionuclides were estimated by the use of numerical models. Separate modelling approaches were used to assess additional concentrations in the near-field of installations and the far-field across the OSPAR Maritime Area.

4.4.1 Near field

The numerical model DREAM (Dose related Risk and Effect Assessment Model), developed by the Foundation for Scientific and Industrial Research (SINTEF), was used to assess initial dilution factors, at a distance of 500 m from selected discharging installations, based on discharge characteristics and the nature of the receiving environment (e.g. wind and currents and turbulence in the sea). This tool is routinely used for regulatory assessments associated with chemical water quality management in the oil and gas sector.

The activity concentrations in the near-field of individual installations are localised and transient and do not represent the situation across OSPAR Regions, or the wider Maritime Area. Such approaches are therefore not directly relevant to the Fifth Periodic Evaluation. However, this approach was applied to provide a conservative estimate of the local conditions around discharging installations, in the interests of completeness and transparency, as described in more detail in OSPAR Publication 925[18].

4.4.2 Far field

Additional concentrations across the OSPAR Maritime Area arising from discharges of produced water into the different OSPAR RSC sub-regions were estimated using the PC CREAM 08 assessment software (Version 2.0), and more specifically, the marine modelling module 'DORIS'[19]. DORIS is a compartmental model consisting of a water dispersion model and a sedimentation model. The 55 DORIS compartments were primarily set-up to support the radiological assessment of radioactive releases from nuclear facilities in Europe and do not fully match those of the OSPAR Regions of (I) Arctic Waters; (II) Greater North Sea; (III) Celtic Sea; (IV) Bay of Biscay and Iberian Coast; and (V) Wider Atlantic. The spatial relationship between the DORIS compartments, and the OSPAR RSC sub-regions is shown in Figure 4.2.

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[18] Modelling and assessment of additional concentrations of Naturally Occurring Radioactive Materials (NORM) in seawater from discharges of produced water from the offshore oil and gas sector in the North-East Atlantichttps://www.ospar.org/documents?v=48505

[19] Health Protection Agency (2015). The Methodology for Assessing the Radiological Consequences of Routine releases of Radionuclides to the Environment Used in PC-CREAM 08. Ref. HPA-RPD-058, Report Version 1.1, June 2015 (first published in November 2009)

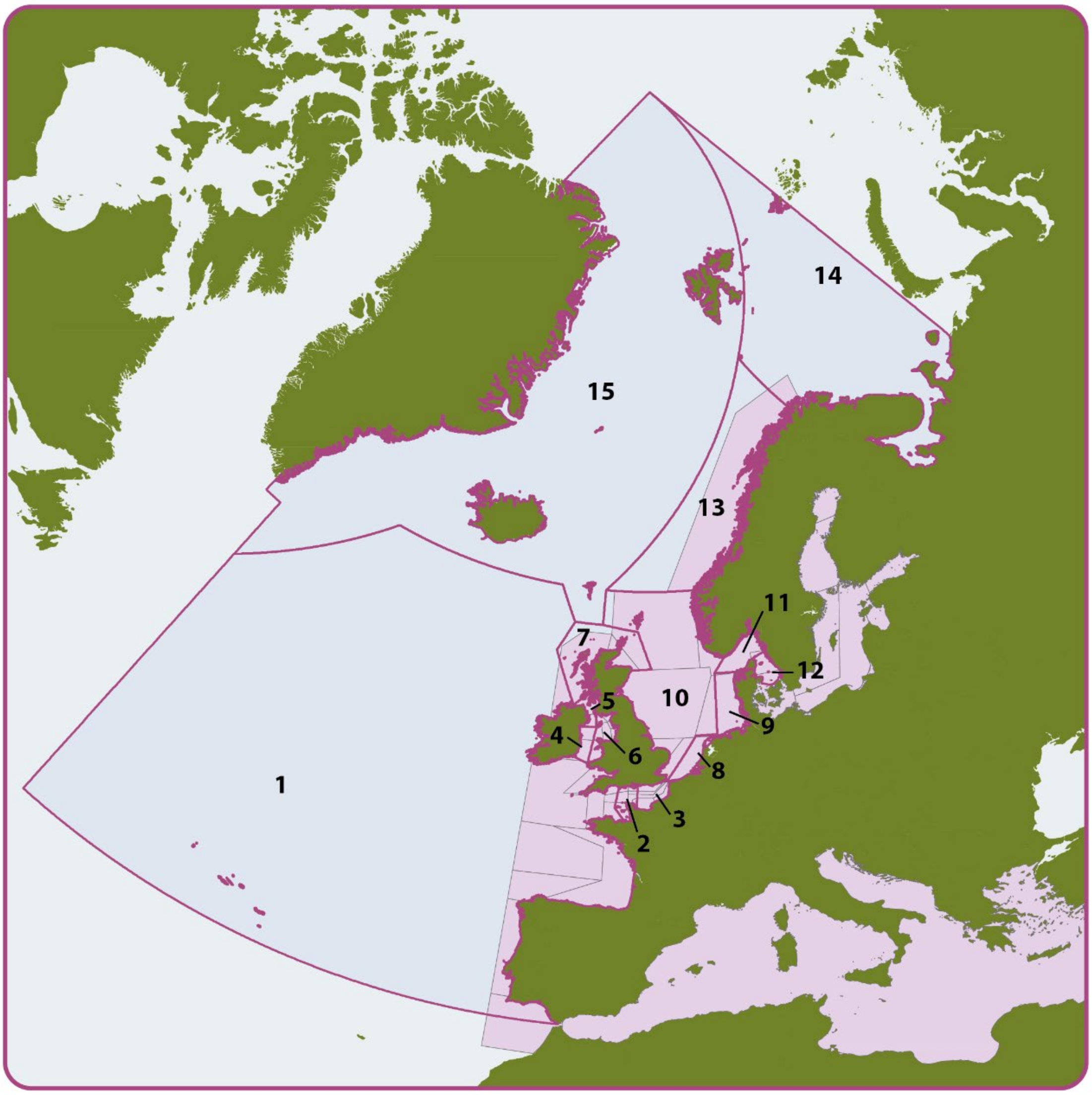


Figure 4.2: Spatial relationship between the DORIS compartments and the 15 OSPAR RSC sub-regions. The 15 OSPAR RSC sub regions are: 1. Wider Atlantic, 2. Cap de la Hague Channel, 3. Channel East, 4. Irish Sea (Rep. of Ireland), 5. Irish Sea (Northern Ireland), 6. Irish Sea, 7. Scottish waters, 8. North Sea South (Belgian and Dutch Coast), 9. German Bight, 10. North Sea (NW, SE, and Central), 11. North Sea (Skagerrak), 12. Kattegat, 13. Norwegian Coastal Current, 14. Barents Sea and 15. Norwegian, Greenland Seas and Icelandic Waters.

Discharging installations were identified using the location data in the OSPAR Offshore Installations Inventory, and overlaid on the DORIS compartments, as illustrated in Figure 4.3.

Figure 4.3: Spatial distribution of discharging installations in relation to the DORIS marine compartments.

The following nine DORIS compartments were identified, containing varying numbers of discharging installations, and referred to as 'source compartments':

1. Atlantic Ocean North-East
2. Celtic Sea
3. Irish Sea South
4. Scottish Waters
5. North Sea Central
6. North Sea North
7. North Sea South-East
8. North Sea South-West
9. Norwegian Sea

The total annual discharge of indicator radionuclides associated with produced water (Pb-210, Ra-226 and Ra-228) into each source compartment was evaluated and the additional concentrations of these radionuclides in these 'source compartments', and in the remaining 46 'recipient compartments', were estimated by modelling the movements of radioactivity between compartments. Instantaneous uniform mixing within each compartment was assumed and the transfer of activity between interlinked compartments was assumed to be proportional to the inventory of material in the source compartment. The radionuclide transport in the water column was modelled by an advective flux, representing the action of currents, and turbulent diffusion. The depletion of activity from the water phase due to both the partitioning of the activity between the liquid phase and the solid phase, and the removal of activity from the water column direct to bottom sediments, was also modelled. These processes are controlled by the chemical properties of each radionuclide. DORIS also accounted for radioactive decay and ingrowth of decay progeny.

DORIS was run for the total discharges for each radionuclide into each source compartment for each year (2006 – 2015), in order to estimate activity concentrations in filtered seawater (i.e., the dissolved activity) and bed sediment in each of the 55 compartments resulting from the cumulative discharges over the 10-year period of discharges. In addition to the reported discharges of Pb-210, Ra-226 and Ra-228, it was assumed that bismuth-210 (Bi-210) and polonium-210 (Po-210) were in secular equilibrium with the discharged Pb-210, and so discharged at the same level of activity and modelled explicitly.[20]

The modelled activity concentrations of these naturally occurring radionuclides in sea water in the source compartments were higher than those in recipient compartments, due to the increasing dilution with distance from the discharge location. Analysis of results of running DORIS for unit discharges demonstrated that the activity concentrations in these compartments effectively reach a steady-state condition after 10 years of discharge. The activity concentrations in source compartments following 10 years' discharge were therefore used as upper estimates of the additional concentrations arising from discharges for comparison purposes.

4.4.3 Comparison of far field values

As for environmental concentrations, modelled additional concentrations of these naturally occurring radionuclides in the source compartments were compared against their respective Cref/100 values in seawater in order to assess their radiological impact. The additional concentrations were also considered in the context of measured environmental concentrations in the OSPAR Maritime Area, as described in more detail in OSPAR publication 925[21].

5. Evaluation of discharges from the nuclear sector

The stated aim of the first objective of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy 2010-2020 is to prevent pollution of the OSPAR Maritime Area from ionising radiation through progressive and substantial reductions of discharges, emissions and losses of radioactive substances, with the ultimate aim of

[20] DORIS also explicitly models radioactive progeny, which are not in secular equilibrium with their immediate parent within 1 year, while those which are in secular equilibrium are assumed to have the same activity as their immediate parent.

[21] Modelling and assessment of additional concentrations of Naturally Occurring Radioactive Materials (NORM) in seawater from discharges of produced water from the offshore oil and gas sector in the North-East Atlantichttps://www.ospar.org/documents?v=48505

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:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

In this section, results are presented that address whether there have been progressive and substantial reductions in discharges from the nuclear sector. In situations where the statistical assessments indicate that progressive and substantial reductions in discharges from the nuclear sector have not occurred, further information and explanations are given to provide the context to these results.

Background information on discharges from the nuclear sector is given in Section 2 and detailed descriptions of the methodological approaches used for data processing and statistical assessments are given in Section 4. An explanation of the symbols used to indicate assessment results in this section is given in Table 5.1. Tables of derived baseline values, assessment values and the results of the statistical tests employed for the evaluation of discharges from the nuclear sector are given in Annex 1. Figures showing annual discharges (including tritium) for each nuclear sub-sector for individual Contracting Parties are given in Annex 2.

Table 5.1. Symbols used to indicate the different possible results for the statistical assessment of discharges from the nuclear sector.

Result of the Kendall's Tau Coefficient*	Symbol	Result of the two simple statistical tests**	Symbol
Evidence of a downward trend	↘	Evidence of a reduction	↓↓
Evidence that there has been no overall trend	→	Some evidence of a reduction	↓
Evidence of an upward trend	↗	No evidence of any change	↔
		Some evidence of an increase	↑
		Evidence of an increase	↑↑

* Kendall's Tau Coefficient is used to test whether any changes in discharges have been progressive.

** The two simple statistical tests are used to test whether any changes in discharges have been substantial.

5.1 Nuclear power station sub-sector

5.1.1 Contracting Parties

Discharges over the period 1995 to 2018 have been reported for the nuclear power station sub-sector by Belgium, France, Germany, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom for the indicators total alpha, total beta (excluding tritium) and Cs-137. The assessment results from the sub-sector for these Contracting Parties are summarised in

Table 5.2. The assessment results showed that there was evidence of reductions in discharges between the assessment and baseline periods in 16 out of the 22 cases, and some evidence of reductions in discharges in 2 cases. In 17 of these 18 cases, there was evidence of downward trends in discharges between 1995 to 2018.

In the case of total beta (excluding tritium) for Spain, although there was evidence of a reduction in discharges between the assessment and baseline periods, there was no overall trend in discharges of this indicator between 1995 to 2018. In the case of total alpha for Germany and the United Kingdom, although there was evidence of downward trends in discharges between 1995 to 2018, there was no evidence of any change in discharges of this indicator between the respective assessment and baseline periods.

For total alpha for Belgium and for the Netherlands, there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of this indicator between 1995 to 2018. The assessment value for total alpha for the Netherlands was 1.7 fold lower than the baseline value. The assessment value for total alpha for Belgium was 2.3 fold higher than the baseline value.

For Belgium, the increase in total alpha in the 5PE compared to the previous 4PE was due to a change in the way in which discharges were reported from 2011 onwards. Previously, measurements that were below detection limits were reported as ‘zero’. In 2011, when the European Recommendation 2004/2/Euratom was implemented for measurements that were below the decision threshold (and therefore also the detection limit), a value of half the decision threshold (or a quarter of the detection limit) was reported. This has led to a 100 to 1000 fold increase in the apparent discharged activity that has been reported to OSPAR compared to the years prior to 2011. The magnitude of discharges reported for the baseline period was therefore somewhat underestimated, whereas the magnitude of discharges reported for assessment period was somewhat overestimated.

For the Netherlands, total alpha discharges of the only nuclear power station are often at very low levels. In some years these levels are above the limit of detection and in other years they are below the limit of detection. The fact that the discharges during the assessment period are not statistically different from the baseline period can therefore be attributed to the fact that the measured levels are around the limit of detection and that significant reduction is either not possible or difficult to detect.

In summary and when considering the combined outcomes from both statistical assessments of the 22 cases where indicators were reported by Contracting Parties under the nuclear power station sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 15 cases.
- There was evidence that there have been progressive reductions in discharges and some evidence of substantial reductions in discharges in 2 cases.
- There was evidence that there had been only progressive reductions in discharges in 2 cases.

- There was evidence that there had been only substantial reductions in discharges in 1 case.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 2 cases.

Table 5.2: Assessment results for indicators for the nuclear power station sub-sector by Contracting Party and fold change between baseline and assessment values.

Contracting Party	Indicator	Progressive	Substantial
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 alpha	→	↔
	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 5.1.

5.1.2 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 station sub-sector is summarised in Table 5.3 and in Figures 5.1 to 5.3. The assessment results for the sub-sector showed that there was evidence of reductions in discharges of total beta (excluding tritium) and Cs-137 between the assessment and baseline periods and that there was evidence of downward trends in discharges of these indicators between 1995 to 2018. The overall assessment values for total beta (excluding tritium) and Cs-137 showed reductions of 1.5 fold and 6.8 fold respectively, when compared to the overall baseline values for this sub-sector.

For total alpha, there was no evidence of any change in discharges between the assessment and baseline periods and no overall trend in discharges of this indicator between 1995 to 2018. The overall assessment value for total alpha showed a reduction of 1.9 fold when compared to the overall baseline value for this sub-sector.

In summary and when considering the combined outcomes from both statistical assessments of the 3 indicators under the nuclear power station sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 2 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 1 case.

Table 5.3: Overall assessment results for indicators for the nuclear power station sub-sector.

Indicator	Progressive	Substantial
Total alpha	→	↔
Total beta (excluding tritium)	↘	↓↓
Cs-137	↘	↓↓

(An explanation of the symbols used to indicate the assessment results is given in Table 5.1.)

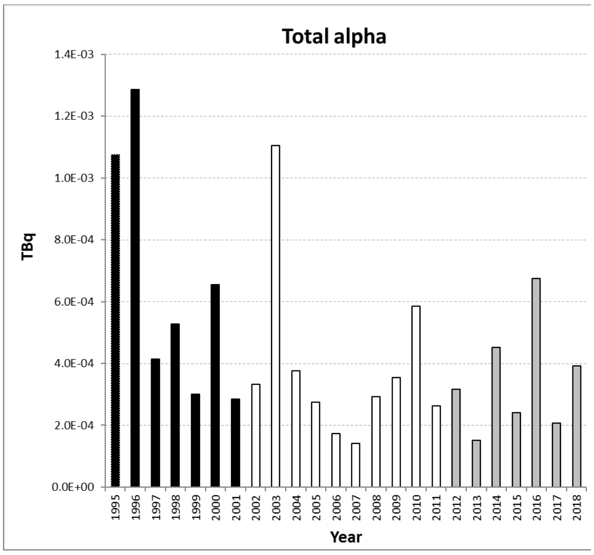


Figure 5.1: Total alpha discharges from the nuclear power station sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

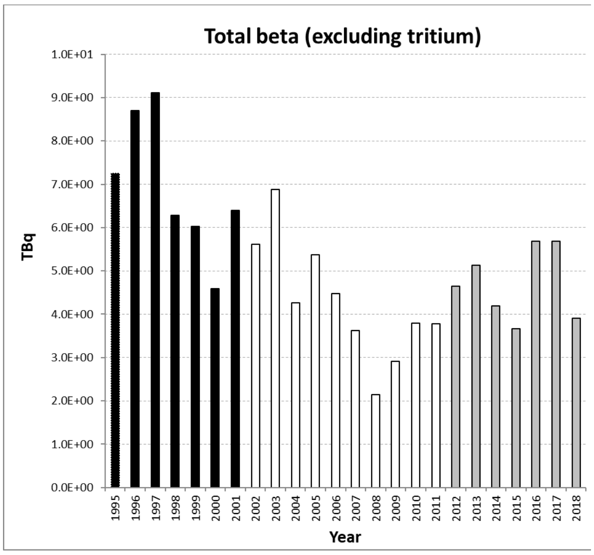


Figure 5.2: Total beta (excluding tritium) discharges from the nuclear power station sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

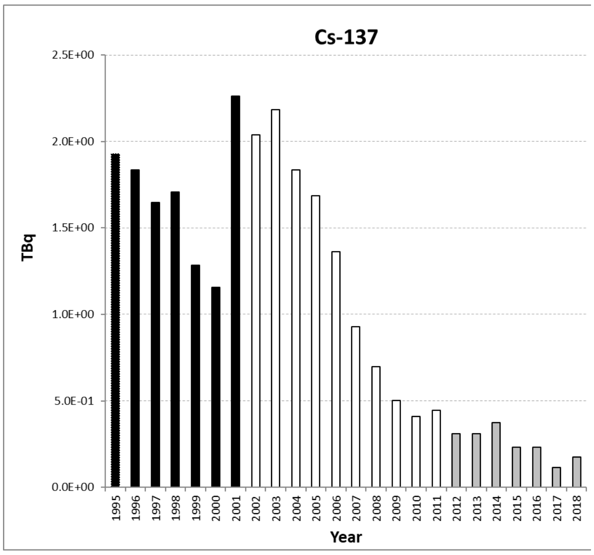


Figure 5.3: Cs-137 discharges from the nuclear power station sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

5.2 Nuclear fuel reprocessing sub-sector

5.2.1 Contracting Parties

Discharges have been reported for the nuclear fuel reprocessing sub-sector by France and the United Kingdom for the indicators total alpha, total beta (excluding tritium), Tc-99, Cs-137 and Pu-239,240. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.4. The assessment results showed that there was evidence of reductions in discharges between the assessment and baseline periods in 8 out of the 10 cases. In each of these 8 cases, there was evidence of a downward trend in discharges between 1995 to 2018.

For total alpha and Pu-239,240 for the United Kingdom, there was no evidence of any changes in discharges between the assessment and baseline periods and there were no overall trends in discharges of these indicators between 1995 to 2018. The assessment values for total alpha and Pu-239,240 for the United Kingdom were 1.2 and 1.1 fold lower than the respective baseline values.

It should be noted that the pattern of discharges from Sellafield is heavily influenced by the complex nature of the site, which involves a mix of reprocessing, fuel management and legacy waste retrievals, noting that Best Available Techniques (BAT) is required to be applied at all times. In late 2018 (towards the end of the assessment period), reprocessing at THORP ceased. The other reprocessing stream (Magnox) is nearing completion, as the emphasis at Sellafield is shifting to environmental remediation, decommissioning and clean-up of the historical legacy waste. Over longer time periods than that covered by the baseline in the Fifth Periodic Evaluation, discharges have fallen even more dramatically. For example, the average discharge of Pu isotopes in 1970’s was 48 TBq compared to 0.17 TBq in the 1990’s, whilst the average discharge of total alpha in 1970’s was 98 TBq compared to 1.1 TBq in 1990’s. More generally, liquid radioactive discharges from Sellafield remain well below permitted site limits, many of which were substantially reduced in 2020 as a result of a major permit review, including limits for Pu isotopes and total alpha.

In summary and when considering the combined outcomes from both statistical assessments of the 10 cases where indicators were reported by Contracting Parties under the nuclear fuel reprocessing sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 8 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 2 cases.

Table 5.4: Assessment results for indicators for the nuclear fuel reprocessing sub-sector by Contracting Party.

Contracting Party	Indicator	Progressive	Substantial
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 5.1.

5.2.2 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 is summarised in Table 5.5 and in Figures 5.4 to 5.8. The assessment results for the sub-sector showed that there was evidence of reductions in discharges total beta (excluding tritium), Tc-99 and Cs-137 between the respective assessment and baseline periods. In each of these 3 cases, there was evidence of a downward trend in discharges between 1995 to 2018. The overall assessment values for total beta (excluding tritium), Tc-99 and Cs-137 showed reductions of 11 fold, 68 fold and 2.8 fold respectively, when compared to the overall baseline values for this sub-sector.

For total alpha and Pu-239,240, there was no evidence of any changes in discharges between the assessment and baseline periods and there were no overall trends in discharges of these indicators between 1995 to 2018. The overall assessment values for total alpha and Pu-239,240 showed reductions of 1.3 fold and 1.2 fold respectively, when compared to the overall baseline values for this sub-sector. It is anticipated that discharges of Pu-239,240 will continue to decrease following the cessation of fuel reprocessing operations at Sellafield which is expected by the end of 2022.

In summary and when considering the combined outcomes from both statistical assessments of the 5 indicators under the nuclear fuel reprocessing sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 3 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 2 cases.

Table 5.5: Overall assessment results for indicators for the nuclear fuel reprocessing sub-sector.

Indicator	Progressive	Substantial
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 5.1.

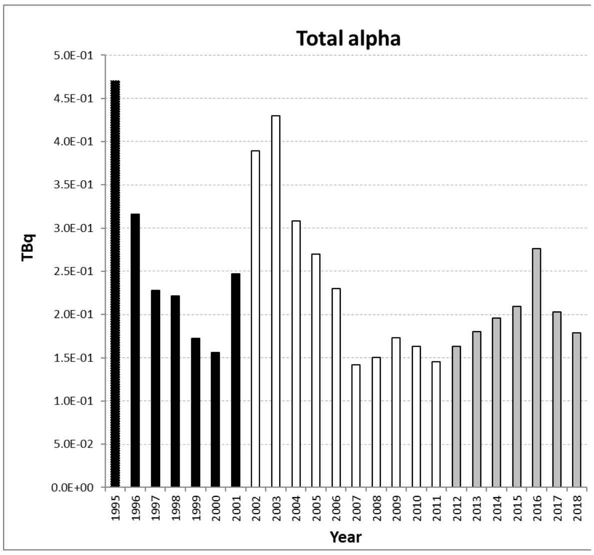


Figure 5.4: Total alpha discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

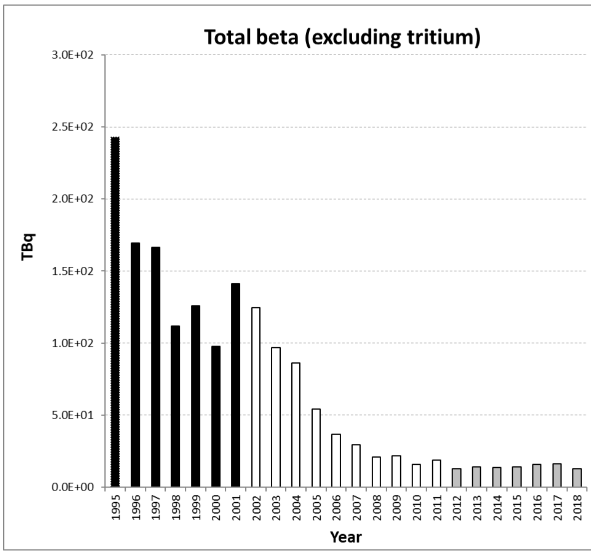


Figure 5.5: Total beta (excluding tritium) discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

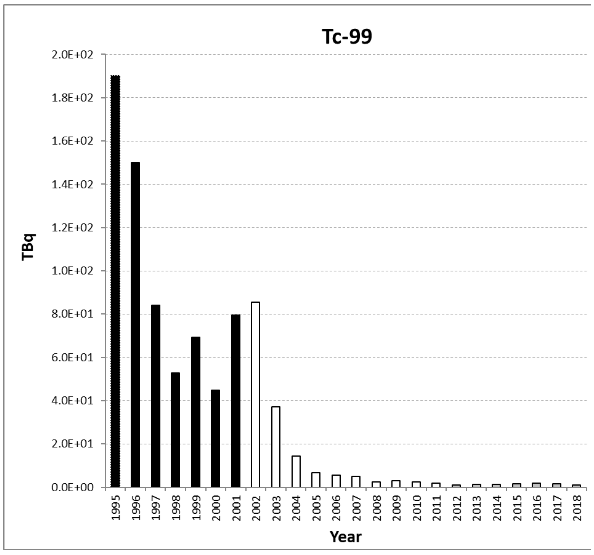


Figure 5.6: Tc-99 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

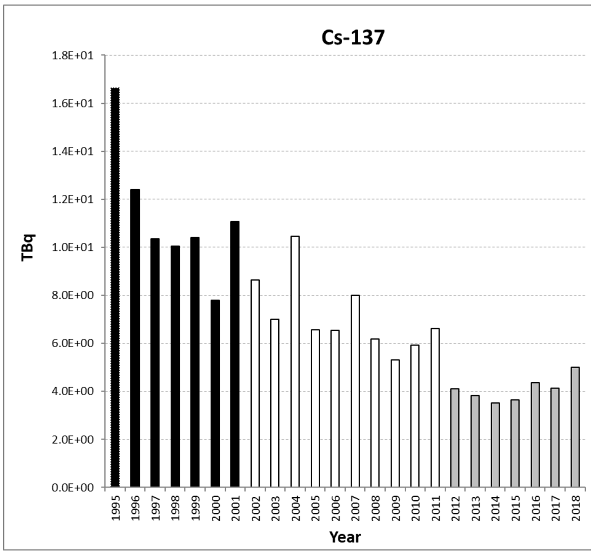


Figure 5.7: Cs-137 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

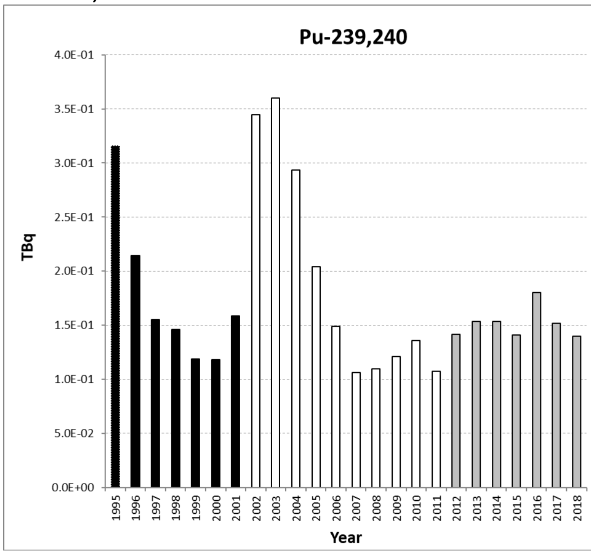


Figure 5.8: Pu-239,240 discharges from the nuclear fuel reprocessing sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

5.3 Nuclear fuel fabrication and enrichment sub-sector

5.3.1 Contracting Parties

Discharges have been reported for the nuclear fuel fabrication and enrichment sub-sector by Germany, the Netherlands, Spain and the United Kingdom for the indicators total alpha, total beta (excluding tritium) and Tc-99. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.6. The assessment results showed that there was evidence of reductions in discharges between the assessment and the baseline periods in 6 out of the 8 cases. In 5 of these 6 cases, there was evidence of downward trends in discharges between 1995 to 2018. In the case of total beta (excluding tritium) for Germany, although there was evidence of a reduction in discharges between the assessment and baseline periods, there was no overall trend in discharges of this indicator between 1995 to 2018.

For total alpha for Spain and Tc-99 for the United Kingdom, there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of these indicators between 1995 to 2018. The assessment value for total alpha for Spain was 1.4 fold lower than the baseline value. The assessment value for Tc-99 for the United Kingdom was 1.7 fold higher than the baseline value.

For the United Kingdom fuel fabrication and enrichment sub-sector, there were occasional increases in discharges of Tc-99 during various years (2012, 2013 & 2017) in the assessment period. These discharges were due to a campaign to process historic residues as part of ongoing decommissioning operations. These residues were created during routine fuel production operations over a number of years and have now been successfully treated. From 2018 onwards the discharges have decreased significantly, and residue processing has now been completed. At the peak of the campaign, Tc-99 discharges were at 20% of the site discharge limit. Discharges from 2018 were at 1% of the site limit for Tc-99.

In summary and when considering the combined outcomes from both statistical assessments of the 8 cases where indicators were reported by Contracting Parties under the nuclear fuel fabrication and enrichment sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 6 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 2 cases.

Table 5.6: Assessment results for indicators for the nuclear fuel fabrication and enrichment sub-sector by Contracting Party.

Contracting Party	Indicator	Progressive	Substantial
Germany	Total alpha	↘	↓↓
	Total beta (excluding tritium)	→	↓↓
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 5.1.

5.3.2 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha and total beta (excluding tritium) from the nuclear fuel fabrication and enrichment sub-sector is summarised in Table 5.7 and in Figures 5.9 and 5.10. The assessment results for the sub-sector showed that there was evidence of reductions in discharges of total alpha and total beta (excluding tritium) between the assessment and baseline periods. In each case, there was evidence of a downward trend in discharges between 1995 to 2018. The overall assessment values for total alpha and total beta (excluding tritium) showed reductions of 9.8 fold and 56 fold respectively, when compared to the overall baseline values for this sub-sector.

In summary and when considering the combined outcomes from both statistical assessments of the 2 indicators under the nuclear fuel fabrication and enrichment sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in the 2 cases.

Table 5.7: Overall assessment results for indicators for the nuclear fuel production and enrichment sub-sector.

Indicator	Progressive	Substantial
Total alpha	↘	↓↓
Total beta (excluding tritium)	↘	↓↓

An explanation of the symbols used to indicate the assessment results is given in Table 5.1.

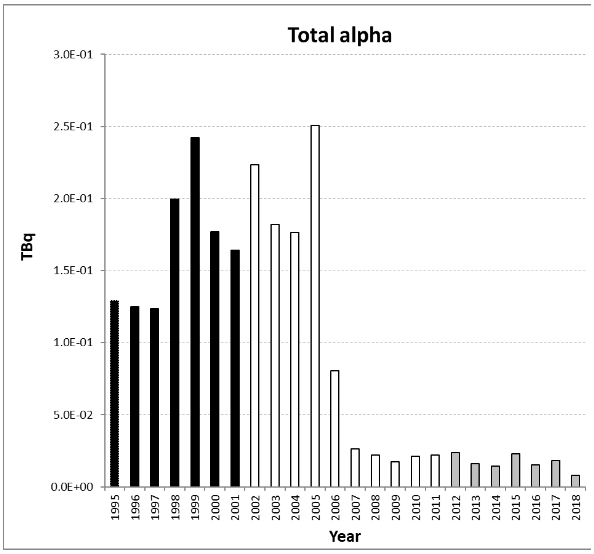


Figure 5.9: Total alpha discharges from the nuclear fuel fabrication and enrichment sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

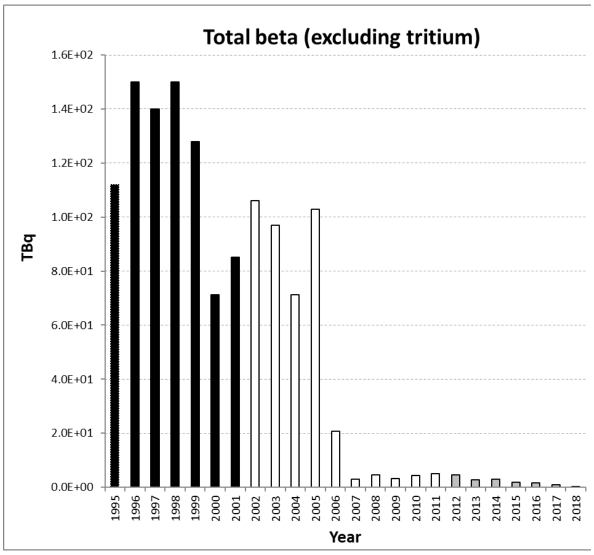


Figure 5.10: Total beta (excluding tritium) discharges from the nuclear fuel fabrication and enrichment sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

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 for the indicators total alpha, total beta (excluding tritium), Cs-137 and Pu-239,240. The assessment results from the sub-sector for these Contracting Parties are summarised in Table 5.8. The assessment results showed that there was evidence of reductions in discharges between the assessment and baseline periods in 10 out of the 22 cases and some evidence of reductions in discharges in 3 cases. In each of these 13 cases, there was evidence of downward trends in discharges between 1995 to 2018.

For total alpha for Belgium, Germany, the Netherlands and Norway there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of this indicator between 1995 to 2018. The assessment values for total alpha for Belgium was 1.1 fold lower than the baseline value. The assessment values for total alpha for Germany, the Netherlands and Norway were 8.5, 2.8 and 1.1 fold higher than the respective baseline values.

For Norway, it should be noted that the total alpha discharges from the nuclear research and development sub-sector over the last few years are mainly linked to clean-up activities and the treatment of particular wastes. These discharges will continue for a limited period until this work is completed.

For Belgium, the increase in total alpha in the Fifth Periodic Evaluation compared to the previous Fourth Periodic Evaluation and baseline period is mainly due to roadworks performed in the vicinity of the underground release channel in 2015 and 2016. These roadworks caused underground vibrations leading to the detachment of historical deposits and sediments within the pipeline which in turn were picked up and carried away by the discharge water. Results showed that even a contribution of a few mg/l of sediment from the pipe was enough to cause a doubling of the average discharged amount of radioactivity. In the next 10 years or so, the pipeline will be cleaned and/or replaced.

For the Netherlands, the discharges which are reported for this sector, in addition to discharges which are linked to decontamination work (decommissioning activities) that started in 2017, also include increasing volumes of discharges from unrelated decontamination work of naturally occurring radionuclides. As a consequence, the reported total alpha discharges for the facility do not directly reflect the discharges of this subsector and cannot therefore show the achieved reduction in discharges.

For Germany total alpha discharges have been at a stable low level. Variations in reported discharges are typically due to varying research activities or decommissioning of nuclear research facilities. However, in some cases discharge data were not reported for all years and facilities in former times. Hence, baseline values might be underrepresenting former total alpha discharges.

For total beta (excluding tritium) for Denmark, Portugal and Switzerland there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of this indicator between 1995 to 2018. The assessment values for total beta (excluding tritium) for Portugal and Switzerland were 1.5 and 2.3 fold lower than the respective baseline values. The assessment values for total beta (excluding tritium) for Denmark was 1.7 fold higher than the baseline value.

For Denmark the discharge of total beta (excluding tritium) was at a stable low level and was further reduced in 2017 and 2018. The discharge is primarily a result of the ongoing decommissioning of the nuclear facilities at the Risoe research site. The decommissioning is planned to conclude in 2023 or shortly thereafter at which time discharges are expected to be significantly lower than current levels.

For Cs-137 for Switzerland there was no evidence of any change in discharges between the assessment and baseline periods and no overall trend in discharges of this indicator between 1995 to 2018. The assessment value for Cs-137 for Switzerland was 1.1 fold higher than the baseline value.

For Switzerland the discharges from the nuclear research and development sub-sector in terms of total beta (excluding tritium) and Cs-137 were at a stable low level. It should be noted that they were linked with a research centre consisting of former nuclear facilities currently in decommissioning, as well as research units not classified as nuclear facilities (accelerators and radiopharmaceutical laboratories), with however increasing research activities.

For Pu-239,240 for Norway there was no evidence of any change in discharges between the assessment and baseline periods and no overall trend in discharges of this indicator between 1995 to 2018. The assessment value for Pu-239,240 for Norway was 3.9 fold lower than the baseline value.

For Norway, the discharges of Pu-239,240 were at a consistently low level. Both the discharges of Pu-239,240 and total alpha from Norway were linked with the two research reactors at Kjeller and Halden, and both of these reactors have now been closed down in preparation for decommissioning.

In summary and when considering the combined outcomes from both statistical assessments of the 22 cases where indicators were reported by Contracting Parties under the nuclear research and development sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 10 cases.
- There was evidence that there have been progressive reductions in discharges and some evidence of substantial reductions in discharges in 3 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 9 cases.

Table 5.8: Assessment results for indicators for the nuclear research and development sub-sector by Contracting Party.

Contracting Party	Indicator	Progressive	Substantial
Belgium	Total alpha	→	↔
	Total beta (excluding tritium)	↘	↓↓
	Cs-137	↘	↓↓
Denmark	Total beta (excluding tritium)	→	↔
France	Total alpha	↘	↓↓
	Total beta (excluding tritium)	↘	↓↓
Germany	Total alpha	→	↔
	Total beta (excluding tritium)	↘	↓↓
Netherlands	Total alpha	→	↔
	Total beta (excluding tritium)	↘	↓↓
Norway	Total alpha	→	↔
	Total beta (excluding tritium)	↘	↓↓
	Cs-137	↘	↓↓
	Pu-239,240	→	↔
Portugal	Total beta (excluding tritium)	→	↔
Switzerland	Total alpha	↘	↓↓
	Total beta (excluding tritium)	→	↔
	Cs-137	→	↔
	Pu-239,240	↘	↓↓
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 5.1.

5.4.2 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha, total beta (excluding tritium), Cs-137 and Pu-239,240 from the nuclear research and development sub-sector is summarised in Table 5.9 and in Figures 5.11 and 5.14. The assessment results for the sub-sector showed that there was evidence of reductions in discharges of Pu-239,240 between the assessment and baseline periods, and some evidence of reductions in discharges of total alpha, total beta (excluding tritium) and Cs-137. In each case, there was evidence of a downward trend in discharges between 1995 to 2018. The overall assessment values for total alpha, total beta (excluding tritium), Cs-137 and Pu-239,240 showed reductions of 65 fold, 43 fold, 147 fold and 38 fold respectively, when compared to the overall baseline values for this sub-sector.

In summary and when considering the combined outcomes from both statistical assessments of the 4 indicators under the nuclear research and development sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 1 case.
- There was evidence that there have been progressive reductions in discharges and some evidence of substantial reductions in discharges in 3 cases.

Table 5.9: Overall assessment results for indicators for the nuclear research and development sub-sector.

Indicator	Progressive	Substantial
Total alpha	↘	↓
Total beta (excluding tritium)	↘	↓
Cs-137	↘	↓
Pu-239,240	↘	↓↓

An explanation of the symbols used to indicate the assessment results is given in Table 5.1.

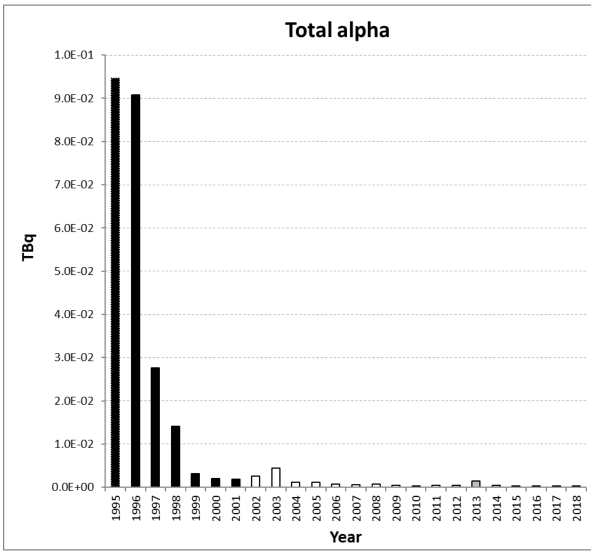


Figure 5.11: Total alpha discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

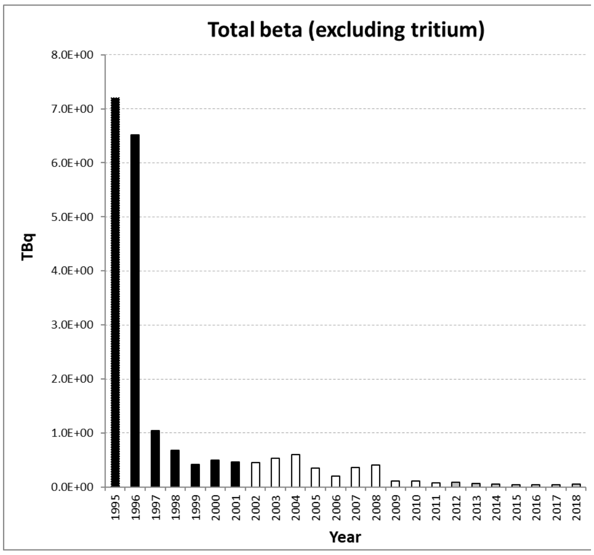


Figure 5.12: Total beta (excluding tritium) discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

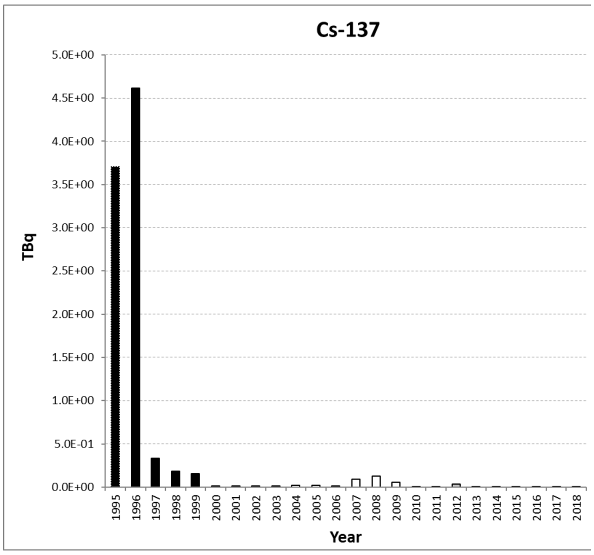


Figure 5.13: Cs-137 discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

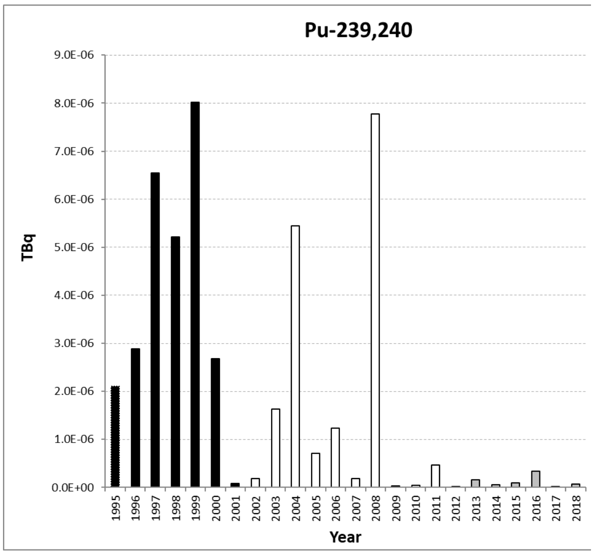


Figure 5.14: Pu-239,240 discharges from the nuclear research and development sub-sector for all Contracting Parties for the period 1995 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns).

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 was evidence for substantial and progressive reductions in discharges in many cases across all four nuclear sub-sectors.

Figures 5.15 and 5.16 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 92% and 67% to the respective assessment values for total alpha and total beta (excluding tritium). It should be noted that discharges for the nuclear reprocessing sub-sector include contributions from activities such as decommissioning and processing of legacy wastes which are an essential activity to aid overall hazard reduction in older nuclear facilities.

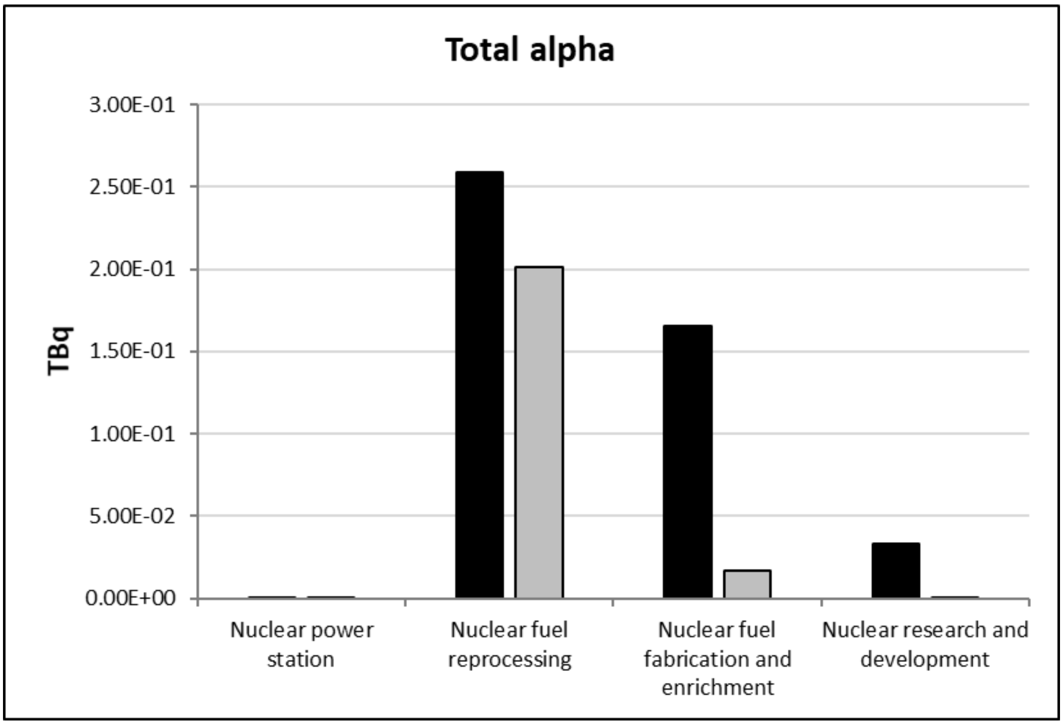


Figure 5.15: Comparison of total alpha overall baseline (black columns) and assessment (grey columns) values for the different nuclear sub-sectors.

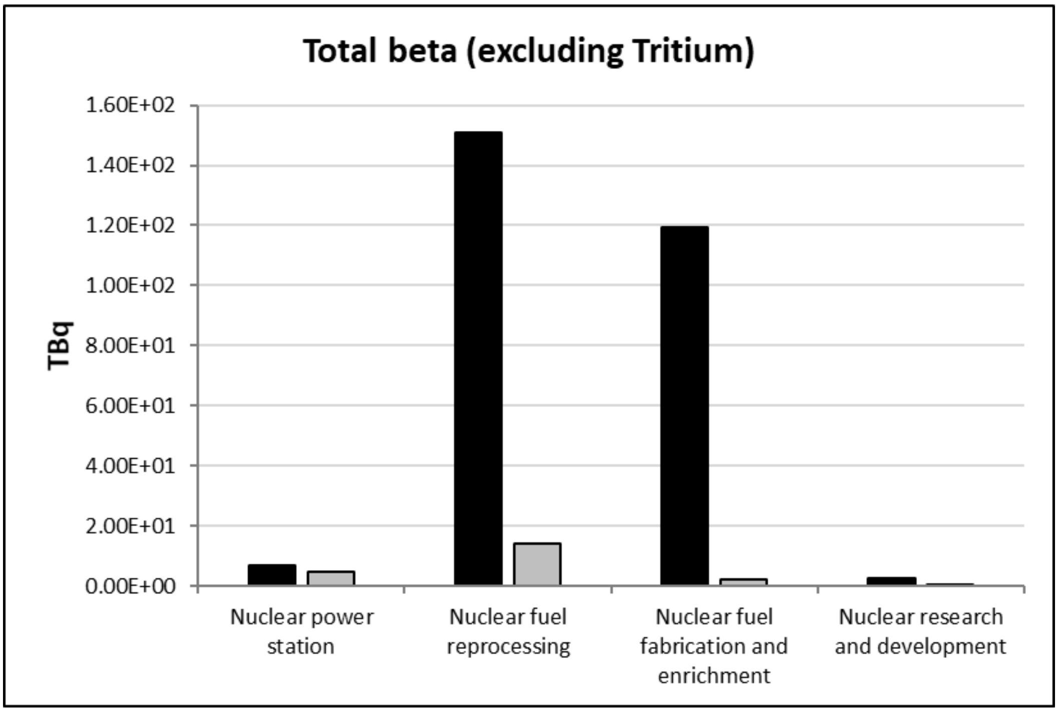


Figure 5.16: Comparison of total beta (excluding tritium) overall baseline (black columns) and assessment (grey columns) values for the different nuclear sub-sectors.

The overall situation for discharges of total alpha, total beta (excluding tritium), Tc-99, Cs-137 and Pu-239,240 from the nuclear sector is summarised in Table 5.10. The assessment results for the nuclear sector as a whole showed that there was evidence of reductions in discharges of total alpha, total beta (excluding tritium), Tc-99 and Cs-137 between the assessment and baseline periods. In each case, there was evidence of a downward trend in discharges between 1995 to 2018. The overall assessment values for total alpha, total beta (excluding tritium), Tc-99 and Cs-137 showed reductions of 2.1 fold, 13 fold, 66 fold and 3.3 fold respectively, when compared to the overall baseline values for the nuclear sector as a whole.

Overall for Pu-239,240, there was no evidence of any change in discharges between the assessment and baseline periods and no overall trend in discharges of this indicator between 1995 to 2018. The assessment value for Pu-239,240 showed a reduction of 1.2 fold when compared to the overall baseline value for the nuclear sector as a whole. It is anticipated that discharges of Pu-239, 240 will continue to follow a decreasing trend following the cessation of nuclear fuel reprocessing operations at Sellafield which is expected during 2022.

In summary and when considering the combined outcomes from both statistical assessments of the 5 indicators under the nuclear sector as a whole:

- There was evidence that there have been progressive and substantial reductions in discharges in 4 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 1 case.

Table 5.10: Overall assessment results for indicators for the nuclear sector.

Indicator	Progressive	Substantial
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 5.1.

6. Evaluation of discharges from the non-nuclear sector

The stated aim of the first objective of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy 2010-2020 is to prevent pollution of the OSPAR 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:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

In this section, results are presented that address whether there have been progressive and substantial reductions in discharges from the non-nuclear sector. In situations where the statistical assessments indicate that progressive and substantial reductions in discharges from the non-nuclear sector have not occurred, explanations are given to provide the context to these results.

Discharge data for the non-nuclear sub-sector is reported to OSPAR for a number of different sub-sectors, but the OSPAR Radioactive Substances Committee (RSC) has agreed that only discharges of naturally occurring radionuclides from the oil and gas sub-sector should be assessed using the agreed assessment methodologies. When considering the results presented in this section, it should be noted that Contracting Parties apply OSPAR Recommendation 2001/1 (as amended) for the implementation of Best Available Techniques (BAT) for the treatment and discharge of produced water from the oil and gas sub-sector, but this is not specific to radioactive discharges. Although discharges of produced water from oil and gas installations can be reduced by re-injection, this is not possible for all installations. Further information on issues related to discharges from the non-nuclear sub-sector and from the oil and gas sub-sector in particular are given in Section 2. Detailed descriptions of the methodological approaches used for data processing and statistical assessments are given in Section 4. An explanation of the symbols used to indicate assessment results in this section is given in Table 6.1. Tables of derived baseline values, assessment values and the results of the statistical tests employed for the evaluation of discharges from the oil and gas sub-sector are given in Annex 3. Figures showing annual discharges for the oil and gas sub-sector for individual Contracting Parties are given in Annex 4.

Table 6.1. Symbols used to indicate the different possible results for the statistical assessment of discharges from the non-nuclear oil and gas sub-sector.

Result of the Kendall's Tau Coefficient*	Symbol	Result of the two simple statistical tests**	Symbol
Evidence of a downward trend	↘	Evidence of a reduction	↓↓
Evidence that there has been no overall trend	→	Some evidence of a reduction	↓
Evidence of an upward trend	↗	No evidence of any change	↔
		Some evidence of an increase	↑
		Evidence of an increase	↑↑

* Kendall's Tau Coefficient is used to test whether any changes in discharges have been progressive.

** The two simple statistical tests are used to test whether any changes in discharges have been substantial.

6.1 The oil and gas sub-sector

6.1.1 Contracting Parties

Discharges over the period 2005 to 2018 have been reported for the oil and gas sub-sector by Denmark, Germany, Ireland, the Netherlands, Norway, Spain and the United Kingdom for total alpha, total beta (excluding tritium), Pb-210, Ra-226, Ra-228 and where appropriate Th-228. Spain has only reported discharges under this sub-sector for the years 2017 and 2018 and as such cannot be assessed. Assessment of discharges of Th-228 for individual Contracting Parties was only possible for the United Kingdom.

The assessment results from the sub-sector for these Contracting Parties are summarised in Table 6.2. The assessment results showed that there was evidence of reductions in discharges between the assessment and baseline periods in 10 out of the 31 cases, and some evidence of a reduction in discharges in 1 case. In 9 of these 11 cases, there was evidence of downward trends in discharges between 2005 to 2018. In the cases of Ra-226 for Norway and Pb-210 for the United Kingdom, although there was evidence of reductions in discharges between the assessment and baseline periods, there were no overall trends in discharges of these indicators between 2005 to 2018.

For Denmark, Germany and the Netherlands there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of any of the indicators between 2005 to 2018. The assessment values for Pb-210 for Denmark and the Netherlands were both 1.1 fold lower than the respective baseline values. The assessment value for Pb-210 for Germany was less than 1.1 fold lower than the baseline value. The assessment value for Ra-226 for Denmark was 1.3 fold lower than the baseline value. For all other indicators for Denmark, Germany and the Netherlands, assessment values were between 1.1 and 1.9 fold higher than the respective baseline values.

For Germany, there was only one oil and one gas platform in 2018. As the oil platform is situated in a nature reserve area all produced water is re-injected. The discharged activities from the single German gas platform were 5-6 orders of magnitude below the total amount of all OSPAR members in 2018. Thus, the potential for further reduction of radioactive discharges from the German oil and gas sub-sector is negligible.

For the Netherlands there were no statistically significant differences in discharges due to variations in the amount of produced water and in the productivity of the platforms. In addition, there are natural variations in the activity concentrations of the indicator radionuclides in the discharged produced water.

For Norway, there was no evidence of any change in discharges of Ra-228 between the assessment and baseline periods and no overall trend in discharges of this indicator between 2005 to 2018. The assessment value for Ra-228 for Norway was less than 1.1 fold lower than the baseline value.

The discharges from the Norwegian oil and gas sub-sector have been at a similar level since such discharge data was first reported to OSPAR in 2005. The changes in discharges are mainly due to changes in production. In addition, most of the Norwegian oil and gas producers have changed the laboratories that have carried out the analysis of the discharges during the period 2005 to 2018, leading to improvements in the analytical detection limits. This change has probably resulted in the apparent reduction in discharges of Pb-210 as reported activity concentrations of Pb-210 are based on detection limits. In addition, this change in analytical detection limits may have affected the reported discharges of Ra-226 and Ra-228 in later years leading to an apparent slight decrease. It should be noted that Norwegian oil and gas producers are required to re-inject produced water where possible to minimise discharges of radioactive material to sea. Justification for not complying with the requirement to re-inject has to be accepted on a case by case-basis by the regulatory authority.

For the United Kingdom, there was no evidence of any changes in discharges of total alpha, total beta (excluding tritium), Ra-226 and Ra-228 between the assessment and baseline periods and in each case there were no overall trends in discharges of these indicators between 2005 to 2018. The assessment values for these indicators were not more than 1.1 fold higher than the respective baseline values.

For the United Kingdom, re-injection can reduce radioactive discharges from the oil and gas sub-sector, but it has its limitations. This is reflected in the discharges of total alpha, total beta (excluding tritium), Ra-226 and Ra-228 for the assessment period where reductions in discharges remained within the baseline range but were not found to be progressive or substantial.

In summary and when considering the combined outcomes from both statistical assessments of the 31 cases where indicators were reported by Contracting Parties under the oil and gas sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 8 cases.
- There was evidence that there have been progressive reductions in discharges and some evidence of substantial reductions in discharges in 1 case.
- There was evidence that there had been only substantial reductions in discharges in 2 cases.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 20 cases.

Table 6.2: Assessment results for indicators for the oil and gas sub-sector by Contracting Party.

Contracting Party	Indicator	Progressive	Substantial
Denmark	Total alpha	→	↔
	Total beta (excluding tritium)	→	↔
	Pb-210	→	↔
	Ra-226	→	↔
	Ra-228	→	↔
Germany	Total alpha	→	↔
	Total beta (excluding tritium)	→	↔
	Pb-210	→	↔
	Ra-226	→	↔
	Ra-228	→	↔
Ireland	Total alpha	↘	↓↓
	Total beta (excluding tritium)	↘	↓↓

	Pb-210	↘	↓↓
	Ra-226	↘	↓↓
	Ra-228	↘	↓↓
Netherlands	Total alpha	→	↔
	Total beta (excluding tritium)	→	↔
	Pb-210	→	↔
	Ra-226	→	↔
	Ra-228	→	↔
Norway	Total alpha	↘	↓↓
	Total beta (excluding tritium)	↘	↓↓
	Pb-210	↘	↓↓
	Ra-226	→	↓↓
	Ra-228	→	↔
United Kingdom	Total alpha	→	↔
	Total beta (excluding tritium)	→	↔
	Pb-210	→	↓↓
	Ra-226	→	↔
	Ra-228	→	↔
	Th-228	↘	↓

An explanation of the symbols used to indicate the assessment results is given in Table 6.1.

6.1.2 Overall situation

The overall situation across all Contracting Parties for discharges of total alpha and total beta (excluding tritium), Pb-210, Ra-226, Ra-228 and Th-228 from the oil and gas sub-sector is summarised in Table 6.3 and in Figures 6.1 to 6.6. The assessment results for the sub-sector show that there was evidence of a reduction in discharges of Pb-210 and some evidence of a reduction in discharges of Th-228 between the assessment and baseline periods. In both these cases, there was evidence of a downward trend in the reduction in discharges between 2005 to 2018. The overall assessment values for Pb-210 and Th-228 showed reductions of 2 fold and 12 fold respectively, when compared to the overall baseline values for this sub-sector as a whole.

For total alpha, total beta (excluding tritium) and Ra-226 there was no evidence of any changes in discharges between the assessment and baseline periods and no overall trends in discharges of these indicators between 2005 to 2018. In the case of Ra-228, although there was evidence of an upward trend in discharges between 2005 to 2018, there was no evidence of any change in discharges of this indicator between the assessment and baseline periods. The overall assessment values for total alpha, total beta (excluding tritium) and Ra-228 were less than 1.1 fold higher than their respective baseline values for the sub-sector as a whole. The overall assessment value for Ra-226 was less than 1.1 fold lower than the baseline value for the sub-sector as a whole.

In summary and when considering the combined outcomes from both statistical assessments of the 6 indicators under the oil and gas sub-sector:

- There was evidence that there have been progressive and substantial reductions in discharges in 1 case.
- There was evidence that there have been progressive reductions in discharges and some evidence of substantial reductions in discharges in 1 case.
- There was no evidence of progressive and substantial reductions in discharges in the remaining 4 cases.

Table 6.3: Overall assessment results for indicators for the oil and gas sub-sector.

Indicator	Progressive	Substantial
Total alpha	→	↔
Total beta (excluding tritium)	→	↔
Pb-210	↘	↓↓
Ra-226	→	↔
Ra-228	↗	↔
Th-228	↘	↓

An explanation of the symbols used to indicate the assessment results is given in Table 6.1.

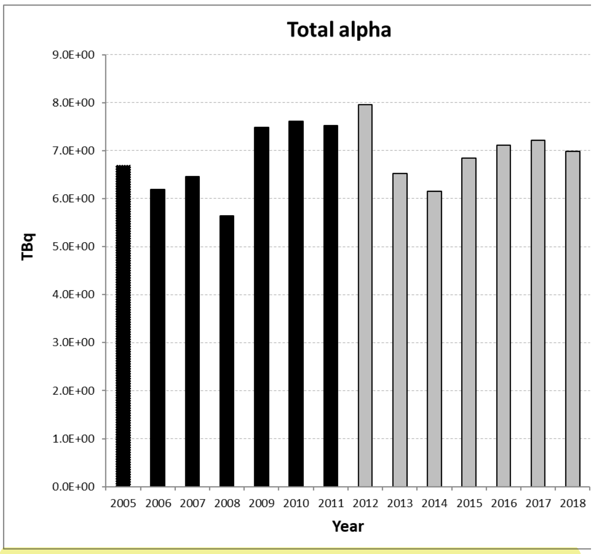


Figure 6.1: Total alpha discharges from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

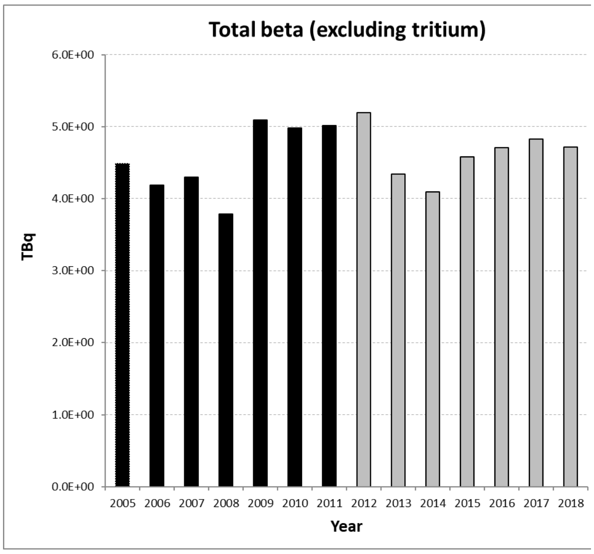


Figure 6.2: Total beta (excluding tritium) discharges from oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

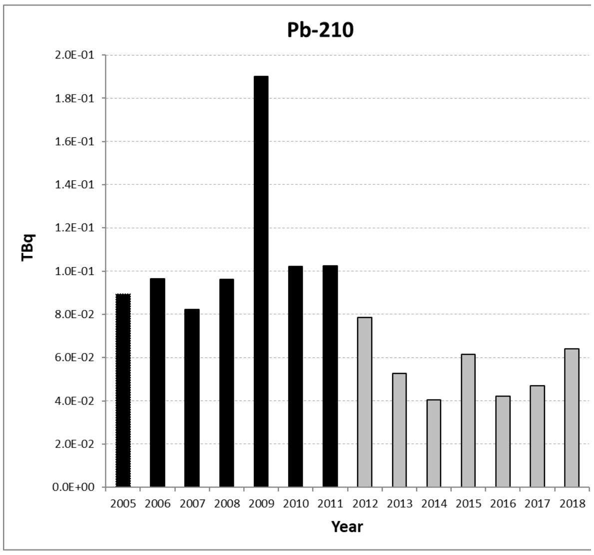


Figure 6.3: Pb-210 discharges from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

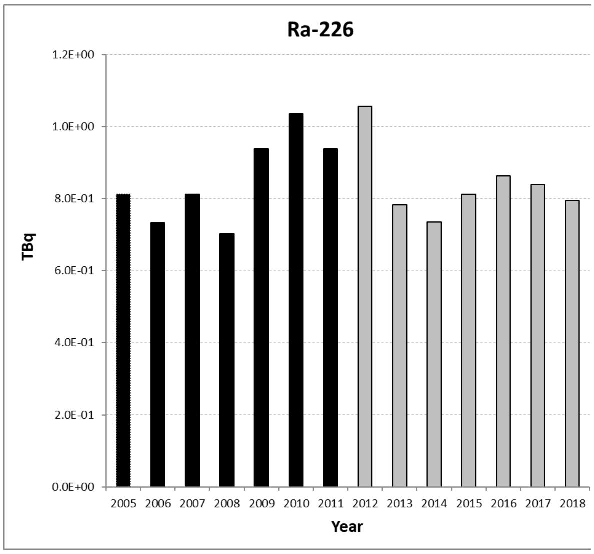


Figure 6.4: Ra-226 discharges from oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

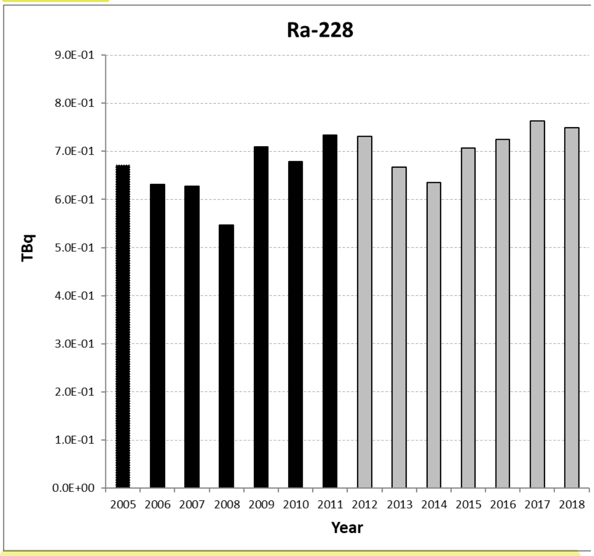


Figure 6.5: Ra-228 discharges from the oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

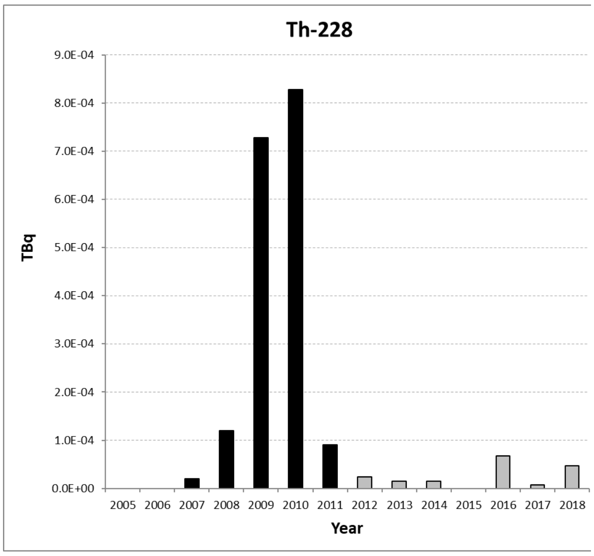


Figure 6.6: Th-228 discharges from oil and gas sub-sector for all Contracting Parties for the period 2005 to 2018. Time periods indicated are baseline period (black columns), assessment period (grey columns).

7. Evaluation of environmental concentrations

The stated aim of the second objective of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy 2010-2020 is to ensure that by the year 2020 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.

In this section, results are presented that address whether environmental concentrations of indicator radionuclides for the nuclear sector in the assessment period (2012 to 2018) are at levels that are close to (or lower than) historic levels (defined as the baseline period of 1995 to 2001) in the different OSPAR Radioactive Substances Committee (RSC) sub-regions. In situations where environmental concentrations in the assessment period are at levels that are higher than historic levels, explanations are included in order to provide context.

Background information on the monitoring of radionuclides in the marine environment by OSPAR RSC are given in Section 3, and detailed descriptions of the methodological approaches used for data processing and statistical assessments are given in Section 4. An explanation of the symbols used to indicate assessment results in this section is given in Table 7.1. Tables of derived baseline values, assessment values and results (P values) of the statistical tests employed for the evaluation of environmental concentrations in seawater and marine biota are given in Annexes 5 and 7, respectively. Examples of figures of annual means for environmental concentrations of individual indicators are given in this section. Figures of annual means of all indicator radionuclides in the 15 OSPAR RSC sub-regions (where data is available) for seawater and marine biota are given in Annexes 6 and 8, respectively.

Table 7.1. Symbols used to indicate the different possible results of the statistical assessment of environmental concentrations and conclusions against historic levels

Result of the two simple statistical tests	Symbol	Compared to historic levels
Evidence of a decrease	↓↓	Lower
Some evidence of a decrease	↓	Lower
No evidence of any change	↔	Close
Some evidence of an increase	↑	Higher
Evidence of an increase	↑↑	Higher
No statistics possible	NS	-

7.1 Seawater

Environmental concentration data for seawater used in this assessment has been reported by Belgium, Denmark, France, Germany, Iceland, Ireland, the Netherlands, Norway, Sweden, Spain and the United Kingdom. The assessment results for the indicator radionuclides H-3, Tc-99, Cs-137 and Pu-239,240 in seawater for the different OSPAR RSC sub-regions are summarised in Table 7.2.

Table 7.2: Assessment results for H-3, Tc-99, Cs-137 and Pu-239,240 in seawater by OSPAR RSC sub-region

OSPAR RSC sub-Region	Assessment result H-3	Tc-99	Cs-137	Pu-239,240
1	↔	NS	NS	NS
2	↓↓	NS	NS	↔
3	↑↑	NS	NS	NS
4	NS	NS	↓↓	NS
5	↔	↓↓	↓↓	NS
6	↓↓	↓↓	↓↓	↔
7	↔	NS	↓	↓
8	↔	NS	↓↓	↔
9	↔	NS	↓↓	↓↓
10	↓↓	↓↓	↓↓	↓↓
11	NS	NS	↓↓	↔
12	↔	NS	↓↓	NS
13	NS	↓↓	↓	↓↓
14	NS	↔	↓↓	↓↓
15	NS	↔	↓↓	↔

An explanation of the symbols used to indicate the assessment results is given in Table 7.1.

7.1.1 Tritium (H-3)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for H-3 in seawater in 10 sub-regions. For the 5 OSPAR RSC sub-regions where statistical assessments were not possible, this was because of insufficient annual mean values (n<2) for the baseline and/or assessment period due to either no available data or that where data had been reported for certain years, more than 80% of this data was below the detection limit.

The assessment results showed that there was evidence of reductions in environmental concentrations of H-3 in seawater between the assessment and baseline periods in OSPAR RSC sub-regions 2, 6 and 10, evidence of an increase in environmental concentrations in OSPAR RSC sub-region 3 and no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 1, 5, 7, 8, 9 and 12. The assessment values for OSPAR RSC sub-regions 5, 7 and 9 were 7, 3.3 and less than 1.1 fold lower than the respective baseline value. The assessment values for OSPAR RSC sub-regions 1, 8 and 12 were 1.8, 1.1 and 1.1 fold higher than the respective baseline values.

In OSPAR RSC sub-region 3, the evidence of an increase in environmental concentrations of H-3 in seawater between the assessment and baseline periods reflects the influence of the discharges from the French nuclear fuel reprocessing facility at la Hague in OSPAR RSC sub-region 2.

In OSPAR RSC sub-region 2, H-3 in seawater is not expected to decline, since there is no decline of H-3 discharges from the la Hague nuclear fuel reprocessing facility in OSPAR RSC sub-region 2. In this case, the significant decrease between the baseline and the assessment periods shown by the statistical analysis is the result of a change in sampling stations. The sampling stations (Jobourg and Anse des Moulinets) in use from 1995 were discontinued in 2009 as they were located close to the discharge outlet of the nuclear fuel reprocessing facility, and they were not representative of environmental concentrations throughout OSPAR RSC sub-region 2. These 2 stations were replaced in 2009 by a sampling station at Goury, that is approximately 6 km from the discharge outlet.

In summary, for the 10 cases where statistical assessments were possible for H-3 in seawater:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 3 cases.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 6 cases.
- There was evidence that environmental concentrations in the assessment period were higher than historic levels in 1 case.

In the 5 cases where it was not possible to carry out any statistics, this was because:

- In 3 cases there was insufficient data available to derive a baseline value.
- In 2 cases there was insufficient data available to derive a baseline and an assessment value.

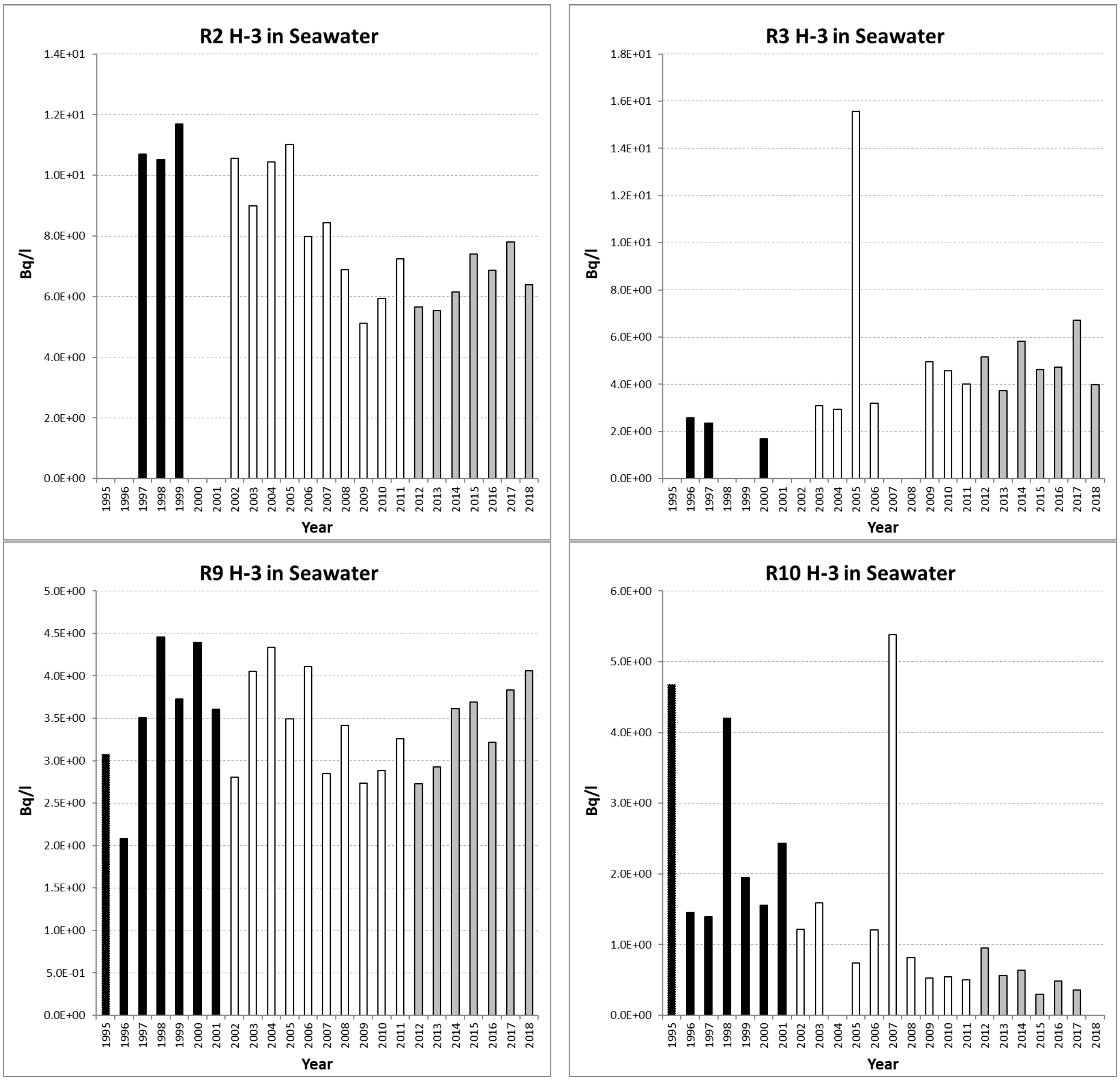


Figure 7.1: Examples of H-3 environmental concentrations in seawater (Bq/l) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing OSPAR RSC sub-regions 2 (evidence of a reduction), 3 (evidence of an increase), 9 (no evidence of any change) and 10 (evidence of a reduction). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.1.2 Technetium-99 (Tc-99)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Tc-99 in seawater in 6 sub-regions. Of the 9 OSPAR RSC sub-regions where statistical assessments were not possible, in 7 cases this was because no or insufficient data was available for the assessment period, despite baseline values having been established previously. This is reflection of the reduction in the monitoring Tc-99 in seawater by Contracting Parties since the baseline period as environmental concentrations have reduced over time. In the other 2 cases, data was only available for 2 years in each case over the entire period 1995 to 2018 and no baseline or assessment value could be established.

The assessment results showed that there was evidence of reductions in environmental concentrations of Tc-99 in seawater between the assessment and baseline periods in OSPAR RSC sub-regions 5, 6, 10 and 13, with no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 14 and 15. The assessment values for OSPAR RSC sub-regions 14 and 15 were 7.9 and 1.5 fold lower than the respective baseline values.

In summary, for the 6 cases where statistical assessments were possible for Tc-99 in seawater:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 4 cases.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 2 cases.

In the 9 cases where it was not possible to carry out any statistics, this was because:

- In 7 cases there was no or insufficient data available to derive an assessment value.
- In 2 cases there was no or insufficient data available to derive a baseline and an assessment value.

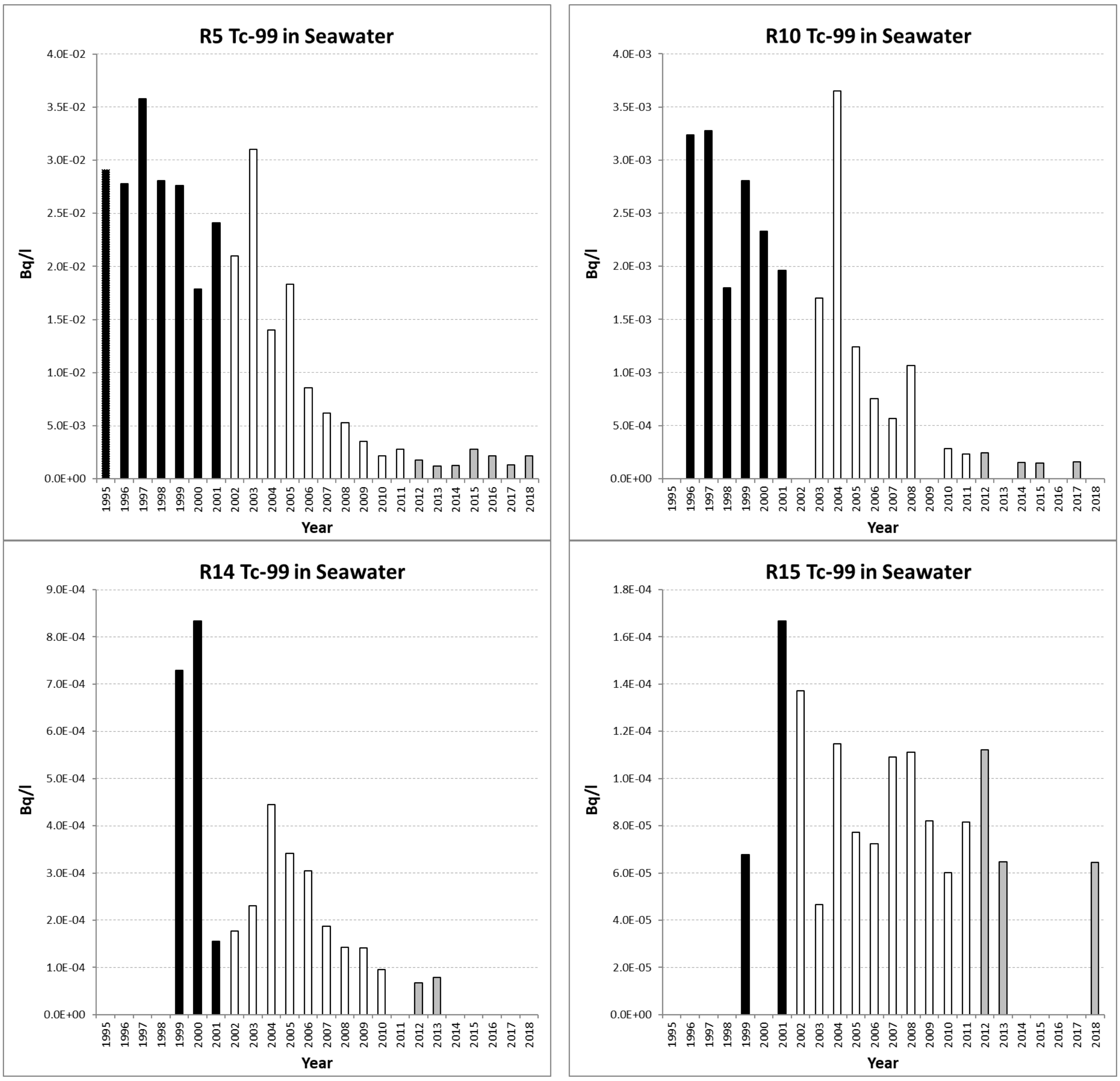


Figure 7.2: Examples of Tc-99 environmental concentrations in seawater (Bq/l) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing OSPAR RSC sub-regions 5 and 10 (evidence of a reduction), and 14 and 15 (no evidence of any change). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.1.3 Caesium-137 (Cs-137)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Cs-137 in seawater in 12 sub-regions. For the 3 OSPAR RSC sub-regions where statistical assessments were not possible, this was because it was not possible to derive baseline values for these sub-regions as in each case more than 80% of data reported for at least six of the seven baseline period years was below the detection limit.

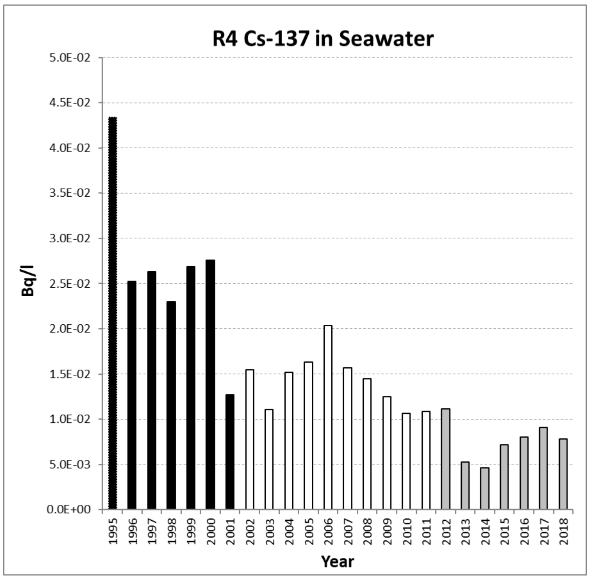
The assessment results showed that there was evidence of reductions in environmental concentrations of Cs-137 in seawater between the assessment and baseline periods in OSPAR RSC sub-regions 4, 5, 6, 8, 9, 10, 11, 12, 14 and 15, with some evidence of reductions between the assessment and baseline periods in OSPAR RSC sub-regions 7 and 13.

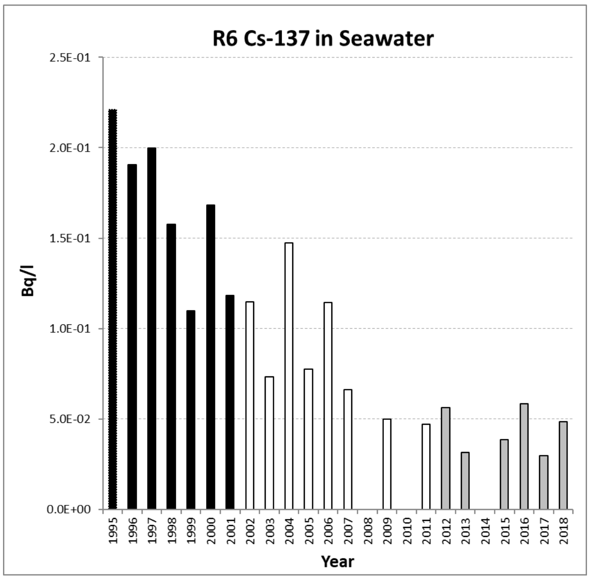
In summary, for the 12 cases where statistical assessments were possible for Cs-137 in seawater:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 10 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 2 cases.

In the 3 cases where it was not possible to carry out any statistics, this was because:

- In 2 cases more than 80% of the data reported for all years of the baseline period was below the detection limit.
- In 1 case more than 80% of the data reported for years of the baseline period, where data was available, was below the detection limit.





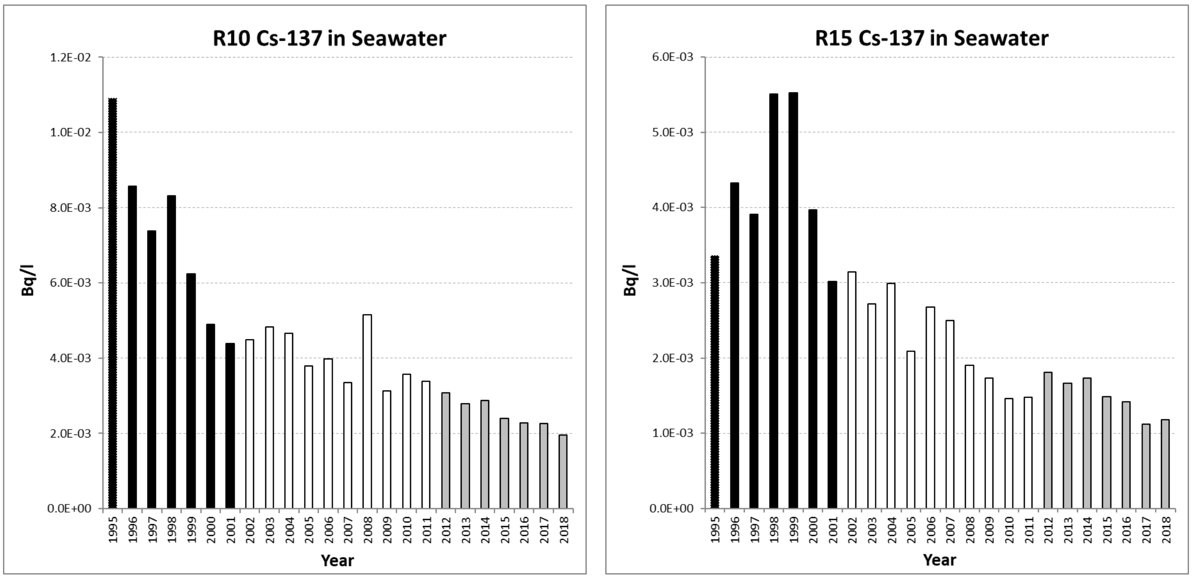


Figure 7.3: Examples of Cs-137 environmental concentrations in seawater (Bq/l) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing OSPAR RSC sub-regions 4, 6, 10 and 15 (evidence of a reduction). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above

7.1.4 Plutonium-239 and Plutonium-240 (Pu-239,240)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Pu-239,240 in seawater in 10 sub-regions. Of the 5 OSPAR RSC sub-regions where statistical assessments were not possible, in 3 cases this was because this was insufficient annual values (n<2) for the assessment periods. In the remaining 2 cases, data was only available for 1 year in each case over the entire period 1995 to 2018, so no baseline or assessment value could be established.

The assessment results showed that there was evidence of reductions in environmental concentrations of Pu-239,240 in seawater between the assessment and baseline periods in OSPAR RSC sub-regions 9, 10, 13 and 14, with some evidence of a reduction between the assessment and baseline periods in OSPAR RSC sub-region 7. There was no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 2, 6, 8, 11 and 15. The assessment values for OSPAR RSC sub-regions 2, 6, 8, 11 and 15 were 1.5, 1.2, 1.2, 1.1 and 1.2 fold lower than the respective baseline values.

In summary, for the 10 cases where statistical assessments were possible for Pu-239,240 in seawater:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 4 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 1 case.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 5 cases.

In the 5 cases where it was not possible to carry out any statistics, this was because:

- In 3 cases there was no or insufficient data available to derive an assessment value.
- In 2 cases there was no or insufficient data available to derive a baseline and an assessment value.

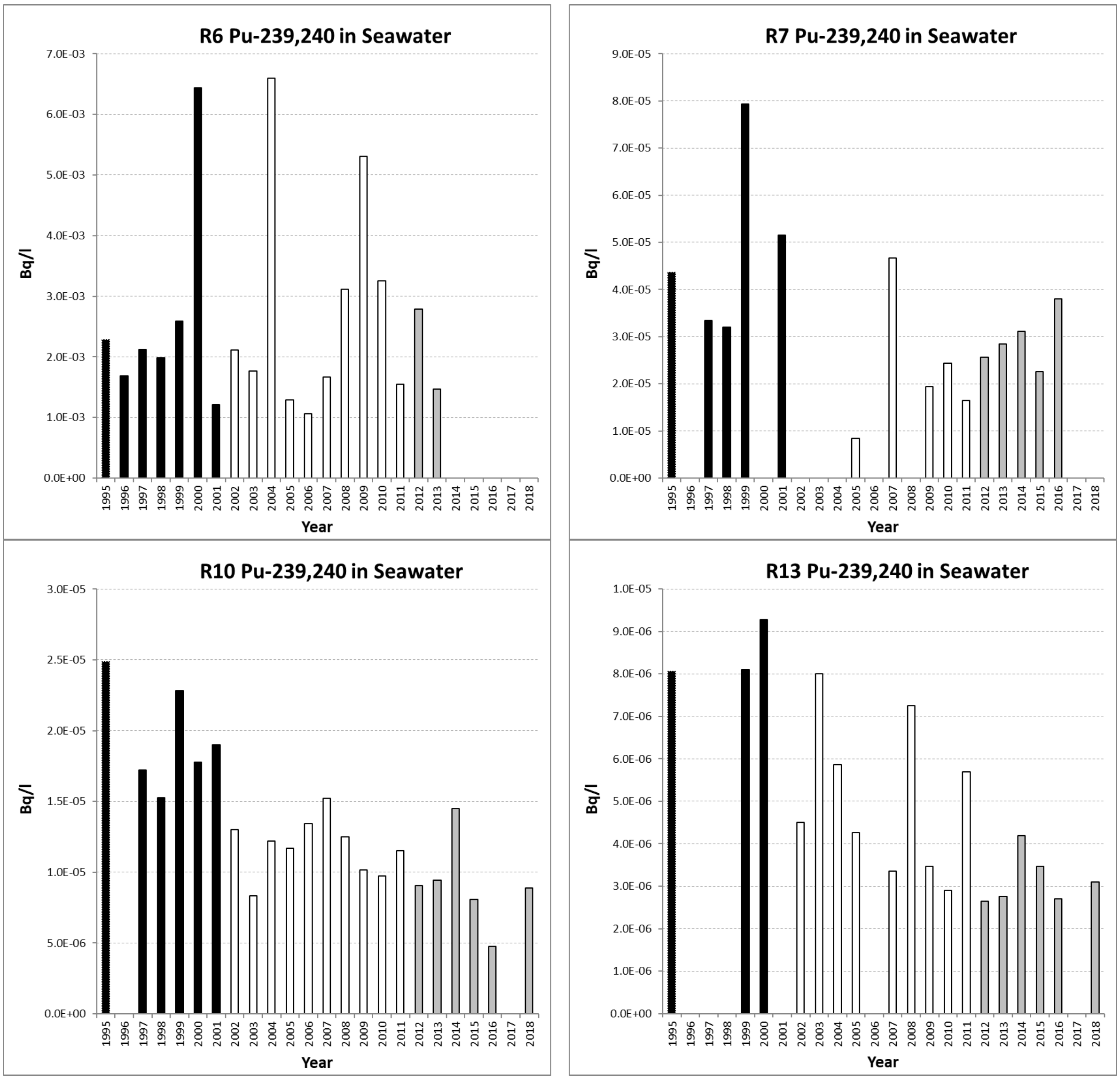


Figure 7.4: Examples of Pu-239,240 environmental concentrations in seawater (Bq/l) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing OSPAR RSC sub-regions 6 (no evidence of any change), 7 (some evidence of a reduction), and 10 and 13 (evidence of a reduction). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.1.5 Overall situation for seawater

Overall, and in terms of the assessment results for environmental concentrations of H-3, Tc-99, Cs-137 and Pu-239,240 in seawater, for the 38 cases where statistical assessments were possible:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 21 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 3 cases.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 13 cases.
- There was evidence that environmental concentrations in the assessment period were higher than historic levels in 1 case.

In the 22 cases where it was not possible to carry out any statistics, this was because:

- In 3 cases there was no or insufficient data available to derive a baseline value.
- In 10 cases there was no or insufficient data available to derive an assessment value.
- In 6 cases there was no or insufficient data available to derive a baseline and an assessment value.
- In 2 cases more than 80% of the data reported for all years of the baseline period was below the detection limit.
- In 1 case more than 80% of the data reported for years of the baseline period, where data was available, was below the detection limit.

7.2 Marine biota

Environmental concentration data for marine biota (seaweed, molluscs and fish) used in this assessment has been reported by Belgium, Denmark, France, Germany, Iceland, Ireland, the Netherlands, Norway, Sweden, Spain and the United Kingdom. The assessment results for the indicator radionuclides Tc-99, Cs-137 and Pu-239,240 in marine biota are summarised in Table 7.3.

Table 7.3: Assessment results for Tc-99, Cs-137 and Pu-239,240 in seaweed (S), molluscs (M) and fish (F) by OSPAR RSC sub-region

OSPAR RSC sub-Region	Assessment result Tc-99			Cs-137			Pu-239,240		
	S	M	F	S	M	F	S	M	F
1	NS	NS	NS	↓↓	NS	NS	NS	NS	NS
2	NS	NS	NS	↓↓	NS	↔	NS	↓	NS
3	↓↓	NS	NS	↓	NS	↓↓	NS	↔	NS
4	↓↓	↓↓	NS	↓↓	↓↓	NS	NS	↓	NS
5	↓↓	NS	NS	↓↓	↓↓	↓↓	↔	↔	NS
6	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↔
7	↓↓	NS	NS	↓↓	NS	NS	NS	↓	NS
8	NS	NS	NS	NS	NS	NS	NS	↔	NS
9	NS	NS	NS	NS	NS	↓↓	NS	NS	NS
10	↓↓	NS	NS	↓↓	↓↓	↓↓	NS	↓↓	NS
11	↓	NS	NS	↓↓	NS	NS	NS	NS	NS
12	↓	NS	NS	↓↓	NS	↓↓	NS	NS	NS
13	↓↓	NS	NS	↓↓	NS	↔	NS	NS	NS
14	↓↓	NS	NS	↔	NS	↓↓	NS	NS	NS
15	↓↓	NS	NS	↔	NS	↓↓	NS	NS	NS

An explanation of the symbols used to indicate the assessment results is given in Table 7.1.

7.2.1 Technetium-99 (Tc-99)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Tc-99 in marine biota in 11 sub-regions for seaweed, 2 sub-regions for molluscs and 1 sub-region for fish. Of the 4 OSPAR RSC sub-regions where statistical assessments were not possible for seaweed, in 2 cases this was because no data was available for the assessment period, despite baseline values having been established previously. In the remaining 2 cases, no baseline values had been established. Of the OSPAR RSC sub-regions where statistical assessments were not possible for molluscs and fish, in 24 out of 27 cases this was because there was no data available. In the remaining 3 cases, this was because of insufficient annual values (n<2) for the baseline and/or assessment period. The differences in availability of data for Tc-99 in seaweed compared to molluscs and fish reflects the fact that it is more common for Contracting Parties to monitor environmental concentrations of Tc-99 in seaweed, as certain types of seaweed can accumulate Tc-99 to a relatively high degree.

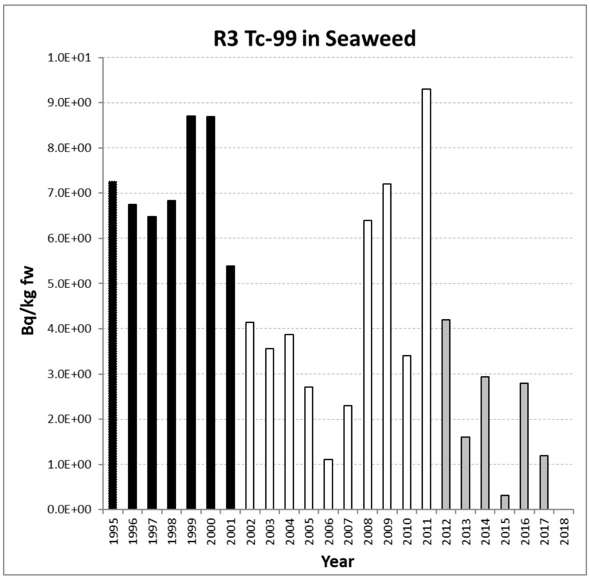
The assessment results showed that there was evidence of reductions in environmental concentrations of Tc-99 in seaweed between the assessment and baseline periods in OSPAR RSC sub-regions 3, 4, 5, 6, 7, 10, 13, 14 and 15, with some evidence of reductions between the assessment and baseline periods in OSPAR RSC sub-regions 11 and 12. For molluscs, the assessment results showed that there was evidence of reductions in environmental concentrations of Tc-99 between the assessment and baseline periods in OSPAR RSC sub-regions 4 and 6. For fish, the assessment result showed that there was evidence of a reduction in environmental concentrations of Tc-99 between the assessment and baseline periods in OSPAR RSC sub-region 6.

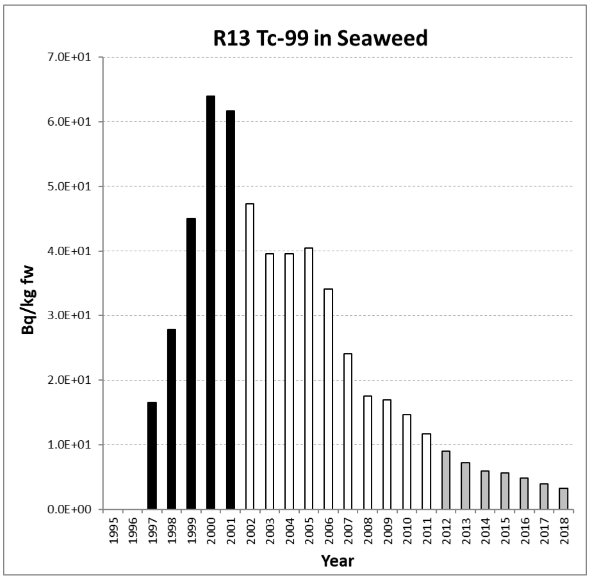
In summary, for the 14 cases where statistical assessments were possible for Tc-99 in marine biota:

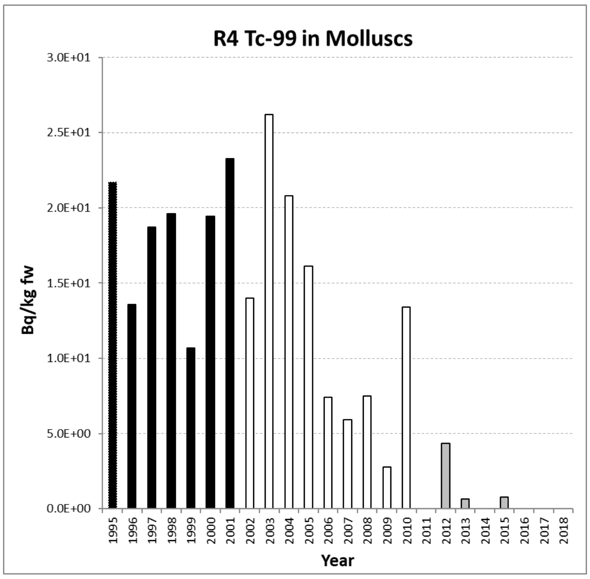
- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 12 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 2 cases.

In the 31 cases where it was not possible to carry out any statistics, this was because:

- In 3 cases there was no data available to derive a baseline value.
- In 3 cases there was no data available to derive an assessment value.
- In 1 case there was no or insufficient data available to derive a baseline and an assessment value.
- In 24 cases no data was available for any year in the period 1995 to 2018.







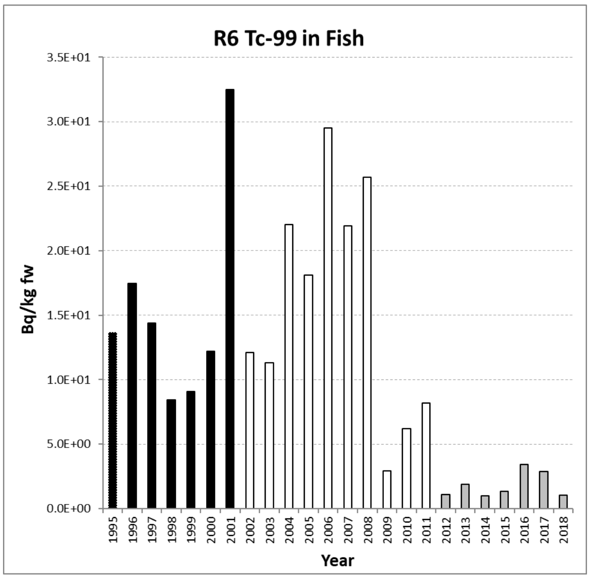


Figure 7.5: Examples of Tc-99 environmental concentrations in marine biota (Bq/kg f.w.) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing seaweed in OSPAR RSC sub-regions 3 and 13, molluscs in OSPAR RSC sub-region 4 and fish in OSPAR RSC sub-region 6 (evidence of a reduction in all cases). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.2.2 Caesium-137 (Cs-137)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Cs-137 in marine biota in 13 sub-regions for seaweed, 4 sub-regions for molluscs and 10 sub-regions for fish. Of the 2 OSPAR RSC sub-regions where statistical assessments were not possible for seaweed, in 1 case this was this was because it was not possible to derive any annual values for the assessment period as for each year more than 80% of the data reported was below the detection limit. In the other case, no baseline value had been established. Of the 11 OSPAR RSC sub-regions where statistical assessments were not possible for molluscs, in 5 cases this was because it was not possible to derive any annual values for the baseline or assessment periods as more than 80% of the data reported for each year was below the detection limit. In the remaining 6 cases, no data was available for the baseline and/or assessment periods. Of the 5 OSPAR RSC sub-regions where statistical assessments were not possible for fish, in 4 cases this was because of insufficient annual mean values (n<2) or that no data was available for the baseline and/or assessment periods. In the remaining case, this was because it was not possible to derive any annual values for the assessment period as more than 80% of the data reported for each year was below the detection limit.

The assessment results showed that there was evidence of reductions in environmental concentrations of Cs-137 in seaweed between the assessment and baseline periods in OSPAR RSC sub-regions 1, 2, 4, 5, 6, 7, 10, 11, 12 and 13, with some evidence of a reduction between the assessment and baseline periods in OSPAR RSC sub-region 3. There was no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 14 and 15. The assessment values for OSPAR RSC sub-regions 14 and 15 were 1.4 and 1.2 fold higher than the respective baseline values. For molluscs, the assessment results showed that there was evidence of reductions in environmental concentrations of Cs-137 between the assessment and baseline periods in OSPAR RSC sub-regions 4, 5, 6 and 10. For fish, the assessment results showed that there was evidence of reductions in environmental concentrations of Cs-137 between the assessment and baseline periods in OSPAR RSC sub-regions 3, 5, 6, 9, 10, 12, 14 and 15, with no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 2 and 13. The assessment value for OSPAR RSC sub-region

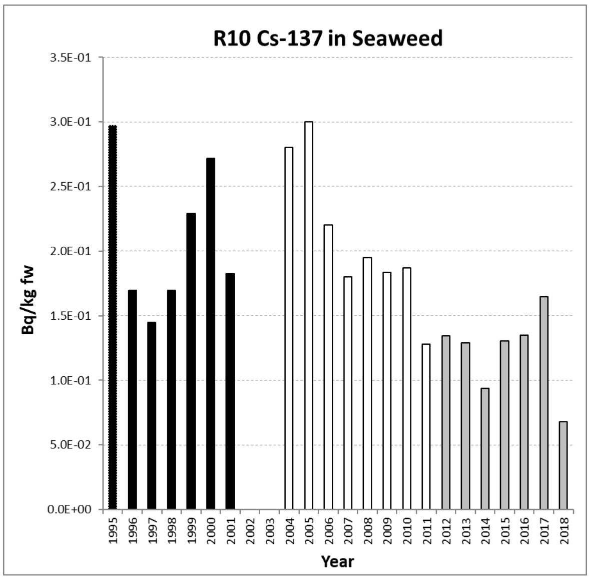
2 was 2.5 fold lower than the baseline value. The assessment value for OSPAR RSC sub-region 13 was 1.3 fold higher than the baseline value.

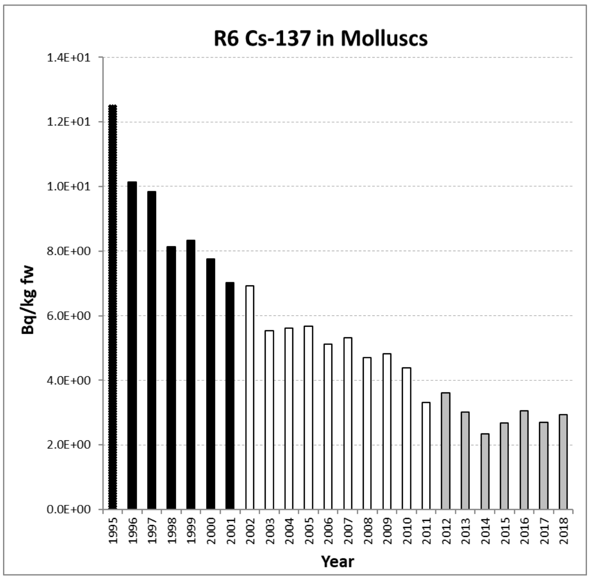
In summary, for the 27 cases where statistical assessments were possible for Cs-137 in marine biota:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 22 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 1 case.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 4 cases.

In the 18 cases where it was not possible to carry out any statistics, this was because:

- In 4 cases there was no or insufficient data available to derive a baseline value.
- In 3 cases there was no or insufficient data available to derive an assessment value.
- In 3 cases there was no or insufficient data available to derive a baseline and an assessment value.
- In 6 cases more than 80% of the data reported for years of the assessment period, where data was available, was below the detection limit.
- In 1 case more than 80% of the data reported for years of the baseline and assessment period, where data was available, was below the detection limit.
- In 1 case no data was available for any year in the period 1995 to 2018.





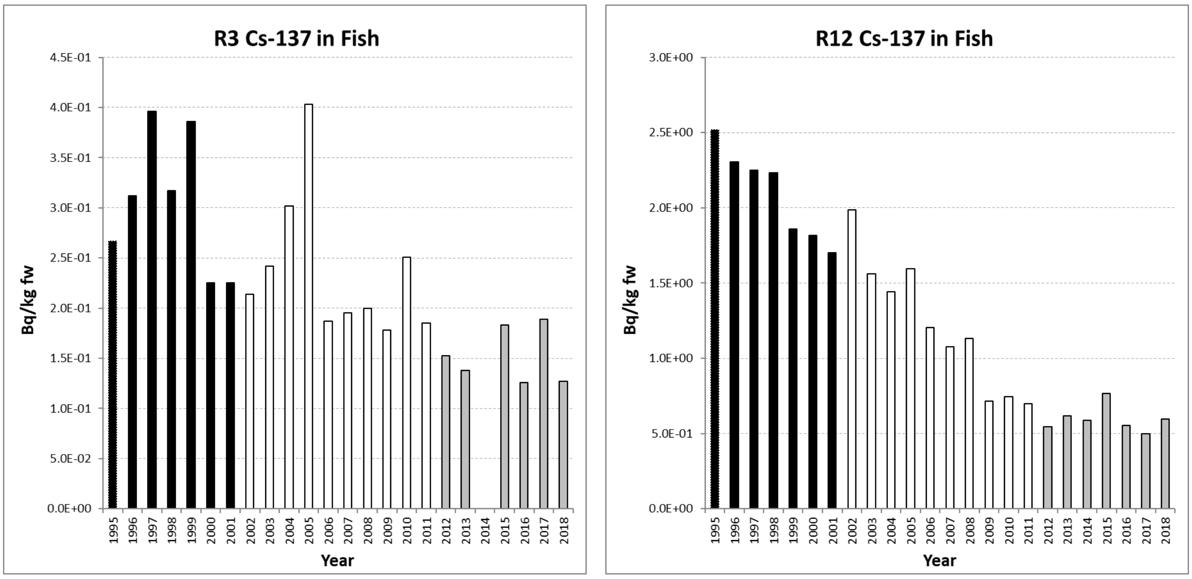


Figure 7.6: Examples of Cs-137 environmental concentrations in marine biota (Bq/kg f.w.) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing seaweed in OSPAR RSC sub-region 10, molluscs in OSPAR RSC sub-region 6 and fish in OSPAR RSC sub-regions 3 and 12 (evidence of a reduction in all cases). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.2.3 Plutonium-239 and Plutonium-240 (Pu-239,240)

Of the 15 OSPAR RSC sub-regions, statistical assessments were possible for Pu-239,240 in marine biota in 2 sub-regions for seaweed, 8 sub-regions for molluscs and 1 sub-region for fish. Of the 13 OSPAR RSC sub-regions where statistical assessments were not possible for seaweed, in 12 cases this was because there was no or insufficient data available. In the remaining case, it was not possible to derive any annual values for the assessment period as more than 80% of the data reported for each year was below the detection limit. In all 7 OSPAR RSC sub-regions where statistical assessments were not possible for molluscs, this was because there was no or insufficient data available. Of the 14 OSPAR RSC sub-regions where statistical assessments were not possible for fish, in 9 cases this was because there was no or insufficient data available. In 4 cases was because there was no data available for the assessment period, despite baseline values having been established previously. In the remaining case, this was because it was not possible to derive any annual values for the assessment period as for each year more than 80% of the data reported was below the detection limit. The differences in availability of data for Pu-239,240 in molluscs compared to seaweed and fish reflects the fact that it is more common for Contracting Parties to monitor environmental concentrations of Pu-239,240 in molluscs, as molluscs are filter feeding organisms that may accumulate Pu-239,240 bound to particulate material.

The assessment results showed that there was evidence of a reduction in environmental concentrations of Pu-239,240 in seaweed between the assessment and baseline periods in OSPAR RSC sub-region 6, with no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-region 5. The assessment value for OSPAR RSC sub-region 5 was 1.1 fold higher than the baseline value. For molluscs, the assessment results showed that there was evidence of reductions in environmental concentrations of Pu-239,240 between the assessment and baseline periods in OSPAR RSC sub-regions 6 and 10, with some evidence of reductions between the assessment and baseline periods in OSPAR RSC sub-regions 2, 4 and 7. There was no evidence of any change between the assessment and baseline periods in OSPAR RSC sub-regions 3, 5 and 8. The assessment values for OSPAR RSC sub-regions 3, 5 and 8 were 1.1, 2 and 1.6 fold lower than the respective baseline values. For fish, the assessment results showed that there was no evidence of any change in environmental concentrations of Pu-239,240 between the assessment and baseline periods in OSPAR RSC sub-region

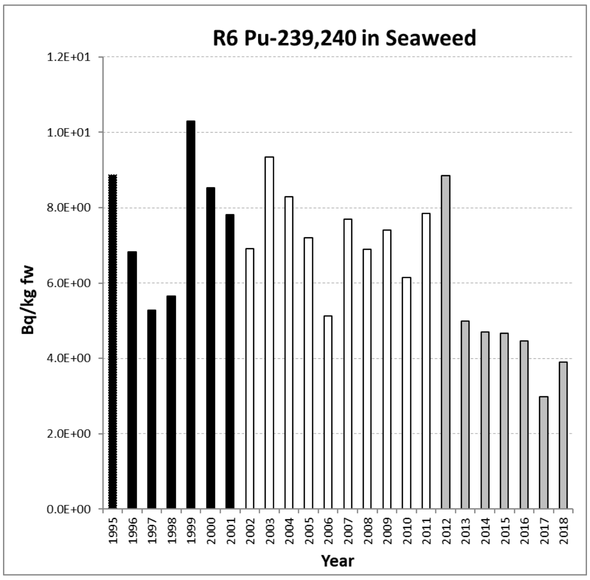
6. The assessment value for OSPAR RSC sub-region 6 was less than 1.1 fold lower than the baseline value.

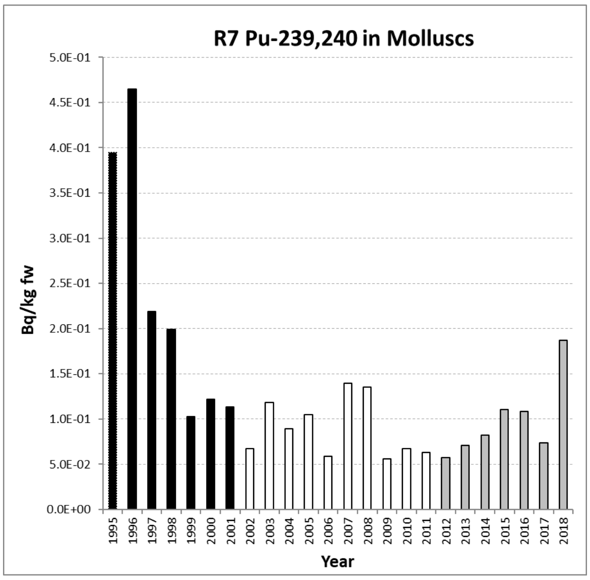
In summary, for the 11 cases where statistical assessments were possible for Pu-239,240 in marine biota:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 3 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 3 cases.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 5 cases.

In the 34 cases where it was not possible to carry out any statistics, this was because:

- In 1 case there was insufficient data available to derive a baseline value.
- In 4 cases there was no data available to derive an assessment value.
- In 4 cases there was no or insufficient data available to derive a baseline and an assessment value.
- In 2 cases more than 80% of the data reported for all years of the assessment period was below the detection limit.
- In 23 cases no data was available for any year in the period 1995 to 2018.





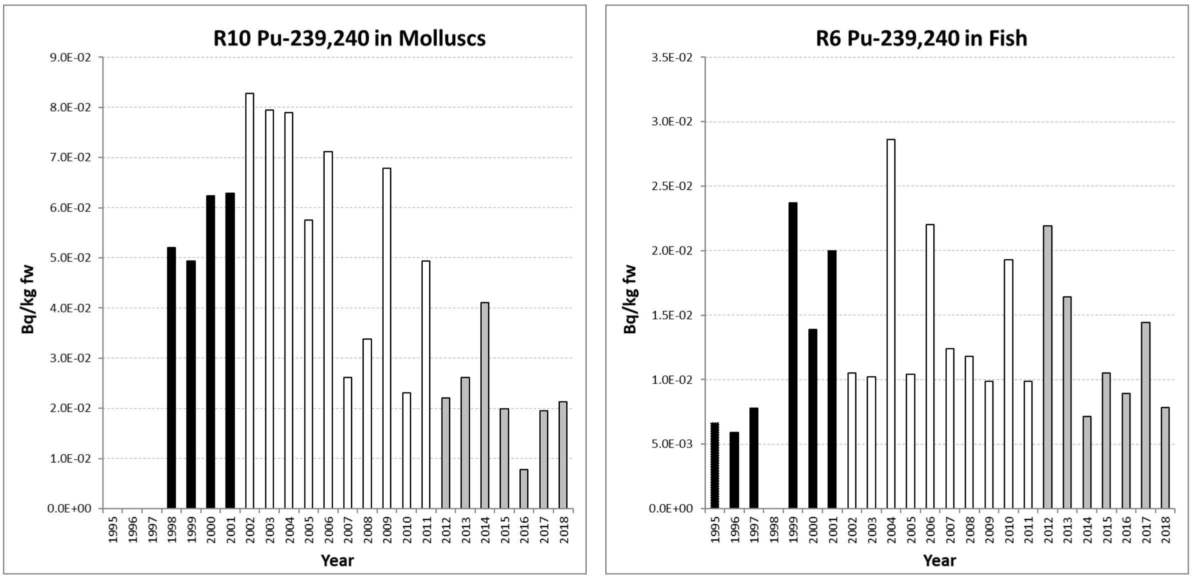


Figure 7.7: Examples of Pu-239,240 environmental concentrations in marine biota (Bq/kg f.w.) for the period 1995 to 2018 for different OSPAR RSC sub-regions, showing seaweed in OSPAR RSC sub-region 6 (evidence of a reduction), molluscs in OSPAR RSC sub-regions 7 and 10 (evidence of a reduction) and fish in OSPAR RSC sub-region 6 (no evidence of any change). Time periods indicated are baseline period (black columns), assessment period (grey columns) and intervening years (white columns). Note, different scales are used for the vertical axes in the examples above.

7.2.4 Overall situation for marine biota

Overall, and in terms of the assessment results for environmental concentrations of Tc-99, Cs-137 and Pu-239,240 in marine biota, for the 52 cases where statistical assessments were possible:

- There was evidence that environmental concentrations in the assessment period were lower than historic levels in 37 cases.
- There was some evidence that environmental concentrations in the assessment period were lower than historic levels in 6 cases.
- There was evidence that environmental concentrations in the assessment period were close to historic levels in 9 cases.

In the 83 cases where it was not possible to carry out any statistics, this was because:

- In 8 cases there was no or insufficient data available to derive a baseline value.
- In 10 cases there was no or insufficient data available to derive an assessment value.
- In 8 cases there was no or insufficient data available to derive a baseline and an assessment value.
- In 8 cases more than 80% of the data reported for years of the assessment period, where data was available, was below the detection limit.
- In 1 case more than 80% of the data reported for years of the baseline and assessment period, where data was available, was below the detection limit.
- In 48 cases no data was available for any year in the period 1995 to 2018.

8. Evaluation of the radiological impact of environmental concentrations

The stated aim of the first objective of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy 2010-2020 is to prevent pollution of the OSPAR 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:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

In this section, results are presented that address the radiological impact of indicator radionuclides associated with discharges from the nuclear sector (H-3, Tc-99, Cs-137 and Pu-239,240) in seawater and for the additional concentrations of indicator naturally occurring radionuclides resulting from discharges of produced water from the non-nuclear oil and gas sub-sector (Po-210, Pb-210, Ra-226 and Ra-228). Simple comparisons are made with a fraction (1/100) of activity concentration reference values (Cref) for each indicator radionuclide in seawater that would correspond in each case to a trivial annual dose of 10 µSv from defined exposure pathways (Table 8.1). A description of the methodology used to derive Cref/100 values for the indicator radionuclides in seawater is given in Section 4. In situations where values of any indicator radionuclides are greater than the respective Cref/100 values, explanations are included in order to provide context.

Table 8.1 Cref/100 seawater values for indicator radionuclides associated with discharges from the nuclear sector and naturally occurring radionuclides in discharges of produced water from the non-nuclear oil and gas sub-sector.

Indicator	Cref/100 value (Bq/l)
H-3	5.60E+03
Tc-99	1.80E-01
Cs-137	4.50E-02
Pu-239,240	2.80E-04
Po-210	1.10E-06
Pb-210	8.80E-06
Ra-226	2.60E-04
Ra-228	6.70E-04

8.1 Radiological impact of indicator radionuclides for the nuclear sector

For environmental concentrations of the indicator radionuclides associated with discharges from the nuclear sector in seawater, comparisons are made with the assessment values derived for each OSPAR Radioactive Substances Committee (RSC) sub-region where possible. In cases where data is available, but it was not possible to derive an assessment value according to the agreed statistical methodology (See Section 4), the comparison has been made with an overall assessment period mean, where such values have been derived from the average of all data and using the full value of any data reported as a detection limit. Assessment values and overall assessment means for indicator radionuclides of environmental concentrations in seawater are given in Table 8.2. For Tc-99, no data at all was available for the assessment period for OSPAR RSC sub-regions 1, 2, 3, 4, 7, 8, 9 and 12. For Pu-239,240, no data at all was available for the assessment period for OSPAR RSC sub-regions 4 and 5. Overall assessment period means were derived for H-3 OSPAR RSC sub-regions 14 and 15, Tc-99 OSPAR RSC sub-region 11 and Pu-239,240 OSPAR RSC sub-regions 1, 3 and 12. Assessment values were available for all other indicators and OSPAR RSC sub-regions.

The comparison shows (Table 8.3) that in all cases except one, assessment values and overall assessment period means are lower than the respective Cref/100 values for these indicator radionuclides in seawater. In all such cases the annual doses from these indicator radionuclides will be below the environmental reference levels and the trivial annual dose of 10 µSv. This will not result in a significant radiological impact to humans or the marine environment.

For Pu-239,40 in OSPAR RSC sub-region 6, the comparison showed that the assessment value for Pu-239,40 was 7.6 fold higher than the respective Cref/100 value for this indicator in seawater.

Although the discharges Pu-239,240 to OSPAR RSC sub-region 6 over the assessment period have remained fairly constant, such discharges have in fact decreased over a much longer time frame than is covered by the data reported to OSPAR. At present, the dominant factor controlling current levels of Pu-239,240 in seawater is likely to be the remobilisation of this radionuclide present in sediments as a result of previous discharges, rather than from levels of Pu-239,240 currently discharged. This is demonstrated by examination of normalised activity concentrations of Pu-239,240 in seawater at St Bees and Southerness (Hunt et al., 2013)[22].

The methodology in OSPAR Agreement 2016-07 (2022 update) for deriving environmental assessment criteria (EAC) for activity concentrations of radioactive substances in the marine environment of the OSPAR Maritime Area takes a more conservative approach than more focussed area specific radiological environmental assessments. More detailed radiological assessments of the area within OSPAR RSC sub-region 6, have recently been carried out as part of a permit review for the nuclear fuel reprocessing facility at Sellafield[23,24]. These assessments, which were overseen by the national regulator, have demonstrated that the impacts from plutonium in seawater in this area are low. The Pu-239,240 Cref/100 value used in comparison above is based on the most conservative reference level, which is for phytoplankton. The radiological assessment carried out as part of the Sellafield permit review included modelling the impact of plutonium isotopes on phytoplankton[233]. This assessment concluded that phytoplankton would receive a dose of 17.7 µGy/hr from the discharges of Pu isotopes at the maximum permitted limit, which is considerably lower than the 70 µGy/hr phytoplankton reference level used to derive the Cref value for Pu-239,240 in the Fifth Periodic Evaluation.

In addition, the independent United Kingdom environmental monitoring programme assesses the dose to members of the public from radioactivity in the environment on an annual basis[24]. This assessment has determined the average radiation dose to the most exposed members of the public (in OSPAR RSC sub-region 6) from Pu-239,240 during the assessment period to be approximately 10 µSv/yr which is 1% of the public dose limit.

Over time it can be expected that the level of Pu-239,240 in seawater in the Eastern part of the Irish Sea in OSPAR RSC sub-region 6, where activity concentrations are currently highest, will decrease. This, combined with the recently lowered liquid discharge limit for Pu isotopes at Sellafield, and the

[22] Hunt, J., Leonard, K., & Hughes, L. (2013). Artificial radionuclides in the Irish Sea from Sellafield: remobilisation revisited. Journal of Radiological Protection, 33(2), 261.
[23] Environment Agency Prospective Radiological Assessment for Sellafield (Part B: Modified Permit Variation Request) September 2019.
[24] Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resources Wales, Northern Ireland Environment Agency, Scottish Environment Protection Agency, 2020. Radioactivity in Food and the Environment (RIFE) 26.

fact that actual discharges are lower than current limits, provides the expectation of even lower doses received by humans and non-human biota from Pu-239,240 in the future.

In conclusion, whilst it cannot be said that the dose is trivial using the OSPAR methodology, it can be asserted that the dose impacts resulting from Pu-239,240 in seawater in OSPAR RSC sub-region 6 are very low and are currently around 1% of the public dose limit.

Table 8.2 Assessment values (no shading) and overall assessment period means (grey shading) for indicator radionuclides of environmental concentrations in seawater (Bq/l).

OSPAR RSC sub-region	Indicator			
	H-3	Tc-99	Cs-137	Pu-239,240
1	9.33E-01	ND	1.51E-03	3.54E-05
2	6.54E+00	ND	1.70E-03	8.47E-06
3	4.97E+00	ND	1.29E-03	5.50E-06
4	1.81E+00	ND	7.58E-03	ND
5	4.43E+00	1.82E-03	8.39E-03	ND
6	6.00E+00	1.96E-02	4.39E-02	2.12E-03
7	6.00E-01	ND	2.42E-03	2.92E-05
8	4.32E+00	ND	1.52E-03	1.06E-05
9	3.44E+00	ND	1.79E-03	4.27E-06
10	5.48E-01	1.75E-04	2.52E-03	9.12E-06
11	1.75E+00	4.80E-04	7.54E-03	4.13E-06
12	2.03E+00	ND	1.16E-02	3.60E-06
13	1.50E-01	2.99E-04	2.35E-03	3.14E-06
14	4.80E+00	7.28E-05	1.62E-03	5.05E-06
15	4.88E+00	8.04E-05	1.49E-03	6.41E-06

ND - no data at all was available for the assessment period for this indicator radionuclide in this OSPAR RSC sub-region.

Table 8.3 Comparison of assessment values (no shading) and overall assessment period means (grey shading) with Cref/100 values for indicator radionuclides of environmental concentrations in seawater

OSPAR RSC sub-region	Are assessment values and overall assessment period means less than respective Cref/100 values for each indicator in seawater?			
	H-3	Tc-99	Cs-137	Pu-239,240
1	Y	-	Y	Y
2	Y	-	Y	Y
3	Y	-	Y	Y
4	Y	-	Y	-
5	Y	Y	Y	-
6	Y	Y	Y	N
7	Y	-	Y	Y

8	Y	-	Y	Y
9	Y	-	Y	Y
10	Y	Y	Y	Y
11	Y	Y	Y	Y
12	Y	-	Y	Y
13	Y	Y	Y	Y
14	Y	Y	Y	Y
15	Y	Y	Y	Y

Comparison for indicator radionuclides not possible where no data was available for the assessment period in OSPAR RSC sub-regions.

8.2 Radiological impact of additional concentrations of indicator radionuclides in produced water from the non-nuclear oil and gas sub-sector

It is not possible to measure additional concentrations of naturally occurring radionuclides from discharges of produced water in seawater by analytical methods due to natural background levels of these radionuclides. In order to determine the magnitude of such additional concentrations and to assess their radiological impact, the dispersion of produced water discharges must be modelled. The dispersion of produced water discharges has been modelled in the immediate vicinity around discharge points (near-field) and over the wider OSPAR Maritime Area (far-field) (OSPAR publication 925[25]). OSPAR Publication 925 includes indicative information on the temporal and spatial variation of additional concentrations of naturally occurring radionuclides from discharges of produced water in the near-field around a number of installations. The near-field modelling has demonstrated that additional concentrations close to installations can be highly localised and transient and as such are not appropriate for use with the agreed methodology for assessing radiological impact in the Fifth Periodic Evaluation. Due to these reasons, the radiological impact of indicator radionuclides from discharges of produced water has only been considered for the far-field. Far field modelling was carried out using the DORIS model which comprises 55 compartments broadly representing the OSPAR Maritime Area and includes the modelling of any radioactive progeny such as Po-210. The dispersion of reported discharges of Pb-210, Ra-226 and Ra-228 and any radioactive progeny over the period 2006 to 2015 from a total of 180 installations were modelled. The highest modelled additional concentrations were observed in the model compartments where discharges occurred (Table 8.4) and were predicted to reach a steady state after around 10 years. Only data for these compartments is shown, but additional concentrations were modelled for all compartments in the model. As shown in Section 6, discharges of produced water to the OSPAR Maritime Area have either reduced or were similar when comparing the assessment period with the baseline period. Therefore, the predicted additional concentrations based on discharges over the period 2006 to 2015 are likely to be representative of discharges over the entire assessment period (2005 to 2018) for the non-nuclear oil and gas sub-sector.

Table 8.4. Modelled additional concentrations (Bq/l) for indicator radionuclides of naturally occurring radionuclides in discharges of produced water after 10 years of discharges of produced water (2006 – 2015) in model compartments where discharges of produced water have occurred.*

Model Compartment	Po-210	Pb-210	Ra-226	Ra-228
North Sea Central	1.03E-06	1.30E-06	1.34E-05	6.67E-06

[25] Modelling and assessment of additional concentrations of Naturally Occurring Radioactive Materials (NORM) in seawater from discharges of produced water from the offshore oil and gas sector in the North-East Atlantichttps://www.ospar.org/documents?v=48505

North Sea South-West	9.21E-07	1.23E-06	1.24E-05	8.27E-06
North Sea South-East	6.03E-07	7.32E-07	1.58E-05	1.88E-05
Irish Sea South	3.18E-07	4.16E-07	6.20E-06	2.99E-06
Scottish Waters East	8.17E-08	9.92E-08	8.20E-07	2.38E-07
Norwegian Sea	1.57E-08	1.94E-08	4.21E-06	1.96E-06
North Sea North	4.06E-09	3.21E-09	8.62E-06	6.29E-06
Celtic Sea	1.46E-09	1.82E-09	2.56E-08	1.01E-08
Atlantic Ocean North-East	5.19E-10	5.14E-10	3.54E-09	7.81E-10

* The dispersion of reported discharges of Pb-210, Ra-226 and Ra-228 and any radioactive progeny (e.g. Po-210) were modelled.

In comparison with the respective Cref/100 values for indicator radionuclides of naturally occurring radionuclides in discharges of produced water, the modelled additional concentrations were lower in all cases (Table 8.5). Therefore, the annual doses from the modelled additional concentrations will be below the environmental reference levels and the trivial annual dose of 10 µSv. This will not result in a significant radiological impact to humans or the marine environment.

Table 8.5. Comparison of modelled additional concentrations with Cref/100 values for indicator radionuclides of naturally occurring radionuclides in discharges of produced water

Compartment	Are modelled additional concentrations less than the respective Cref/100 values for each indicator in seawater?			
	Po-210	Pb-210	Ra-226	Ra-228
North Sea Central	Y	Y	Y	Y
North Sea South-West	Y	Y	Y	Y
North Sea South-East	Y	Y	Y	Y
Irish Sea South	Y	Y	Y	Y
Scottish Waters East	Y	Y	Y	Y
Norwegian Sea	Y	Y	Y	Y
North Sea North	Y	Y	Y	Y
Celtic Sea	Y	Y	Y	Y
Atlantic Ocean North-East	Y	Y	Y	Y

9. Conclusions of the Fifth Periodic Evaluation

9.1 Background

The stated objectives of the OSPAR Radioactive Substances Strategy (RSS) under the North-East Atlantic Environment Strategy (NEAES) 2010-2020 are:

1) To prevent pollution of the OSPAR 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:

a. radiological impacts on man and biota;

b. legitimate uses of the sea;

c. technical feasibility.

2) To ensure that by the year 2020 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.

In regard to the stated aim of the first objective of the OSPAR RSS under the NEAES 2010-2020 that pollution of the OSPAR Maritime Area from ionizing radiation should be prevented, pollution is defined in the OSPAR convention as:

"the introduction by man, directly or indirectly, of substances or energy into the maritime area which results, or is likely to result, in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea."

This Fifth Periodic Evaluation builds on the Third and Fourth Periodic Evaluations (published in 2009 and 2016 respectively). The assessments and scope of the Fifth Periodic Evaluation has allowed Contracting Parties to draw conclusions as to whether progressive and substantial discharges from the nuclear and non-nuclear sectors have occurred and whether additional environmental concentrations of indicator radionuclides for the nuclear sector above historic levels are close to zero. Conclusions are based on evidence from statistical assessments of reported discharge and environmental concentration data. Additionally, the Fifth Periodic Evaluation makes conclusions on the radiological impact from the environmental concentration of indicator radionuclides for the nuclear sector and the modelled additional concentrations of indicator radionuclides in produced water from the non-nuclear oil and gas sub-sector.

Taken together, the assessments in this Fifth Periodic Evaluation allow Contracting Parties to conclude whether they have succeeded in preventing pollution of the OSPAR Maritime Area from ionising radiation. They also allow Contracting Parties to consider what progress has been made towards the ultimate aim of concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances

9.2 Conclusions for discharges from the nuclear sector

In the Fifth Periodic Evaluation, assessments have been carried out for indicators for each nuclear sub-sector (for individual Contracting Parties where discharges from these sub-sectors occur to the OSPAR Maritime Area and the sum of all such discharges) as well as for the nuclear sector as a whole (the sum of all such discharges from all sub-sectors) as to whether there have been progressive reductions and substantial reductions in discharges (Section 5).The combination of these outcomes has been used to determine whether the discharge element of the first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled. From the assessments carried out there is clear evidence that the discharge element of the first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in the majority of cases. i.e. in these situations there have been progressive and substantial reductions in discharges. Further, it should be noted that none of the assessments carried out in the Fifth Periodic Evaluation for individual Contracting Parties revealed any actual increase in discharges. In the cases were there was no statistical evidence that the discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 had been fulfilled, Contracting Parties have provided information and explanations that set the statistical results and magnitude of discharges into context (Section 5).

9.2.1 Conclusions for discharges from the individual nuclear sub-sectors

The conclusions for each of the nuclear sub-sectors are as follows:

Nuclear power sub-sector

i. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in 15 of the 22 assessments for individual Contracting Parties and there is some evidence that it has been fulfilled in a further 5 assessments.

ii. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for total beta (excluding tritium) and Cs-137 for the sub-sector as a whole.

Nuclear fuel reprocessing sub-sector

i. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in 8 out of 10 assessments for individual Contracting Parties.

ii. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for total beta (excluding tritium), Tc-99 and Cs-137 for the sub-sector as a whole.

Nuclear fuel fabrication and enrichment sub-sector

i. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in 6 out of the 8 assessments for individual Contracting Parties.

ii. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for total alpha and total beta (excluding tritium) for the sub-sector as a whole.

Nuclear research and development sub-sector

i. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in 10 out of 22 assessments for individual Contracting Parties and there is some evidence that it has been fulfilled in a further 3 assessments.

ii. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for Pu-239,240 and there is some evidence that it has been fulfilled for total alpha, total beta (excluding tritium) and Cs-137 for the sub-sector as a whole.

9.2.2 Conclusions for discharges from the nuclear sector as a whole

For the nuclear sector as a whole there was evidence that the discharge element of the first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for total alpha, total beta (excluding tritium), Tc-99 and Cs-137. The Fifth Periodic Evaluation has shown that there have been reductions in discharges by 2.1 fold for total alpha and 13 fold for total beta (excluding tritium) since the baseline period. Discharges of Tc-99 and Cs-137 showed reductions by 66 fold and 3.1 fold respectively since the baseline period. In the case of Pu-239,240, although the statistical assessment showed no evidence that the discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled, discharges of Pu-239,240 from the nuclear sector as a whole showed a reduction by 1.2 fold. It is anticipated that discharges of Pu-239,240 will continue to follow a decreasing trend following the cessation of nuclear fuel reprocessing operations at Sellafield which is expected during 2022, although fluctuations will occur due to decommissioning activities.

While discharges from the nuclear fuel reprocessing sub-sector are much reduced compared to the baseline period, it remains the dominant source of discharges from the nuclear sector in the assessment period. It has contributed 92% of total alpha discharges and 67% of total beta (excluding tritium) discharges. The relative contribution of the other sub-sectors has changed between the baseline and assessment periods primarily due to strategic changes in specific sub-sectors, as previously reported in the Third Periodic Evaluation.

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 the Fifth Periodic Evaluation. While relatively low when compared to overall operational discharges, the contribution of exceptional discharges from decommissioning activities is growing as a proportion of total discharges and this is expected to continue as essential work to reduce hazards and decommission redundant nuclear installations increases.

9.2.3 The implementation of best available techniques to control discharges from the nuclear sector

In order to help achieve the objectives of the OSPAR RSS under the NEAES 2010-2020, the OSPAR Radioactive Substances Committee (RSC) have agreed measures to scrutinise the development in, and encourage Contracting Parties to apply, best available techniques (BAT) to control discharges of radioactive substances from the nuclear sector. Contracting Parties have completed 7 rounds of reporting under PARCOM Recommendation 91/4 on the implementation of BAT and have now begun a further round of reporting under the new OSPAR Recommendation 2018/01 (as amended). PARCOM Recommendation 91/4 and OSPAR Recommendation 2018/01 (as amended) concerns the use of BAT to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including nuclear power plants, reprocessing facilities, fuel fabrication facilities, research reactors, and their associated radioactive waste treatment facilities and decommissioning activities into the marine environment. PARCOM Recommendation 91/4 requested that Contracting Parties reported on the implementation of BAT in such facilities on a four-year basis, while OSPAR Recommendation 2018/01 (as amended) requires reporting every six years. Implementation reports for individual Contracting Parties and overviews of all national statements after the completion of each round of reporting under PARCOM Recommendation 91/4 have been published by OSPAR. All Contracting Parties have been found to be applying BAT under PARCOM Recommendation 91/4 which has in turn contributed to meeting the objectives of the OSPAR RSS under the NEAES 2010-2020.

9.3 Conclusions for discharges from the non-nuclear sector

Although Contracting Parties report discharge data for a number of non-nuclear sub-sectors, OSPAR RSC has agreed to only assess discharges from the oil and gas sub-sector. Discharges from other non-nuclear sub-sectors are not assessed as they are either not significant contributors to total alpha and total beta (excluding tritium) discharges or there are uncertainties associated with the reported data and the amount entering the marine environment (Section 2). In the Fifth Period Evaluation, assessments have been carried out for the oil and gas sub-sector as to whether there have been progressive and substantial reductions in discharges (Section 6). The combination of these outcomes has been used to determine whether the discharge element of the first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled. From the assessments carried out, there is evidence that the discharge element of the first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in some cases. Further, it should be noted that none of the assessments carried out for individual Contracting Parties revealed any actual increase in discharges. In the cases were there was no evidence that the discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 had been fulfilled, Contracting Parties have provided explanations that set the statistical results and magnitude of discharges into context (Section 6).

The conclusions for the oil and gas sub-sector are as follows:

i. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled in 8 of the 31 assessments for individual Contracting Parties and there is some evidence that it has been fulfilled in a further 3 assessments.

ii. The discharge element of first objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for Pb-210 and there is some evidence that it has been fulfilled for Th-228 for the sub-sector as a whole.

9.3.1 The implementation of best available techniques to control discharges from the non-nuclear sub-sector

The previous PARCOM Recommendation 91/4 and the current OSPAR Recommendation 2018/01 (as amended) does not cover the implementation of best available techniques (BAT) in the non-nuclear sector. However, across the different Contracting Parties BAT or the optimisation of protection is required for discharges from the various non-nuclear sub-sectors. For instance, in the medical sub-sector the use of delay tanks can lead to significant reductions in the discharges of medical radionuclides to the OSPAR Maritime Area. For the oil and gas sub-sector, OSPAR Recommendation 2001/1 (as amended), requires the application of BAT to prevent pollution from oil and 'other substances' caused by discharges of produced water. Whilst this Recommendation is not specific to radioactive substances, its implementation can result in reduced discharges of produced water and hence reduced discharges of naturally occurring radionuclides. In some circumstances, discharges of produced water from oil and gas installations can be reduced by re-injection. Re-injection as an option depends on a number of variables such as having a suitable sub-surface formation; a dedicated disposal well to re-inject produced water; having the necessary infrastructure on the installation to re-inject produced water or the possibility to retrofit re-injection equipment on existing installations. Not all production fields have sub-surface geology that would allow or accommodate the re-injection of produced water. Where produced water is routinely re-injected, the availability of the injection system can also result in periodic discharges of produced water.

The Offshore Industry Committee Expert Assessment Panel (OIC EAP) concluded in 2018 that there were currently no suitable techniques that could selectively reduce levels of radionuclides in produced water as it was being extracted and discharged[26]. Any future implementation of such techniques, should they be developed, would depend on several factors including efficiency and cost compared to discharging to the sea.

9.4 Conclusions for environmental concentrations

In the Fifth Periodic Evaluation, assessments have been carried out as to whether environmental concentrations of indicator radionuclides for the nuclear sector in the assessment period were close to historic levels (Section 7).

From the assessments carried out there is clear evidence that the second objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled or more than fulfilled in all of the cases except one. i.e. in these situations, it is clear that environmental concentrations in the assessment period were close to or lower than historic levels. In OSPAR RSC sub-region 3, the statistical assessment showed evidence of an increase in environmental concentrations of H-3 in seawater between the assessment and baseline periods which reflected the influence of the tritium discharges from the French nuclear fuel reprocessing facility at la Hague in OSPAR RSC sub-region 2. OSPAR RSC has recognised in previous Periodic Evaluations that the industrial scale abatement of tritium in the liquid effluent of nuclear power stations and nuclear reprocessing facilities is currently not technically feasible. These discharges have not been assessed as part of the Fifth Periodic Evaluation but are reported in Annex 2.

The conclusions for environmental concentrations for individual indicator radionuclides for the nuclear sector are as follows:

Seawater

[26] RSC 2019 Summary Record

i. The second objective of the OSPAR RSS under the NEAES 2010-2020 has been more than fulfilled in 21 of the 38 assessments and there is some evidence that it has been more than fulfilled in a further 3 assessments.

ii. The second objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for 13 of the 38 assessments.

Marine biota

i. The second objective of the OSPAR RSS under the NEAES 2010-2020 has been more than fulfilled in 37 of the 52 assessments and there is some evidence that it has been more than fulfilled in a further 6 assessments.

ii. The second objective of the OSPAR RSS under the NEAES 2010-2020 has been fulfilled for the remaining 9 assessments.

9.5 Conclusions on the Radiological impact of environmental concentrations

9.5.1 Conclusions on the radiological impact of indicator radionuclides for the nuclear sector

In the Fifth Periodic Evaluation, assessments have been carried out to determine the radiological impact of mean values of environmental concentrations of indicator radionuclides for the nuclear sector (H-3, Tc-99, Cs-137 and Pu-239,240) in seawater in the assessment period (Section 8). In all cases except one the annual doses from the indicator radionuclides would be below the environmental reference levels[27] and the trivial annual dose of 10 µSv. This would not result in a significant radiological impact to humans or the marine environment. This includes the situation in OSPAR RSC sub-region 3 where there was evidence of an increase in environmental concentrations of H-3 in seawater between the assessment and baseline periods. The impact of the environmental concentration of H-3 in the OSPAR Maritime Area is far lower than the trivial dose. The one case where the OSPAR methodology did not conclude that the impact was trivial, was for Pu-239,240 in seawater in OSPAR RSC sub-region 6. However, more focused assessments have been carried out by Sellafield Ltd and by the independent United Kingdom environmental monitoring programme on the radiological impact from plutonium isotopes in seawater in the same area. Both these assessments have been overseen by the United Kingdom national regulator. These assessments confirm that the annual doses to the public from plutonium isotopes in seawater in OSPAR RSC sub-region are around 10 µSv and that the maximum dose to the worst affected marine organism (phytoplankton) was around 25% of the reference dose value for phytoplankton used in the Fifth Periodic Evaluation. Therefore, whilst it cannot be said that the dose in this case is trivial using the OSPAR methodology, it can be concluded that the radiological impacts resulting from Pu-239,240 in seawater in OSPAR RSC sub-region 6 are very low.

9.5.2 Conclusions on the radiological impact of modelled additional concentrations of indicator radionuclides in produced water from the oil and gas sub-sector

In the Fifth Periodic Evaluation, assessments have been carried out to determine the radiological impact of modelled additional concentrations of naturally occurring radionuclides resulting from discharges of produced water from the oil and gas sub-sector over the wider OSPAR Maritime Area (Section 8). In all cases the annual doses from the additional concentrations of these indicator radionuclides in seawater would be below the

[27] OSPAR Agreement 2016-07 (2022 Update)

environmental reference levels and the trivial annual dose of 10 µSv. This would not result in a significant radiological impact to humans or the marine environment.

9.6 Progress towards meeting the ultimate aims of the OSPAR radioactive substances strategy

The first objective of the OSPAR RSS under the NEAS 2010-2020 contains the ultimate aim of concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances. The ultimate aim reflects the aspiration of OSPAR to have an environment as free as possible from radioactive substances arising from human activities, an aspiration in the line with the precautionary principle, a general obligation the Contracting Parties have committed to apply as signatories to the OSPAR Convention.

As the ultimate aim is aspirational, it is an on-going objective with no fixed timescale by which it is to be achieved. In particular, it is recognised that historic human activities (e.g. discharges from nuclear and non-nuclear sectors, global fallout from atmospheric testing of nuclear weapons and accidents) have resulted in the introduction of radionuclides into the OSPAR Maritime Area that will continue to be present for the foreseeable future. Despite this, it is expected that work towards and delivery of the specific elements of the OSPAR RSS will contribute to progress towards meeting the ultimate aim. It is therefore also appropriate to consider the progress that has been made towards meeting the ultimate aim. The approach to assessing progress is a semi-quantitative assessment that draws together the outcome of the assessments presented in the Fifth Periodic Evaluation along with other relevant information.

9.6.1 Progress towards environmental concentrations of artificial radionuclides being close to zero

The Fifth Periodic Evaluation has shown that there have been progressive and substantial reductions in the discharges of radionuclides from the nuclear sector and that, in many cases, environmental concentrations of indicator radionuclides for the nuclear sector in the assessment period were lower than historic levels. In all but one case, the environmental concentrations of these indicator radionuclides were a small fraction of the relevant environmental reference levels and that they would not result in a significant radiological impact to humans or the marine environment. Furthermore, many of the measurements undertaken by contacting parties, as part of the OSPAR coordinated environmental monitoring programme, show that environmental concentrations are below the limits of detection of analytical techniques used for routine environmental monitoring purposes. All of this information together indicates that environmental concentrations are either close to zero or tending towards being close to zero.

In summary, the assessments in this evaluation and the data routinely reported to OSPAR indicate that considerable progress has been made towards the ultimate aim of ‘environmental concentrations of artificial radionuclides are close to zero’, and that in many cases that the ultimate aim is likely to have been achieved. Nevertheless, the ultimate aim is retained as a Strategic Objectives in NEAES 2030[28] and it is recognised that it is ongoing task to achieve and maintain concentrations at this level.

9.6.2 Progress towards environmental concentrations of naturally occurring radionuclides being near background

The ultimate aim for naturally occurring radionuclides is that concentrations should be near background levels. The Fifth Periodic Evaluation has shown that there has not been a general progressive and substantial reduction in the discharges of produced water from the oil and gas sub-

[28] Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2030 (Agreement 2021-01). (https://www.ospar.org/documents?v=46337)

sector. However, it was concluded that the modelled additional environmental concentrations of naturally occurring radionuclides in seawater resulting from these discharges were a small fraction of relevant environmental reference levels that they would not result in a significant radiological impact to humans or the marine environment.

To determine whether these discharges result in total environmental concentrations that may be considered to be near background levels, the modelled additional concentrations were compared with the magnitude and range of typical background levels reported in the OSPAR Maritime Area[29]. The modelled additional concentrations in seawater were far less than variations in background levels and a small fraction of typical low-end background levels. In practice, this means that any additional concentrations would likely be indistinguishable from background levels measured by routine analytical techniques for environmental monitoring purposes. These comparisons, taken together with the assessment of radiological impact indicate that it is reasonable to consider, for seawater, that the ultimate aim of 'total environmental concentrations of naturally radionuclides are near background levels' is likely to have been achieved. Nevertheless, the ultimate aim is retained as a Strategic Objective in NEAES 2030[30] and it is recognised that it is ongoing task to achieve and maintain concentrations at this level.

9.7 Steps taken by OSPAR to promote and monitor progress on Radioactive Substances

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, superseded by OSPAR Recommendation 2018/01 (as amended)) and corresponding guidelines.
- 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; 2018 update) 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 for the reporting of discharge data from the nuclear (OSPAR Agreement 2013-10; 2021 update) and non-nuclear sectors (OSPAR Agreement 2013-11; 2021 update).
- The adoption of definitions for historical or legacy wastes discharges in Contracting Parties' nuclear sector data reporting.
- 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.

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[29] OSPAR Publication 925: Modelling and assessment of additional concentrations of Naturally Occurring Radioactive Materials (NORM) in seawater from discharges of produced water from the offshore oil and gas sector in the North-East Atlantic https://www.ospar.org/documents?v=48505

[30] Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2030 (Agreement 2021-01). (https://www.ospar.org/documents?v=46337)

- 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 (OSPAR Agreement 2016-07; 2022 update).
- The modelling of additional concentrations of naturally occurring radionuclides in discharges of produced water from the oil and gas sub-sector (OSPAR Publication 925)

9.8 Overall statement on the achievement against the OSPAR Radioactive Substances Strategy

The Fifth Periodic Evaluation is the culmination of more than two decades of cooperation and hard work by Contracting Parties on the issue of Radioactive Substances under OSPAR and there have been a number of significant achievements and successes. OSPAR RSC has successfully established the necessary monitoring and data reporting programmes and developed the necessary assessment methodologies in order to be able to determine whether the objectives of the OSPAR RSS under the NEAES 2010-2020 have been fulfilled. The measures developed by OSPAR RSC, as well as action by national authorities, has ensured that significant progress could be made against these objectives. When taking into account the assessments carried out in the Fifth Periodic Evaluation for discharges from the nuclear sector and non-nuclear sector and environmental concentrations and their radiological impact and any context provided, it can be concluded that:

Contracting Parties have successfully fulfilled the objectives of the OSPAR RSS for 2020 under the NEAES 2010-2020 and have made significant progress towards fulfilling 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 doing so, Contracting Parties have prevented pollution of the OSPAR Maritime Area by ionising radiation.

This is evidenced by:

- Discharges from the nuclear sector have shown progressive and substantial reductions.
- Discharges from the oil and gas sub-sector have mostly remained unchanged, but are not as yet amenable to reduction where the option of re-injection is not possible.
- Environmental concentrations of indicator radionuclides for the nuclear sector are close to or lower than historic levels.
- Environmental concentrations of indicator radionuclides for the nuclear sector and modelled additional concentrations of indicator radionuclides for the non-nuclear oil and gas sub-sector would not result in a significant radiological impact to humans or the marine environment.

9.9 Future directions for OSPAR's work on Radioactive Substances

Contracting Parties have made considerable progress in delivering the objectives of OSPAR RSS under the NEAES 2010-2020 but delivering the aims of the OSPAR convention, including preventing pollution of the Maritime Area is an ongoing task. It is also recognized that there is a need to continue to examine the robustness and weaknesses of all the assessment methodologies that have been developed. New strategic and operational objectives for radioactive substances have been agreed by the Ministerial Meeting of the OSPAR Commission 2021 in Cascais, Portugal under the North-East Atlantic Environment Strategy 2030. Under the theme of clean seas, the new strategic objective for radioactive substances states that:

OSPAR will prevent pollution by radioactive substances in order to safeguard human health and to protect the marine environment, with the ultimate aim of achieving and maintaining concentrations in the marine environment at near background values for naturally occurring radioactive substances and close to zero for human made radioactive substances.

This work will be carried forward through the delivery of the following operational objectives:

S3.O1: On an ongoing basis OSPAR will further prevent, progressively reduce or, where that is not practicable, minimise discharges of radioactive substances through the application of Best Available Techniques (BAT), taking into account technical feasibility, radiological impact and legitimate uses of the sea.

S3.O2: By 2025 OSPAR will identify and consider any obstacles in achieving further reductions in environmental concentrations of radioactive substances in the marine environment and examine possible solutions where appropriate.

S3.O3: By 2025 OSPAR will identify the different types of loss of radioactive substances that may contribute to pollution of the marine environment. By 2027 OSPAR will determine if any additional measures are required to prevent such pollution, to the extent that such pollution is not already the subject of effective measures agreed by other international organisations or prescribed by other international conventions.

S3.O4: By 2028 OSPAR will, following the outcome of the Quality Status report 2023, address, where appropriate, any uncertainties by reviewing and updating methodologies to better determine the possible impact of releases, emissions and losses of radioactive substances on marine ecosystems.

Previous Periodic Evaluations

OSPAR, 2006. Revised First Periodic Evaluation of Progress Towards the Objective of the OSPAR Radioactive Substances Strategy. Publication 302/2006. (https://www.ospar.org/documents?v=7053)

OSPAR, 2007. Second Periodic Evaluation of Progress Towards the Objective of the OSPAR Radioactive Substances Strategy. Publication 338/2007. (https://www.ospar.org/documents?v=7085)

OSPAR, 2009. Towards the Radioactive Substances Strategy Objectives. Third Periodic Evaluation. Radioactive Substances Series. Publication 455/2009. (https://www.ospar.org/documents?v=7135)

OSPAR, 2016. Towards the Radioactive Substances Strategy Objectives. Fourth Periodic Evaluation. Radioactive Substances Series. Publication 687/2016. (https://www.ospar.org/documents?v=35337)

OSPAR's Quality Status Report 2023

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Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

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