OSPAR
COMMISSION

Report on implementation of PARCOM Recommendation 91/4 on radioactive discharges by the Netherlands 2008-2011

Radioactive Substances Series

2013

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

PARCOM Recommendation 91/4 concerns the use of Best Available Technologies (BAT) to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including research reactors and reprocessing plants, into the marine environment. The guidelines for the implementation of this Recommendation request that Contracting Parties to the OSPAR Convention report on a four-year basis on progress in the implementation of BAT in such facilities. This is the report of the Netherlands for the sixth round of implementation reporting (2012 - 2015). The information is submitted according to the OSPAR “Guidelines for the submission of information about, and assessment of, the application of BAT in nuclear facilities” (OSPAR Agreement 2004-03).

The information presented in this report indicates that BAT/BEP has been applied to all nuclear installations in the Netherlands: the only operational nuclear power plant in the Netherlands, the nuclear fuel enrichment plant, two research reactors (since 2010 the Low Flux Reactor in Petten is no longer in use), and the nuclear waste treatment and storage plant. For completeness, we note that the nuclear power plant Dodewaard, which ceased operations in 1997 and is presently in the state of Safe Enclosure, has discharged no radionuclides to water since July 2005.

Récapitulatif

La Recommandation PARCOM 91/4 porte sur l’utilisation des meilleures technologies disponibles (BAT) afin de minimiser et, le cas échéant, de supprimer la pollution provoquée par les rejets radioactifs de l’ensemble des industries nucléaires, notamment les réacteurs de recherche et les usines de retraitement, dans le milieu marin. Les lignes directrices pour la mise en œuvre de cette recommandation exigent que les Parties contractantes de la Convention OSPAR notifient, tous les quatre ans, les progrès réalisés dans la mise en œuvre de BAT dans de telles installations. Le présent rapport représente la sixième série de notification de mise en œuvre des Pays-Bas (2012 - 2015). Les informations sont communiquées conformément aux « Lignes directrices OSPAR relatives à la communication des informations sur, et à l’appréciation de l’application de la BAT dans les installations nucléaires » (Accord OSPAR 2004-03).

Les informations présentées dans ce rapport indiquent que des BAT/BEP ont été appliquées par toutes les installations nucléaires des Pays-Bas: la seule centrale nucléaire opérationnelle des Pays-Bas, l’usine d’enrichissement du combustible nucléaire, deux réacteurs de recherche (le réacteur à bas flux de Petten n’est plus exploité depuis 2010) et l’usine de traitement et de stockage des déchets nucléaires. On note, à titre d’informations complémentaires, que la centrale nucléaire de Dodewaard, qui a cessé toute activité en 1997 et est actuellement dans une enceinte de confinement, n’a pas rejeté de radionucléides dans l’eau depuis juillet 2005.

Abstract

This report presents the discharges of radioactive substances to sea by nuclear installations in the Netherlands between 2008 and 2011. The preceding ten-year period 1998-2007 is covered by the previous report [OSPAR09, also available as RIVM09], so this report focuses on the changes and additional information since the year 2007. The techniques used to reduce these discharges and details on the nuclear installations are described in the previous report over the period 1998-2007. This report fulfills the recommendation of the OSPAR Convention to report regularly on these discharges and techniques.

The Netherlands has ratified the OSPAR Convention, which entered into force in 1998. The aim of the OSPAR Convention is to prevent and eliminate pollution and to protect the marine environment of the North-East Atlantic (including the North Sea) against the adverse effects of human activities. The agreement is to prevent pollution as much as possible and to terminate discharges where possible.

The highest radiation dose resulting from the discharges to sea has been assessed for each of the nuclear installations. Each dose is less than one thousandth of the average radiation dose for individuals in the Netherlands.

Key words:
OSPAR, radioactive substances, nuclear power plant, nuclear installation, discharges, water, marine environment, North Sea, the Netherlands

1. Introduction

PARCOM Recommendation 91/4 states that Contracting Parties agree "to respect the relevant recommendations of the competent international organisations and to apply the Best Available Technology (BAT) to minimise and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries, including research reactors and reprocessing plants, into the marine environment. Contracting Parties shall present a statement on progress made in applying such technology every four years in accordance with the guidelines annexed to this recommendation".

After the third round of implementation reporting on PARCOM Recommendation 91/4, OSPAR agreed revised guidelines for the submission of information about, and the assessment of, the application of BAT in nuclear facilities (OSPAR Agreement 2004-03 [OSPAR04]). This document has been written according to these guidelines, focusing on the changes which have occurred since the previous round of reporting.

This document reviews the situation in the Netherlands over the period 2008 − 2011, and is part of the 6th round of implementation reporting. The previous report [OSPAR09] contains information covering the years 1998 − 2007.

The nuclear power plant Dodewaard, which ceased operations in 1997 and is presently in the state of Safe Enclosure, has discharged no radionuclides to water since July 2005.

Annex A to this report provides additional information on the location of the nuclear installations and specific sampling locations of the national monitoring programme. Figures showing the discharges and emissions normalized to the granted limits and annual production figures can be found in Annex B. The environmental impact is illustrated in Annex C, and Annex D reports a choice of the environmental measurements in the vicinity of the nuclear power plant of Borssele. In Annex E the specific references for the discharge data since 2008 are given for each year and for each installation.
Information on the radiological discharges of nuclear (and non-nuclear) industries are collected by the National Institute for Public Health and the Environment (RIVM) and reported to the Ministry of Economic Affairs. Information on emissions to the environment is made available on the internet at www.rivm.nl/brs [RIVM12].

2. General information

2.1 Implementation of BAT/BEP in terms of the OSPAR convention in national legislation/regulation

There have not been any relevant changes in legislation since the previous report [OSPAR09], with the exception of the fact that the Ministry of Economic Affairs (http://www.government.nl/ministries/ez) is since 2010 tasked with policy issues regarding nuclear energy.

2.2 Dose limits/constraints for nuclear installations

There have not been any relevant changes in legislation since the previous report [OSPAR09].

2.3 Discharge limits

There have not been any relevant changes in legislation since the previous report [OSPAR09].

2.4 Monitoring programmes of environmental concentrations of radionuclides

Rijkswaterstaat, Centre for Water Management[1], monitors the activity concentrations of radionuclides in inland waters and the marine environment. It is the executive arm of the Dutch Ministry of Infrastructure and the Environment.

There have not been any relevant changes in legislation since the previous report [OSPAR09].

2.5 National authority responsible for supervision of discharges

The Nuclear Safety Service ("Kernfysische Dienst", KFD) is the national authority responsible for the supervision of discharges of radionuclides into air and water. The KFD is part of the Human Environment and Transport Inspectorate (ILT), which was formed in 2012 following a merger of the Inspectorate for Housing, Spatial Planning and the Environment (VROM-Inspectie) and the Transport and Public Works Inspectorate (IVW).

2.6 Nature of inspection and surveillance programmes

There have not been any relevant changes in legislation since the previous report [OSPAR09].

[1] Before 2008 these tasks were carried out by RIZA, National Institute for Inland Water Management and Waste Water Treatment, and RIKZ, National Institute for Coastal and Marine Management.

3. The Nuclear Power Plant in Borssele

The information on production and discharges over the years 2008-2011, together with other changes since the previous report [OSPAR09], which covers the preceding ten-year period 1998-2007, is given here. Information on the year 2007 is also added here, for convenience.

In June 2011 the plant has been licensed to use other fuels in addition to enriched Uranium (to a maximum of 2.5% in weight of U-235), namely MOX (to a maximum of 5.41% in weight of fissile Pu, with a maximum allowed number of MOX fuel elements in the reactor of 48, which corresponds to 40% of the total), and compensated enriched reprocessed uranium (c-ERU, enriched to a maximum of 4.6% in weight of U-235 to compensate for U-236 content), and to burn a nuclear fuel element up to a maximum of 68 MWd/kgU (pin average).

Table 3.1: *Annual electric output of net produced electricity*

	2007	2008	2009	2010	2011
GWh	3994	3934	4019	3755	3917
GWa	0.455	0.450	0.459	0.429	0.447

Table 3.2*: Liquid discharges of gamma and beta emitters of the Borssele NPP, excluding tritium (in TBq/GWa)*

	2007	2008	2009	2010	2011
Cr-51	2.2E-06	3.1E-06	<DL	4.2E-06	6.7E-07
Mn-54	2.0E-06	4.0E-06	5.5E-07	1.4E-06	< DL
Fe-55	8.9E-05	2.4E-05	3.2E-05	2.8E-05	6.3E-06
Co-58	6.0E-06	9.2E-06	2.5E-06	3.8E-06	2.7E-07
Co-60	1.4E-04	1.5E-04	1.2E-04	1.4E-04	9.1E-05
Ni-63	1.7E-04	1.4E-04	1.4E-04	8.8E-05	4.5E-05
Zr-95	2.3E-05	1.2E-05	1.4E-06	8.4E-06	1.0E-06
Nb-95	3.7E-05	2.0E-05	3.2E-06	1.5E-05	2.6E-06
Ag-110m	5.8E-06	1.5E-05	1.7E-05	3.0E-05	7.0E-06
Te-123m	2.2E-07	2.1E-07	1.4E-07	1.5E-06	3.1E-08
Sb-124	1.3E-06	5.5E-06	1.7E-07	3.5E-08	1.1E-06
I-131	1.4E-05	3.1E-05	<DL	1.9E-05	5.5E-06
Cs-134	6.0E-06	2.2E-06	1.8E-06	3.1E-06	<DL
Cs-137	2.6E-05	2.8E-05	2.4E-05	3.0E-05	1.6E-05

<DL is below detection limit

Table 3.3*: Liquid discharges of H-3 of Borssele NPP (in TBq/GWa)*

	2007	2008	2009	2010	2011
H-3	13	15	16	15	15

Table 3.4: *Liquid discharges of alpha emitters of Borssele NPP (in TBq/GWa)*

	2007	2008	2009	2010	2011
Alpha	2.0E-07	2.0E-07	7.4E-07	<DL	<DL

<DL is below detection limit

Comparison with similar reactors

UNSCEAR [UNSC08] reports for the years 1998-2002 an average value of 20 TBq/GWa of H-3 in liquid discharges for PWRs in the world. The reported discharges of tritium in liquid effluents of the PWR reactor Borssele are below this value since 2007.

***Table 3.5**: Emissions to air of Borssele NPP (in TBq/GWa)*

	2007	2008	2009	2010	2011
H-3	5.7E-01	7.1E-01	5.8E-01	5.8E-01	6.6E-01
C-14	3.1E-01	2.7E-01	3.4E-01	3.8E-01	4.0E-01

Emissions of I-129 to air are not measured.

***Table 3.7:** Effective dose per year caused by liquid discharges of the Borssele NPP (in μSv)*

	2007	2008	2009	2010	2011
E (μSv)	6.8E-06	6.7E-06	5.6E-06	6.3E-06	4.2E-06

In Annex B figures are given which show the discharges normalized to these limits and to the annual electric output.

The tritium discharge in waste water remains at a constant level. The tritium emissions to air also remain at a constant level.

The liquid discharges of beta/gamma emitters vary in the period 1998-2011 between 0.04% and 0.29% of the discharge limit and show since 2007 a downward trend.

3.1 Summary evaluation

According to the OSPAR guidelines [OSPAR04], an indication that BAT/BEP has been applied is a downward trend in the liquid discharges and dose estimates. In the case of the NPP in Borssele the emissions to air and water, normalized to the production in GWa, have been reduced where technologically possible. A downward trend is apparent for discharges of total gamma and residual beta to water, and the emissions remain constant at a relatively low level. The calculated dose is consistently below 2E-05 microSv/a over the years 1998 to 2011. It follows that, according to these indicators, BAT/BEP has been applied in NPP Borssele.

Also, in the Netherlands, compliance with the ALARA principle is considered sufficient evidence that the requirements of BAT/BEP in terms of the OSPAR Convention have been met. At present, the NPP in Borssele is judged to be compliant with the ALARA principle. Furthermore, the discharges are low compared to the licensed discharge limits in the license and largely fulfill the site internal discharge targets. The normalized tritium discharges are, with the sole exception of the year 2006, equal or less than the reference data for the same type of reactor in the UNSCEAR report [UNSC08].
The information presented above is in accordance with the OSPAR guidelines [OSPAR04] and includes indicators that BAT/BEP has been applied in the NPP in Borssele.

4. The Fuel Enrichment Plant in Almelo

The information on production and discharges over the years 2008-2011, together with other changes since the previous report [OSPAR09], which covers the preceding ten-year period 1998-2007, is given here. Information on the year 2007 is also added here, for convenience.

The licensed production capacity was increased from 4500 tSW/y in 2007 to 4950 tSW/y in 2010, to 6200 tSw/y since 15 December 2011 (tSW stands for tonnes of Separative Work).

Table 4.1: *The fuel enrichment production (in tSW/y)*

	2007	2008	2009	2010	2011
tSW/y	3554	3644	4078	4550	4659

Table 4.2: *Liquid discharges of Almelo facility (in TBq/tSW)*

	2007	2008	2009	2010	2011
total alpha	1.7E-10	1.7E-10	1.5E-10	1.6E-10	1.5E-10
beta/gamma	6.4E-10	8.1E-10	7.7E-10	3.0E-10	3.8E-10

In Annex B figures show the discharges normalized to the limits and to production.

4.1 Summary evaluation

According to the Guidelines an indication that BAT/BEP has been applied is a downward trend in the liquid discharges [OSPAR04]. A downward trend can be observed in the discharges of radionuclides. This is mainly due to do the closing of separation plant SP3 and the expansion of the modern separation plant SP5.

Moreover, in the Netherlands compliance with the ALARA principle is deemed sufficient to meet the requirements of BAT/BEP in terms of the OSPAR Convention. At present, the fuel enrichment plant in Almelo is considered to comply with the ALARA principle.

The discharges are low compared to the discharge limits in the license. Also, the estimated dose for the critical group due to liquid discharges is very low, less than 1 μSv/year.
The information presented above is in accordance with the OSPAR Agreement 2004-03 and includes indicators that BAT/BEP has been applied in the fuel enrichment plant in Almelo.

5. The Research Facility in Petten

The information on discharges over the years 2008-2011, together with other changes since the previous report [OSPAR09], which covers the preceding ten-year period 1998-2007, is given here. Information on the year 2007 is also added here, for convenience.

The LFR ("Low Flux Reactor") is since December 2010 no longer in use, and there are plans to dismantle it. Since 2011, the only operational reactor on the Petten site is the HFR ("High Flux Reactor") research reactor owned by the European Commission. The reactor type is a swimming pool reactor, with an installed capacity of 50 MW (th)

The liquid discharges of the HFR and, until 2010, LFR are presented as a total of the Petten site. The Petten site includes research laboratories and auxiliary industry like Covidien, and the discharges cannot easily be separated. Therefore, the data presented here are an overestimation of the actual discharges of the HFR (and – until 2010 – of the LFR). The decreased discharges of radioactivity to water between 2008 and 2010 are due to reduced operations of the HFR (limited operations in 2008, an operational stop in 2009 and repairs to the Bottom Plug Liner in 2010).

Table 5.1: *Liquid discharges of Petten site (in GBq: i.e. not normalized)*

(GBq)	2007	2008	2009	2010	2011
H-3	2.7E+02	2.0E+02	6.7E+01	2.6E+02	1.5E+02
Na-22	5.1E-02	5.2E-02	4.3E-02	6.9E-02	7.7E-02
Cr-51	7.8E-02	1.5E-03	<DL	7.2E-04	5.5E-03
Mn-54	8.2E-02	1.3E-02	1.2E-02	1.5E-02	<DL
Co-57	1.8E-02	3.2E-02	3.4E-03	2.4E-02	1.5E-01
Co-58	5.2E-02	6.9E-03	2.9E-03	3.1E-03	1.4E-02
Co-60	1.2E+00	3.8E-01	5.3E-01	2.7E-01	5.4E-01
Zn-65	5.0E-01	2.3E-01	5.8E-01	2.6E-01	1.8E-01
Mo-99	3.0E+00	3.5E-01	3.8E-01	2.3E-01	9.7E-02
Ru-103	5.5E-03	3.5E-03	6.7E-04	5.4E-04	3.5E-03
Cd-109	2.1E+01	1.6E+00	1.3E+00	1.3E-01	7.1E-02
Sb-124	4.1E-01	3.3E-01	5.5E-02	1.9E-01	1.8E-01
Sb-125	3.1E-01	2.0E-01	5.7E-02	1.9E-01	1.8E-01
I-131	4.6E-01	2.3E-01	2.6E-01	1.3E+01	3.5E+00
Cs-134	5.5E-01	1.0E-01	7.5E-02	5.0E-02	3.3E-02
Cs-137	1.4E+00	6.3E-01	4.8E-01	7.0E-01	8.3E-01
W-181	1.3E-01	2.8E-01	8.6E-03	8.2E-03	8.9E-02
W-188	2.5E-02	6.4E-02	<DL	6.3E-04	7.6E-03
Re-186	<DL	9.0E-03	<DL	<DL	2.8E-03
Tl-202	1.4E-03	2.9E-03	1.1E-02	5.4E-03	2.8E-03
Alpha	2.4E-03	4.9E-03	2.4E-03	9.1E-04	1.9E-03
Beta	9.8E+01	6.0E+01	1.5E+01	1.4E+01	1.4E+01

<DL is below detection limit

Table 5.2: *Tritium emissions to air from all facilities combined on the Petten site (in TBq: i.e. not normalized)*

(TBq)	2007	2008	2009	2010	2011
H-3	0.3	0.3	0.4	0.3	0.4

Table 5.3*: Effective dose per year caused by the liquid discharges of the Petten site (in µSv)*

	2007	2008	2009	2010	2011
E (µSv)	9E-03	1E-03	7E-04	5E-04	6E-04

5.1 Summary evaluation

According to the Guidelines, an indication that BAT/BEP has been applied is a downward trend in the liquid discharges [OSPAR04]. The annual liquid discharges of the Petten site do not show such a downward trend, but vary from year to year. The effective dose due to the liquid discharges shows the same variation. Also the estimated dose for the critical group due to liquid discharges is very low, much less than 1 μSv/y.

In the Netherlands, the requirements of BAT/BEP in terms of the OSPAR Convention are met when the ALARA principle is applied. At present the Petten site is considered to comply with the ALARA principle.

The information presented above is in accordance with the OSPAR Agreement 2004-03 [OSPAR04] and includes indicators that BAT/BEP has been applied in the Petten site.

6. The Research Facility in Delft

The information on discharges over the years 2008-2011 is given here. The previous report [OSPAR09] covers the preceding ten-year period 1998-2007. Information on the year 2007 is also added here, for convenience.

Table 6.1: *Liquid discharges of Delft facility (in GBq: i.e. not normalized)*

(GBq)	2007	2008	2009	2010	2011
Alpha	< 0.59E-03	< 0.1E-03	< 0.1E-03	< 0.3E-03	< 0.1E-03
Beta	4.67E-03	4.92E-03	2.0E-03	1.06E-02	6.0E-03
Gamma	< 2.89E-03	< 2.58E-03	1.0E-03	5.51E-03	3.6E-03

6.1 Summary Evaluation

According to the Guidelines, an indication that BAT/BEP has been applied is a downward trend in the liquid discharges [OSPAR04]. The annual liquid discharges of the research facility in Delft do not show such a downward trend but vary from year to year. However, the question whether or not BAT/BEP has been applied, is not only a matter of downward trends.

In the Netherlands, the requirements of BAT/BEP in terms of the OSPAR Convention are met when the ALARA principle is applied. At present, the research facility in Delft is considered to comply with the ALARA principle.

The discharges are low compared to the discharge limits in the license. Also the estimated dose for the critical group due to liquid discharges is very low, less than 0.009 μSv/y.
The information presented above is in accordance with the OSPAR Agreement 2004-03 [OSPAR04] and includes indicators that BAT/BEP has been applied in the research facility in Delft.

7. Waste Treatment Plant COVRA in Vlissingen

The information on discharges over the years 2008-2011, together with other changes since the previous report [OSPAR09], which covers the preceding ten-year period 1998-2007, is given here. Information on the year 2007 is also added here, for convenience.

Since 2008 the COVRA switched to air cooling, so that the use of rainwater (which was previously discharged to the surface waters) as a cooling agent has ceased.

The efficiency of the waste water treatment system is given in the following table. For each nuclide in this table the activity concentration after the treatment is divided by the activity concentration before. A “slip-through” factor of 0.3 therefore means a wastewater cleaning efficiency of 70%.

A report of 2006 [VL06] shows that BAT/BEP are applied to the wastewater treatment systems.

***Table 7.1:** Slip-through factors for the wastewater treatment system*

nuclide	2007	2008	2009	2010	2011
Co-60	0.2	0.3	0.2	0.1	0.1
Cs-137	0.8	0.7	0.9	0.73	0.83
I-125	0	0	< 0.1	0.17	< 0.01
H-3	0.9	1.0	1.0	0.75	0.86
C-14	1.0	0.2	0.4	0.23	0.32
Alpha	0.1	0.2	0.1	0.03	0.1
Gross γ	0.8	0.7	0.9	0.73	0.83

***Table 7.2:** Liquid discharges of COVRA (in GBq: i.e. not normalized)*

(GBq)	2007	2008	2009	2010	2011
H-3	6.0E-01	4.0E-01	7.1E+00	6.4E+01	4.6E+00
C-14	2.5E-02	6.0E-03	3.2E-02	8.4E-03	1.1E-03
gross-alpha	2.6E-03	6.9E-04	1.4E-03	1.4E-04	1.2E-04
residual beta	5.0E-02	2.9E-02	9.4E-01	2.2E-01	9.5E-02
gamma	5.2E-02	2.9E-02	1.0E+00	2.0E-01	8.9E-02

***Table 7.3:** Emissions to air of COVRA (in GBq: i.e. not normalized)*

(GBq)	2007	2008	2009	2010	2011
H-3	3.8E+02	4.0E+02	7.5E+00	8.3E+01	4.0E+01
C-14	7.6E-01	3.0E-01	2.0E-01	1.4E+01	3.7E+00
gross-alpha	1.0E-05	3.7E-06	3.4E-06	3.2E-06	4.4E-06
residual beta	1.4E-04	5.9E-05	2.5E-04	1.1E-04	7.3E-05
gamma	9.5E-04	1.9E-04	1.5E-03	8.2E-04	1.9E-04

7.1 Summary Evaluation

According to the Guidelines, an indication that BAT/BEP has been applied is a downward trend in the liquid discharges [OSPAR04]. The annual liquid discharges of COVRA do not show such a downward trend but vary from year to year. However, the question whether or not BAT/BEP has been applied, is not only a matter of downward trends.
In the Netherlands, the requirements of BAT/BEP in terms of the OSPAR Convention are met when the ALARA principle is applied. At present, COVRA is considered to comply with the ALARA principle.
The discharges are low compared to the discharge limits in the license. Also the estimated dose for the critical group due to liquid discharges is very low, much less than 0.001 μSv/y.
The information presented above is in accordance with the OSPAR Agreement 2004-03 [OSPAR04] and includes indicators that BAT/BEP has been applied in the research facility in the COVRA facility.

8. The Nuclear Power Plant in Dodewaard (in decommissioning)

From June 2005 onwards (Safe Enclosure) no liquid discharges have taken place. Since the final transport of the last spent fuel elements to a reprocessing facility in 2003, there are no longer emissions to air.

8.1 Summary Evaluation

The last discharge of waste water took place in the first half of 2005. From July 2005 onwards, the plant is in a state of Safe Enclosure. Liquid discharges no longer take place and neither H-3 nor C-14 can be measured in ventilation air.
The information presented above is in accordance with the OSPAR-guidelines 2004-03 [OSPAR04] and includes indicators that BAT/BEP has been applied in NPP Dodewaard in its present state of Safe Enclosure.

References

[KCB93] Safety Report, Nuclear Power Plant Borssele 1993. Moddoc.no. 063-000 Rev. 1. 1996 (in Dutch).

[OSPAR04] Guidelines for the Submission of Information about, and the Assessment of, the Application of BAT in Nuclear Facilities. OSPAR Convention for the protection of the marine environment of the North-East Atlantic. Reference number 2004-03.

[OSPAR09] Report on Information about, and the Assessment of, the Application of BAT in Nuclear Facilities, OSPAR Publication 2009/391 Report from the Netherlands. ISBN 978-1-906840-31-0.

[RIVM09] Report on implementation of PARCOM Recommendation 91/4 on radioactive discharges by the Netherlands. OSPAR: nuclear installations, CP Tanzi, PJM Kwakman, RIVM Rapport 610790005, 2009.

[RIVM12] http://www.rivm.nl/brs/reguleerbare-stralingsbronnen/lozingen-en-externe-straling/nucleaire-installaties/ last consulted on 22 October 2012 (in Dutch).

[UNSC08] UNSCEAR 2008 report: Sources and effects of ionizing radiation: volume I: Sources - Report to the General Assembly Scientific Annexes A and B. UN, United Nations Office at Vienna, 2008.

[VL06] Efficiency of water treatment systems, COVRA report no. 06.037, 2006 (in Dutch).

Annex A: Locations of Sites

Location of nuclear sites in the Netherlands, including the Dodewaard Nuclear Power Plant, which is in Safe Enclosure since July 2005.

Map of Nuclear Facilities

Map of measurement points.

Annex B: Normalized discharges

The normalized discharges of the Nuclear Power Plant and of the fuel enrichment facility are shown here (a logarithmic scale is used for the y-axis).

NPP Borssele

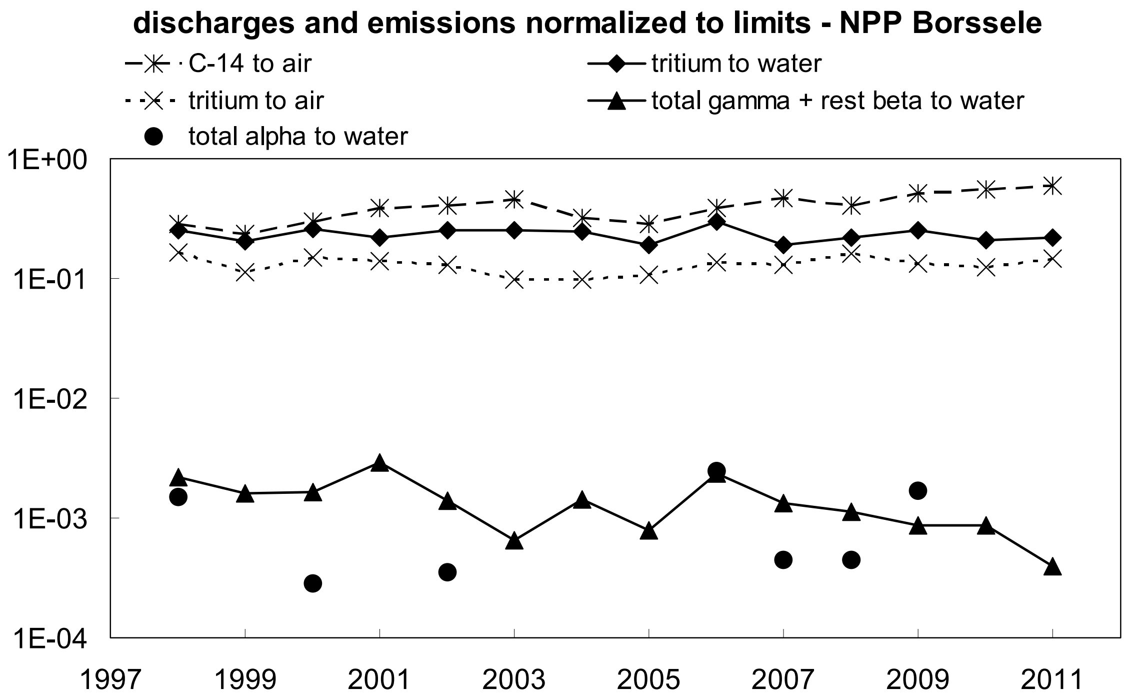


Figure B1: *Discharges and emissions normalized to limits, NPP Borssele*

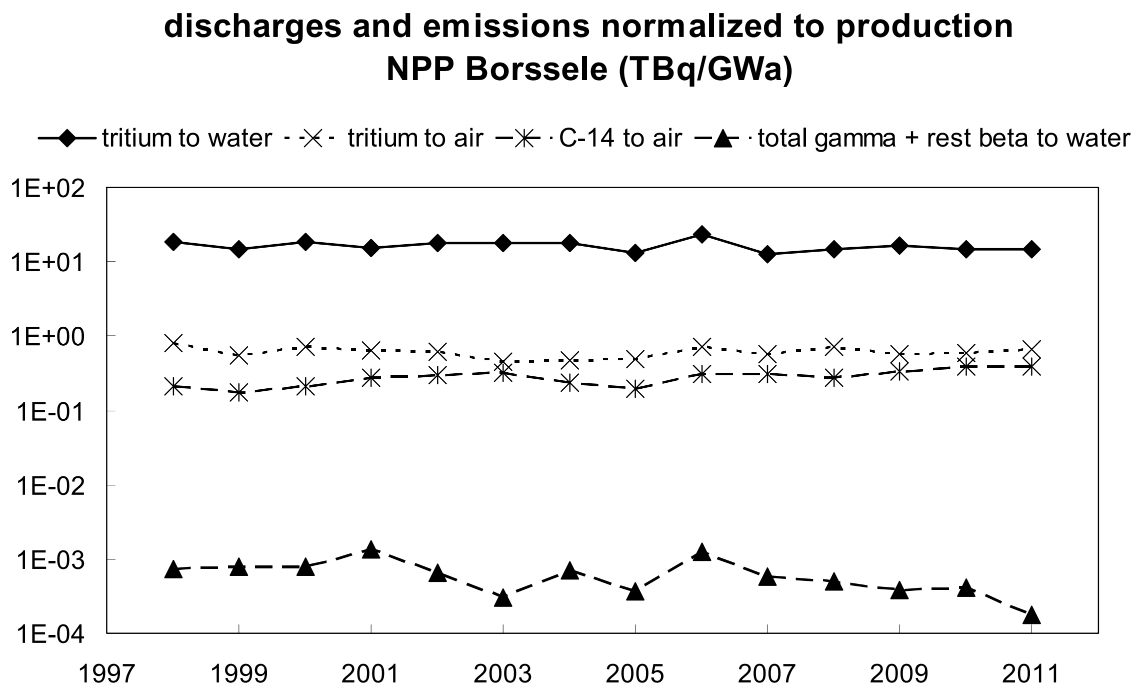


Figure B2: *Discharges and emissions normalized to production, NPP Borssele*

Fuel enrichment facility URENCO

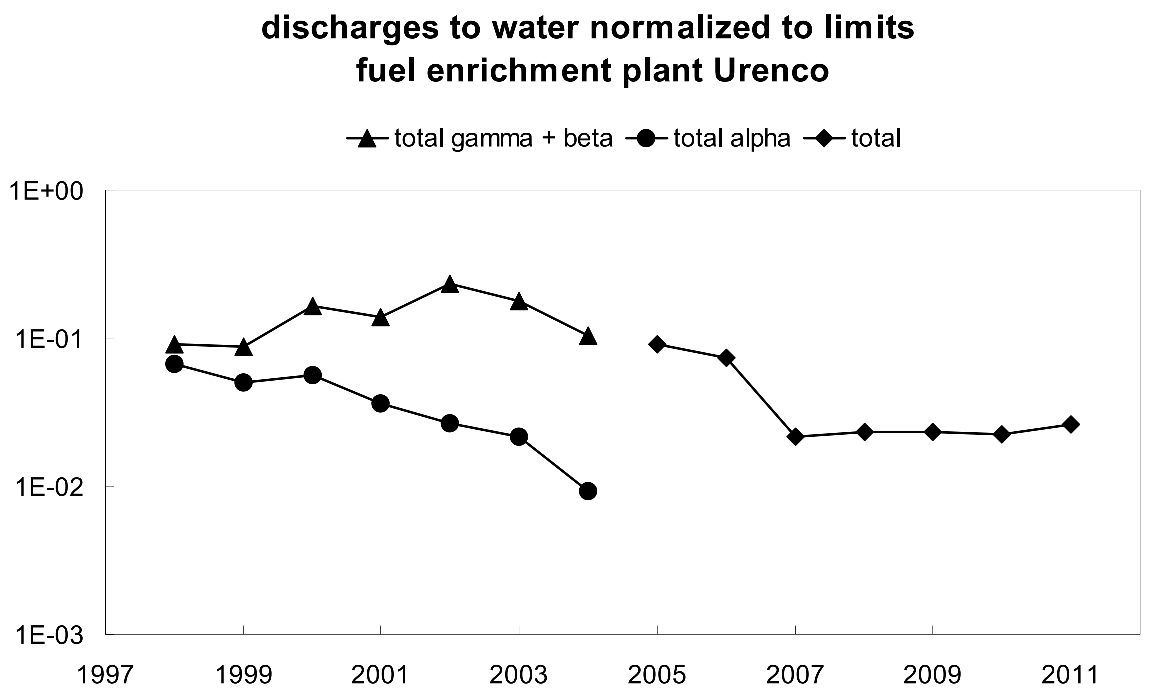


Figure B3: *Discharges to water normalized to limits of the fuel enrichment plant Urenco*

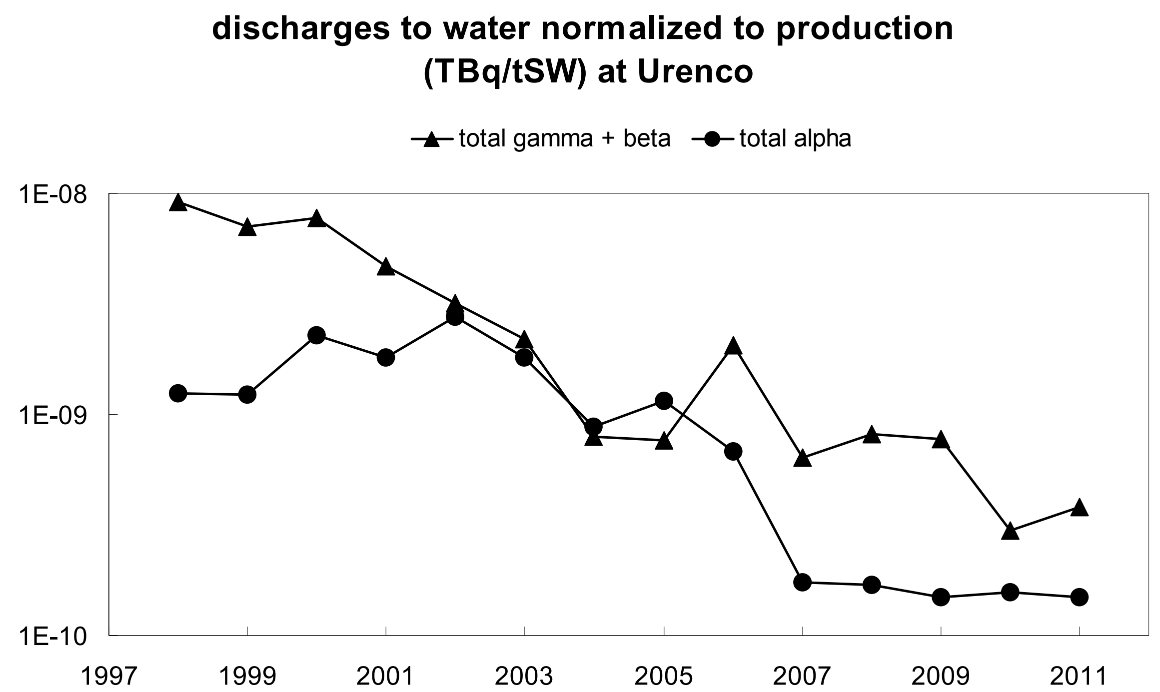


Figure B4: *Discharges to water normalized to production (TBq/tSW) at Urenco*

Annex C: Environmental Impact in the Netherlands

Although discharges of Dutch and foreign nuclear installations lead to an increase of the activity concentrations in the environment, it cannot be expected that the environmental monitoring data are associated to a unique discharge source. For this reason the environmental impact is presented in this appendix and not in the main text.

Concentrations of radionuclides in samples

Activity concentrations are frequently measured in environmental samples from specific locations in waters of the Netherlands, see map in Annex A. The median value for the measured activity concentrations in a year is given. The data are extracted from http://www.waterbase.nl.

Table C1: *Alpha activity concentration (in Bq.m^{-3})*

	Dantzig gat	Eijsden ponton	Vrouwe zand	Haring-vlietsluis	Lobith ponton	Maas-sluis	Marsdiep noord	Sas van Gent	Wester-scheldt
1998	NI	3.8E+01	4.6E+01	5.3E+01	7.1E+01	1.2E+02	4.2E+02	8.7E+01	4.5E+02
1999	6.1E+02	5.0E+01	5.0E+01	5.1E+01	7.8E+01	1.0E+02	5.1E+02	1.5E+02	6.6E+02
2000	3.0E+02	3.1E+01	5.2E+01	3.7E+01	5.6E+01	4.8E+01	2.1E+02	4.9E+01	2.0E+02
2001	5.4E+02	3.9E+01	4.0E+01	4.4E+01	6.0E+01	8.5E+01	3.6E+02	7.1E+01	4.0E+02
2002	4.2E+02	3.7E+01	3.6E+01	4.6E+01	6.0E+01	8.3E+01	3.6E+02	7.5E+01	3.2E+02
2003	5.2E+02	2.5E+01	3.4E+01	3.3E+01	4.6E+01	9.8E+01	3.4E+02	1.0E+02	4.8E+02
2004	4.4E+02	3.8E+01	4.6E+01	3.7E+01	5.3E+01	8.8E+01	3.3E+02	1.2E+02	5.1E+02
2005	5.4E+02	3.8E+01	3.3E+01	3.4E+01	5.9E+01	1.0E+02	7.0E+02	1.2E+02	7.0E+02
2006	8.0E+02	3.7E+01	4.7E+01	3.9E+01	5.9E+01	1.2E+02	7.3E+02	1.3E+02	6.1E+02
2007	3.6E+02	4.4E+01	4.1E+01	3.8E+01	5.5E+01	9.2E+01	4.4E+02	9.3E+01*	4.1E+02
2008	3.9E+02	4.8E+01	4.7E+01	4.1E+01	5.3E+01	9.7E+01	5.2E+02	1.2E+02	5.6E+02
2009	9.8E+02	3.3E+01	3.9E+01	3.5E+01	6.0E+01	9.2E+01	7.6E+02	1.1E+02	7.0E+02
2010	3.1E+02	3.0E+01	3.3E+01	2.9E+01	5.5E+01	6.1E+01	2.9E+02	7.5E+02	4.5E+02
2011	2.1E+02	2.9E+01	4.8E+01	3.6E+01	5.4E+01	1.2E+02	2.5E+02	1.8E+02	3.0E+02

NI: No Information * Mistakenly reported as 9.3E02 in the previous report [OSPAR09]

Table C2: *Residual beta activity concentration (in Bq.m^{-3})*

	Dantzig gat	Eijsden ponton	Vrouwe zand	Haring-vlietsluis	Lobith ponton	Maas-sluis	Mars-diep noord	Sas van Gent	Wester-scheldt
1998	NI	3.2E+01	2.7E+01	2.7E+01	3.8E+01	4.8E+01	8.1E+01	2.9E+01	8.6E+01
1999	9.4E+01	2.5E+01	3.1E+01	2.1E+01	4.2E+01	5.7E+01	4.8E+01	2.9E+01	6.2E+01
2000	1.2E+02	1.7E+01	3.6E+01	1.9E+01	3.6E+01	3.6E+01	4.5E+01	2.3E+01	6.4E+01
2001	1.3E+02	2.2E+01	3.2E+01	2.9E+01	4.6E+01	7.4E+01	6.2E+01	4.1E+01	8.9E+01
2002	1.4E+02	2.0E+01	2.0E+01	1.8E+01	3.0E+01	7.3E+01	8.7E+01	4.6E+01	1.1E+02
2003	1.1E+02	1.3E+01	1.8E+01	8.0E+00	2.9E+01	2.5E+01	4.3E+01	3.0E+01	6.8E+01
2004	1.4E+02	1.7E+01	2.2E+01	1.3E+01	2.5E+01	5.2E+01	5.9E+01	3.2E+01	7.8E+01
2005	1.5E+02	1.8E+01	3.8E+01	8.0E+00	3.5E+01	4.2E+01	5.0E+01	2.8E+01	7.5E+01
2006	1.0E+02	3.4E+01	3.1E+01	1.5E+01	4.3E+01	4.1E+01	6.3E+01	2.3E+01	6.8E+01
2007	1.3E+02	2.7E+01	2.6E+01	1.5E+01	3.0E+01	5.4E+01	8.1E+01	3.1E+01	5.8E+01
2008	2.0E+02	3.2E+01	4.8E+01	2.4E+01	4.9E+01	4.3E+01	8.1E+01	2.9E+01	8.3E+01
2009	1.4E+02	2.7E+01	3.6E+01	2.7E+01	5.3E+01	4.4E+01	9.5E+01	3.6E+01	1.3E+02
2010	1.5E+02	1.8E+01	1.7E+01	1.1E+01	3.6E+01	4.3E+01	7.9E+01	2.8E+01	1.1E+02
2011	1.4E+02	1.6E+01	3.0E+01	9.0E+00	2.8E+01	4.5E+01	8.3E+01	3.8E+01	1.1E+02

Table C3: *Tritium activity concentration (in Bq.m^{-3})*

	Dantzig gat	Eijsden ponton	Vrouwe zand	Haring-vlietsluis	Lobith ponton	Maas-sluis	Mars-diep noord	Sas van Gent	Wester-scheldt
1998	NI	2.8E+03	3.4E+03	5.5E+03	4.6E+03	4.7E+03	4.3E+03	1.7E+03	5.4E+03
1999	3.5E+03	2.4E+04	3.6E+03	5.3E+03	4.6E+03	5.1E+03	5.2E+03	2.0E+03	5.4E+03
2000	3.7E+03	3.4E+03	2.5E+03	6.1E+03	4.3E+03	5.1E+03	5.5E+03	1.5E+03	5.2E+03
2001	2.4E+03	3.5E+03	2.6E+03	3.3E+03	3.4E+03	3.7E+03	2.6E+03	1.1E+03	3.9E+03
2002	2.7E+03	1.5E+04	2.7E+03	4.1E+03	3.3E+03	4.4E+03	3.1E+03	1.7E+03	4.5E+03
2003	3.7E+03	2.0E+04	3.7E+03	5.3E+03	5.1E+03	6.0E+03	3.5E+03	2.0E+03	5.2E+03
2004	4.7E+03	1.2E+04	3.2E+03	5.0E+03	4.1E+03	5.5E+03	4.7E+03	1.7E+03	6.5E+03
2005	4.8E+03	9.2E+03	3.3E+03	4.6E+03	4.8E+03	4.7E+03	4.9E+03	1.4E+03	6.2E+03
2006	5.2E+03	1.5E+04	4.2E+03	4.1E+03	5.9E+03	4.2E+03	5.4E+03	1.3E+03	6.6E+03
2007	3.7E+03	1.5E+04	3.2E+03	4.2E+03	3.3E+03	4.1E+03	3.4E+03	5.6E+02	4.8E+03
2008	4.5E+03	2.8E+04	3.1E+03	4.5E+03	4.0E+03	4.2E+03	4.0E+03	1.1E+03	5.2E+03
2009	2.7E+03	2.4E+03	3.3E+03	4.8E+03	3.4E+03	4.9E+03	3.5E+03	1.4E+03	4.2E+03
2010	3.1E+03	2.0E+04	3.3E+03	4.8E+03	4.1E+03	5.1E+03	3.1E+03	1.6E+03	4.8E+03
2011	3.7E+03	3.0E+04	2.6E+03	5.4E+03	4.3E+03	4.9E+03	3.8E+03	2.1E+03	5.0E+03

NI: No Information

Table C4: *Ra-226 activity concentration (in Bq.m^{-3})*

	Dantzig gat	Eijsden ponton	Vrouwe zand	Haring-vlietsluis	Lobith ponton	Maas-sluis	Mars-diep noord	Sas van Gent	Wester-scheldt
1998	NI	7E+00	NI	NI	9E+00	2E+01	7E+00	1.3E+01	9E+00
1999	6E+00	6E+00	NI	NI	8E+00	8E+00	6E+00	1.1E+01	9E+00
2000	6E+00	4E+00	NI	NI	5E+00	7E+00	6E+00	7.0E+00	6E+00
2001	5E+00	3E+00	NI	NI	4E+00	4E+00	4E+00	5.5E+00	5E+00
2002	5E+00	3E+00	NI	NI	4E+00	5E+00	4E+00	7.0E+00	5E+00
2003	4E+00	4E+00	NI	NI	5E+00	4E+00	4E+00	7.0E+00	5E+00
2004	4E+00	4E+00	NI	NI	4E+00	4E+00	3E+00	8.0E+00	6E+00
2005	4E+00	4E+00	NI	NI	4E+00	4E+00	3E+00	7.0E+00	5E+00
2006	3E+00	3E+00	NI	NI	4E+00	5E+00	4E+00	6.0E+00	5E+00
2007	4E+00	2E+00	NI	NI	3E+00	4E+00	3E+00	6.0E+00	5E+00
2008	4E+00	3E+00	NI	NI	4E+00	4E+00	3E+00	7E+00	4E+00
2009	4E+00	3E+00	NI	NI	4E+00	4E+00	4E+00	5E+00	4E+00
2010	5E+00	3E+00	NI	NI	4E+00	4E+00	4E+00	5E+00	5E+00
2011	4E+00	3E+00	NI	NI	3E+00	2E+00	2E+00	6E+00	5E+00

NI: No Information

Nuclide libraries

The reported activity concentrations are total alpha, total and residual beta, H-3, Pb-210/Po-210, Sr-90 and Ra-226. Residual beta is the total beta activity excluding K-40, H-3 and short-lived radon daughters.
The nuclide library Nuchart, a product of Canberra, is used to identify gamma emitting radionuclides in environmental samples. However, only Co-58, Co-60, Cs-134, Cs-137, I-131 and Mn-54, are reported, if the radionuclides are detected. The library is based on NUDAT (produced by the National Nuclear Data Center, Brookhaven National Laboratory).

Environmental monitoring program

The environmental monitoring programme consists of measuring water samples and suspended particles. The frequency of sampling is variable per year per nuclide and per location. For each of the alpha, residual beta and tritium activity measurements an average sampling frequency of 12 times per year per location is kept. Ra-226, Sr-90, Sr-89, Po-210 and gamma (Cs-137, etc.) activity is measured with a sampling frequency between 4 and 13 times per year per location. The Rijkswaterstaat Centre for Water Management monitors the activity concentrations at 10 locations in inland waters and at 11 locations at sea.

National target levels of radioactive substances

National target levels of activity of radionuclides in the environment are defined for inland waters, as mentioned in section 2.4. Compliance is assessed by comparing the 90th percentile of the measured data, which is not given in this report, with the target levels.

***Table C5**: National target levels (in $Bq.m^{-3}$) [TPW98].*

Total alpha	1.0E+02
Residual beta	2.0E+02
Tritium	1.0E+04

Quality assurance of systems for environmental monitoring

The methodology of environmental monitoring is according to NEN 5622[2], NEN 5623[3], and NEN 6421[4] for the determination of alpha, gamma and beta activities respectively. NEN is a Dutch quality assurance standard. Beta and alpha emitters are monitored according to KTA 1504[5].

Relevant information not covered by previous sections

There is no relevant information not covered by the previous sections.

2 NEN5622: Radioactivity measurements - Determination of massic gross-alpha activity of a solid counting sample by the thick source method. Date of most recent version: 2006.

3 NEN5623: Radioactivity measurements - Determination of the activity of gamma ray emitting nuclides in a counting sample by semiconductor gammaspectrometry. Date of most recent version: 2002.

4 NEN6421: Water - Determination of volumic gross-beta activity and volumic residual beta activity of non-volatile compounds. Date of most recent version: 2006.

5 Kerntechnischer Asschuss (KTA 1504) Überwachung der Ableitung radioaktiver Stoffe mit wasser. Kerntechnischer Ausschuss 1504, Fassung 6/94. Carl Heymans Verlag KG, Luxemburger Strasse 449, 50939 Köln, Germany. 1994 (In German).

Annex D: Environmental Measurements in the Vicinity of NPP Borssele and the Waste Treatment Plant COVRA in Vlissingen

Since the year 2007, the results of the monitoring programme around NPP Borssele are made available through the reports on environmental radioactivity which are compiled by the Netherlands within the framework of the EURATOM Treaty. This is a collation of data from those reports:

Environmental radioactivity in the Netherlands.
Results in 2007, G.J. Knetsch (editor), RIVM Report 610791002/2008
Results in 2008, G.J. Knetsch (editor), RIVM, RIVM Report 610791003/2010
Results in 2009, M.C.E. Groot and G.J. Knetsch (editors), RIVM Report 610891002/2011
Results in 2010, G.J. Knetsch (editor), RIVM Report 610891003/2012

The Nuclear Research & consultancy Group (NRG) is commissioned by Elektriciteits-Productiemaatschappij Zuid-Nederland (N.V. EPZ) to perform monthly measurements on environmental samples taken in the vicinity of the nuclear power plant at Borssele (owned by N.V. EPZ). NPP Borssele and the waste treatment plant COVRA make use of the same wastewater outlet into the Westerscheldt. Samples are taken to monitor the compartments air (not shown here), water and soil. The monitoring program presented here [Donk, 2008, Delorme, 2009 and Donk, 2011] forms only part of the total monitoring program performed near the nuclear power plant. A more detailed description of the monitoring program and underlying strategy is reported in KEMA, 1994. The monitoring programme over the years 2007 to 2010 is shown in Table D.1, with the locations given in Figure D.1. The measurements of radionuclides in water (Tables D.2 and D.3, Figures D.2 and D.3), suspended solids (Table D.4 and Figure D.4), seaweed and sediment (Tables D.5 and D.6) are reported here.

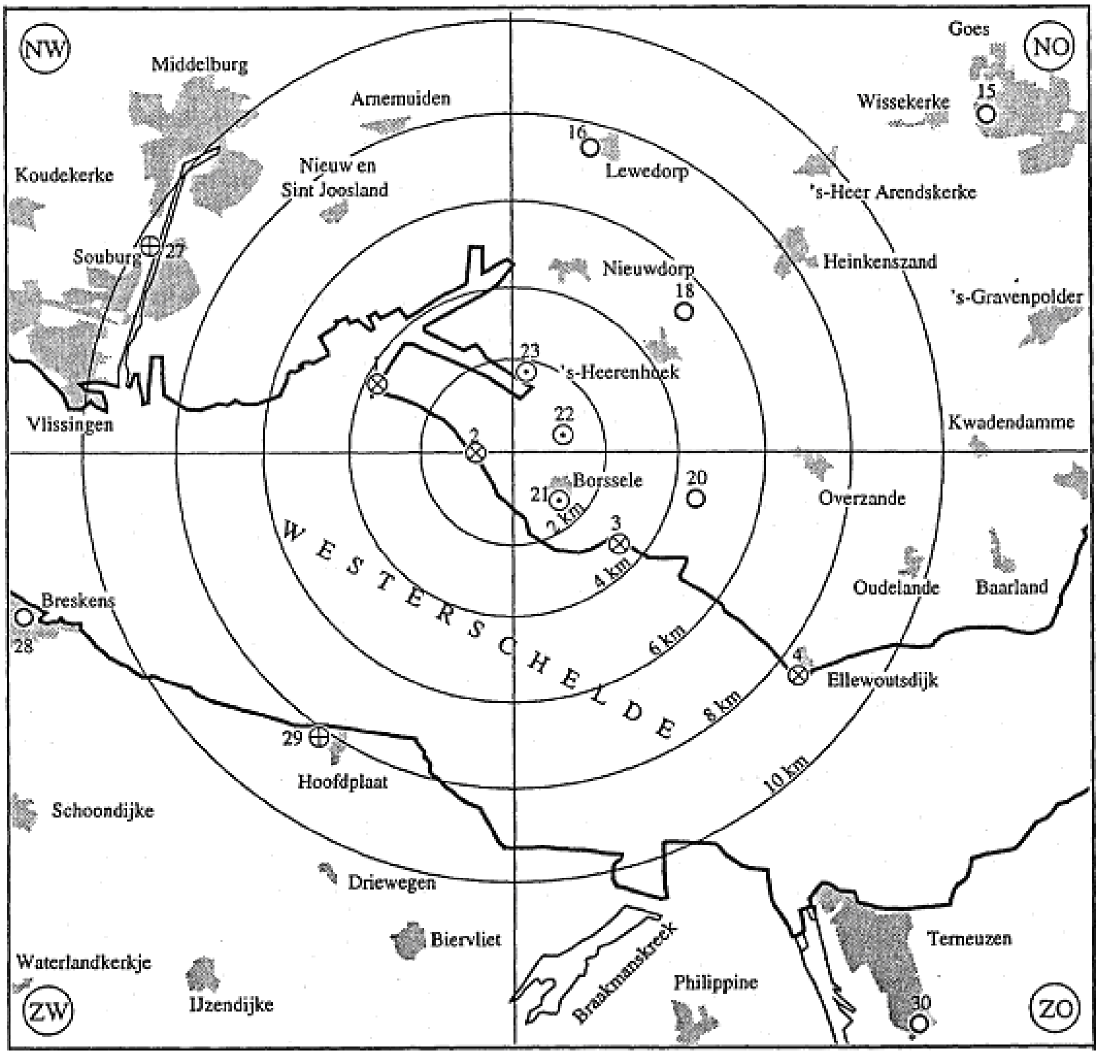
Table D.1: Monitoring program relevant to this report for environmental samples in the vicinity of the nuclear power plant at Borssele. The location numbers correspond with the location numbers given in Figure D.1.

Matrix	Location	Parameter	Monitoring frequency (per year)
Water	1, 2, 3 and 4	residual β, ^{3}H	12
Suspended solids	1, 2, 3 and 4	gross β	12
Seaweed	1, 2, 3 and 4	γ-emitters (1)	12 (2)
Sediment	1, 2, 3 and 4	γ-emitters (1)	12 (2)

(1) *γ-spectroscopic analysis of specific γ-emitting nuclides: ^{60}Co, ^{131}I and ^{137}Cs.*

(2) *Analysis is performed on a combined sample of monthly samples of all four or five locations.*

Figure D.1: *Monitoring program for environmental samples in the vicinity of the nuclear power plant at Borssele (centre of the map) and the waste treatment plant COVRA in Vlissingen located at approximately 1 km in North-West direction.*



The residual β and H-3 activity concentrations in water and gross β-activity concentrations in suspended solids from the Westerscheldt are presented in Tables D.2, D.3 and D.4. The respective yearly averages are shown in Figure D.2, D.3 and D.4.

The results for the nuclides considered in the gammaspectroscopic analysis (Co-60, I-131 and Cs-137) in seaweed and sediment are given in Tables D.5 and D.6.

Figure D.2: *Yearly averaged residual β-activity concentrations from Table D.2 in water from the Westerscheldt at four locations in the vicinity of NPP Borssele (see Figure D.1 for locations).*

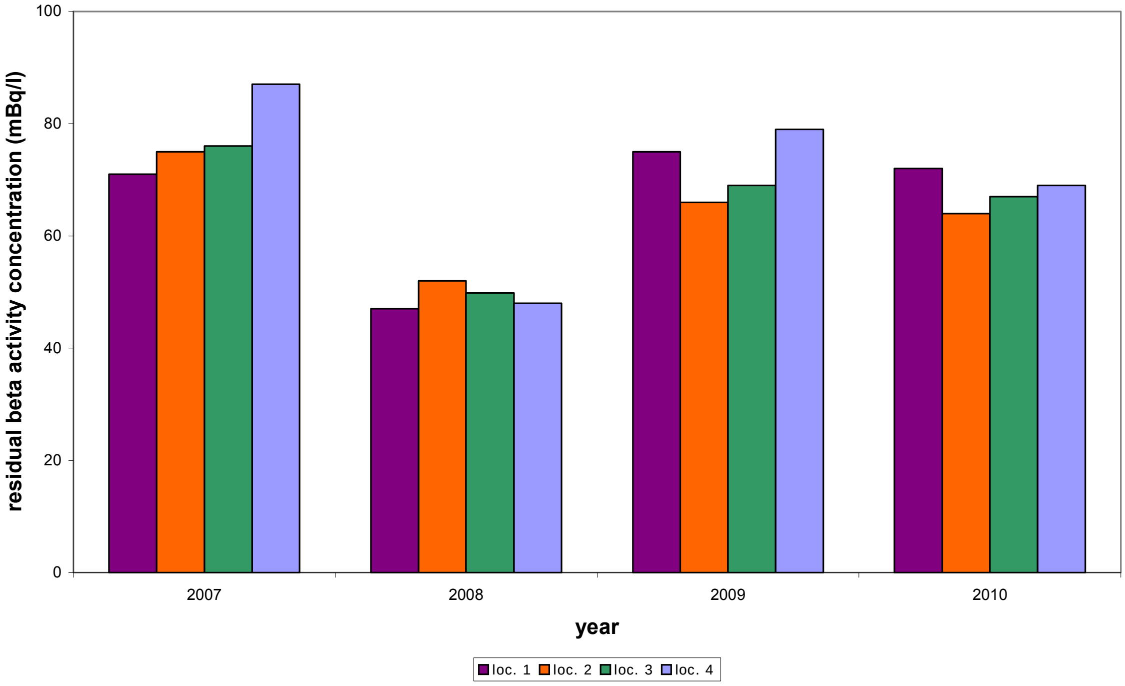


Figure D3: *Yearly averaged H-3 activity concentrations from Table D.3 in water from the Westerscheldt at four locations in the vicinity of NPP Borssele (see Figure D.1 for sampling locations).*

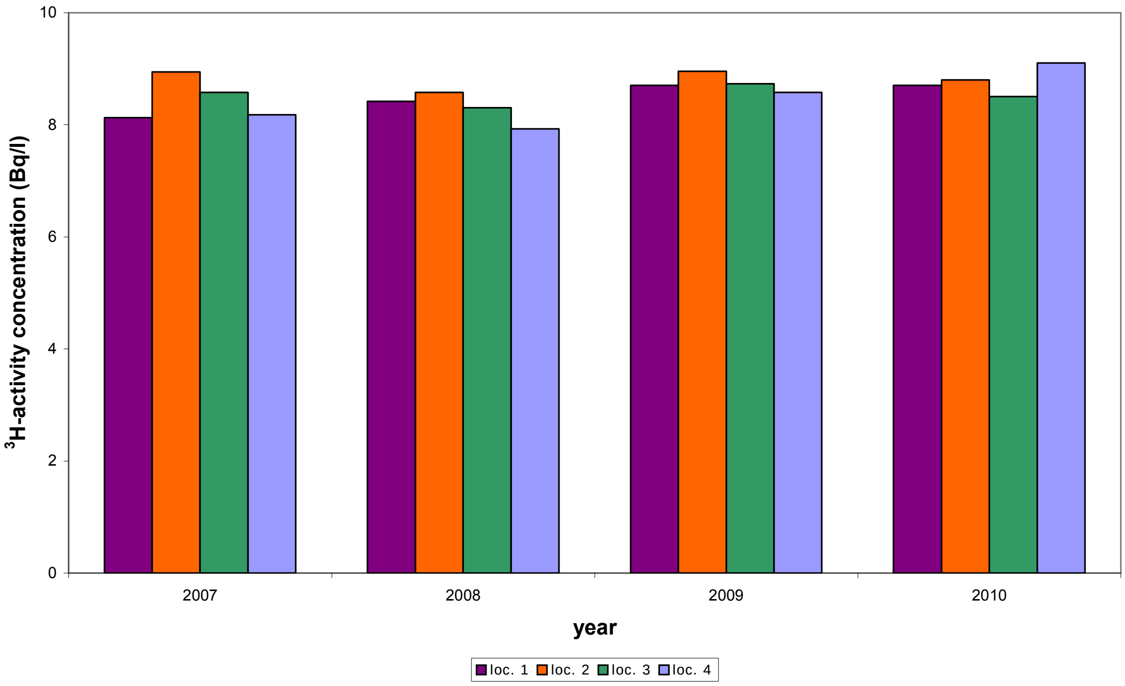


Figure D.4: *Yearly averaged gross β-activity activity concentrations from Table D.4 in suspended solids from the Westerscheldt at four locations in the vicinity of NPP Borssele (see Figure D.1 for sampling locations).*

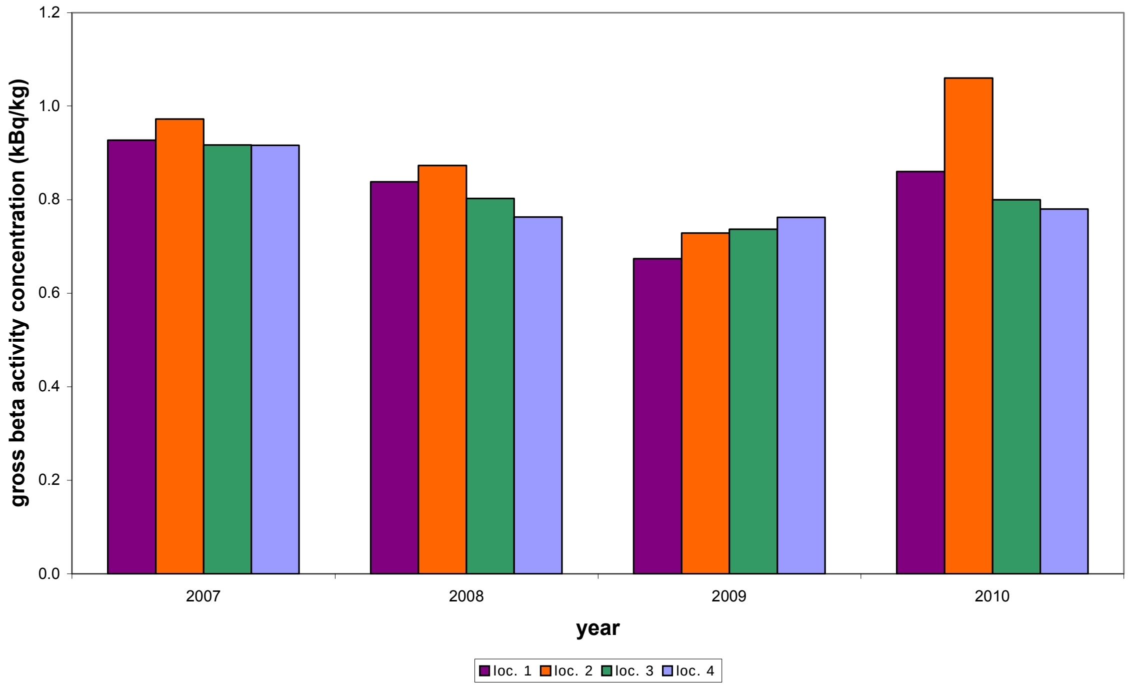

gross beta activity concentration (kBq/kg)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2007
2008
2009
2010
year
loc. 1
loc. 2
loc. 3
loc. 4

Table D.2 *Residual β-activity concentrations in water from the Westerscheldt (see Figure D.1 for sampling locations).*

Date	Residual β (Bq/l)			
Location	**1**	**2**	**3**	**4**
07/02/07	0.036 ± 0.006	0.033 ± 0.005	0.052 ± 0.006	0.048 ± 0.005
07/03/07	0.093 ± 0.006	0.114 ± 0.006	0.087 ± 0.005	0.042 ± 0.005
05/04/07	0.036 ± 0.006	0.030 ± 0.006	0.062 ± 0.006	0.041± 0.006
03/05/07	0.153 ± 0.008	0.114 ± 0.007	0.193 ± 0.007	0.101± 0.006
06/06/07	0.070 ± 0.007	0.058 ± 0.006	0.060 ± 0.006	0.085 ± 0.005
05/07/07	0.083 ± 0.007	0.092 ± 0.008	0.059 ± 0.006	0.084 ± 0.007
06/08/07	0.053 ± 0.007	0.069 ± 0.006	0.031 ± 0.006	0.201± 0.009
05/09/07	0.073 ± 0.007	0.069 ± 0.007	0.064 ± 0.007	0.097 ± 0.005
03/10/07	0.037 ± 0.006	0.063 ± 0.007	0.061± 0.006	0.113 ± 0.006
07/11/07	0.129 ± 0.008	0.125 ± 0.007	0.130 ± 0.007	0.066 ± 0.006
06/12/07	0.048 ± 0.006	0.082 ± 0.006	0.065 ± 0.006	0.132 ± 0.006
07/01/08	0.043 ± 0.005	0.053 ± 0.006	0.042 ± 0.005	0.031± 0.004
07/02/08	0.030 ± 0.007	0.025 ± 0.006	0.046 ± 0.007	0.029 ± 0.004
04/03/08	0.051 ± 0.008	0.106 ± 0.007	0.069 ± 0.008	0.070 ± 0.008
02/04/08	0.038 ± 0.006	0.022 ± 0.005	0.025 ± 0.006	0.026 ± 0.004
08/05/08	0.033 ± 0.008	0.035 ± 0.006	0.064 ± 0.006	0.038 ± 0.006
04/06/08	0.051 ± 0.008	0.037 ± 0.007	0.035 ± 0.007	0.047 ± 0.005
03/07/08	0.063 ± 0.011	0.030 ± 0.008	0.029 ± 0.007	0.043 ± 0.007
06/08/08	0.060 ± 0.006	0.047 ± 0.006	0.043 ± 0.006	0.134 ± 0.008
08/09/08	0.064 ± 0.007	0.057 ± 0.006	0.067 ± 0.007	0.031 ± 0.006
01/10/08	0.053 ± 0.007	0.094 ± 0.006	0.061 ± 0.006	0.021 ± 0.006
06/11/08	0.051 ± 0.007	0.050 ± 0.006	0.070 ± 0.006	0.061 ± 0.006
04/12/08	0.042 ± 0.006	0.050 ± 0.006	0.031 ± 0.006	0.029 ± 0.005
08/01/09	0.030 ± 0.005	0.073 ± 0.006	0.057 ± 0.006	0.043 ± 0.005
06/02/09	0.080 ± 0.008	0.062 ± 0.006	0.073 ± 0.006	0.058 ± 0.005
05/03/09	0.052 ± 0.006	0.079 ± 0.008	0.055 ± 0.005	0.046 ± 0.005
02/04/09	0.040 ± 0.013	0.031 ± 0.005	0.055 ± 0.006	0.036 ± 0.004
06/05/09	0.083 ± 0.014	0.073 ± 0.006	0.047 ± 0.008	0.057 ± 0.005
04/06/09	0.084 ± 0.008	0.064 ± 0.006	0.054 ± 0.006	0.057 ± 0.006
08/07/09	0.077 ± 0.005	0.071 ± 0.006	0.046 ± 0.005	0.041 ± 0.008
06/08/09	0.067 ± 0.007	0.075 ± 0.011	0.073 ± 0.006	0.115 ± 0.006
07/09/09	0.134 ± 0.008	0.078 ± 0.007	0.077 ± 0.007	0.178 ± 0.008
08/10/09	0.090 ± 0.009	0.085 ± 0.012	0.102 ± 0.008	0.092 ± 0.007
05/11/09	0.056 ± 0.012	0.061 ± 0.007	0.110 ± 0.007	0.086 ± 0.007
03/12/09	0.086 ± 0.007	0.061 ± 0.007	0.087 ± 0.009	0.065 ± 0.005
07/01/10	0.051 ± 0.007	0.056 ± 0.006	0.046 ± 0.005	0.116 ± 0.006
04/02/10	0.046 ± 0.006	0.038 ± 0.006	0.061 ± 0.006	0.053 ± 0.007
03/03/10	0.047 ± 0.006	0.043 ± 0.006	0.032 ± 0.005	0.083 ± 0.006
01/04/10	0.051 ± 0.005	0.049 ± 0.006	0.034 ± 0.005	0.042 ± 0.005
07/05/10	0.039 ± 0.004	0.042 ± 0.005	0.055 ± 0.012	0.045 ± 0.004
03/06/10	0.083 ± 0.007	0.047 ± 0.007	0.068 ± 0.006	0.091 ± 0.008
08/07/10	0.048 ± 0.006	0.060 ± 0.006	0.063 ± 0.006	0.059 ± 0.007
05/08/10	0.078 ± 0.006	0.062 ± 0.007	0.048 ± 0.006	0.051 ± 0.006
02/09/10	0.099 ± 0.007	0.082 ± 0.006	0.095 ± 0.007	0.080 ± 0.006
04/10/10	0.088 ± 0.006	0.081 ± 0.010	0.097 ± 0.006	0.093 ± 0.010

03/11/10	0.096 ± 0.015	0.101 ± 0.012	0.065 ± 0.005	0.076 ± 0.011
09/12/10	0.099 ± 0.008	0.093 ± 0.009	0.089 ± 0.006	0.093 ± 0.006
05/01/11	0.086 ± 0.008	0.070 ± 0.006	0.096 ± 0.006	0.067 ± 0.005

Table D.3 *^{3}H-activity concentrations in water from the Westerscheldt (see Figure D.1 for sampling locations).*

Date	**H-3 (Bq/l)**			
Location	**1**	**2**	**3**	**4**
07/02/07	7.8 ± 1.3	8.9 ± 1.3	10.4 ± 1.4	9.0 ± 1.4
07/03/07	7.9 ± 1.3	9.9 ± 1.4	8.3 ± 1.3	7.1 ± 1.3
05/04/07	7.3 ± 1.4	8.1 ± 1.4	7.6 ± 1.4	8.0 ± 1.3
03/05/07	8.1 ± 1.4	8.7 ± 1.4	8.4 ± 1.4	7.1 ± 1.4
06/06/07	6.6 ± 1.4	8.5 ± 1.4	9.1 ± 1.4	6.8 ± 1.4
05/07/07	7.5 ± 1.4	9.2 ± 1.4	7.8 ± 1.4	8.1 ± 1.4
06/08/07	8.8 ± 1.4	9.6 ± 1.4	9.7 ± 1.4	8.9 ± 1.4
05/09/07	8.8 ± 1.4	9.8 ± 1.5	9.0 ± 1.4	8.7 ± 1.4
03/10/07	9.1 ± 1.4	9.3 ± 1.4	8.3 ± 1.4	8.6 ± 1.4
07/11/07	8.6 ± 1.4	8.9 ± 1.4	9.1 ± 1.4	8.0 ± 1.4
06/12/07	9.0 ± 1.4	9.0 ± 1.4	8.1 ± 1.4	8.7 ± 1.4
07/01/08	8.1 ± 1.4	7.4 ± 1.4	7.1 ± 1.4	9.1 ± 1.4
07/02/08	7.8 ± 1.4	8.7 ± 1.4	8.8 ± 1.4	7.5 ± 1.4
04/03/08	7.8 ± 1.5	8.2 ± 1.5	7.0 ± 1.5	7.2 ± 1.5
02/04/08	9.9 ± 1.6	8.5 ± 1.5	7.7 ± 1.5	8.3 ± 1.5
08/05/08	9.2 ± 1.5	8.9 ± 1.5	8.7 ± 1.5	7.3 ± 1.4
04/06/08	7.3 ± 1.5	8.2 ± 1.5	8.3 ± 1.5	7.6 ± 1.5
03/07/08	8.4 ± 1.3	8.3 ± 1.3	9.8 ± 1.5	7.8 ± 1.3
06/08/08	8.3 ± 1.3	8.6 ± 1.3	7.7 ± 1.3	7.5 ± 1.3
08/09/08	8.0 ± 1.3	8.8 ± 1.3	8.5 ± 1.3	9.1 ± 1.3
01/10/08	9.1 ± 1.3	8.6 ± 1.3	8.0 ± 1.3	7.9 ± 1.3
06/11/08	8.7 ± 1.3	9.4 ± 1.3	9.1 ± 1.3	8.4 ± 1.3
04/12/08	8.3 ± 1.3	9.3 ± 1.3	8.4 ± 1.3	8.1 ± 1.3
08/01/09	8.2 ± 1.3	7.5 ± 1.2	7.6 ± 1.2	8.5 ± 1.3
06/02/09	8.2 ± 1.3	8.7 ± 1.3	9.3 ± 1.4	8.4 ± 1.4
05/03/09	9.2 ± 1.4	8.6 ± 1.4	7.8 ± 1.3	9.3 ± 1.4
02/04/09	9.5 ± 1.4	9.6 ± 1.4	8.5 ± 1.4	8.9 ± 1.4
06/05/09	8.4 ± 1.4	8.0 ± 1.4	7.6 ± 1.3	9.2 ± 1.4
04/06/09	7.3 ± 1.4	9.1 ± 1.5	8.7 ± 1.4	7.2 ± 1.4
08/07/09	9.3 ± 1.4	8.0 ± 1.4	9.1 ± 1.4	8.9 ± 1.4
06/08/09	7.2 ± 1.4	9.3 ± 1.4	8.8 ± 1.4	9.4 ± 1.4
07/09/09	8.7 ± 1.3	9.0 ± 1.3	8.6 ± 1.4	7.6 ± 1.4
08/10/09	8.4 ± 1.4	9.4 ± 1.4	8.8 ± 1.4	7.6 ± 1.3
05/11/09	8.7 ± 1.4	9.3 ± 1.4	8.8 ± 1.4	9.1 ± 1.4
03/12/09	9.1 ± 1.3	9.4 ± 1.3	8.9 ± 1.3	7.8 ± 1.3
07/01/10	10.4 ± 1.4	9.0 ± 1.4	9.8 ± 1.4	9.6 ± 1.4
04/02/10	8.5 ± 1.4	9.2 ± 1.4	8.9 ± 1.4	9.9 ± 1.4
03/03/10	9.2 ± 1.4	8.4 ± 1.4	8.3 ± 1.4	7.2 ± 1.4
01/04/10	7.4 ± 1.4	7.9 ± 1.4	7.7 ± 1.4	8.8 ± 1.4
07/05/10	8.9 ± 1.4	9.1 ± 1.4	8.0 ± 1.4	9.4 ± 1.4
03/06/10	8.6 ± 1.4	9.1 ± 1.4	8.5 ± 1.4	10.3 ± 1.4

08/07/10	8.7 ± 1.4	8.0 ± 1.4	9.1 ± 1.4	9.9 ± 1.2
05/08/10	7.9 ± 1.4	9.2 ± 1.4	8.2 ± 1.5	10.1 ± 1.2
02/09/10	8.7 ± 1.5	8.0 ± 1.5	8.1 ± 1.5	7.9 ± 1.3
04/10/10	8.9 ± 1.5	8.8 ± 1.5	9.2 ± 1.5	8.1 ± 1.3
03/11/10	8.3 ± 1.3	9.3 ± 1.4	8.8 ± 1.3	8.7 ± 1.1
09/12/10	9.5 ± 1.3	9.2 ± 1.4	8.9 ± 1.3	10.1 ± 1.2
05/01/11	9.6 ± 1.4	9.2 ± 1.3	8.6 ± 1.3	8.7 ± 1.1

Table D.4 *Gross β-activity concentrations in suspended solids from the Westerscheldt (see Figure D.1 for sampling locations).*

Date	**Gross β (kBq/kg)**			
Location	**1**	**2**	**3**	**4**
07/02/07	0.71 ± 0.03	0.85 ± 0.04	0.85 ± 0.03	0.65 ± 0.02
07/03/07	0.81 ± 0.06	0.90 ± 0.07	0.69 ± 0.06	0.90 ± 0.06
05/04/07	1.2 ± 0.2	1.08 ± 0.10	0.87 ± 0.06	0.96 ± 0.08
03/05/07	0.93 ± 0.09	1.40 ± 0.11	1.77 ± 0.11	1.24 ± 0.05
06/06/07	1.16 ± 0.16	0.68 ± 0.06	0.83 ± 0.03	0.78 ± 0.04
05/07/07	0.80 ± 0.05	0.96 ± 0.05	0.64 ± 0.02	0.66 ± 0.03
06/08/07	0.82 ± 0.05	0.95 ± 0.06	0.73 ± 0.03	0.88 ± 0.06
05/09/07	0.647 ± 0.16	0.75 ± 0.03	0.88 ± 0.04	1.04 ± 0.10
03/10/07	0.69 ± 0.05	0.96 ± 0.07	0.68 ± 0.08	0.95 ± 0.06
07/11/07	0.99 ± 0.06	1.49 ± 0.08	1.31 ± 0.09	1.19 ± 0.06
06/12/07	1.22 ± 0.05	0.74 ± 0.11	0.80 ± 0.04	0.95 ± 0.05
07/01/08	1.15 ± 0.06	0.90 ± 0.06	0.95 ± 0.06	0.79 ± 0.05
07/02/08	0.46 ± 0.10	0.68 ± 0.12	0.75 ± 0.03	0.45 ± 0.05
04/03/08	0.60 ± 0.09	0.78 ± 0.04	0.71 ± 0.02	0.61 ± 0.14
02/04/08	0.71 ± 0.14	0.80 ± 0.12	0.71 ± 0.11	0.49 ± 0.14
08/05/08	1.06 ± 0.14	0.60 ± 0.06	0.89 ± 0.06	0.79 ± 0.11
04/06/08	1.05 ± 0.07	1.29 ± 0.11	0.86 ± 0.06	1.01 ± 0.11
03/07/08	0.77 ± 0.07	0.66 ± 0.05	0.79 ± 0.08	0.76 ± 0.03
06/08/08	1.26 ± 0.12	0.80 ± 0.05	0.62 ± 0.05	1.59 ± 0.13
08/09/08	0.77 ± 0.03	0.79 ± 0.06	0.89 ± 0.08	0.55 ± 0.04
01/10/08	0.74 ± 0.04	1.32 ± 0.05	0.74 ± 0.04	0.42 ± 0.13
06/11/08	0.90 ± 0.04	0.81 ± 0.04	1.01 ± 0.05	0.77 ± 0.05
04/12/08	0.81 ± 0.07	0.73 ± 0.05	0.59 ± 0.03	0.61 ± 0.05
06/02/09	0.94 ± 0.06	0.75 ± 0.04	0.58 ± 0.02	0.291 ± 0.018
05/03/09	0.44 ± 0.03	0.49 ± 0.03	0.61 ± 0.03	0.42 ± 0.03
02/04/09	0.61 ± 0.05	0.61 ± 0.07	0.66 ± 0.04	1.33 ± 0.13
06/05/09	0.31 ± 0.05	0.63 ± 0.07	0.96 ± 0.06	0.66 ± 0.05
04/06/09	0.89 ± 0.19	0.75 ± 0.15	0.91 ± 0.04	0.92 ± 0.05
08/07/09	0.94 ± 0.08	0.96 ± 0.08	0.64 ± 0.06	0.72 ± 0.03
06/08/09	0.41 ± 0.07	0.66 ± 0.02	0.66 ± 0.02	0.617 ± 0.019
07/09/09	0.22 ± 0.03	0.20 ± 0.03	0.95 ± 0.05	0.89 ± 0.06
08/10/09	0.69 ± 0.03	0.79 ± 0.05	0.70 ± 0.04	0.77 ± 0.04
05/11/09	0.83 ± 0.05	1.15 ± 0.12	0.78 ± 0.05	0.73 ± 0.11
03/12/09	1.02 ± 0.07	1.00 ± 0.04	0.84 ± 0.04	1.20 ± 0.07
07/01/10	0.79 ± 0.03	0.76 ± 0.03	0.55 ± 0.02	0.60 ± 0.03
04/02/10	0.71 ± 0.05	0.64 ± 0.03	0.161 ± 0.017	0.56 ± 0.03

03/03/10	0.74 ± 0.08	0.79 ± 0.09	0.71 ± 0.08	0.10 ± 0.02
01/04/10	0.54 ± 0.04	0.75 ± 0.04	0.73 ± 0.04	0.57 ± 0.03
07/05/10	0.81 ± 0.16	1.18 ± 0.09	0.92 ± 0.13	0.61 ± 0.12
03/06/10	1.05 ± 0.06	0.84 ± 0.03	0.78 ± 0.03	0.81 ± 0.08
08/07/10	1.62 ± 0.10	0.74 ± 0.05	0.58 ± 0.17	0.33 ± 0.05
05/08/10	0.35 ± 0.10	0.94 ± 0.16	0.74 ± 0.09	0.65 ± 0.05
02/09/10	0.98 ± 0.08	0.95 ± 0.15	0.76 ± 0.08	0.99 ± 0.08
04/10/10	0.86 ± 0.14	1.76 ± 0.16	0.91 ± 0.07	1.01 ± 0.08
03/11/10	0.95 ± 0.09	1.58 ± 0.10	1.03 ± 0.07	1.68 ± 0.07
09/12/10	0.70 ± 0.03	1.11 ± 0.05	0.90 ± 0.04	0.98 ± 0.03
05/01/11	0.97 ± 0.05	1.47 ± 0.05	1.32 ± 0.05	1.11 ± 0.05
04/02/10	0.71 ± 0.05	0.64 ± 0.03	0.161 ± 0.017	0.56 ± 0.03

Table D.5 *Activity concentrations of γ-emitters in seaweed from the Westerscheldt. Analysis is performed on a combined sample of the monthly samples of all four locations (1, 2, 3 and 4).*

Date	Mass	^{60}Co	^{131}I	^{137}Cs
	kg	Bq/kg (1)	Bq/kg (1)	Bq·kg (1)
07/02/07	0.198	< 2	2.0 ± 0.3	< 2
07/03/07	0.165	< 3	1.7 ± 0.3	0.6 ± 0.3
05/04/07	0.107	< 4	< 3	2.1 ± 0.6
03/05/07	0.186	< 3	< 2	< 2
06/06/07	0.051	< 8	< 7	< 6
05/07/07	0.099	< 4	1.4 ± 0.5	< 3
06/08/07	0.031	< 4	< 3	< 3
05/09/07	0.024	< 8	< 7	< 7
03/10/07	0.026	< 7	< 4	< 5
07/11/07	0.025	< 5	< 3	< 3
06/12/07	0.028	< 5	< 4	< 4
07/02/08	0.08	< 5	< 4	< 3
04/03/08	0.574	< 0.7	< 0.5	1.80 ± 0.18
02/04/08	0.786	< 0.6	< 0.4	1.52 ± 0.11
08/05/08	0.313	< 2	< 1	< 1
04/06/08	0.305	< 1	< 0.9	0.91 ± 0.15
03/07/08	0.208	< 2	< 1	< 1
06/08/08	0.171	< 2	< 2	< 2
08/09/08	0.2	< 2	< 2	< 2
01/10/08	0.207	< 2	< 1	< 1
06/11/08	0.256	< 2	< 1	< 1
04/12/08	0.179	< 2	< 2	< 2
08/01/09	0.031	< 5	< 3	< 3
06/02/09	0.16	< 3	< 0.8	< 2
05/03/09	0.15	< 3	< 2	< 2
02/04/09	0.077	< 5	< 5	< 4
06/05/09	0.069	< 6	< 4	1.6 ± 0.8
04/06/09	0.105	< 4	< 3	< 3
08/07/09	0.116	< 4	< 2	< 3
06/08/09	0.122	< 4	< 3	1.2 ± 0.6
07/09/09	0.091	< 4	< 3	< 3
08/10/09	0.106	< 4	< 2	< 2
05/11/09	0.201	< 2	< 2	< 2

03/12/09	0.046	< 4	< 3	< 4
04/02/10	0.100	< 4	< 4	< 3
03/03/10	0.094	< 4	< 3	< 3
01/04/10	0.128	< 3	3.3 ± 0.4	< 2
07/05/10	0.142	< 3	< 2	< 2
03/06/10	0.116	< 3	< 3	0.9 ± 0.4
08/07/10	0.158	< 2	< 2	< 2
05/08/10	0.156	< 3	< 2	0.8 ± 0.4
02/09/10	0.119	< 4	< 2	< 3
04/10/10	0.206	< 2	< 2	< 2
03/11/10	0.115	< 3	< 2	< 2
09/12/10	0.242	< 2	< 1	< 1
05/01/11	0.109	< 4	< 3	< 3
04/02/10	0.100	< 4	< 4	< 3
03/03/10	0.094	< 4	< 3	< 3

Table D.6 *Activity concentrations of γ-emitters in sediment from the Westerscheldt. Analysis is performed on a combined sample of the monthly samples of all four locations (1, 2, 3 and 4) (see Figure D.1 for sampling locations).*

Date	**Mass**	**^{60}Co**	**^{131}I**	**^{137}Cs**
	kg·m^{-2}	**Bq/kg (1)**	**Bq/kg (1)**	**Bq·kg (1)**
07/02/07	38.5	< 0.3	< 0.2	0.56 ± 0.07
07/03/07	38.9	< 0.3	< 0.2	0.74 ± 0.06
05/04/07	31.8	< 0.3	< 0.2	0.93 ± 0.08
03/05/07	31.0	< 0.3	< 0.2	1.52 ± 0.08
06/06/07	37.1	< 0.3	< 0.3	1.06 ± 0.06
05/07/07	38.3	< 0.3	< 0.2	1.19 ± 0.07
06/08/07	31.6	< 0.3	< 0.3	1.24 ± 0.07
05/09/07	35.7	< 0.3	< 0.2	1.34 ± 0.07
03/10/07	31.4	< 0.3	< 0.2	1.22 ± 0.12
07/11/07	29.3	< 1	< 0.9	0.9 ± 0.3
06/12/07	30.7	< 0.4	< 0.3	1.19 ± 0.10
07/02/08	35.1	< 0.3	< 0.3	1.30 ± 0.07
04/03/08	34.8	< 0.3	< 0.2	1.01 ± 0.08
02/04/08	33.1	< 0.3	< 0.3	1.25 ± 0.09
08/05/08	36.8	< 0.2	< 0.1	0.70 ± 0.05
04/06/08	31.7	< 0.3	< 0.2	1.24 ± 0.08
03/07/08	43.7	< 0.5	< 0.3	1.43 ± 0.12
06/08/08	37.0	< 0.3	< 0.2	0.99 ± 0.09
08/09/08	34.0	< 0.3	< 0.2	1.03 ± 0.07
01/10/08	37.0	< 0.3	< 0.2	1.05 ± 0.07
06/11/08	34.8	< 0.3	< 0.2	1.20 ± 0.07
04/12/08	32.1	< 0.3	< 0.2	1.03 ± 0.08
06/02/09	35.7	< 0.3	< 0.3	< 0.5
05/03/09	34.5	< 0.4	< 0.3	< 0.3
02/04/09	30.4	< 0.4	< 0.5	< 0.3
06/05/09	26.7	< 0.4	< 0.3	1.04 ± 0.08
04/06/09	29.1	< 0.3	< 0.2	1.19 ± 0.08
08/07/09	23.8	< 0.3	< 0.3	1.11 ± 0.08

06/08/09	29.5	< 0.3	< 0.2	1.13 ± 0.08
07/09/09	35.1	< 0.3	< 0.2	0.84 ± 0.07
08/10/09	56.3	< 0.3	< 0.2	0.95 ± 0.08
05/11/09	60.8	< 0.3	< 0.3	1.31 ± 0.11
03/12/09	66.7	< 0.3	< 0.2	1.33 ± 0.07
07/01/10	62.0	< 0.3	< 0.3	1.24 ± 0.08
04/02/10	47.5	< 0.5	< 0.3	1.08 ± 0.11
03/03/10	58.0	< 0.4	< 0.3	1.27 ± 0.09
01/04/10	60.1	< 0.4	< 0.3	1.02 ± 0.08
07/05/10	48.6	< 0.4	< 0.3	0.85 ± 0.09
03/06/10	52.4	< 0.4	< 0.3	1.27 ± 0.09
08/07/10	50.5	< 0.4	< 0.3	0.96 ± 0.10
05/08/10	47.4	< 0.5	< 0.4	0.64 ± 0.08
02/09/10	63.9	< 0.4	< 0.3	1.29 ± 0.08
04/10/10	55.4	< 0.4	< 0.3	1.17 ± 0.09
03/11/10	52.1	< 0.4	< 0.3	1.06 ± 0.10
09/12/10	54.4	< 0.4	< 0.3	0.97 ± 0.09
05/01/11	43.6	< 0.5	< 0.3	0.85 ± 0.10
04/02/10	47.5	< 0.5	< 0.3	1.08 ± 0.11
03/03/10	58.0	< 0.4	< 0.3	1.27 ± 0.09

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Annex E: References for yearly discharges

The references for the yearly discharges of each installation are given here.

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