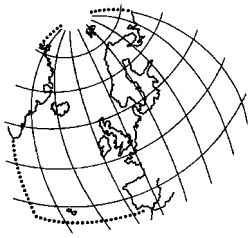
Radioactive Substances Series

The Application of BAT in UK Nuclear Facilities Report

(UK's Report on the Implementation of PARCOM Recommendation 91/4)



OSPAR Commission

2005

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. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

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. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, 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 et la Suisse et approuvée par la Communauté européenne et l'Espagne.

ISBN 1-904426-70-0
Publication Number: 2005/241

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Summary

This report has been prepared for the Radioactive Substances Committee of the OSPAR Commission as the UK statement on the application of Best Available Technology (BAT) to minimise and, where appropriate, eliminate radioactive discharges from the nuclear industry (including research and reprocessing facilities, but excluding defence and medical facilities) into the marine environment.

Operations at UK nuclear installations are governed by various acts, most notably the Radioactive Substances Act (1993, as amended), through which control of discharges to the environment from nuclear licensed sites is exercised. The UK requires operators to apply Best Practicable Means (BPM) to implement the Best Practicable Environmental Option (BPEO). This obligation, together with a continuing review process, places a requirement on operators not only to use the best available technologies but also to apply best practice. In combination this delivers a level of discharge control that is at least consistent with that implied by BAT, as defined by OSPAR.

In this report, current practices at each relevant site and facility and the detailed application of BPM and BPEO (and by extension BAT) in the UK nuclear industry are reviewed. These considerations are grouped by the following nuclear industry sectors: fuel manufacture, power generation, fuel reprocessing, research and development and radioisotope manufacture. The low level solid waste disposal site is also included, under the reprocessing section. The practices and impacts arising from operational and decommissioning nuclear power stations are presented separately at a site level. Facilities which changed status during the reporting period (i.e. were operational in 1998 but had ceased operating or commenced decommissioning by the end of 2003) are also addressed separately. Complex sites, where individual plants may be operational whilst others are undergoing decommissioning are considered according to the sector and status of their main process (e.g. BNFL Sellafield is addressed as an operational reprocessing site, although a number of individual facilities are currently undergoing decommissioning).

In addition to the review of the application of BAT, based on current practices, technologies that are under development in the UK and elsewhere have been identified and comparisons with performance of similar plants world-wide have been made where appropriate.

The UK Government is of the opinion that the procedures and techniques applied in the UK nuclear industry are consistent with those identified in recent international reports and with the implementation of BAT. Furthermore, the authorisation review process requires that technological developments continue to be reviewed and implemented where appropriate.

Furthermore, a number of processes currently being pursued merit particular mention:

- Abatement of ^{99} Tc discharges from current and future MAC arisings through diversion to vitrification;
- Abatement of ^{99} Tc discharges from treatment of stored MAC by use of TPP in EARP;
- The use and effective combination of SIXEP and EARP plants at Sellafield;
- The construction and commissioning of the new Low Level Liquid Effluent Treatment Plant at Dounreay;
- The development and use of Submersible Caesium Removal Units (IONSIV IE-911) in Magnox fuel storage ponds;
- The combination of techniques (segregation, collection, oxidation, isotopic enrichment) under development at GE Healthcare's Maynard Centre for the recycling, rather than discharge, of ^{3}H and ^{14}C;
- Diversion of high concentration radioactive aqueous effluents to cementation, rather than treatment and discharge, at Harwell.

The UK concludes that these examples demonstrate the progress made in the application of BAT in UK nuclear facilities, and furthermore, the combination of the regulatory requirement to demonstrate the use of Best Practicable Means to minimise discharges and the periodic review of authorisations, which entails, inter alia, a review of BPEO, ensures that effectively the application of BAT in UK nuclear facilities is incorporated in UK regulatory practice.

During this reporting period a number of important changes have been made in the Governmental and legislative structure. Although these are not strictly relevant to the application of BAT, they do affect the regulatory arrangements at sites and are therefore noted here.

Most notably, devolved administrations for Scotland and Wales have been introduced. The establishment of a Nuclear Decommissioning Authority (NDA) has also been announced. From April 2005, this body will take ownership of all sites undergoing major decommissioning (including all BNFL and UKAEA sites).

The UK has laid out its Discharge Strategy for the period 2001-2020, in accordance with its commitment to achieve the aims of the OSPAR Commission. Finally, the Authorisation process in the UK, and authorisation conditions related to periodic review, ensure that BAT will continue to be implemented through the application of BPEO and BPM and each site.

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 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."

At its 2004 meeting in La Rochelle, France, the OSPAR Radioactive Substances Committee agreed to the use, on a trial basis, of revised "Guidelines for the submission of information on the assessment of the application of BAT in nuclear facilities" (RSC 04/6/1-E) and this submission has been prepared in accordance with the annex and appendices therein. It covers the six-year period 1998-2003 inclusive.

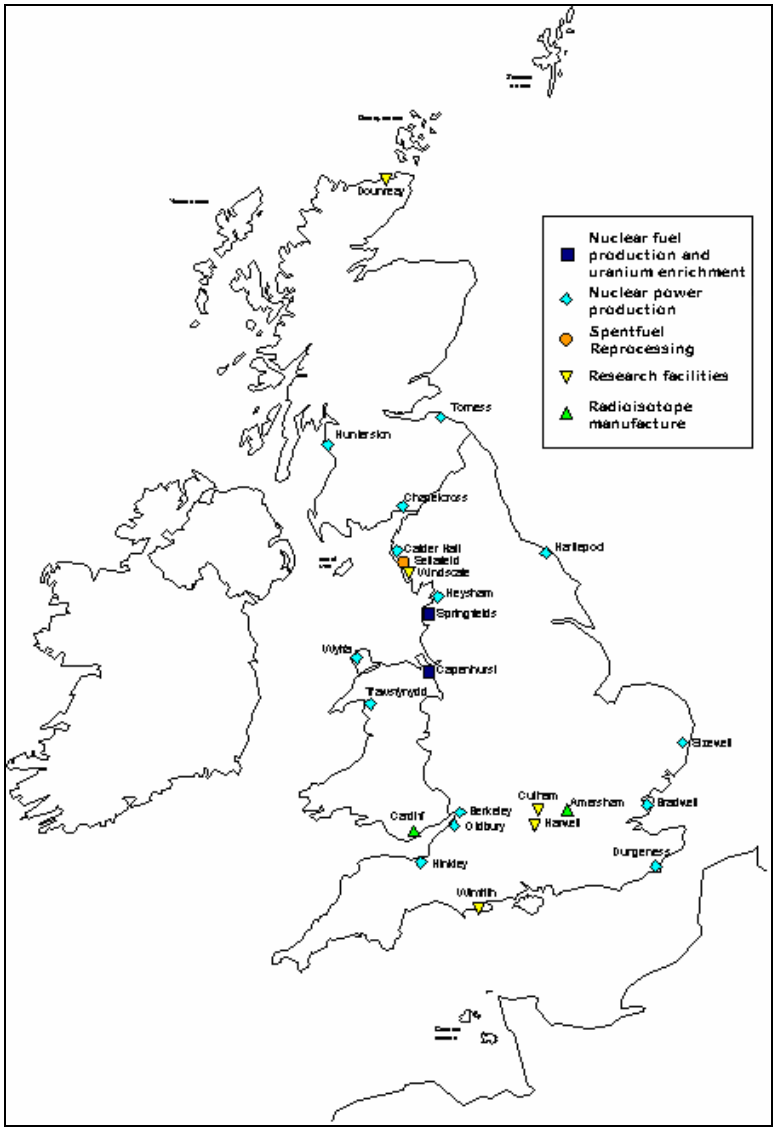
This report, which is the fourth in the series of submissions from the UK to the OSPAR Radioactive Substances Committee, contains information relating to all UK civil nuclear licensed sites, illustrated in Figure 1.

In this report, current practices at each relevant site and facility and the detailed application of Best Practicable Means and Best Practicable Environmental Option (and by extension BAT) in the UK nuclear industry are reviewed. These considerations are grouped by the following nuclear industry sectors: fuel manufacture, power generation, fuel reprocessing, research and development and radioisotope manufacture. The low level solid waste disposal site is also included, under the reprocessing section. The practices and impacts arising from operational and decommissioning nuclear power stations are presented separately at a site level. Facilities which changed status during the reporting period (i.e. were operational in 1998 but had ceased operating or commenced decommissioning by the end of 2003) are also addressed separately. Complex sites, where individual plants may be operational whilst others are undergoing decommissioning are considered according to the sector and status of their main process (e.g. BNFL Sellafield is addressed as an operational reprocessing site, although a number of individual facilities are currently undergoing decommissioning).

In addition to the review of the application of BAT, based on current practices, technologies that are under development in the UK and elsewhere have been identified and comparisons with performance of similar plants world-wide have been made where appropriate.

In addressing primarily the marine environment in this report, we are mindful also of cross-over from atmospheric discharges and of the need to maintain an holistic view to provide the Best Practicable Environmental Option, bearing in mind the balance of radioactive and non-radioactive discharges, the relative environmental impacts of discharges to the aquatic and terrestrial environments, and the issues arising from a policy of containment and land-based disposal as solid wastes.

Figure 1. UK Nuclear Licensed Sites



2. General information

2.1 National legislation and basis for regulation

The formal basis of the control of radioactive discharges, and other aspects of the control of radioactive materials in the UK, is the Radioactive Substances Act 1993 (RSA 93), as amended by the Environment Act (1995) and by legislation implementing the Basic Safety Standards (BSS) Directive. Other relevant legislation includes the Environmental Protection Act (1990) and the Nuclear Installations Act (1965, as amended). Specific plants and operations may also be governed through the Pollution Prevention and Control Act (2000), the Control of Major Accident and Hazards Act (1999) and the Water Industry Act (1991). These acts make available to the regulatory authorities a number of tools including, within the PPC (2000), the prescription of use of BAT. This legislation provides a framework for the standards, practices and objectives in the field of radioactive waste management articulated in UK Government policy statements.

The UK has consistently applied the radiological protection principles recommended by the International Commission on Radiological Protection (ICRP) to reduce levels of radioactive discharges and doses of ionising radiation to humans, and in so doing has reduced concentrations in the wider environment. Dose limits, intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances, have long been established, and a dose limit for members of the public of 1 mSv y^{-1} has been adopted in the UK since 1993. The legislation, regulatory provisions and principles in

place during previous reporting period (1993-1998) are described in the corresponding UK submission. In accordance with the revised guidelines for reporting on the application of BAT, adopted at the meeting of the Radioactive Substances Committee in La Rochelle in 2004, the focus of this section will be on legislation, regulations and policies that have been implemented since the previous report.

In 2002, the UK Strategy for Radioactive Discharges 2001-2020 (the UK Strategy) was published (Defra, 2002), which describes how the UK will implement the agreements reached at the 1998 Ministerial meeting, set out in the OSPAR Strategy with regard to Radioactive Substances. This provides more detail on the national and international context for the regulation of radioactive discharges. In addition to detailed strategic policy for each sector of the nuclear industry, this report includes estimates of future annualised average discharges. If these are realised as expected the estimated mean dose to a representative member of a critical group will fall to 0,02 mSv y^{-1}, at most, as a result of operational nuclear discharges from 2020 onwards. This Strategy will shortly be subject to a full review and further public consultation.

During the reporting period, the organisational and legal arrangements under which decommissioning activities will be performed in the future have been reviewed. The White Paper Cm 5552, entitled, "*Managing the Nuclear Legacy: a strategy for action*", was issued in July 2002. In 2003, the Government published its Energy Bill to implement the White Paper and pave the way for setting up the Nuclear Decommissioning Authority (NDA). The Energy Bill became law in the summer of 2004 and the NDA will begin operating on 1 April 2005 and responsibility for undertaking the decommissioning programme will be contracted out to a site licensee. Although this arrangement will not come into being until April 2005, a pre-cursor unit (the Liabilities Management Unit) has been operating and establishing the general principles for the NDA. This and related changes will improve the consistency and transparency of operational policies and processes.

The NDA will provide overall management and direction for cleaning up the nuclear legacy. This impending change has already had an effect on some of the documentary materials being put together for sites at which decommissioning is underway or planned in the near future and will have further effects on the way in which parts of the industry will be organized and managed in the future. For example, Lifecycle Baselines (LCBL) are already being compiled to establish a long range plan for each site, which the NDA and its site contractors will use to manage, monitor and control the discharge of the relevant nuclear liabilities.

Since the last reporting period, some responsibilities and powers have also been devolved to the Scottish Executive and the National Assembly for Wales, which assumed full powers and duties on 1 July 1999. The Scottish Parliament has the power to make primary legislation on environmental issues and radioactive waste policy. The Scottish Executive and the National Assembly for Wales are required to provide guidance to the Scottish Environment Protection Agency (SEPA) and the Environment Agency (EA) respectively, on devolved matters in Scotland and Wales.

2.2 The application of BAT in UK legislation

The regulation of radioactive waste discharges and disposals is governed by two optimisation concepts that have been part of UK pollution law for many years and which, taken together with the ongoing pressure for review and improvement underlying their application, are considered to be at least equivalent to BAT. These concepts are Best Practicable Environmental Option (BPEO) and Best Practicable Means (BPM). If BPEO and BPM are applied to a set of processes, facilities and methods of operation, then it is considered that radiation risks to the public and the environment will conform to the ICRP principle of being as low as reasonably achievable (ALARA). BPEO and BPM have been described as follows by the NEA Expert Group Report on Effluent Release Options (OECD, 2003).

> *The BPEO is the outcome of a systematic consultative and decision making procedure which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term.*
>
> *BPM is a term used by the Environment Agency and the Scottish Environment Protection Agency in authorisations issued under the Radioactive Substances Act. Essentially, it requires operators to take all reasonably practicable measures in the design and operational management of their facilities to minimise discharges and disposals of radioactive waste, so as to achieve a high standard of protection for the public and the environment. BPM is applied to such aspects as minimising waste creation, abating discharges, and monitoring plant discharges and the environment. It takes account of such factors as the availability and cost of relevant measures, operator safety and the benefits of reduced discharges and disposals.*

BPEO is about global optimisation (for example, of an entire facility), with respect to its environmental impact, whereas BPM is about optimising individual waste streams. The practical implementation of BPEO and BPM is highly case dependent.

The UK Strategy also requires observance of the Precautionary Principle, the Polluter Pays Principle and a proportionate approach. It is UK Government policy that '*the unnecessary introduction of radioactivity into the environment is undesirable, even at levels where the doses to both humans and non-human species are low and, on the basis of current knowledge unlikely to cause harm*'.

Together, these concepts, and the way in which they are incorporated within the process of authorisation review, place a continuous pressure for improvement on operators which is consistent with the objectives of BAT.

Best Available Techniques (BAT) has been defined for the purposes of OSPAR as follows:

a) The term "best available techniques" means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste. In determining whether a set of processes, facilities and methods of operation constitute the best available techniques in general or individual cases, special consideration shall be given to:

   i. comparable processes, facilities or methods of operation which have recently been successfully tried out;

   ii. technological advances and changes in scientific knowledge and understanding;

   iii. the economic feasibility of such techniques;

   iv. time limits for installation in both new and existing plants;

   v. the nature and volume of the discharges and emissions concerned.

b) It therefore follows that what is "best available techniques" for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

c) If the reduction of discharges and emissions resulting from the use of best available techniques does not lead to environmentally acceptable results, additional measures have to be applied.

d) "Techniques" include both the technology used and the way in which the installation is designed, built, maintained, operated and dismantled.

In practice, the common regulatory understanding in the UK is that if an identified BPEO is put into effect using BPM, an operator can confidently claim that BAT has been applied.

A study to determine the contribution of aerial radioactive discharges to radionuclide concentrations in the marine environment was undertaken on behalf of the Department of Environment, Food and Rural Affairs (Defra) to support the continued development of the UK Strategy. The main conclusion of the study is that aerial radioactive discharges from the UK's nuclear and non-nuclear sectors do not make a significant contribution to concentrations of radionuclides in the marine environment. This finding implies that it is reasonable to focus on marine discharges in the context of the OSPAR Strategy.

The UK Government's commitment to achieving the goals of the OSPAR Strategy with regard to Radioactive Substances may also be illustrated by another study commissioned by Defra on methods to distinguish between the impacts of current and historic radioactive discharges to sea from UK nuclear sites. The methods were then used to investigate the impact of illustrative future discharges in relation to the OSPAR Strategy requirements. It is anticipated that the results of this and other research projects may be used in the formulation of future Government policy and in the review of the UK strategy for radioactive discharges.

2.3 Dose limit, constraints and discharge limit setting rationale

As indicated above, the dose limit of 1mSv y^{-1} is set in accordance with both the recommendations of the ICRP and the BSS Directive. This level is intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances.

In 2000, the Secretary of State for the Environment, Transport and the Regions issued a Direction, extending to England and Wales, implementing elements of the BSS Directive. This requires the Environment Agency to ensure, whenever applicable, that:

- All public radiation exposures from radioactive waste disposal are kept ALARA;

- The sum of such exposures does not exceed the dose limit of 1 mSv y^{-1};
- The dose received from any new source does not exceed 0,3 mSv y^{-1};
- The dose received from any single site does not exceed 0,5 mSv y^{-1}.

In Scotland, the Scottish Environment Protection Agency (SEPA) is subject to a similar but separate Direction (The Radioactive Substances (Basic Safety Standards) (Scotland) Direction, 2000). Regulations to implement the BSS Directive are currently being made in Northern Ireland.

The limits, source and site constraints, included in the Directions of 2000, were already in use before that date (Cm 2919 "*Review of Radioactive Waste Management Policy*", 1995), as indicated in the previous UK submission on this subject. In addition, Cm 2919 included a lower bound or threshold to optimisation of 0,02 mSv y^{-1} below which operators are not required to secure further reductions in exposures to members of the general public, providing that they have satisfied the regulators that BPM is being applied to limit discharges.

In 2001, the Department of Environment, Transport and the Regions (now Defra) issued a consultation paper containing draft statutory guidance to the Environment Agency on the regulation of radioactive discharges from nuclear sites, prepared in parallel with the consultation paper on the UK Discharge Strategy. This paper highlighted the importance of comprehensive, rigorous, prospective and transparent regulation that was based on the following principles and objectives:

- Waste minimisation.
- Best practicable environmental option.
- Concentrate and containment (rather than) dilution and dispersion.
- Best practicable means.
- Progressive reduction of discharges.

In this draft guidance the need to set both site and individual plant limits was recognised and the importance of setting individual radionuclide-specific limits where radionuclides are, for example, of significance in terms of their impact on humans and non-human species; have the potential to persist and/or accumulate in the environment or are indicators of plant performance and process control. The objective of minimising the 'headroom' between actual levels of discharge expected during normal operation and discharge limits was also noted.

The EA has responded to this draft guidance by developing further its approach to authorisation and regulation to improve and protect the environment, with the aim of establishing an outcome-focussed approach that is risk-based, clearly communicated and delivered in a consistent manner (Environment Agency, 2004). Authorisation conditions include BPM, BPEO, management systems, monitoring arrangements and improvement conditions to initiate studies of options for modifying plant, systems or procedures that may be relevant to the next review of the authorisation. In order to secure improved environmental outcomes, the Environment Agency has adopted an integrated approach to regulation, as demonstrated by the revised authorisation for the Sellafield site that came into force on 1 October 2004. The following key elements of this new authorisation are as follows:

- Reductions to site limits for radioactive discharges from the Sellafield site and no increases in discharge limits;
- Significant reduction in the 'headroom' between the limit set and expected discharge levels;
- Controls placed on individual plants as well as the site as a whole;
- New conditions requiring best practicable means (BPM) to be used;
- A new integrated (multi-media) authorisation replacing six authorisations for regulating disposals to air, sea and land;
- New conditions related to management systems, organisational structures and resources to achieve compliance with the authorisation;
- A significant programme of environmental improvements.

In 1998 the EA published a technical guidance note on the abatement of atmospheric radioactive releases from nuclear facilities. The report detailed the main types of abatement technique in use in UK facilities and associated record keeping and site inspection (EA, 1998).

2.4 Regulation, surveillance and monitoring

Since their formation in July 1999, the Devolved Administrations have had responsibility for issues arising relative to the provisions of the RSA 93. Although the UK as a single unitary state retains ultimate responsibility for compliance with international conventions and European Union legislation, the Devolved Administrations are responsible for the detailed implementation and compliance in their respective countries, so far as these relate to devolved matters.

In the UK, certain aspects of radioactive waste management are the responsibility of the regulators and the producers of the waste, but the Government decides on the overall policy. The relevant Departments are the Department for Environment, Food and Rural Affairs (in England); the National Assembly for Wales; the Scottish Executive and the Department of the Environment, Northern Ireland. The relevant regulatory authorities are the Environment Agency (for England and Wales), the Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service of the Department of the Environment, (EHS) Northern Ireland. These authorities grant authorisations subject to a periodic review cycle.

The Environment Agency seeks to review each Authorisation approximately every four years to ensure it is still suitable and does not require a major revision. A major review and reauthorisation process will be carried out as and when required. This process involves widespread consultation with relevant Government Departments, other stakeholders and the general public, post-consultation review and final decision and authorisation revision. The revised authorisation review process takes account of all relevant activities conducted or foreseen including any modifications, processing (including legacy wastes) and decommissioning. A number of authorisations have been reviewed and revised during or shortly after the reporting period, including Sellafield, Springfields, Dounreay, Hunterston A, the Maynard Centre in Cardiff and 8 Magnox power stations. Reviews are currently in progress for 6 British Energy sites and Dounreay. These changes are outlined in more detail under the relevant sections of this report.

The regulatory authorities identified above work in close concert with the Health and Safety Executive's Nuclear Installations Inspectorate (NII) which regulates the safety of plant (including that for waste storage) and workers. Authorisations are issued only after consultation with the Health and Safety Executive (HSE) and the Food Standards Agency (FSA).

Regulation and surveillance take a number of forms, for example, site inspection, scrutiny of waste disposal (including discharge and emission) returns, independent sampling, and environmental monitoring. It is undertaken to ensure that the operator is complying with the conditions, including the discharge and emission limits, set out in the RSA 93 authorisation which is enforceable in UK law with heavy fines (and custodial sentences if necessary) for offenders.

Inspectors from the regulating bodies visit sites regularly, the frequency depending on the nature of the site but generally not less than monthly and considerably more often for major and complex sites. This is to observe *inter alia* physical conditions on the site, adherence to system maintenance schedules and operating procedures, and competence of staff. Major in-depth multi-inspectorate inspections are occasionally undertaken and these may be of a week or more in duration.

In addition to the annual limits for discharges and emissions, the Environment Agency (EA) authorisations include quarterly notification levels which are not limits, but exceedance of which triggers an investigation as to whether BPM has been applied in the control of the relevant discharge; failure to adopt BPM is a breach of the authorisation.

The operator is also required to take duplicate samples of discharges and to provide these to the regulator as required. These are analysed by the regulator's independent analyst as a check in order to be assured that the operator's measurements of discharges are accurate.

2.5 Environmental monitoring programmes

All operators of nuclear facilities undertake environmental monitoring, not only to comply with conditions in authorisations but also to provide the general public with information regarding the impact of the facility on the local environment. Monitoring programmes include sampling of both marine food chain and indicator species, local food produce, direct radiation from facilities, and external radiation from publicly accessible places (e.g. beaches).

Independent monitoring is undertaken by the regulators and by government bodies as follows.

In England and Wales, the EA undertakes a programme of monitoring to provide checks on site operators' data and an independent assessment of the exposure to non-food pathways. It encompasses liquid effluents (as described above), quality checking of solid waste disposals, measurement of radiation and radioactivity in the environment, air, rainwater and drinking water sources. This work is undertaken by

contractors according to technical and quality assurance specifications laid down by the EA (and independently witnessed where appropriate). Results are openly published on an annual basis.

Also in England and Wales, the FSA undertakes a programme of surveillance of radioactivity in a range of foodstuffs, both marine and terrestrial, and other materials close to nuclear sites throughout the UK, and the results are used to estimate the doses to members of critical groups (which are identified through habit surveys). The programmes take in locations remote from nuclear sites; for example, many areas along the coastline of the Irish Sea are monitored. In addition, the programmes encompass Northern Ireland, the Isle of Man and the Channel Islands. Results are openly published annually. In Scotland monitoring is undertaken by SEPA.

Since 2003 the RIFE publications have included the environmental monitoring programmes of all the relevant UK authorities: SEPA, FSA, EHS, DOENI and EA.

2.6 Radiation dose assessment methods

Radiation dose assessments for members of the public arising from discharges of radioactive materials are routinely estimated, independently by site operators, the regulatory authorities and FSA, as part of the authorisation setting and review process. The doses to those members of the public likely to be most exposed as a result of their habits and/or location (the critical group) are generally assessed for the purposes of comparison with dose limits and constraints. Total doses are assessed, taking account of both intakes of radionuclides and external irradiation pathways. Data to support these assessments are collected by the relevant operators, regulatory authorities and other bodies, such as the FSA, with relevant responsibilities.

Habit surveys identify the members of the public who will be most exposed. In instances where measurements are not possible, mathematical models have been used to provide supplementary information on intakes derived from particular pathways (e.g. sea-to-land transfer). Application of dosimetric data to the survey and sample measurement information yields the relevant doses to members of the local critical group. Estimated marine critical group doses are set down in the tables for the individual sites in this report. Dose estimates based on measurement data will reflect both current and past discharges. To separate the effects of current and historic discharges it is often necessary to use complex environmental models.

Since the last reporting period, a working group called the National Dose Assessment Working Group (NDAWG) has been established with the aim of bringing together people and organisations with responsibility for, and/or an interest in, the assessment of radiation doses to the public from the nuclear industry and from minor users of radioactivity. The objectives of this group are *inter alia* to facilitate the exchange of data and views between all parties on assessment methodologies, to advance the understanding between groups likely to have differing views and to facilitate the development of coherent and transparent methods. The main focus of the work of NDAWG is the contribution of dose arising from past, present and future authorised discharges and direct radiation. The group includes representatives of regulatory and advisory organizations, industry and independent specialists and representatives from non-Governmental organizations.

2.7 Environmental norms and standards

Other initiatives have had an increasing effect on the way in which assessments in support of discharge authorisations are conducted and assessed, and are relevant to the scope of the OSPAR Strategy with regard to Radioactive Substances. There has been an increasing focus on the potential effects of ionising radiation on non-human species in a number of international fora, as indicated by recent reports to OSPAR RSC from the European Community and the International Atomic Energy Agency. For instance, ICRP has proposed a framework for the assessment of radiation effects in non-human species in its Publication No. 91 (2003) and a work programme has been established to develop an agreed set of reference organisms and corresponding dose models and data.

The ICRP initiative has been supported by work undertaken in the EC-funded research programmes known as FASSET (Framework for the Assessment of Environmental Impact) and ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management), in which the EA and other UK bodies have been and continue to be heavily involved.

The FASSET project was completed towards the end of 2003 and resulted in an overall assessment framework and supporting models and data. The ERICA programme began in March 2004 and will continue until 2007. It will build on the results of the FASSET programme to provide an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation.

In the UK context, the EU Birds and Habitats Directives were introduced into UK legislation by the Conservation (Natural Habitats) Regulations 1994, and amended by the Conservation (Natural Habitats) (England) Regulations 2000. Under these regulations the environment agencies have an obligation to review all existing authorisations that may have an adverse effect on identified European sites. In order to fulfil its obligations with regard to radioactive substances, the Environment Agency, in conjunction with English Nature, undertook the collection of relevant information on ionising radiation impacts and the development of a robust assessment approach. Scoping assessments of the impacts on designated species have been completed for relevant sites in the UK.

2.8 Quality Assurance

Quality Assurance and ISO Accreditation are common to UK operators to demonstrate commitment to quality management and sustainable development. Two well known standards include the ISO 9000 family which is primarily concerned with "quality management" and the ISO 14000 family, primarily concerned with "environmental management" to minimize harmful effects on the environment caused by its activities, and to achieve continual improvement of its environmental performance (www.iso.org). Such standards are globally recognised. Most UK operators demonstrate QA and sound environmental management through ISO 9000 and ISO 14000 accreditation. Organisations that are not accredited use in-house management techniques, often based on ISO standards.

The quality of environmental and discharge sample measurements, and the assessment of the impact of discharges and emissions on members of the general public is based not only on the work of operators but also on a national system of independent regulators (e.g. EA, SEPA), advisers (e.g. NRPB) and government bodies, each relying on accreditation to an appropriate International Standards Organisation (ISO) or other standard. Quality is therefore an in-depth feature of the system and arises from both the standard of individual laboratories and from cross-checking results and intercomparison of assessment techniques.

Operators' laboratories possess radiation standards which are traceable to national standards and they are required to undertake analyses in accordance with procedures set down in Implementation Documents (which are agreed with the regulators and are descriptions of the procedures the operator will use to comply with conditions in the RSA 93 Authorisation).

Laboratories undertaking analyses for the EA, SEPA and DOENI are required to do so in accordance with technical and quality assurance specifications laid down by the respective Agencies. The laboratories that perform analyses for FSA are accredited by the United Kingdom Accreditation Service whereby they meet the requirements of ISO/IEC Guide 25 and EN 45001, the European standard for the operation of calibration and testing laboratories; this implies compliance with the ISO 9000 series of standards. Quality control procedures also involve regular calibration of detectors and intercomparison exercises with other laboratories, both national and international. All laboratories have secondary standards traceable to primary standards.

2.9 References

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OSPAR 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic. APPENDIX 1- Criteria for the Definition of Practices and Techniques Mentioned In Paragraph 3(B)(I) of Article 2 of the Convention.

3. Fuel manufacture

Two sites are concerned with the manufacture of reactor fuel, namely the uranium enrichment plant at Capenhurst, and the uranium purification and fuel manufacture plant at Springfields. Details are given in Tables 9-16. Both sites are certificated to ISO 14001.

3.1 Capenhurst

The Capenhurst site is concerned with uranium enrichment. The site was split into two companies in March 1993: URENCO (Capenhurst) Limited (UCL), which owns and operates the centrifuge plants on the site and BNFL Capenhurst, which is primarily concerned with the decommissioning of the redundant gaseous diffusion plant. UCL has authorisations from the EA to discharge and transfer radioactive wastes to BNFL. There is a gaseous discharge authorisation and two inter-site authorisations for the transfer of solids and liquid radioactive waste from UCL operations to BNFL facilities. These wastes are accounted for in BNFL's liquid discharge figures.

3.1.1 Sources of liquid effluent

The main activities undertaken on this site during the reporting period were:

- operation of the centrifuge plants;
- decommissioning of the gaseous diffusion plant;
- decommissioning of a small redundant facility used to process tritium gas (by BNFL); and
- decommissioning of an older centrifuge plant (by URENCO).

Liquids are discharged into Rivacre Brook under two BNFL authorisations for uranic materials and for discharges from the former tritium processing facility.
The primary source of liquid effluent for the combined site is URENCO operations. At BNFL Capenhurst the primary source is the decommissioning of the old gaseous diffusion plant. The decontamination plant which handles scrap, mainly aluminium, arising from the decommissioning operations employs acidic solutions in tanks. These liquors are recycled to minimise liquid waste arisings. During the reporting period, decontaminated aluminium was melted at a facility on site. Resulting liquid effluent was negligible and operation of the melter ceased on 2 March 2004. Other sources of liquid effluents include the URENCO laboratories and the laundry facility. During the reporting period, BNFL Capenhurst continued to provide a uranic storage service to the nuclear industry.

3.1.2 Liquid effluent treatment and abatement

Waste streams from the decontamination plant, containing uranium radionuclides, small amounts of ^{99}Tc, and very small amounts of ^{237}Np are segregated, treated by ion-exchange, and held in delay tanks for sampling before discharge to Rivacre Brook (which flows into the tidal section of the River Mersey).

3.1.3 Trends in discharge over the 1998-2003 period

Discharges from Capenhurst over the reporting period are given in Table 9. The level of liquid effluent discharge has continued at around the 1998 level throughout the reporting period. The total alpha activity is

less than 1 Bq l^{-1} in all cases, compared to an authorised limit of 100 Bq l^{-1}, and the annual discharge of uranium alpha activity has remained at a little over 1 GBq which is a small fraction of the relevant authorised limit of 20 GBq. The variations in these discharges reflect the phasing of decommissioning activities.
Atmospheric discharges principally arise from incinerator gases and ventilation air from decommissioning operations. The trends in these discharges are explained by the phasing of decommissioning operations. The discharges consist mainly of uranium, uranium progeny and low levels of ^{99}Tc. Tritium is also discharged from the former processing facility. The level of these discharges decreased over the reporting period and ceased in 2003.

3.1.4 Radiological impact of liquid discharges

BNFL undertakes an environmental monitoring programme around the Capenhurst site which includes sampling silt at two locations (at the plant outlet and at around 1,5 km downstream) with additional samples of water and water weed (*Cladophora*) at the more distant location. The reported levels of radioactivity have remained relatively steady over this period (see Table 10), and in many instances are below detection limits.
The only identified critical pathway for liquid discharges is the dose due to the inadvertent ingestion of water or silt by children playing in or near Rivacre Brook. This dose is estimated to be <1 μSv y^{-1} for combined site discharges (see Table 11).

3.1.5 The application of BAT

The discharges and the environmental impact of this site are so low, that it may be concluded that the present arrangements for treating liquid effluents represent BPM. Discharges will reduce further as work continues towards site closure expected in 2006, when the only operational facility remaining will be a uranic store.

3.1.6 Comparison with performance of similar plants world-wide

The details of operation and impact may differ between sites and the activities currently being undertaken at Capenhurst do not easily lend themselves to comparisons with other plants world wide. UCL and BNFL maintains a watching brief on international practice.

3.2 Springfields

The BNFL Westinghouse Springfields site produces fuel and intermediate fuel products for the nuclear industry in the UK and other countries. Uranium ore concentrates (UOC) are received on site and are processed to either uranium metal for use in Magnox reactors or to UF_6. The latter is sent for enrichment at Capenhurst or abroad. Enriched uranium hexafluoride is also received on site for processing to oxide fuel or intermediates for use in Advanced Gas Cooled Reactors or Light Water Reactors. Recycled uranium, a product of reprocessing irradiated fuel, can also be processed.

Decommissioning of a wide variety of buildings and plants continues across the site and is scheduled to continue according to the Springfields site plan.

The Springfields site has an integrated management system (IMS) which is ISO 14001 certified. It is implemented by site and local business unit procedures, which provide for the measurement, monitoring, auditing and review of all site processes. Analysis is provided by UKAS accredited laboratories and direct measurement equipment is calibrated to appropriate standards and used by trained personnel according to approved operating instructions.

3.2.1 Sources of liquid effluent

The majority of activity is associated with beta emitters in the raffinate stream. Discharge is made through a pipeline to the Ribble estuary. The pipeline receives both storm and trade discharges which are routed via a site-wide drain network through the site effluent complex. The effluents are collected, sampled and analysed prior to discharge.

3.2.2 Liquid effluent treatment and abatement

Over the last few years efforts have been made to develop a modified discharge system that will allow better time control of discharges to the River Ribble estuary and the more efficient dilution of the effluent. The method of sentencing effluent containing uranium allows for the recirculation and further purification of the effluent if uranium content exceeds a set 'action level'.

A BPEO study in 1993 suggested that a reduction in discharges and impact could be achieved by a voluntary ban on the processing of certain UOCs containing above-average levels of thorium. The ban was implemented in 1993 and in 2000 it was decided that the highest thorium UOC would no longer be processed. Stocks were transferred to another processor outside the UK. The Toxic Metal Calculator (TMC)

is now used to balance high impurity ores with others to ensure moderation of thorium and other items in the effluent. The TMC is a spreadsheet-based computer programme that is used to control the impurities in the ore-processing effluent stream by balancing the inputs. Ore is obtained from a range of sources. Some ores have a higher content of specific impurities than others. For instance, a given ore may have a high copper content. This may be balanced with other ores so that if say ten drums were to be used into the process, two may be high Cu while the other eight may be low Cu so as to reduce the overall burden. It is not possible to estimate the effectiveness of this ban or the use of the TMC because other signals may mask the effects.

3.2.3 Trends in discharge over the 1998-2003 period

The discharges have remained well within the authorised limits throughout the reporting period. As indicated in detail in Table 13, liquid discharges of total beta activity have decreased over the reporting period, while the total alpha activity discharged has remained largely unchanged. The beta discharges reflect the throughput in the UOC purification plant, while the total alpha, ^{230}Th and ^{232}Th levels reflect the throughput and the thorium content of the ore concentrates purified. Discharges of ^{237}Np and ^{99}Tc arise from trace activities in processing residues, including those from decommissioning activities and remain a small fraction of the authorised limits. The apparent increase in ^{237}Np is thought to be due to operational variations in analytical equipment that is due to be upgraded. The most significant radioactive liquid effluent discharges are associated with the purification of UOC (uranium ore concentrate), which is scheduled to cease in March 2006. Further significant reductions in liquid discharges can therefore be expected beyond that date.

The discharges of uranium to atmosphere have decreased steadily over the reporting period. This is a consequence of the fact that a number of older plants have shut down since 1998 and are currently undergoing decommissioning and demolition.

3.2.4 Radiological impact of liquid discharges

BNFL Springfields routinely monitor surface sediments (quarterly), shellfish (biannually) and surface beta gamma dose rates at various locations in the estuary, to around 15 km from the discharge point. In addition, its terrestrial sampling programme includes grass and soil measurements around the site perimeter (quarterly) and the seasonal collection of leafy and salad vegetables. Analysis for the following radionuclides is routinely undertaken: ^{40}K, ^{60}Co, ^{137}Cs, ^{212}Pb, ^{214}Bi, ^{228}Ac, ^{234m}Pa, ^{228}Th, ^{230}Th, ^{232}Th, ^{238}Pu, $^{239/240}$Pu, ^{241}Pu, ^{241}Am. Detailed results are given in Table 14, from which it can be seen, that the activity levels have remained relatively stable over the reporting period.

Doses to members of the public are estimated using a combination of measurements and modelling. Generally speaking, the radionuclides discharged from Springfields are relatively short-lived such that estimated doses do not include a significant historical component.

The following potentially exposed groups from liquid discharges from Springfields have been identified: including houseboat dwellers, anglers, wildfowlers and seafood consumers. These groups may receive similar annual doses (of around 20 μSv). The annual variations in discharges may result in any one of these groups being the critical group in a particular year. In 2003, for example, anglers constituted the critical group with a predicted dose of 23 μSv.

Members of the public in the vicinity of Springfields also receive a component of radiation dose predominantly from discharges from Sellafield largely due to historic ^{137}Cs in estuarine sediments. For example, in 2002 houseboat dwellers received 17 μSv from Springfields discharges (see Table 15) and an additional 50 μSv as a result of Sellafield discharges.

3.2.5 The application of BAT

A review of the environmental benefits, capital costs and timescales associated with a number of abatement options was undertaken as part of the recent review of authorisations for the disposal of radioactive waste from Springfields. The following four options were considered in detail as being potentially technically feasible on a reasonable time scale.

- Neutralisation and store for beta decay;
- Store total effluent for beta decay then neutralise;
- Neutralisation with floc dewatering and encapsulation; and,
- Evaporation and decomposition of nitrates.

The fourth option was considered to be too complex and expensive to be feasible, while the capital cost and timescale to commissioning for the remaining options ranged from £8-12 million and 3-3,5 years[1]. BNFL argued that uranium hexafluoride and Magnox fuel production would cease within 6-12 months of any abatement plant coming into operation, so that building such a plant would not be justified. The Environment Agency agreed that '*the installation and commissioning of abatement plant is not appropriate given BNFL's publicly stated policy of ending uranium ore processing at Springfields. The cessation of ore processing will significantly reduce radioactive effluent discharges without abatement plant.'* This conclusion was dependent upon the current plan. An updated BPEO/BPM study would be needed in any future authorisation review.

3.2.6 Comparison with performance of similar plants world-wide

The details of operation and impact may differ between sites and the activities currently being undertaken at Springfields do not easily lend themselves to comparisons with other plants world wide. BNFL maintains a watching brief on national and international best practice and are required to submit a review of waste minimisation developments to the EA as a condition of the Authorisation that came into force on 1 November 2004.

3.3 References

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4. Power Generation

In the UK, nuclear power generation is currently from three types of power station[2]:

- Magnox designed gas cooled reactors;
- Advanced Gas Cooled Reactors (AGR); and
- Pressurised Water Reactor (PWR).

The UK is the only country to have operational Magnox stations, the majority of which commenced operation in the 1950s and 1960s[3]. They are currently operated by Magnox Electric plc, a subsidiary of British Nuclear Group. All the remaining nuclear power stations are operated by British Energy. Three Magnox power stations began decommissioning before the reporting period (Berkeley, Hunterston A and Trawsfynydd). Three power stations were operating at the beginning of the period and began decommissioning or defuelling between 1998 and 2003 (Bradwell, Chapelcross and Hinkley Point A). The remaining five Magnox stations were operational throughout the reporting period.

The UK is also the only country to have AGR stations in operation. During the period 1998 – 2003 no new AGR stations were commissioned, and none of the existing stations began defuelling or decommissioning. Only one PWR station is operational in the UK, Sizewell B. This station was commissioned in 1995 and remains in operation.

This Section has been divided by status of the power stations depending on whether they were operational throughout the 1998-2003 reporting period, transitional (operation ceased during the reporting period) or began decommissioning before 1998. Those in each Section are set out in the following table.

1 Not including lifetime costs of operation and decommissioning.

2 Other types of nuclear power stations have been operated in the past in the UK, including a steam generating heavy water reactor (at Winfrith) and fast breeder reactors (at Dounreay), but these are now all undergoing decommissioning.

3 The last Magnox station at Wylfa, Anglesey, was commissioned in 1971.

Table 1. Operational status of power stations in the UK

Operational				Transitional	Decommissioning
Dungeness A (Magnox)	Heysham 1 (AGR)	Hunterston B (AGR)	Sizewell B (PWR)	Bradwell (Magnox)	Berkeley (Magnox)
Dungeness B (AGR)	Heysham 2 (AGR)	Oldbury (Magnox)	Torness (AGR)	Hinkley Point A (Magnox)	Hunterston A (Magnox)
Hartlepool (AGR)	Hinkley Point B (AGR)	Sizewell A (Magnox)	Wylfa (Magnox)	Chapelcross (Magnox)	Trawsfynydd (Magnox)
Calder Hall (Magnox)					

Note: Calder Hall ceased operation during 2003. It is considered separately in Section 6.

4.1 Operational sites

4.1.1 Sources of liquid effluent

AGR

The main source of liquid effluent from AGR stations arises from the fuel storage ponds. Only small quantities of this water are discharged as waste, and such discharges are subject to filtration and ion exchange to provide an acceptable working environment for the operators and to reduce radioactive discharges. Pond water is not directly discharged to the environment. Indirect discharges from this source consist of supernatant from filtration and sludge storage tanks. Other sources include dryer liquor and sundry other smaller operations.

The main radionuclides within liquid discharges for the AGRs, (ignoring radiological significance) are ^{3}H, ^{35}S, ^{137}Cs, ^{134}Cs, ^{54}Mn, ^{60}Co, ^{45}Ca, ^{55}Fe and ^{241}Pu. The stations have been in a steady operational state for some years, with negligible environmental impact. There is a permanent requirement to apply BPM to discharges and ALARP to doses. No target level is set but where an opportunity is identified to reduce significantly the impact of discharges, this is undertaken if the effectiveness is commensurate with the cost. At present, discharges are believed to be as low as reasonably practicable.

PWR

At Sizewell B the main radionuclides (ignoring radiological significance) are ^{3}H, ^{55}Fe, ^{137}Cs, ^{134}Cs, ^{60}Co and ^{58}Co. Five principal streams enter the Liquid Radwaste System (LRWS).

- Drain channel A, which collects the clean active waste from the equipment drains, the gaseous waste system and from the Reactor Coolant Drains Tank.
- Drain channel B, which collects leakage from the floor and equipment drains, and is dirtier but less active than drain channel A.
- Chemical drains, which collect chemically contaminated water.
- Laundry and hot shower sub-system which collects liquid from the active laundry facilities and personnel showers.
- Boron recycle system which collects reactor coolant let-down.

In addition, there is a Secondary Liquid Waste System (SLS) which collects effluent from floor drains associated with the secondary circuit and from regeneration of the condensate polishing plant demineralisers. Liquid from the steam generator blow-down system is normally filtered and recycled to the Condensate Storage System. However, during refuelling outages limited quantities are discharged to sea. Discharges are via the main seawater cooling discharge system wherein the effluent is diluted with an enormous quantity of water prior to entering the sea.

MAGNOX

At operational Magnox stations, the radioactive liquid effluents arise from reactor and fuel handling operations. The principal sources for operational stations are:

- the spent fuel ponds (where irradiated fuel is stored under water before being despatched for reprocessing)[4];
- gas processing liquors (from CO_2 gas dehumidifying); and

[4] Spent fuel discharged from Wylfa is stored in a dry spent fuel store.

- laundry operations.

In addition, a Magnox dissolution plant is operated at Dungeness A, and described in Section 5.1.6.

The most radiologically significant source for liquid effluents is the spent fuel storage pond water. Great efforts are made to minimise the release of activity from the spent fuel into the pond water by controlling the pond storage conditions.

4.1.2 Fuel pond management

AGR

Pond water is contained within a closed circuit and is only discharged to the environment in small quantities after treatment. The main source of the more radiologically significant effluent to water is therefore the active effluent treatment plant (AETP) which serves the cooling pond and processes miscellaneous liquid arisings from around the plant.

Any defective fuel element detected within the reactor to be leaking, a very rare occurrence, would normally be held for an extended period in dry buffer storage pending a decision regarding off-site disposal. The leaking element(s) would then be placed in a separate water-tight container before entering the fuel cooling ponds. The residence time in the cooling ponds, and release of radionuclides to pond water, would therefore be minimised. Priority is given to minimising the release of radioactivity to fuel storage ponds.

When the concentration of ^{137}Cs in the fuel cooling pond at the Hartlepool and Heysham 1 plants increased due to the presence of leaking fuel, cation-only ion-exchange resin was introduced into the pond-water treatment plant for better caesium removal. This process successfully reduced pond concentrations to the levels generally encountered in AGR fuel ponds.

Other measures are taken to minimize liquid discharges from the pond as follows.

- The pond water treatment system is a closed system and the discharge route to the sea is only used for small quantities of liquid following treatment;
- pond-water is continuously recirculated through deep bed sand filters and ion exchange filter beds;
- chloride ion concentration is controlled in order to minimise the incidence of stress corrosion of the stainless steel cladding of the fuel, so reducing the chance of fuel corrosion in the pond;
- pond radiochemical factors are monitored through a process of routine sampling and analysis.

In addition, boron is added to eliminate as far as practicable any possibility of a criticality event in the pond. This increases levels of boron in discharge effluent. However, boron is an essential element, typically present at 4 ppm in seawater and is not regarded as highly toxic even at moderately elevated concentrations.

MAGNOX

At Magnox sites still carrying out the process, corrosion of the Magnox fuel cladding is minimised through careful pond management, the main features being:

- maintaining pondwater alkalinity at pH >11,5, to encourage formation of a stable protective film on the Magnox surface;
- maintaining very low anion concentrations using ion exchange plant;
- removal, through high-rate pond water filtration, of particulate (which, if allowed to accumulate on Magnox surface, could accelerate corrosion);
- maintaining pond temperature, i.e. removal of decay heat from spent fuel, by use of pond water cooling plant thus assisting to minimise the rate of Magnox corrosion which is temperature dependent;
- using in the ponds only those fuel storage skips which do not show significant paint damage, thus reducing the possibility of galvanic corrosion of the Magnox cladding; and
- removal of lugs and spacers from fuel pins (desplittering) immediately before being despatched for reprocessing in order to minimise the possibility of fission product leakage from mechanically damaged fuel being in the ponds.

The ion exchange plants used to control pondwater chemistry consist of regenerable anion and cation beds. The regeneration liquors contain the radioactivity removed from pondwater. The use of non-regenerable

beds is not appropriate because the solid waste so generated would not be consistent with the identified BPEO.

Notwithstanding the measures described above to minimise release of activity into pondwater, there is a degree of leakage from fuel elements, leading to the inclusion of a wider range of fission products in liquid discharges compared with an AGR, the most radiologically significant being the fission product ^{137}Cs. Reduction of radiocaesium activity in pondwater (and hence discharge) is achieved either by removal of any leaking fuel element(s) and by suitably treating the pondwater.

Removal of a leaking fuel element requires that it is first identified; thereafter, the offending fuel element(s) is isolated and decay stored separately for a minimum of 90 days before being transferred to Sellafield for reprocessing. On occasion, for example when a number of leaking elements are in the pond simultaneously, the use of a caesium removal unit is warranted- which is quite separate from the pondwater chemistry ion exchange plant described above. This unit employs caesium-specific ion exchange resin absorbers; and a consequence of its use is additional solid waste arisings.

4.1.3 Gas dryer liquors

AGR

The principal source of radioactivity in liquid effluents from AGR stations is the liquor produced from the regeneration of the reactor gas drying plant. This contains tritium and also ^{35}S which arises both from activation of sulphur and from the $^{35}Cl(n,p)^{35}S$ reaction in the graphite. There is a strong correlation between tritium production and reactor power, but discharges of ^{35}S are more variable. Both these radionuclides are of relatively low radiological significance.

MAGNOX

Moisture levels within generating Magnox reactors require careful control in order to prevent fuel element corrosion. Water is removed from the CO_2 coolant using either gas dryers or gas conditioning plant and the condensate is routinely discharged with other liquid effluents. The principal radionuclides in these liquors are tritium and ^{35}Sulphur. This is the main source of liquid discharges. In Magnox reactors, tritium is produced primarily from ternary fission, lithium impurities in the graphite core having burnt out over 40 years generation.

4.1.4 Particulate filters

At AGR stations a number of particulate filters are employed. For instance, liquid effluents may be passed through a sand pressure filter and a back-up filter that is provided to trap any loose sand particles. At Dungeness B, a BPM study is planned to consider the possible provision of a second stage of filtration to a particular route at Dungeness that only has low levels of activity.

At Heysham 1, up-stands have been installed in the final monitoring tanks to reduce potential discharges of particulate. Up-stands bring the end of the discharge pipe above the base of the tank, ensuring that any layer of sediment at the bottom of the tank will not be discharged during normal discharge operations.
At Hinkley Point B there is:

- Improved Final Monitoring and Delay Tank (FMDT) (for most active effluent) and Tritiated Water Storage Tank (TWST) (for gas dryer liquors) level indication to allow early identification of anomalies;
- Improvements made to cleaning of sea water-cooled heat exchangers within the reactor building has resulted in less particulate material getting into AETP system hence reducing burden on filtration plant and improving performance;
- improved trending of pond water specific activity and pond Mixed Bed Unit (MBU) (ion exchange resins) efficiency;
- improved trending FMDT discharge activity;
- Improved operational procedures, data logging and trending of sand pressure filter and cloth/ceramic filter differential pressure readings.

At Hunterston B the oil separator supplied at the AETP reception tanks in 1976 was replaced with an improved version in 2003 so as to reduce the quantity of oil reaching the AETP (and sand filters in particular) with miscellaneous effluent. There is no quantitative expectation for discharge reduction. The relevance of this change is to reduce the risk of oil causing channelling in the sand filters, thus potentially reducing filtration efficiency.

The effluent plant is subject to a programme of routine inspection and testing. Over the last few years the final delay tank linings were stripped out and renewed with a modern coating, the effluent sand filters were rebuilt and several design changes made to improve their operability, improved effluent sampling points were designed, and a new proportional discharge sampler installed.

At Torness there is strict monitoring of the activity levels in routine liquid discharges. Analysis and trending of individual nuclides in each tank can give early indication of plant problems, thus allowing early investigation and remedial action which reduces the potential for discharge.

MAGNOX

Magnox plant are generally equipped with sand pressure filters in their active effluent treatment plant and pond water treatment plant for the removal of particulate matter. These are supplemented at some sites as follows.
At Dungeness A effluent is passed through a Doulton filter before it enters the final delay tanks for discharge. The Doulton filter is a ceramic filter with a washable cloth insert.
Wylfa has no ponds, so there are no arisings from this source. Within the reporting period, the sand pressure filters on the active effluent treatment plant have been replaced with a FilTore, a radial filtration device that cycles the filter medium through a clean-up process as it operates. This has the advantage of removing any traces of oil from the liquid effluent stream.

4.1.5 Laundry (AGR and Magnox)

Staff wear protective clothing when working in contaminated or potentially contaminated areas; this clothing is laundered on site. Only extremely low levels of radioactivity are observed in laundry liquors with no individual nuclide being significant.

4.1.6 Magnox Dissolution Plant (MXD)

This is located at Dungeness A station and is designed to reduce the volume of solid waste arising from the removal of lugs etc from the external surface of Magnox spent fuel elements. The plant dissolves the essentially inactive debris in carbonic acid and leaves a residue of insoluble mildly-radioactive solids. The process effluent passes through a sand bed and a 5µm cartridge filter (resulting in very low levels of radioactivity) and is discharged with the station's other routine active effluents. The MXD plant is operating in a campaign mode. In 2004 the project to completely empty the splitter vaults was finished. The next campaign is to clear the lug vaults, this process will start in September 2005.

4.1.7 Liquid effluent treatment and discharge

AGR

All AGR sites are certified to ISO 14001 and are therefore subject to external audit. There is also an internal quality management system for all sites. Through sampling and analysis of the discharged effluent, abatement has been shown to be effective.

Each AGR station has a laboratory capable of performing the measurements necessary to demonstrate compliance with RSA authorisations. However, additional analysis is performed elsewhere under contract (currently by BNFL). Intercomparisons are performed quarterly.

At Dungeness B during the period of interest, 1998 to 2003, work has been carried out to improve the reliability of the coolant dryers (this would potentially affect airborne emissions, but not liquid discharges) but it is not considered to be economically practicable to retro-fit abatement to the effluent from the coolant dryers because the radiological impact of these discharges is very small. This is true for all AGR sites. The site's active laundry was also decommissioned. An offsite contracting company now washes active laundry. This has lead to a significant reduction in the volume of active liquid processed.

At both Hartlepool and Heysham 1 leaking fuel was inadvertently introduced into the cooling pond during 2002 instead of being held in dry storage. This resulted in increased discharges of "other activity" (principally radiocaesium). Cation-only ion-exchange resin was introduced into the pond-water treatment plant for better caesium removal.

Despite the introduction of an ion-exchange resin, there was a small increase in discharges of ^{137}Cs from the pond-water treatment plant. Discharges of pond-water have been re-routed to benefit from the 2-stage filtration provided by the effluent treatment plant in addition to the single stage provided by the pond-water treatment plant.

Again at both Hartlepool and Heysham 1 AGR stations, trace quantities of carbonyl sulphide (COS) were used to modify the coolant gas chemistry in order to control carbonaceous deposition on boiler tubes that was impairing efficient heat transfer. This action was justified as BPM to the EA, and wider BPEO issues

were also addressed. Increased radioactive discharges were set against increased conventional emissions from replacement generation (SOx, NOx & CO_2). The increase in discharges of ^{35}S, may have been aggravated by other factors that are currently under investigation. The behaviour of sulphur in AGR coolant circuits is complex. The higher discharges at Hartlepool relative to Heysham 1 may relate to details of the operation of the Recombination Unit in the gas bypass plant (the Recombination Unit is provided to oxidise CO to CO_2), however, to date no conclusions have been reached as to what they may be.

Several modifications have been made to the Heysham 2 plant to demonstrate compliance for example through timing and monitoring, and the modifications were not intended to reduce the quantity of discharges. Some modifications have been used to reduce the potential of inadvertent discharge of liquid effluent, and reduce the potential activity in liquid discharges (but increase solid waste arisings):

Pond Resin: Following a BPEO assessment, for a trial period in Spring 2004, 100 litres of caesium removal resin were loaded into one of the two mixed beds in service in the pond-water treatment plant at Heysham 2. This is to manage the rising caesium level as a result of pick up of activity from fuel skips returned from Sellafield. The intention of using resin for removing caesium from the ponds is to control dose-rate for people working in that area and to reduce discharges of caesium that would be associated with discharges of pond-water. At Hartlepool and Heysham 1 the aim was to return pond-water levels towards normal after the increase associated with the presence of leaking fuel. At Heysham 2 the aim was primarily to reduce dose-rate, their discharges of pond-water to sea being less than most other AGRs. whilst this did not occur during the period of interest, the BPEO and the trial do demonstrate British Energy's continuing consideration of environmental and radiation protection.

AETP Pump Suction Lines: The active effluent treatment system collects all radioactive or potentially radioactive liquid effluent arisings in a series of tanks, before being treated and filtered for final disposal. During the collection and treatment stages, sludge is left as a residue in the tank bottoms. This sludge is generally directed to long term storage, for subsequent specialist disposal. A modification has been implemented to address the issue of sludge carry-over from the collection tanks by shortening the pump suction lines, thereby allowing liquid only to be carried over. The sludge will be retained in the tanks and removed under controlled conditions on a routine basis.

PWR

Sizewell B is a relatively new facility, therefore the latest radioactive waste management technologies were incorporated into the design and commission stages. Sampling and analysis of effluent before and after abatement demonstrates that abatement is effective. Intercomparisons of the main discharge analytical methods are performed quarterly with an independent laboratory. However, as with all British Energy sites, a condition of the authorisation is to consider BPM for all operations.

MAGNOX

At Magnox stations all aqueous effluents are filtered prior to discharge to remove residual particulate matter. Effluents are accumulated in delay tanks, sampled and, if their activity content is acceptably low, are discharged via the station's cooling water ensuring considerable dilution and the avoidance of high local concentrations near the discharge outfall.

Where spent fuel is cooled in ponds, stations are also equipped with a variety of caesium removal plant to reduce the discharge of radiocaesium. In many cases, this plant treats the pond water, to remove radiocaesium at source. The most recent development (employed at Dungeness A, Oldbury and Sizewell A) takes the form of a submersible unit that is installed directly in the pond. These submersible units are equipped with a pumping system, a cartridge containing a molecular sieve designed to target caesium, together with filters either side of the IONSIV cartridge. Older units are situated within the pond water treatment plant and are usually charged with a suitable ion exchange medium.

4.1.8 Trends in discharge over the 1998-2003 period

A detailed breakdown of the discharges over this period are provided for each site in Tables 29, 35, 39, 43, 48, 55, 62, 69, 75, 82, 89 and 96. However, some general features of the liquid discharge profiles may be identified.

AGR

At Dungeness B, the lowest level of radioactivity in discharges occurred in 2000, and since then, for a number of radionuclides including, ^{3}H, total beta, ^{134}Cs, ^{137}Cs and ^{35}S, there has been an increase, so that in 2003, the discharges were higher than in 1998. The general trend observed for emissions to air is also upwards.

Peak discharges for Hartlepool AGR occurred in 2001-2002, primarily attributed to the presence of leaking fuel. For radionuclides where 2003 data is available, the trend is downwards but is usually higher than 1998 values, for example for ^{35}S and total activity excluding ^{3}H, ^{35}S and ^{60}Co, however the impact of discharges is low.

At Heysham 1, the discharges have a similar trend to Hartlepool. That is total activity excluding ^{3}H, ^{35}S and ^{60}Co and ^{35}S have increased from 2000-2003. The ^{35}S increase is mainly associated with the introduction of COS to the gas coolant. Tritium and total alpha discharges have remained fairly constant, but total beta has increased and in 2003 was approximately 60% higher than in 1998.

Total beta and ^{35}S have increased at Heysham 2 since 1999. Other radionuclides have remained fairly constant with the lowest discharges occurring in 2000 or 2001. Despite the increases, the discharges are still considerably lower than the authorised discharge limits.

At Hinkley Point B, discharges have remained fairly constant during the period of interest, however there was a slight increase in 2001.

At Hunterston B power station discharges have decreased slightly for all radionuclides and are therefore lower in 2003 than 1998, with the exception of tritium, which remained constant during this period.
A peak in 2000 and 2002, followed by a decrease in 2001 and 2003 of radionuclide discharges from Torness can be observed. For total beta and ^{35}S, there was a drop from 1999 to 2000 from when discharges remained stable.

PWR

At Sizewell B the liquid discharges were of low radiological significance. Within the time period, the discharges for tritium were considerably higher than those for other radionuclides. In addition, the discharges of tritium increased over the reporting period. This trend can not yet be fully explained. A recent change of secondary neutron sources has coincided with a slight reduction in circuit activity, suggesting that the previous sources may, at least in part, explain the higher tritium discharges in recent years. Total activity (excluding tritium) rose from 1998 to 2000 but since then has decreased to approximately three quarters of its highest value. For other specific radionuclides, discharges were very low, and in general peaked in either 2000 or 2001, although ^{134}Cs and ^{137}Cs increased during the period, as did antimony. The increase in the discharges of these elements was associated with the presence of leaking fuel pins in the reactor.

MAGNOX

The liquid discharges from Dungeness A were generally lower in 2003 than in 1998 (e.g., the beta discharges were a factor of around 2 lower) because the cation beds were isolated as a successful experiment related to mechanisms used to balance of levels of sodium within the pond. However, during the period 1999-2002 there was a general increase in tritium and total alpha discharge levels due to improved generation. In 1999 the anion resin was replaced to facilitate the isolation of the cation beds; unfortunately the resin used was unsuitable and raised the chloride levels in the ponds causing some fuel corrosion and hence an increase in some radioisotopes within the ponds. This is indicated by the presence of some short-lived isotopes such as ^{95}Nb and ^{95}Zr (from the fuel) increasing significantly during this period.

At Oldbury power station, radionuclide discharges decreased for the first half of the reporting period. An increase in 2001 occurred, which was particularly noticeable for total beta and ^{3}H. The liquid and atmospheric discharges from Sizewell A have increased during the reporting period. The alpha and beta liquid discharges from Sizewell A increased in 2001 and have been maintained that level, such that in 2003 the beta discharge level is approximately 4 times that in 1998 and the alpha discharge 10 times that in 1998. Oldbury and Sizewell A have seen some increase in ^{137}Cs which was mainly due to Caesium from skips returning from Sellafield.

At Wylfa there were reductions in both the atmospheric and liquid discharges over the period 1999-2002, due to a prolonged period of maintenance. However, following the return to generation, levels increased to around 1998 levels (or a little higher for alpha discharges) in 2003.

4.1.9 Radiological impact of liquid discharges

AGR and PWR

The environmental monitoring programme undertaken by British Energy addresses the principal radionuclides of potential significance and the principal pathways. The radiation exposure to the marine critical group is typically <0,005 mSv which is well within the national constraint of 0,3 mSv for current arisings from individual sites. The dose estimates are sufficiently reliable and realistic to demonstrate that doses are well below the constraint.

The radiological impact on the public arises primarily from consumption of local fish and shellfish. The characteristics of the reference group have been derived from habit surveys. Details of the radiological impact are given in tables at the end of this section.

At Dungeness, Hartlepool, Heysham 1 and 2, and Hinkley Point B AGR stations, routine samples are taken of intertidal sediment, fish, and seaweed from several sites ranging from close to the discharge point up to a distance of several km. Gamma dose-rate is measured on beaches. The radionuclides that are monitored are ^{3}H, ^{60}Co, ^{65}Zn, ^{134}Cs, ^{137}Cs, ^{155}Eu and ^{241}Am. At Hartlepool and Heysham 1 and 2 routine samples are also taken of mussels and at Hartlepool, seacoal is also sampled. At Hinkley Point B routine samples are currently taken of fishing nets/equipment, and the beach strandline is monitored.

^{137}Cs in seaweed and winkles is monitored at Hunterston. The station also monitors environmental samples for a much wider range of radionuclides than those required by the regulator. Quarterly routine samples are taken of sea water, fish (as available), winkles, and seaweed. Gamma dose-rate is measured on beaches and at other locations inland. Takishades (deposition collectors) are positioned in coastal areas and indicate activity in wind blown sea spray.

Quarterly reporting at Torness includes ^{137}Cs, ^{60}Co, ^{54}Mn, ^{110m}Ag, total Beta in seaweed, winkles, nephrops, lobster, crab, intertidal sediment, gadoid and demersal fish and seawater and gross alpha for sediment and seaweed on an annual basis.

The maximum radiation dose to a member of a critical group due purely to discharges from a station was less than 0,005 mSv y^{-1} which is well within the national constraint of 0,3 mSv y^{-1}.

Sizewell A and B stations both discharge into the same immediate environment, where monitoring has been undertaken for many years. The impact of Sizewell B cannot be estimated separately from Sizewell A from environmental monitoring results alone.

The maximum radiation dose to a member of a critical group due purely to discharges from the station was less than 0,005 mSv y^{-1} which is well within the national constraint of 0,3 mSv. The above doses are measured activity concentrations which include the effects of historical discharges from this and other sites, including Sizewell A.

The environmental monitoring programme addresses the principal radionuclides of potential significance and the principal pathways. The critical group assumptions are based on surveys of local habits undertaken on behalf of the regulators. The dose estimates are sufficiently reliable and realistic to demonstrate that doses are well below the constraint. Further details are provided at the end of this Section.

MAGNOX

As with the AGRs and PWR, environmental monitoring around Magnox stations is designed to address the principal radionuclides of potential significance and the principal pathways. Where a Magnox station adjoins to an AGR or PWR, the stations share a common monitoring programme, the exceptions being at Hinkley Point A (defuelling) and Hunterston A (decommissioning) where monitoring for any short-lived radionuclides (such as ^{35}S and ^{131}I in milk) is carried out only for the neighbouring AGR. The levels of radionuclides in environmental materials around Magnox sites are generally below the lower limits of detection (see Tables 36, 44, 51 and 92). The doses to the most exposed members of the public from the marine pathway are presented in Tables 37, 45, 52 and 93[5]. A number of general features are outlined below.

The highest dose assessed for 2003 around the operating Magnox stations was that for Dungeness A at 32 μSv, mainly due to external irradiation over inter-tidal sediments. The lowest was 0,85 μSv, reported for Oldbury (which shares a common aquatic sampling programme with the nearby decommissioning site at Berkeley), mainly due to consumption of fish. There are some fluctuations but a general downward trend in doses is discernable over the reporting period.

4.1.10 The application of BAT

AGR

- The main source of radioactivity in liquid waste is the fuel storage ponds. Only small quantities of this water are discharged as waste, and such discharges are subject to filtration and ion exchange to provide an acceptable working environment for the operators and reduce radioactive discharges;
- Pond water is not directly discharged to the environment. Indirect discharges from this source consists of supernatant from filtration and sludge storage tanks;

[5] Trawsfynydd discharges into an inland lake; marine pathways are not relevant.

- The stations have been in a steady operational state for some years with negligible environmental impact;
- Measures to reduce the radiological impact of the radioactive effluent discharged are considered when these produce a significant decrease in environmental impact without disproportional financial costs;
- Systems are in place to manage discharges, in a relevant and reliable manner for an AGR station; and
- There is a requirement to apply BPM to discharges and ALARP to doses. No target level is set but where an opportunity is identified to reduce the impact of discharges this is undertaken if the effectiveness is commensurate with the cost.

The management system that controls discharges has evolved over the years and is appropriate in terms of relevance to the discharge and the plant, its reliability, available technology and regulatory requirement. Current discharges are believed to be as low as reasonably practicable, although measures to further reduce discharges remain under consideration.

PWR

At Sizewell B, systems are in place to manage discharges, and they are relevant and reliable. Discharges are filtered, and ion exchange is used when the activity of effluent is such that significant reductions can be achieved. There are no target values, instead there is a requirement to apply BPM to discharges and ALARP to doses. There is some evidence that discharges have reached a steady state after increasing through the first few operational cycles. The environmental impact is negligible. Nonetheless, measures to further reduce discharges remain under consideration.

MAGNOX

The abatement technologies used at Magnox power stations are not identical, as illustrated in Table 2. The efficiencies of each abatement technique depend on the specific use and characteristics of the waste streams at the stations and therefore any figures given are only approximate. Generally, the abatement technology falls into three categories:

- Caesium removal technology;
- Ion exchange plant;
- Particulate filtration.

CRU (Caesium Removal Unit): the Caesium removal units use a non-regenerable resin to remove Caesium. The CRUs are between 60-98% efficient depending on the time for which they are used.

SCRU (Submersible Caesium Removal Unit): the resin used is IONSIV IE-911 which has a great affinity for Caesium. This is a resin filter, which produces waste resin and is about 90% efficient. Efficiency will decrease over time and with increased pre-filter blinding.

These technologies will remove soluble ^{134}Cs and ^{137}Cs. It should be noted that the reduction of caesium in liquid effluent discharges is at the expense of producing ILW in the form of used resins from CRUs and SCRUs.

Ion Exchange Plant: This consists of a cation unit and/or an anion unit. The cation ion exchange unit removes sodium ions, and some soluble metal ions (e.g. caesium). The resin in the cation bed can be regenerated using sulphuric acid. The anion exchange unit removes sulphate, silica, chloride, and other non-metallic elements. The anion is regenerated with sodium hydroxide. The ion exchange units are efficient at removing ^{90}Sr and ^{35}S as well as caesium.

Particulate filters: There are a number of particulate filter systems used at the stations, which include:

- Fine Filters of 5 to 10 micron filters often used in conjunction with coarse filters (15 micron) to remove particulate from the waste stream.
- The 'FilTore' is used at Wylfa and with a 10 micron filter is 97,7 % efficient. This filter is also 90% efficient at removing particles of 5 microns.
- Doulton filters that are specific to Dungeness A and are ceramic filters.
- Most stations also use Sand Pressure Filters (SPFs).

Table 2. Operational Magnox Station Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
Chapelcross	2 stage filter system: fine (5-10 µm)and coarse meshes (15 µm).	HEPA filter. Charcoal Iodine absorber on gas circuit.
Dungeness A	IONSIV, CRU and anion unit on pond water treatment plant. Effluent treated with SPF, Doulton filters and CRU.	Candle filters and iodine bed (emergency use only) on blowdown stack, roll filters on shield cooling air and HEPA on contaminated ventilation systems.
Oldbury	IONSIV and SPF on pond water treatment plant. Effluent treated with SPF, oil-water separator and fine filters.	Charcoal iodine absorbers (emergency only) and sintered metal candle filters on blowdown stack and HEPA filters on contaminated ventilation systems.
Sizewell	Sand pressure filters and IONSIV on pond water treatment plant. Effluent treated with SPF.	Charcoal iodine absorbers (emergency only) and ceramic filters on blowdown stack, glass fibre for shield cooling and HEPA filters on contaminated ventilation systems.
Wylfa	No ponds. All effluent from laundry, labs, waste humidifier treated with a FilTore system for filtration and oil removal.	Charcoal iodine absorbers (emergency only) and sintered metal filters on blowdown stack and HEPA filters on contaminated ventilation systems.

The current techniques being used for the control of liquid discharges are regarded as BPM and therefore, by extension, BAT. The industry is keeping a close watch on, and contributing to, developments in liquid effluent processing and, as demonstrated in the past, is most willing to embrace proven technology.

4.1.11 Comparison with performance of similar plants world-wide

AGR

There are no directly comparable AGR installations outside the UK, but the dose impact is comparable to that from other types of power station. Discharges from the various stations have generally been typical of each other. The only exception is Hartlepool, where ^{35}S, has recently been at the higher end of the typical AGR range; this is associated with COS injection which began in 1999 but other possible factors are currently under investigation.
Reviewing alternative abatement techniques in use is a part of the Schedule 8 Authorisation requirements; this work is currently on-going.

PWR

PWRs are the most common type of reactor in the western world. However, many reactors are inland and discharge to rivers, whereas Sizewell B discharges to the marine environment. This is established practice in the UK and is acknowledged to represent BPEO. British Energy maintains a watching brief on international developments regarding PWR performance.

MAGNOX

There are no Magnox reactors now operating elsewhere in the world so no meaningful comparisons of the application of BAT or of environmental performance are possible.

Table 3. Normalised Liquid Discharges from Nuclear Reactors

	UNSCEAR Report [a]		EC Report [b]
	1990-1994	1995-1997	1995-1999
H-3 (TBq/GW h)	2,5E-3	2,2E-3	2,71E-3
All other radionuclides (GBq/GW h)	2,2E-3	9,1E-4	4,19E-4[c]

a UNSCEAR (2000), normalized to 'per hour' using 8766 hours per year; b EC (2001); c beta gamma emitters only.

The above data may be compared with UK AGR and PWR data included in Tables 49, 56, 63, 70, 76, 83, 90 and 97. The data within the UNSCEAR and EC reports may be for dissimilar reactors and the basis for calculating values is not explicit so caution must be exercised when making any comparison.

4.2 Transitional sites

4.2.1 Sources of liquid effluent

Radioactive liquid effluents arise from reactor and fuel handling operations and the principal sources for operational stations are:

- the spent fuel ponds (where irradiated fuel is stored under water before being despatched for reprocessing);

- gas processing liquors (from CO_2 gas dehumidifying) only before generation ceased;
- laundry operations; and
- reactor defuelling and decommissioning operations.

During defuelling, as with operational stations, the most radiologically significant source for liquid effluents is the spent fuel storage pond water. Great efforts are made to minimise the release of activity from the spent fuel into the pond water by controlling the pond storage conditions.

Details regarding fuel pond management, pondwater activity control, laundry and gas conditioning liquors can be found in Section 5.1.1.

4.2.2 Liquid effluent treatment and discharge

All aqueous effluents are filtered prior to discharge to remove residual particulate matter. Effluents are accumulated in delay tanks, sampled and, if their activity content is acceptably low, are discharged via the station's cooling water ensuring considerable dilution and the avoidance of high local concentrations near the discharge outfall.

4.2.3 Trends in discharge over the 1998-2003 period

A detailed breakdown of the discharges over this period is provided in Tables 21, 25 and 31. In all cases, the liquid discharges are a small fraction of the authorised limits.

Hinkley Point A and Bradwell ceased operation in 2002 and are currently being defuelled. Atmospheric discharges reduced significantly following shut down. The liquid discharges of tritium were also reduced significantly. While total beta discharges are largely unchanged, total alpha levels at Bradwell reduced over the period up to 2000 but have since increased to around twice the value reported in 1998. ^{90}Sr and ^{125}Sb discharges have also increased since 2002 while ^{137}Cs is relatively stable. The alpha and ^{90}Sr increases are normal feature of the defuelling process. At Hinkley A, the total alpha levels are a little lower in 2003 than in 1998.

Chapelcross ceased operation during 2004 but was operational throughout the reporting period. There is a general increase in the level of the liquid discharges over this period, with the most substantial increase occurring in the year 2000 (followed by reduction in 2001 and then an increase again in 2002. The increase in discharges in 2000 was the result of the pond being emptied twice in that year (normally only once). The beta discharge level in 2003 is approximately four times that in 1998 while the corresponding difference in alpha discharges increased by a factor of 2.

4.2.4 Radiological impact of liquid discharges

The levels of radionuclides in environmental materials around these sites are generally below the lower limits of detection. The resultant doses to the most exposed members of the public from the marine pathway are presented in detail in Tables 23, 27, and 79.

Doses around Bradwell power station peaked to a level of 45 μSv in 1999. The estimated dose for 2003 is 20 μSv and at Hinkley A power station the critical group dose from discharges to sea in 2003 was 19 μSv as a result of external exposure and consumption of fish.

4.2.5 The application of BAT

Further detail of abatement techniques used at Magnox power stations are provided above in Section 5.1.5.

Table 4. Abatement Techniques at Transitional Magnox Stations

Station	Liquid Abatement	Aerial Abatement
Bradwell	Sand pressure filter (SPF), caesium removal unit (CRU), IONSIV on pond water treatment plant. Effluent treated with SPF and CRU.	Iodine beds (redundant- now defuelling) and candle filters on blowdown stack, roll filter for shield cooling air and HEPA filters on contaminated ventilation systems.
Hinkley Point A	IONSIV, SPF, anion and cation ion exchange units on pond water treatment plant. Effluent treated with SPF and CRU.	Charcoal iodine absorbers (redundant now defuelling) and sintered ceramic candle assemblies with quartz fibre candles on blowdown stack, fabric roll filter on shield cooling air, HEPA filters on contaminated ventilation systems.

4.2.6 Comparison with performance of similar plants world-wide

There are no reactors of this type now operating elsewhere in the world so no meaningful comparisons of the application of BAT or of environmental performance are possible. However, in accordance with revised EA

authorisations, the operator is required to review alternative abatement techniques as an Authorisation requirement.

4.3 Decommissioning Power Stations

Berkeley, Hunterston A and Trawsfynydd power stations all began decommissioning before 1998.

4.3.1 Sources of liquid effluent

Radioactive liquid effluents arise from reactor and fuel handling operations and the principal sources for operational stations are:

- laundry operations; and
- reactor defuelling and decommissioning operations.

At decommissioning stations, site dryer liquors and spent fuel are no longer a source of activity. Any additional effluent that is produced as a result of reactor defuelling and decommissioning activities is considered within a BPEO.

4.3.2 Liquid effluent treatment and discharge

All aqueous effluents are filtered prior to discharge to remove residual particulate matter. Effluents are accumulated in delay tanks, sampled and, if their activity content is acceptably low, are discharged via the station's cooling water ensuring considerable dilution and the avoidance of high local concentrations near the discharge outfall.

4.3.3 Trends in discharge over the 1999-2003 period

A detailed breakdown of the discharges over this period is provided in Tables 17, 33 and 41. In all cases, the liquid discharges are a small fraction of the authorised limits. Some general features of the liquid discharge profiles may be identified. Those stations that ceased operation before this reporting period (Berkeley, Hunterston A and Trawsfynydd) exhibited significant reductions in their discharges over this period.

4.3.4 Radiological impact of liquid discharges

The levels of radionuclides in environmental materials around these sites are generally below the lower limits of detection. The resultant doses to the most exposed members of the public from the marine pathway are presented in detail in Tables 19 and 86. Trawsfynydd discharges into an inland lake therefore the marine pathways are not relevant at this site.

Doses to the most exposed groups around Berkeley and Hunterston A reduced over the reporting period, with some fluctuation. The estimated dose around Berkeley for 2003 is 0,85 μSv due to consumption of fish while in the vicinity of Hunterston A it was around 29 μSv due to external exposure.

4.3.5 The application of BAT

Further details of the abatement techniques employed can be found in Section 5.1.5.

Table 5. Decommissioning Magnox Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
Berkeley	Sand pressure filters (10 micron)	HEPA filters on contaminated ventilation systems, gas scrubber on incinerator
Hunterston A	SPF, ion-exchange removed. Awaiting new IONSIV.	HEPA (scrubber now defunct). No shield cooling or iodine filters
Trawsfynydd	Sand pressure filters and ion exchange units	HEPA filters on contaminated ventilation systems

The discharge control measures applied during decommissioning are the same as those applied during operations. Where possible discharges will be from the same discharge points, using the same abatement equipment. However as plant and ponds are decommissioned and removed discharges will decrease and abatement equipment will be removed as it becomes obsolete. Any new facilities constructed (such as intermediate level waste stores) are likely to use similar abatement technology as is currently employed. However, the BPEO process will be employed at the design stage to determine the best way forward.

4.3.6 Comparison with performance of similar plants world-wide

As for transitional and operational sites, no meaningful comparisons of the application of BAT or of environmental performance are possible. However, in accordance with revised EA authorisations, the operator is required to review alternative abatement techniques as an Authorisation requirement.

4.4 References

UNSCEAR (2000). Sources and Effects of Ionizing Radiation. Report to the General Assembly. United Nations Scientific Committee on the Effects of Atomic Radiation.

EC (2001). Radioactive effluents from nuclear power stations and nuclear fuel reprocessing plants in the European Union, 1995 – 1999. European Commission, Luxembourg 2001.

5. Fuel reprocessing

The Sellafield site is the largest nuclear complex in the UK and undertakes the reprocessing of all fuel connected with the UK nuclear electricity generation programme and spent oxide fuel from other countries. The site is currently owned and operated by British Nuclear Fuels and is certificated under ISO14001. The NDA will take over responsibility for this site from 1 April 2005.

5.1 Sellafield

During the reporting period, the main process activities on this site were:

- Storage of irradiated Magnox, AGR and LWR fuels in water-filled ponds;
- Reprocessing of Magnox and oxide fuels;
- Recovered Plutonium and Uranium storage;
- Mixed oxide fuel fabrication;
- Processing and storage of HLW and ILW;
- Processing of LLW for disposal to Drigg;
- Decommissioning of redundant facilities and treatment/conditioning of backlogs of liquid and solid wastes;
- Operation of Calder Hall nuclear power plant (which ceased operation in 2003).

Reprocessing takes the form of nitric acid dissolution of spent fuel with subsequent chemical separation of useful species. The liquid wastes arising from this and other processes contain the complete range of fission products, activation products and actinides and, in consequence, radioactive waste management in all its forms is a major activity on this site.

Since the previous submission, the Thermal Oxide Reprocessing Plant (THORP) and the Magnox Reprocessing Plant (MRP) have continued to operate. A new mixed oxide fuel fabrication facility, the Sellafield MOX Plant (SMP) commenced active commissioning in 2001. The Calder Hall Magnox reactors were shut down in 2003 and defuelling and decommissioning will commence in 2005.

More recently, with the conception of the Nuclear Decommissioning Authority, the site's primary function has changed to clean up and decommissioning of its nuclear facilities. Life Cycle Base Line (LCBL) programmes and Near Term Work Plans (NTWP) are being developed which will focus on an enhanced clean up programme. The Magnox reprocessing programme is scheduled to be complete by 2012, with the future of oxide reprocessing beyond about 2010 (through THORP) dependent on the receipt and approval, by Government, of new orders. Any proposals for new contracts would be reviewed to take account of, inter alia, their consistency with the UK's environmental objectives and international obligations.

A new multimedia discharge authorisation was introduced in October 2004, following a detailed review of the operations on the site up to the year 2008. This single authorisation replaces the 6 separate authorisations previously in force. In many areas limits have been substantially reduced and there are no increases in discharge limits. All authorisations are subject to review, and the Sellafield enhanced clean up programme will necessitate a further consideration of the suitability of the discharge authorisation. An increase in the discharge of some radionuclides is possible in the interests of achieving the maximum risk reduction on site, while continuing to be subject to the strict application of BPEO and BPM. Any increases to support clean-up operations will be set in the context of major reductions in discharges when reprocessing ends.

5.1.1 Sources of liquid effluent

Radioactive liquid effluents arise from fuel reprocessing and storage operations, Calder Hall, on-site decommissioning operations, and the laboratories of the UKAEA. Liquors from the reprocessing plant which contain the highest levels of activity are routed directly to storage pending incorporation into solid glass form in the Waste Vitrification Plant; they are not therefore discharged from the site (BNFL, 2003).

By far the largest contributors to waste arisings are the reprocessing operations. Most of the activity is in the high-level liquid waste stream but some medium active liquors are also produced during these operations which are separated into a number of waste streams depending upon their composition and activity.

Effluents from Magnox reprocessing operations are concentrated and collected in storage tanks on site and are commonly referred to as Medium Active Concentrate (MAC). This waste stream is the primary source of a number of radionuclides including ^{99}Tc and ^{90}Sr. The way in which this waste stream is treated prior to discharge has been modified, to reduce the discharge of ^{99}Tc, as will be discussed in Section 6.1.2.

Liquid wastes produced from solvent washing operations in the Magnox and THORP reprocessing plants are another source of liquid effluent. These are known collectively as Salt Evaporator Concentrate (SEC). Liquid effluents also result from purges of liquids from ponds built to store irradiated Magnox and Oxide fuel prior to reprocessing and for the treatment of spent solvent used in reprocessing operations. These waste streams are routed through a range of treatment plants, depending on their composition and activity, as outlined in the following section. Any remaining effluents which may contain trace levels of activity (e.g. rainwater run-off, cooling water, borehole water, and laundry waste and steam condensates) are collected, sampled and pumped to sea via the marine pipeline. The principal radioactive liquid effluents from the Sellafield site are discharged via pipelines which extend some two kilometres off the coast adjacent to the site.

A range of radionuclides are produced, and the sources of some of the most significant radionuclides appearing in liquid effluents are outlined below:

Tritium: Approximately 60% of the tritium disposed of at Sellafield is discharged to sea; almost 90% of that contained in Magnox fuel is discharged to sea, while around half of that present in oxide fuel from THORP is discharged to sea.

Carbon-14: Magnox reprocessing represents the most significant source of ^{14}C discharges to air and sea. The majority of the discharge to sea is due to the operation of caustic scrubbers to remove the radionuclide from atmospheric discharge.

Cobalt-60: The main source of ^{60}Co at Sellafield arises from the storage and handling of BWR and PWR fuel in the THORP fuel pond. Insoluble corrosion products, including ^{60}Co are released into the fuel pond water during fuel handling operations.

Strontium-90: Over 99% of the ^{90}Sr arising from fuel reprocessing is removed in the highly active liquid waste stream. The main source of ^{90}Sr discharged to sea is from the treatment of Medium Active Concentrate (MAC) arising from Magnox reprocessing from EARP. Other sources include the Segregated Effluent Treatment Plant (SETP) and arisings from the redundant facilities in the Magnox Separation Area.

Ruthenium-106: The majority of ^{106}Ru present in both Magnox and oxide fuels is separated out into the highly active liquid waste stream and vitrified. ^{106}Ru is also found in medium active waste streams.

Iodine-129/131: Discharges to sea arise from the treatment, by caustic scrubbing, of the ventilation air stream associated with spent fuel dissolution in the two reprocessing plants. THORP is the main source (around 80% of ^{129}I discharges to sea).

Caesium-137: The majority if ^{137}Cs arising are the result of Magnox reprocessing and miscellaneous historical arisings. Over 99% of the ^{137}Cs arising during the reprocessing of both Magnox and oxide fuel is removed in the high and medium active liquid waste streams and vitrified or encapsulated accordingly. It is also present in effluents from fuel pond purges and is treated, primarily, in the Site Ion eXchange Effluent Plant (SIXEP).

Plutonium: More than 99% of the plutonium in spent fuel is recovered during reprocessing and over 99,9% of the remaining proportion in waste streams is trapped in either a vitrified or encapsulated form. The main source of the small residual liquid discharges of plutonium isotopes and ^{241}Am is from the SETP.

5.1.2 Liquid effluent treatment and abatement

The major liquid effluent treatment facilities operating on the site are the Salt Evaporator designed to condition and concentrate waste streams for interim decay storage prior to treatment in the Enhanced

Actinide Removal Plant (EARP); the Site Ion Exchange Effluent Treatment Plant (SIXEP) designed to reduce fission product discharges; and EARP, which has the primary purpose of reducing the levels of plutonium and other actinides in liquid discharges. The commissioning of these plants pre-dates 1998, but in view of the importance of these plants in reducing the level of liquid effluents from Sellafield, they are introduced briefly below.

The Salt Evaporator enables concentration of salt-bearing liquors from Magnox reprocessing operations. These concentrates are stored to allow for decay and then directed for further treatment at the other plants described here. This process has resulted in reduced discharges of plutonium and in various short-lived fission products such as ^{95}Zr, ^{95}Nb and ^{106}Ru.

SIXEP consists of an array of regenerable sand bed pressure filters, pH reduction using counter flow contact with CO_2, and ion exchange columns containing an alumino-silicate zeolite, clinoptilolite, which is effective in removing caesium and strontium isotopes. This plant has been designed to take purge water from the Magnox fuel storage and decanning facilities, Oxide fuel storage ponds AGR fuel storage and dismantling. The average decontamination factor for caesium is ~3000.

EARP is particularly aimed at removal of alpha activity but a number of beta-emitting radionuclides are also efficiently removed. The process increases the pH of effluent liquors so that the iron present is precipitated in the form of ferric floc. The alpha-emitters, plutonium and americium, together with some beta-emitters co-precipitate with the ferric floc. Additional removal of beta-emitters, particularly caesium, is also achieved by the use of an ion exchanger sodium nickel hexacyanoferrate. The solid precipitate is separated from the very low active liquor by ultrafiltration and these are encapsulated in cement in the Waste Packaging and Encapsulation Plant (WPEP). The low active liquor from the ultrafilters is collected, sampled and analysed prior to discharge to sea. Decontamination factors are >1000 for alpha-activity and >10 for beta activity. The exception is ^{99}Tc, which is not removed by this process. This radionuclide is contained in MAC and liquid discharges of ^{99}Tc to the Irish Sea increased markedly after 1994 as a consequence of commencing EARP treatment of a backlog of MAC accumulated as a result of Magnox reprocessing since 1981. A detailed programme of research and development was initiated to determine the best practicable means for reducing these discharges, the results of which are outlined below.

TECHNETIUM-99

In February 2000 the EA initiated a full re-examination of authorisations for the disposal of radioactive wastes from Sellafield which included a 'fast-track' consideration of its future regulation of ^{99}Tc discharges to the Irish Sea. The review was the most comprehensive and in-depth review ever carried out with respect to a single radionuclide. The review covered aspects such as abatement options, potential process changes, impact assessment, storage options and costs. The UK concludes that it has, thereby, met its commitments, in relation to ^{99}Tc, made at the 1998 OSPAR meeting in Sintra.

Following the review, which included wide public consultation on a set of proposals and then further assessment, the EA published its proposed decision in September 2001 and subsequently placed requirements on BNFL to pursue two approaches to reduce ^{99}Tc discharges:

1. To use the existing vitrification process (used to treat highly radioactive liquid waste from reprocessing) to treat future arisings of medium active concentrate (MAC) from Magnox reprocessing. The treatment of MAC, a radioactive liquid waste, gives rise to the largest source of ^{99}Tc discharge to sea. Vitrification is a way of incorporating liquid radioactive waste into glass blocks in stainless steel drums, which are then stored on site in a purpose built store. This would end the discharge of ^{99}Tc from future arisings of MAC. This is known as "MAC diversion" as it involves the diversion of MAC into a treatment route not previously used for this type of waste.
2. The continuation of research and development work into the potential to use a new precipitant known as TPP (tetraphenylphosphonium bromide) to remove ^{99}Tc from MAC, that has been produced in the past and is currently stored in tanks, when it is treated in the Enhanced Actinide Removal Plant (EARP). This older MAC already in store is incompatible with the vitrification process described above due to its higher salts content.

BNFL implemented the first of the above requirements (MAC diversion) from July 2003. However, ^{99}Tc discharges to sea will not reduce until the 'backlog' of stored MAC had been treated (planned to be completed by the end of 2006) or until the use of TPP were successfully implemented as a result of the EA's second requirement.

Following close collaborative work between BNFL, the EA, the NII and Nirex, a trial of TPP in EARP was carried out in October-November 2003. The trial was a success and from April 2004 the new technique has been in use at EARP and over 95% of the ^{99}Tc contained within the stored MAC is now transferred into a solid waste form for encapsulation. This has led to an overall reduction of about 90% in ^{99}Tc discharges from

the site. There are other, more minor, sources of ^{99}Tc discharge from the site which will not be reduced by the use of TPP.

5.1.3 Other treatment plants and projects

Some of the operations recently introduced to treat waste arisings that result in liquid effluents are outlined below:

- *Solvent Treatment Plant*. STP destroys the solvents currently stored on site, producing an aqueous residue containing the bulk of the radioactivity. This is then sent to EARP for further treatment. STP commenced active commissioning in 2000.
- *Floc Retrieval*. Six sludge tanks have been used for the settling and storage of alumino-ferric flocs produced from effluent treatment operations up to 1987. These sludges will be retrieved and treated in the EARP concentrates plant prior to encapsulation. Commissioning is planned to commence during 2005.
- *Segregated Effluent Treatment Plant (SETP).* The SETP treats low-level effluent streams which are not directed to EARP. Treatment comprises neutralisation of acidic effluent streams before mixing with alkaline effluent streams and removal of particulates using a hydrocyclone.

5.1.4 Treatment plants specific to THORP

In THORP, waste arisings are minimised at source and waste streams are treated according to their activity levels. Medium-active salt streams are sent to the Salt Evaporator and then treated in the EARP concentrates process. Medium-active salt-free liquors are concentrated in a plant within THORP and transferred with high activity streams to the WVP for vitrification; with the result that the contribution of THORP to total site discharges is generally lower than for Magnox reprocessing. Flushings from fuel containers are sent to EARP for treatment, and the remaining low-level effluent streams are sent to SETP. A caustic scrubber is used to remove radio-iodine and ^{14}C from the fuel dissolver off-gases; ^{14}C is precipitated out using barium carbonate, the solid waste arising being encapsulated in cement. The treated liquor is discharged directly to the sea following sampling and analysis, removing the need for acidification of the liquors and release to atmosphere of the radio-iodine (thus keeping to a minimum the environmental impact). Spent fuel storage pond water is monitored and discharged to sea following filtration.

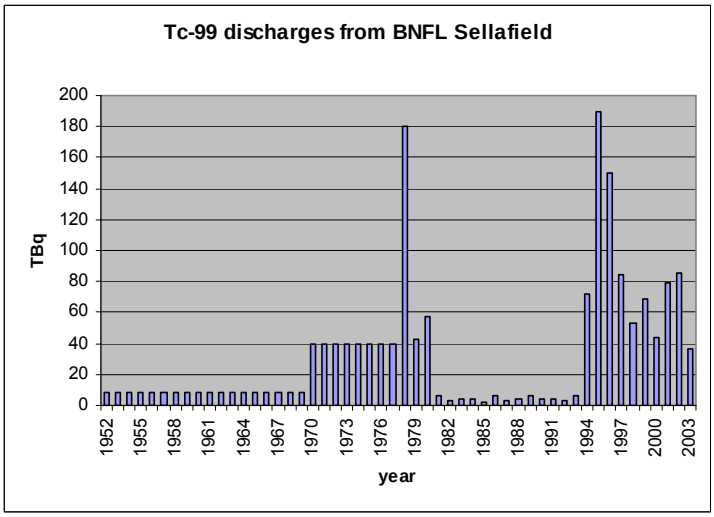
5.1.5 Trends in discharge over the 1998-2003 period

As a consequence of the recent major review of Sellafield authorisations, no discharge limits were increased and significant decreases were possible for most of the individual radionuclide limits.

Discharges of ^{99}Tc and ^{90}Sr increased in 2001 due to the processing of larger quantities of medium active concentrates. There were also increases in discharges of ^{90}Sr, ^{125}Sb, ^{137}Cs and actinides via SIXEP from increased pond water activity concentrations in the Fuel Handling Plant resulting from an increased reprocessing throughput and fuel cladding problems in some containers that led to a loss of gas seal between the water in the containers and in the pond. A recovery programme was instituted during 2002 but elevated discharges continued during 2003. The increased discharges of ‘total beta’ and ‘total alpha’ reflect the increases of individual radionuclides (BNFL, 2002). BNFL has a strategy to reduce alpha discharges through a strategy involving the reprocessing of the long cooled legacy Magnox fuel to an agreed operating plan.

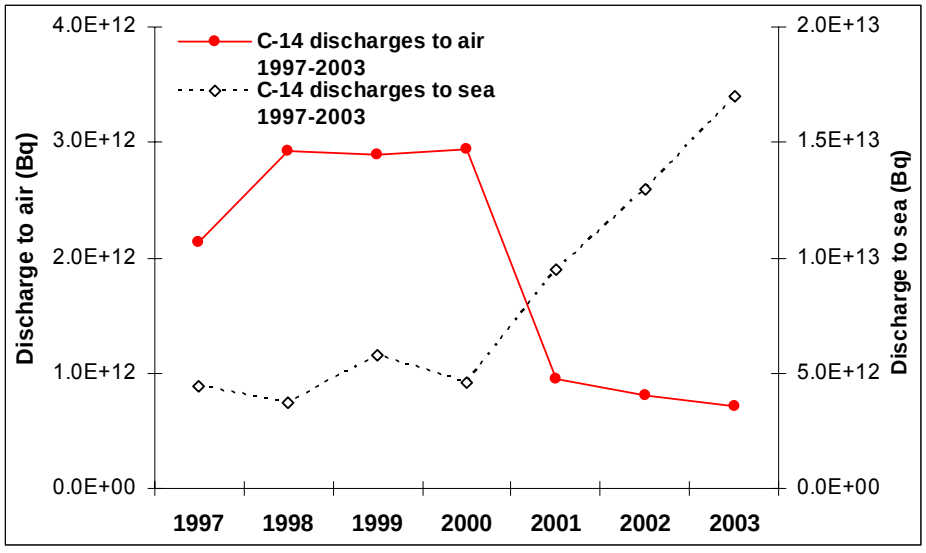
The variation in liquid discharges of ^{99}Tc resulting from the modifications in treatment outlined above, are illustrated in Figure 2 below. The discharge of ^{99}Tc in 2003 was the lowest for 10 years. Progress has been maintained and the discharges during 2004, if extrapolated, may possibly be as low as 10 TBq.

Figure 2. ^{99}Tc Discharges to Sea



There have been other changes in BNFL's site discharge strategy that have affected the overall pattern of discharges. For example, an investigation of the levels of volatilised ^{14}C produced by Highly Active Liquor evaporation prior to vitrification, led to the installation, in 2000, of a caustic scrubber to the ventilation system, and the re-routing of this stream to a high stack. This has significantly reduced the overall dose impact from discharges of ^{14}C from the site, but the liquid discharges have increased as a result, as demonstrated in Figure 3. Overall, however, this represents an effective application of BPM and BPEO, as the impact per unit discharge is lower in the marine environment relative to discharges to atmosphere. An additional component influencing discharge levels is the fuel throughput for reprocessing, which has increased over the reporting period.

Figure 3. ^{14}C Discharges to Sea and Air Following Introduction of Caustic Scrubbers



5.1.6 Radiological impact of liquid discharges

The marine environmental monitoring programme around Sellafield covers a variety of species in a number of locations. The Sellafield monitoring programme is reviewed frequently and the new authorisation requires an annual review. It was last reviewed in 2003. In summary the main changes were:

- Agreement that there will be an investigation (non-routine) element to the programme in 2004, and subsequent years, that will tackle issues and potentially feed into the routine programme. Issues included within the programme for 2004 are sampling and analysis of all surface water outlets leaving Sellafield, uranium monitoring in air, a significant groundwater monitoring programme;

- A change to the use of TLDs, rather than GM dose meters, for dose rate measurements in terrestrial environment;
- The removal of ^{35}S monitoring (due to the closure of the Calder Hall reactors);
- Aerial deposition to be monitored at more sites but sampling frequency and analysis will be aligned to the Euratom monitoring programme; and
- Installation of new modern high volume air samplers to replace all existing on and offsite samplers.

Concentrations of radioactivity in seafood in 2002 were generally similar to those in previous years. The average concentration of ^{99}Tc in crustaceans, which had been in decline from the peak levels observed in 1997, increased in 2002 due to the increased technetium discharge in 2002 compared to those in the period 1998-2001. The seaweed *Fucus vesiculosus* accumulates ^{99}Tc and is particularly sensitive to fluctuations in its concentration in seawater. Concentrations in 2002 at some locations were somewhat higher than in 2001. These concentrations are expected to decrease in line with the reducing discharges of ^{99}Tc, 2004 and beyond.

Concentrations of radioactivity in samples of seawater from the Sellafield area were generally similar to those of recent years except for tritium, which reflected the increased discharge. Concentrations of radioactivity in sediments were also similar to those of recent years.

The main pathways that contribute to critical group dose are internal exposure from the consumption of seafoods (particularly fish and shellfish) and of local agricultural produce (particularly milk), external gamma radiation from exposed intertidal sediments, particularly the fine silts and mud of estuaries and harbours and inhalation of, and exposure to, airborne radioactivity. Therefore the Sellafield 'marine critical group' is identified (in the RIFE report and elsewhere) as high rate consumers of fish and shellfish who also spend time on local beaches. The predicted annual doses to such a group in 2001 and 2002 were 150 and 210 μSv respectively. Other reference groups considered include houseboat dwellers on the Ribble river in Lancashire and stakenet fishermen in southwest Scotland.

Data on doses to biota resulting from discharges of ionising radiation from the BNFL Sellafield site have been determined for discharges occurring in 1998 and 2002 using the Copplestone *et al*. (2001) methodology. Dose calculations are based on monitoring data for marine biota sampled along the Cumbrian coastline.

5.1.7 The Application of BAT

The recent detailed review of authorisations for the Sellafield site included a complete site review of the application of BPM and BPEO for the principal waste streams and radionuclides. The options for treatment and abatement of the liquid and atmospheric discharge routes were considered. For the purposes of this report, the focus is on the review of the liquid discharges and the technologies considered in this review for the main radionuclides are outlined below:

1. Technetium-99: An accelerated review of liquid discharges and abatement options for ^{99}Tc was undertaken during the year 2000, as outlined above. The treatment of the backlog of MAC is likely to continue until 2006, after which time the diversion of MAC will also have the effect of reducing the levels of ^{90}Sr, ^{106}Ru and ^{137}Cs discharged to sea.
2. Tritium: Application of BPEO and plant optimisation in THORP has resulted in recovery of ^{3}H from airborne effluents to the liquid waste stream by dehumidification. This potentially significant reduction was offset by the increase in aerial arisings due to the planned reprocessing of higher burn-up fuel in THORP. The increase in liquid discharges was marginal, however, due to the majority of tritium discharges being via the liquid route. The possibility of immobilization in solid waste was considered as a potential route to reduce liquid discharges of tritium. This could result in large amounts of solid waste that would require storage and disposal. The volume of waste could be reduced by enrichment. Four possible enrichment techniques were identified, all of which would require substantial research and development work: distillation of water; cryogenic distillation; electrolysis and hydrogen/water chemical exchange. The EA accepted BNFL's assessment that the cost of implementing tritium abatement on the liquid waste streams would be grossly disproportionate to the benefit implied, and that the current practices represent the BPEO.
3. ^{14}C: This is removed from the atmospheric waste stream at THORP by caustic scrubbers, followed by treatment and encapsulation in cement. The installation of an ultrafiltration stage was considered but the conclusion was that the disbenefits of providing a similar plant for Magnox reprocessing would outweigh the potential radiological benefits.

4. Cobalt-60: A number of abatement options were considered including chemical dissolution and precipitation or electrolysis and re-routing THORP feed pond purge water to SIXEP before discharge to sea. The most promising abatement option was determined to be the pre-coating of the existing filtration system with an ion exchange material which would remove ^{60}Co-bearing material for encapsulation in cement, when enhanced levels of ^{60}Co occur in the THORP fuel ponds. Plant trials have been undertaken but were not successful in removing ^{60}Co from the containerised water in the THORP ponds, and capturing it in an ion exchange medium. Discharges of ^{60}Co remain low, however, and BPM continues to be applied.
5. Strontium-90: The abatement options considered included re-routing storage pond purges to SIXEP and the diversion of MAC arisings to vitrification. The latter was the option chosen to reduce liquid discharges of ^{99}Tc. With this change (and the transferral of B29 legacy fuel pond purge water to SIXEP where practicable), the EA agreed with BNFL that the current practice is consistent with BPEO.
6. Ruthenium-106: In THORP, the active waste stream, containing this radionuclide, is evaporated, combined with the highly active waste stream and vitrified. Arisings from Magnox reprocessing are evaporated, stored for decay, and then treated in EARP where radionuclides are removed by precipitation with iron salts. The precipitate is encapsulated in cement. This practice is considered to represent BPEO.
7. Iodine-129/Iodine-131: Alternative abatement techniques were considered that would transfer iodine from the gaseous to the solid waste stream, including precipitation of iodine e.g. as a silver salt and absorption on a solid matrix. The current procedure of disposing of ^{129}I to sea is currently considered to be consistent with BPEO. Plant trials of the use of iodic acid to the fuel dissolution process in THORP were monitored by the EA. Although these have been inconclusive, their performance (together with the trials outlined for ^{60}Co) serve to demonstrate that there is on-going commitment and review of BPM.
8. Caesium-137: A number of abatement options that would reduce liquid discharges further were considered, including: further treatment of Magnox fuel pond purge water; the diversion of THORP fuel pond water to SIXEP and alternative ion exchange methods for THORP fuel pond water. The diversion of MAC to vitrification, implemented to reduce discharges of ^{99}Tc, will also reduce discharges of ^{137}Cs. A small proportion of ^{137}Cs discharges to sea arises from B27 fuel storage pond from which liquid effluent is discharged to sea via SETP without further abatement. In the revised authorisation, the Environment Agency requires B27 pond purge water to be transferred to SIXEP for treatment where reasonably practicable.
9. Plutonium isotopes and americium-241: The SETP was designed to deal with high volume/low activity acidic waste streams that are unsuitable for further abatement. The introduction of EARP in 1994 was the culmination of a programme of work to provide a means for removing actinides from various waste streams. It is highly efficient and there is little scope for further improvement, thus, current practices are considered to be BPEO/BPM for these radionuclides.

The following facility will be introduced over the next few years:

A plant to encapsulate retrieved waste from the Dry Storage Silos, Magnox Storage and Decanner facility, Pile Storage Pond and Decanner facility and oversize material from the Magnox Storage Silos either direct or via the Sellafield Drypack Plant (SDP). This plant is scheduled to commence operation later in this decade, subject to the current review into the management of historic liabilities at Sellafield.

To summarise, from a detailed review of available technologies, as part of the recent authorisation review, it was concluded that present arrangements were either consistent with BPEO and BPM, or where improvements in practice would be desirable, specific conditions and requirements were included in the authorisation. Thus, BPEO for disposing of the principal liquid waste streams at Sellafield is considered to be:

- Vitrification of highly active liquid waste;
- Diversion of future MAC arisings to vitrification;
- Removal of radionuclides from SEC and MAC in EARP and subsequent encapsulation in cement;
- Current practice for treating low active waste streams in EARP, SETP and SIXEP;
- Treatment of organic solvent in the Solvent Treatment Plant;
- Incineration of waste lubricating oil.

In addition to BAT detailed above, the new authorisation, effective from 1 October 2004, includes a requirement in Schedule 9 for BNFL to continue to develop BPM for major operations, review current disposal routes to ensure BPEO, and consider a number of other improvement requirements (Environment Agency, 2002).

5.1.8 Comparison with performance of similar plants world-wide

Due to the complex nature of operations and decommissioning activities on the Sellafield site it is difficult to draw direct comparisons with other sites. The reprocessing operations at Sellafield, however, are often considered alongside those of Cap La Hague in France.

The recent authorisation review process for Sellafield included a comparison of the discharge abatement techniques used at Sellafield and the COGEMA Cap La Hague reprocessing plant. COGEMA operates two spent oxide fuel reprocessing plants at this site which have a total fuel throughput capacity of 1700 tonnes (te)/year. In comparison, the Magnox Reprocessing Plant (1750 te/year) and THORP (1200 te/year) have a total design fuel throughput capacity of 2950 te/year.

Fuel reprocessing at La Hague involves oxide fuels only, whereas at Sellafield, both oxide and Magnox fuels are reprocessed. In order to make comparison between the efficiency of processes and abatement measures at the two sites it would be most appropriate to compare discharges from THORP and La Hague, based on unit throughout of fuel. However, liquid waste streams from THORP are fed, together with those from Magnox reprocessing, to common treatment plants (i.e. EARP and SETP). Monitoring carried out in THORP before the waste streams are transferred to treatment plants is limited to total-alpha and total-beta, undertaken solely to ensure compliance with standards for receipt by the treatment plants. It is therefore not possible make direct comparisons between liquid discharges from THORP and La Hague.

Nonetheless, in terms of process, the EA review of the Sellafield authorisation identified the BPEO for disposing of principal liquid waste streams at Sellafield to be vitrification for highly active liquid waste. This is consistent with the management of highly active liquid waste at La Hague.

Schedule 9 of the 1 October 2004 Sellafield Authorisation requires BNFL to submit a report on national and international developments in best practice for minimising waste disposals and a strategy for achieving reductions in discharges. BNFL will therefore consider other plants worldwide during this process.

5.2 The low Level Waste Disposal Site at Drigg, Cumbria

The Drigg site (subsequently referred to here as Drigg) is a low-level solid radioactive waste disposal facility located around 6 km south-east of Sellafield. The majority of the material disposed arises at Sellafield but the site is a national facility for low-level wastes from other nuclear sites in the UK and from non-nuclear establishments such as hospitals, universities etc.

In the early years of waste disposal at Drigg, wastes were 'landfilled', i.e. tipped into open trenches before being covered with a layer of earth. The last trench was filled in March 1995. All trenches have now been covered with an impermeable membrane and landscaped (a final site cap will be installed as part of the eventual site closure).

Since 1995, waste materials are, wherever possible, compacted and placed in containers before transfer to Drigg; for the majority of wastes, this is done at Sellafield. Non-compactable wastes are placed directly into the disposal containers, and immobilised by the addition of grout in the Drigg Grouting Facility. All wastes, in their containers, are placed in an engineered concrete vault.

Table 6. Volume of waste disposed to Drigg 1998-2003

	1998	1999	2000	2001	2002	2003
Volume of radioactive waste disposed (m^3)	12 600	8 000	8 400	6 100	10 800	11 400

5.2.1 Sources of liquid effluent

The principal source of liquid effluent is leachates from the trenches predominantly from earlier less contained waste disposal practices. These arise from rainwater ingress and groundwater movement, and could potentially migrate from the waste burial site. Leachate is now collected in holding tanks and is monitored and discharged to sea rather than discharged into the Drigg Stream.

5.2.2 Liquid effluent treatment and abatement

Following monitoring (since 1991) all trench leachates and surface waters are discharged to sea via a pipeline. The site authorisation places regulatory controls and limits on the pipeline discharges. Discharges

are considerably lower than the authorized limits. The effluent is regularly sampled and analysed. Separate concentration limits are placed on the Drigg stream, which flows off-site. These are: total-alpha 90 Bq l^{-1}, total-beta 1200 Bq l^{-1} and 600 000 Bq l^{-1}.

5.2.3 Trends in discharge over the 1998-2003 period

Discharges to the marine pipeline from Drigg have been consistently low throughout the reporting period but were slightly lower in 2002 than 1998, generally only seasonal variations are discernable. Only total alpha, total beta and tritium are monitored.

5.2.4 Radiological impact of liquid discharges

Discharges of radioactivity from Drigg are very small compared with those from Sellafield. Consequently, the radioactivity in the environment resulting from Drigg is virtually indistinguishable from the Sellafield 'background' and no specific critical groups for marine pathways associated with discharges from Drigg have been identified. Environmental monitoring and sampling does occur in the vicinity of Drigg, on the beach and in the Irish Sea, however, the results reflect discharges from Sellafield. It is possible to estimate their impact from modelling, and this has defined a hypothetical critical group as local seafood consumers who receive doses of the order of 0,01μSv y^{-1} as a result of marine pipeline discharges in 1998 (BNFL, 2002). This estimate is also likely to be relevant to the reporting period.

5.2.5 The application of BAT

Placing impermeable membrane over the trenches and changing disposal practice has had a measurable effect and represents BPM. Future developments in low-level waste disposal site best practice are kept under review, including improvements in vault design.

5.2.6 Comparison with performance of similar plants world-wide

Current disposal of LLW at Drigg is in near surface concrete vaults. This type of disposal also takes place at Centre de l'Aube, France and the Intrusion Resilient Underground Structure (IRUS), Canada. However, due to different Government policies including the classification of waste, any discharges from the sites are not from directly comparable sources.

5.3 Calder Hall

Liquid effluent discharges from the Calder Hall Magnox nuclear power station are considered within the overall Sellafield site authorisation. The impact of discharges from Calder Hall is indistinguishable from other discharge streams. Calder Hall ceased operating in 2002.

Spent fuel from Calder Hall is stored in the main Sellafield receipt and storage ponds. Discharge and abatement technologies described in Sections 6.1.1 and 6.1.2 are therefore inclusive of contributions from Calder Hall.

5.4 References

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6. Research and Development

There are four sites in the UK that are former nuclear research centres (Harwell, Winfrith, Windscale and Dounreay) they are all managed by the United Kingdom Atomic Energy Authority (UKAEA). On some of the sites, there are tenants and neighbouring establishments e.g. Vulcan at Dounreay, the National Radiological Protection Board (NRPB) and the Rutherford Appleton Laboratory (RAL) at Harwell that also produce liquid wastes. Such wastes are transferred to UKAEA systems and are included in the UKAEA discharge data. During the reporting period the UKAEA facilities on the sites were either:

- At various stages of decommissioning, or
- An operational facility supporting commercial programmes or the decommissioning of other facilities.

UKAEA applies BPM at all sites by taking steps to ensure that the effluent management systems and controls are implemented effectively. This includes:

- Acceptance criteria: UKAEA requires consignors of liquid effluents to minimise arisings and to control their consignment for disposal via the active drainage system. This is achieved through compliance with the requirements of site instructions which set out the acceptance conditions for disposal of radioactive and non-radioactive liquid effluents, including the specification of limits on total activity of radionuclides in effluent streams.
- Audits/checks for compliance: The mandatory procedures are enforced through audits/checks of the system to ensure that compliance by consignors, including tenants, is being achieved.
- Maintenance and inspection: Components of the active effluent discharge systems e.g. tanks (where appropriate), drains, discharge pipelines and associated monitoring equipment are subject to programmes of regular inspection and maintenance, and improvements made where necessary.
- Minimising arisings at source: At a local level the managers of facilities in which liquid radioactive wastes are produced are responsible for ensuring that liquid waste arisings are kept to a minimum through appropriate implementation of local working practices and instructions, and for undertaking regular management review of working practices.

There are a number of key elements in minimising effluent arisings at source, including design of operations and implementation of processes. Ensuring that operations are well controlled is one of the best ways of minimising waste arisings. Where practicable, operations which could give rise to liquid wastes are avoided by using "dry" techniques e.g. dry swabbing. Waste liquors generated in laboratories are treated where practicable to precipitate radioactive materials which are concentrated into a solid form. These are disposed of as solid wastes.

UKAEA operates an integrated management system, which satisfies the requirements of international standards. All UKAEA nuclear licensed sites have environmental management systems certified to ISO 14001 and UKAEA works within quality assurance procedures that are ISO 9001:2000 certified, and are regularly audited both internally and externally. All work, including record keeping and management of processes, are carried out to these procedures. Internal UKAEA and external analytical laboratories are used for the analyses performed in support of discharge measurements and environmental sample analysis.

6.1 Dounreay

This site now has no reactors operating; the Prototype Fast Reactor (PFR) ceased operations in March 1994 and the older Dounreay Fast Reactor, DFR ceased operations in March 1977. The work is now decommissioning of the whole site and waste handling (including irradiated fuel).

The authorised annual discharge limits (TBq) for liquid effluents were reduced in July 1999. In 2003, UKAEA was granted a variation to its gaseous discharge authorisation, required to enable commissioning and operation of its new sea discharge tanks. As part of the variation SEPA has reduced the PFR overall gaseous limit and introduced new limits to restrict the minor disposal of gaseous waste from the PFR facility. In October 2004, the authorised liquid waste limits were reduced to reflect the change of activity on site from reprocessing to decommissioning.

UKAEA made an application to SEPA for a new authorisation for the disposal of liquid and gaseous waste during 2003. The application is supported by the Dounreay Site Restoration Plan, which integrates the many separate activities of decommissioning, fuel treatment, waste management and land remediation to restore

the environment on site. The application will be subject to public consultation by SEPA and it is envisaged that a new multi-media authorisation may be in place by 2006.

6.1.1 Sources of liquid effluent

Between 1998-2003 the main sources of liquid effluent were:

- Destruction of the liquid sodium coolant from the PFR;
- Decommissioning of facilities;
- Management of radioactive solid wastes;
- The final category includes removal of liquids resulting from groundwater ingress to the solid waste disposal facility and disposal shaft.

The principal radionuclides are: tritium, total beta (including ^{22}Na and ^{40}K), total alpha (excluding ^{242}Cm), ^{90}Sr, ^{137}Cs.

6.1.2 Liquid effluent treatment and discharges

All major sources of liquid waste are filtered at source and, where ^{137}Cs loading is expected to be significant, ion exchange plants are operated in accordance with BPM considerations. In addition, where appropriate, liquid wastes from small scale operations are evaporated.

During the period 1998 to 2003, destruction of the liquid sodium coolant from the Prototype Fast Reactor commenced. This process involves treatment of sodium metal with sodium hydroxide solution and subsequent neutralisation with hydrochloric acid. The resultant solution of sodium chloride is contaminated with various fission and activation products, the principal examples of which are: tritium, ^{22}Na and ^{137}Cs. The aqueous solution resulting from these operations is treated by filtration and passage through an ion exchange column to remove the majority of the ^{137}Cs.

During early operation of Dounreay, intermediate level waste was placed in a shaft that was originally built as a temporary access route for the removal of earth and rocks during the excavation in the 1950s of a 600 metre long liquid waste discharge pipeline. The UK Government agreed with UKAEA that the waste should be retrieved, treated and stored. This is a potential route for peaks in the liquid discharges. An ion exchange plant was installed in 2000 which is brought into operation in the event of high levels of activity being detected.

Prior to discharge of effluents to the site active drain system and subsequently to the Low Level Liquid Effluent Treatment Plant (LLLETP), there are procedures in place to sample, analyse and approve liquor movements where this is practicable. This analysis allows trend monitoring of cumulative discharges and comparison with internal limits and is part of the process of demonstration of the application of BPM in discharge management.

6.1.3 Trends in discharge over the 1998-2003 period

A detailed breakdown of the discharges over this period is provided in Table 111. In all cases, the liquid discharges are a small fraction of the actual limits in place before they were reduced in October 2004. For all liquid discharges of radionuclides, the actual discharge in 2003 was lower than 1998. There were considerable reductions from 1998 – 1999 including tritium and total beta, reflecting the shut down of operations in 1998. Between 2000- 2003, discharges remained fairly constant.
The actual site annual emissions to air for total beta, total alpha and individual radionuclides remained fairly constant throughout the 1998- 2003 reporting period.

6.1.4 Radiological impact of liquid discharges

Seaweed, winkles, crab and lobster are routinely sampled, and are analysed for gamma emitting radionuclides (principally ^{137}Cs and ^{60}Co) and by alpha spectrometry for ^{238}Pu, $^{239+240}$Pu and ^{241}Am. Some samples are analysed for the beta emitting radionuclides ^{90}Sr and ^{241}Pu.

In addition to the routine monitoring programme, a Site Wide Environmental Study (SWES) was undertaken in 2003/04 to produce a baseline against which future changes can be assessed. This programme involves a wider range of environmental materials, including fish, seawater and seabed sediments than the routine programme. Site specific derived limits have been calculated for the samples collected and the results obtained are much less than 1% of these derived limits.

Sampling of winkles takes place on the foreshore to the west (3 km) and east (4 km and 13 km) from the site discharge point around 600m offshore. Crustaceans are collected from the seabed near to the outfall point as are samples of seabed sediment and seawater.

The main exposure pathway considered is the reference group that collect and consume winkles from the vicinity of the Dounreay site, as identified by habit surveys. Doses are calculated from discharge information and the results are cross-checked against the results of environmental sample analysis. The sample analysis results include a contribution from historic discharges and from other sites discharges, weapons test sand Chernobyl fallout.

The critical group consists of adults with a mean consumption rate of 2,2 kg per year of winkles, resulting in an annual dose of around 0,1 μSv. Other exposure pathways considered are:

- sea-fishermen in the Dounreay area who handle nets;
- sea-fishermen who handle nets in the Dounreay area and consume locally caught fish and crustaceans; and
- people who spend time visiting the Geos (rocky inlets) near the Dounreay site.

These groups are considered separately and the doses are, for current discharges less than those received by the critical group.

6.1.5 Particles on the Dounreay foreshore

The previous UK submission recorded the discovery of particles of irradiated nuclear fuel from Dounreay on a public beach at Sandside Bay. A Precautionary Order, under the Food and Environment Protection Act, was put in place to ban the taking of sea foods in an area of 2 km radius centred on the end of the outfall pipe some 0,6 km from the shore, and advisory signs were erected at Sandside Bay. These measures are still in place and particles continue to be found. In the year 2000, the Dounreay Particles Advisory Group (DPAG) was established to provide scientific advice to SEPA and UKAEA on this issue and has since made considerable progress in understanding:

- the historical events that may have allowed particles to be released into the environment;
- the ability of monitoring systems to detect particles both in the intertidal and marine environment; and
- the behaviour of particles in the marine environment and their distribution, together with modelling of potential particle transport.

Work is continuing on the BPEO for dealing with the particles already in the environment.

6.1.6 The application of BAT

During 2003 the original site liquid effluent collection tanks were replaced by a modern facility LLLETP which is designed to allow neutralisation of the effluent and collection/ removal of any sludge produced. This plant is undergoing active commissioning at present.

6.1.7 Comparison with performance of similar plants world-wide

Although the activities currently being undertaken at Dounreay do not easily lend themselves to comparisons with other plants world wide, UKAEA maintains contact with relevant plants in Europe and the US, to share experience and information regarding international best practice. The details of operation and impact may differ between sites. For example, the PFR and more significantly the DFR sodium coolant contains more ^{137}Cs (due to fuel and coolant contact as a result of fuel pin cladding failure) compared to similar plants elsewhere e.g. EBR2, Phenix and SuperPhenix.

6.2 Harwell

The last test reactors at the Harwell site ceased operation in 1990. All low level liquid discharges are made via a pipeline to the River Thames, and subsequently the Thames estuary, following treatment and monitoring.

6.2.1 Sources of liquid effluent

At Harwell, liquid effluents arise as a result of waste management operations in support of decommissioning operations, commercial tenants on the Harwell nuclear licensed site and some liquid wastes received from neighbouring research and development organisations on the Harwell ‘campus’. There have been no reportable accidents, incidents or other events between 1998 and 2003 that resulted in an uncontrolled radioactive effluent release to the environment.

6.2.2 Liquid effluent treatment and discharges

Liquid effluents are produced from less than twenty buildings on the nuclear licensed site. Many of these buildings have previously been used for different radiological research purposes and are now being decommissioned. A few buildings are still undertaking active operations associated with waste treatment. In addition, a small number of buildings are leased from UKAEA by tenants who undertake commercial activities resulting in the production of radioactive effluent which is discharged to the UKAEA active drainage system. Liquid wastes from the various buildings are directed to the Liquid Effluent Treatment Plant (LETP) in three separate streams depending on the concentrations of radioactivity present:

- medium level active liquors are collected in carboys and monitored before being sent to the LETP;
- low level active liquors, generally in volumes of about 5 to 10 m^3, are held in delay tanks at the individual buildings before being transferred to the LETP by way of either the site active drainage system or by tanker; and
- trade wastes, which are of very low radioactivity content, go direct to the LETP and are generally discharged, following monitoring, with no treatment.

For liquid effluents, current treatment processes use chemical flocculation treatment for precipitation of alpha and beta activity followed by dynasand filters for removal of precipitate. These are continuously operating sand filters that deliver high quality filtrates for a range of effluent contamination levels. The filtrate is pumped into a post-treatment holding tank, sampled to confirm suitability for discharge and then discharged (the effluent is again sampled during the discharge and it is on the basis of this sample that the discharge is calculated). The slurry is pumped into a settling tank, allowing further thickening of solids prior to sampling and cementation.

In the late 1990s, modifications for improved effluent treatment were made to the LETP. These modifications were made to accommodate the reduced volume arisings that are now received and provide a more targeted treatment for the removal of beta emitting radionuclides. When sufficient effluent has been collected in the treatment tank, a sample is taken for analysis and tests are carried out in the laboratory for removal of beta radioactivity. The results of the lab tests are used to decide on the chemical treatment best suited for removal of the principal radionuclides found in the effluent (mainly ^{90}Sr and ^{137}Cs).

6.2.3 Trends in discharge over the 1998-2003 period

Authorised annual discharge limits for liquid effluents at the Harwell site were significantly reduced in 2003 reflecting the reductions in the volume and activity of liquid waste arisings. A detailed breakdown of the discharges over this period are provided in Table 116. In all cases the liquid discharges are within the authorised limits. The trend observed for all monitored radionuclides and radionuclide groups during 1998-2003 was generally downward. However, there was an increase in the tritium discharge in 2002 associated with a discharge of tritiated effluent from a neighbouring establishment.

The emissions to air also show a downward trend in discharges over the reporting period for tritium and total alpha. Total beta emissions increased slightly between 2001 (2,4 MBq) and 2003 (3,7 MBq) but remain low. In 2003, Harwell began reporting iodine, radon-220, radon-222 and krypton 85 discharges as part the requirements in its new RSA 93 Authorisation. It is anticipated that these radionuclides will decrease in the long-term but some short-term increases associated with waste handling operations/decommissioning may be observed.

6.2.4 Radiological impact of liquid discharges

UKAEA makes discharges to the middle reaches of the River Thames which then flows into the Thames estuary. No marine monitoring is undertaken.
UKAEA has identified a hypothetical critical group for modelling and assessing the impact of discharges to the Thames estuary. Modelling includes consideration of consumption of fish, crustaceans, molluscs and seaweed plus exposures due to inhalation and sediment exposure via beach occupancy. Pathways are added together where applicable, e.g. consumers of foods are also assumed to spend time along estuarine beaches. Modelling includes effects from past discharges.

6.2.5 The application of BAT

Current removal rates vary because effluent compositions differ from batch to batch, but typical decontamination factors for alpha removal have been of the order of 10-20. Decontamination factors for beta removal are of the order of 3 to 5, but input concentrations of the effluent are relatively low (typically less than 10 Bq l^{-1} alpha and 100-1000 Bq l^{-1} beta).

During the period 1998 – 2003, UKAEA implemented a programme of diverting the more active liquors to a direct cementation route, thereby avoiding passage through the liquid treatment plant. These liquors would previously have undergone a pre-treatment in storage tanks (where beta decontamination factors would be of the order of 20-50) before adding to the low level plant for further treatment.

UKAEA has been able to achieve virtually year-on-year reductions in liquid discharges as a result of progressive decommissioning and application of waste minimisation. No decisions have been made on new liquid effluent abatement technology, but studies are under way to determine the best practicable environmental option for future treatment. Current decommissioning programmes and plans are expected to result in a continued drop in effluent volumes in the coming years although short-term increases may occur due to waste processing/decommissioning. The focus of effort is on minimising arisings at source and ensuring that dilution of effluents is avoided in order to keep input concentrations high (which facilitates greater decontamination factors). It is anticipated that a replacement site effluent plant will not be needed, as local treatment at source should become a viable option.

6.2.6 Comparison with performance of similar plants world-wide

No similar plants treating the same range of radionuclides have been identified although ferric floc treatments are used at other sites (e.g. AWE Aldermaston). The Harwell site is at a fairly advanced stage of decommissioning and effluent arisings sentenced to the LETP are now low in volume and activity. UKAEA is currently undertaking a review of best practice in waste minimisation techniques and the existing techniques will be assessed against the output of this review.

6.3 Windscale

The reactors at Windscale have been closed for many years. The main activities carried out on site include decommissioning (and the associated ILW storage) of the Windscale Advanced Gas-Cooled Reactor (WAGR) and Pile 1 (one of two piles constructed to produce plutonium for weapons), waste remediation work and post irradiated examination (PIE) of nuclear fuel.

6.3.1 Sources of liquid effluent

The liquid waste arisings at Windscale are very small and contain activity principally from waste remediation, PIE work and general cleaning operations (active side sinks, emergency shower and floor washings) carried out in controlled areas.

6.3.2 Liquid effluent treatment and discharges

Management controls are in place across the site to ensure the production of liquid and aerial effluents are minimised throughout all decommissioning or operational activities. The emphasis is placed upon keeping the radioactive inventory of any waste produced in the solid form in preference to liquid wastes and liquid waste in preference to gaseous waste (as far as is reasonably practicable) as this simplifies containment and in the majority of cases will represent the BPEO.

Productions of liquid effluent from the hand washing facilities at the active side barrier are limited through the use of foot pumps or knee valves and this will prevent excess water being transferred into the low level liquid effluent system as a result of taps not being turned off.

Liquid is transferred, under authorisation, to BNFL either via the Site Low Active drain or via bowsers. When transferring liquid from storage tank to bowser an in-line filter (self-cleaning) is fitted on the transfer line to remove particulate material (duty and standby filters are also incorporated into the system). Facilities that transfer via bowser are WAGR and the fuel handling and examination facility for the WAGR. Additional local management controls are in place for these facilities to allow monitoring of the collection tanks and subsequent transfer to bowser. Transfer via the Low Active drain takes place from the PIE facility, where the effluent is collected in storage tanks prior to sampling and then discharged to the drain. In all cases authorisation for transfer to BNFL Sellafield is requested and received from BNFL prior to dispatch.

Operations within the Pile 1 facility during 1998 – 2003 did not generate any liquid effluent. The only movement of liquid effluent involved the return of fuel pond water from the water duct back to the fuel pond. This is authorised under a cumulative limit on volume and activity within their Inter-Site Transfer Authorisation (ISTA) for liquid low level waste.

6.3.3 Trends in discharge over the 1998-2003 period

Discharges from Windscale are transferred to BNFL, trends for discharges from the Sellafield site is provided in Section 6. However, since 1998, liquid waste transfers have shown a declining trend both in terms of volume and activity transferred.

6.3.4 Radiological impact of liquid discharges

As UKAEA Windscale do not discharge to controlled waters, sampling relating to liquid discharges is not required. BNFL carried out environmental sampling in respect of aerial discharges from both the UKAEA Windscale and BNFL Sellafield sites, data is provided in Table 104 -107.

The critical group at Windscale is only associated with the aerial discharges from the site.

6.3.5 The application of BAT at UKAEA Windscale

Due to the small volumes of liquid waste produced, limited technological systems can be implemented to reduce volumes further. There are no planned abatement techniques for effluent waste streams. However, UKAEA have reviewed the application of BPEO and BPM at a facility level and have provided these assessments to the EA. These assessments include recommendations for improvements, and will be considered during an EA review in 2005 regarding new authorisation arrangements at Windscale.

6.3.6 Comparison with performance of similar plants worldwide

At present UKAEA do not conduct detailed comparisons of Windscale with other plants worldwide. UKAEA does however maintain a watching brief on international best practice and comparison of waste minimisation/ prevention techniques will be a condition of the new multi-media authorisation.

6.4 Winfrith

All test reactors, including the Steam Generating Heavy Water Reactor (SGHWR), DRAGON and ZEBRA on the Winfrith site were shutdown prior to 1995. All liquid discharges are made via a pipeline to the English Channel.

6.4.1 Sources of liquid effluent

Major UKAEA operations at Winfrith are concerned primarily with decommissioning activities which give rise to significantly lower discharges than when reactors were running on-site. Liquid effluents arise at a number of the buildings on the site used for commercial research and development purposes by tenants and the decommissioning activities of UKAEA. The principal radionuclide now discharged is tritium and this arises from the waste processing work of AEA Technology. The bulk of the volume of the discharge arises from the on-site sewage works operated by UKAEA.

6.4.2 Liquid effluent treatment and discharges

Liquid wastes at Winfrith are not treated, with the exception of pH adjustment, prior to discharge; however waste arisings are minimised at source in accordance with standard UKAEA practice and application of best practicable means. As indicated above, current discharges give rise to public doses that are ALARA. It is expected that the active liquid effluent system (ALES) will be decommissioned in around 2015. Further liquid discharges to Weymouth Bay will not be made after it has been decommissioned.

6.4.3 Trends in discharge over the 1998-2003 period

Discharges of radionuclides remain small from Winfrith although there has been an increase in tritium discharges in 2002/03 as a result of processing work carried out by AEA Technology on tritium containing equipment and materials such as telephone dials and exit signs. Also there has recently been a small increase in the other radionuclides discharged which is due to some early decommissioning trials associated with the decommissioning of the Winfrith site. All discharges are a very low fraction of the authorised discharge limits.

6.4.4 Radiological impact of liquid discharges

At Winfrith the (hypothetical) critical group is assumed to be the consumers of seafoods caught in Weymouth Bay. The exposure pathways included in calculations of critical group doses are consumption of seafood, exposure to contaminated beach sediment and inhalation of resuspended beach sediment and seaspray. The critical group for liquid discharges from Winfrith has been defined by FSA, on the basis of habit surveys, as those people who consume the following: 210 g/day fish; 110 g/day whelks; 70 g/day crabs. The mean activity concentrations found in edible parts of seafood have been used to calculate a dose to the critical group. The critical group dose for 2003 was estimated to be 0,6 μSv.

6.4.5 The application of BAT at UKAEA Winfrith

Discharges to the sea are very small and have been very small throughout the time period of interest. UKAEA have taken the decision that additional improvements to reduce the levels of radioactivity in the effluent are not economic since the critical group dose is already well below 20 μSv per year. The

application of BPM at UKAEA Winfrith to liquid waste is based on management controls and minimising arisings at source.

Liquid wastes from AEA Technology and other tenants are handled by the site Active Liquid Effluent System and are included in the UKAEA disposals. The principal radionuclide discharged is tritium, primarily from the recycling of tritium phone dials, from AEA Technology. At present, there is no realistic treatment by which discharges of tritium (which has low radiological impact) can be reduced.

The Waste Encapsulation and Treatment Project (WETP) was constructed to solidify the SGHWR sludge waste by cementation. This plant is undergoing commissioning now and is expected to be operational in 2005. Liquid Waste from WETP will consist of Cross Flow Filter Permeate containing species such as Sodium, Potassium, Calcium, Chloride, Nitrite, Nitrate, Ammonium, Ammonia, and Methyl Amines and trace insoluble species. This effluent will be discharged to sea via the Active Liquid Effluent System (ALES). The predicted volume and quality of aqueous waste for the EAST project during normal operation (2005 -2007) is expected to be about 5 cubic meters per day and a total of about 25 MBq per day of beta gamma radionuclides.

6.4.6 Comparison with performance of similar plants world-wide

The activities currently being undertaken at Winfrith do not easily lend themselves to comparisons with other plants world wide, UKAEA does however maintain a watching brief on international best practice in this field.

6.5 References

EA, EHS, FSA and SEPA (1996-2004). Radioactivity in Food and the Environment, 1995-2003. RIFE 1-9. Preston, Belfast, London and Stirling. [NB: sponsoring departments for this report have been amended over the period cited, the attributions given here are to current UK departments and Agencies].

7. Radioisotope Manufacture

Amersham plc (now part of GE Healthcare) operates two sites in the UK, located in Amersham, Buckinghamshire and Cardiff, South Wales that undertake the manufacture of a wide range of products, primarily for use in healthcare and life science research. Some of these products are radioactive and their production results in the generation of waste materials, in common with any manufacturing process.

The spectrum of radionuclides used at these sites has changed significantly since 1998, when some aspects of their business was transferred to AEA Technology. This has resulted in the declining use of the following radionuclides at the Amersham site: ^{241}Am, ^{137}Cs, ^{90}Sr, ^{60}Co, ^{55}Fe, ^{109}Cd, ^{153}Sm, ^{85}Kr, ^{210}Po. At present, the most common radionuclides used on the site are: ^{201}Tl, ^{67}Ga, ^{111}In, ^{99}Mo (for healthcare imagining); ^{125}I, ^{89}Sr, ^{57}Co, ^{192}Ir (for treatment or diagnostic purposes); ^{57}Co and ^{51}Cr for other purposes. A variety of other radioisotopes (e.g. ^{3}H, ^{14}C, ^{32}P, ^{33}P, ^{35}S and ^{125}I) are supplied for use in biomedical and other research. The manufacture of ^{3}H and ^{14}C represents the main output of the Cardiff site (and it supplies these radionuclides used at the Amersham site). Smaller quantities of other radionuclides are also produced including: ^{32}P, ^{33}P and ^{125}I at the Cardiff site.

For both sites, arrangements for radioactive waste management are based on the UK Strategy for the management of radioactive wastes detailed in the 1995 White Paper Cm 2919 and in line with the UK Strategy. Arrangements are in place to ensure that:

- the generation of waste is minimised at source;
- inactive waste is segregated from active waste;
- active waste is segregated into categories according to its activity content;
- For the Cardiff site, active waste[6] that is suitable for future recycling is stored as feedstock for the Waste Recovery and Recycling Programme, Project Paragon;
- low and intermediate level solid waste of suitable half-life is decayed in appropriate storage facilities to a lower category of waste before disposal;
- very low level and low level solid waste that cannot be decayed is disposed of as soon as possible to appropriate facilities;

[6] For the Cardiff site, the radioactive liquids containing aqueous tritium have been held on site since May 1998, additionally, carbon-14 liquid is no longer absorbed and has been kept as a free liquid since November 2002, whilst organic forms of tritium have been diverted from disposal to drain and stored as a free liquid since April 2003. The liquids are stored in accordance with the Licence Instruments issued under the Nuclear Site Licence.

- low activity liquid and airborne waste is discharged to the environment under the terms of appropriate authorisations; and
- intermediate level waste that is not suitable for future recycling and cannot be decayed, is stored in suitable facilities in a retrievable form pending disposal to an appropriate repository when it becomes available.

The company has a QA management system in respect of safety and environmental protection; this is an obligation of the company's nuclear site licence granted under the Nuclear Installations Act and the arrangements are in accordance with current national and international standards.

7.1 GE Healthcare, Amersham (Grove Centre)

7.1.1 Sources of liquid effluent

All manufacturing processes are carried out in laboratories at the premises and use radioactive material from a variety of sources as the feedstock. A wide variety of waste liquids arise in the production buildings; these are either disposed of as radioactive liquid effluent or are converted into solids. The majority of liquid effluent volume is from support work such as hand washing, cooling water, cleaning the working environment adjacent to the production facilities and from water from non-radioactive processes. The radioactive content is very low and diluted in significant volumes of water.

7.1.2 Liquid effluent treatment and discharges

Disposal of liquid waste to drains is minimised through the use of storage for decay, the solidification of low volume higher specific activity liquids, and the incineration of some categories of liquid.

High volume, low specific activity liquid waste is collected within the site effluent holding tanks and analysed prior to discharge. The activity content is measured and compared with local action levels derived from authorised limits and notification levels within the site authorisation. Liquid waste is well controlled at source and therefore it is very rare that sample results are above set action levels. However, in the event that the liquid effluent exceeds these levels a number of options are available:

- If the nuclide is of a sufficiently short half life it will be held for decay.
- If storage is impracticable due to a longer half life the waste can be chemically treated within the storage tank in order to transfer activity from the liquid effluent to a solid suspension. This can then be removed as active sludge, solidified, and disposed of as Low Level Waste to BNFL Drigg or by incineration.

7.1.3 Trends in discharge over the 1998-2003 period

There has been a general downward trend in the discharges with a greater than 50% reduction since 1998 in most discharge categories. The greater than 70% reduction in discharges of ^{137}Cs, and radionuclides included in the total beta (>0,4 MeV) and 'others' categories is due to the cessation in manufacturing industrial sources and the consequent reduction in throughput of radioactivity. The reductions by just over 50% of ^{3}H and alpha activity reflects a reduction in throughput but also improvements in measurement techniques. Discharges of ^{125}I have reduced by around 90% as a result of reduced throughput and the incineration of wastes following a decay period.

7.1.4 Radiological impact of liquid discharges

Liquid discharges from this site are released into the public sewerage system which enters the Grand Union Canal then the River Colne, a tributary of the River Thames. A reference group for marine pathways is therefore not appropriate.

Habit surveys have identified anglers as the most exposed group affected by disposals into the canal/river system. External exposure at the river bank is the main source of exposure. Doses from the consumption of freshwater fish at a rate of about 1kg/y has been taken into account. The exposure received by this group is well within the relevant dose constraint. For example, the estimate included in the 2003 RIFE Report (2004) was less than 0,005 mSv y^{-1}.

7.1.5 The application of BAT

A site wide BPEO study has been initiated as part of the requirements of the site RSA authorisation. It is possible that the findings of the study may lead to further reductions in discharges. However, the general use of decay for high volume low activity liquid wastes prior to discharge is very effective and results in annual critical group doses well below 10 μSv.

7.1.6 Comparison with performance of similar plants world-wide

No similar plants exist with which such comparisons are possible.

7.2 GE Healthcare, Cardiff (Maynard Centre)

The production of radioisotopes commenced on the Cardiff site in 1980 in new facilities designed on the basis of experience obtained at the Amersham laboratories. Liquid effluents are generated during the manufacture of radioactively labelled products, primarily containing ^{14}C and tritium. Some development work is also carried out using smaller quantities of these and other radionuclides (^{125}I, $^{32/33}P$, ^{35}S).

7.2.1 Sources of liquid effluent

The tritium and ^{14}C labelling process is carried out on laboratory scale equipment using small quantities of materials within ventilated fume cupboards. Gaseous wastes are diluted by a large volume of air before discharge to the atmosphere. Liquid waste generated in the laboratories is managed according to the level of activity, volume and nature of any solvent. An active drain system exists to collect liquid waste and uncontaminated water from the following laboratory drainage points:

- Laboratory sinks;
- Enclosure sinks;
- Glassware washing facilities;
- Condensate outlets from cold rooms;
- Water outlets from freeze-dryers;
- Laboratory floor sinks;
- Additional minor inputs include stack drainage points and plant room sinks.

This system is connected to holding tanks that allow analysis prior to authorised discharge to the sewerage system which discharges into the Severn Estuary. Between 50-80 m^3 per day is discharged in this way. However, since 1998 the majority of the activity (>90%) associated with liquid waste has been accumulated on site. This liquid is held as feedstock for the Waste Recovery and Recycling Programme, Project Paragon, expected to be commissioned during 2005, as outlined in more detail below.

7.2.2 Liquid effluent treatment and discharges

Liquid wastes from the laboratories are routed to the site holding tanks where they are sampled and assayed for radioactive concentration and pH before disposal to the sewer. The short lived isotopes are collected for decay storage on site.

7.2.3 Trends in discharge over the 1998-2003 period

The gaseous discharges of tritium have fluctuated over this period because of throughput while the discharge of ^{14}C demonstrate a general downward trend with the value in 2003 representing around 65% of that in 1998. The liquid discharges of tritium and ^{14}C have been reduced by over 85% over the same period, due to the storage of the more active wastes on site, pending the commissioning of new waste treatment methods. The liquid discharge of ^{125}I has also reduced by a factor of almost 300 since 2001. The low levels of discharge of other radionuclides have fluctuated over this period reflecting the levels of production.

7.2.4 Radiological impact of liquid discharges

The local fishing community represent the most exposed group from marine discharges, as a result of fish and shellfish consumption and external irradiation from sediments. The estimated annual dose to this group included in the RIFE report for 2003 was 16 μSv, including a small component attributed to radionuclides in air.

7.2.5 The application of BAT

While past discharges were within the limits and conditions set by the EA, Amersham plc proposes to introduce new technologies that will lead to the recovery and recycling of much of its current waste effluent, resulting in substantial reductions in both liquid and gaseous discharges of both tritium and ^{14}C within the next few years. The Waste Recovery and Recycling Programme has developed over several years. A review of BAT was initiated in 1998, placing particular emphasis on techniques that would deliver major reductions in discharge without diverting arisings from one discharge route to another and that would provide a significant improvement in a relatively short period of time and without affecting the continuity of supply of products.

Abatement technologies for both gaseous and liquid wastes were reviewed, as outlined in Appendix 7 of the Decision Document on its authorisation review. The following abatement techniques for liquid discharges were considered and rejected for a range of reasons, indicated below:

- Electrochemical oxidation. Such processes are in use by AEA Technology and SCK-CEN and were considered in connection with abatement of tritium and ^{14}C organic wastes. It was found to be unsuitable for this site due to the retention of activity within the electrolyte with resultant inventory and additional discharge issues;
- Ruthenium tetraoxide process. This process is under development by AEA Technology and was rejected primarily due to the early stage of its development;
- Modulox oxidation process. This process was developed by AEA Technology and involves the oxidation of organic material using hydrogen peroxide. It was rejected because of its intrinsic efficiency of only 90% and consequently large amounts of contaminated liquid waste. It was also not able to deal with the wide range of chemical inputs arising from the ^{14}C operations;
- Direct chemical oxidation. This was rejected on the basis that an economical method to release tritium from the process could not be found and, although suitable for ^{14}C operations, it had not been proven as a large-scale facility;
- Flameless thermal oxidation. A process supplied by Thermatrix is not applicable to liquid wastes due to their potential to polymerize when heated, and so was rejected due to its limited application (to gaseous wastes only);
- Molten salt oxidation. This process, available from the Lawrence Livermore Laboratory, is a catalytic liquid phase oxidation in a molten carbonate salt. Recovery of ^{14}C is difficult and there was considered to be a potential for tritium contamination during the salt recycling step;
- Steam reforming. Available from GTS Duratek uses steam to react with organic wastes. Recovery of tritium would be difficult and application to ^{14}C problematic.

In February 1999, Amersham plc announced its initial plans for major reductions in radioactive discharges through a combination of increased capture of waste (that would otherwise have been discharged) and on site storage, coupled with some recycling to generate reusable raw material. Feasibility trials and technology evaluations began in 1999, at the end of which it was clear that the technologies were potentially considerably more powerful than had originally been envisaged. The current internal targets are shown below.

Table 7. Amersham targets for reduction of ^{3}H and ^{14}C discharges

Route	Reduction Targeted*
Gaseous ^{14}C	80%
Liquid ^{14}C	97%
Gaseous soluble tritium	70%
Gaseous insoluble tritium	50%
Liquid tritium	97%

* Reduction targets based on 1997 discharge levels

The recycling process has four principal elements:

- Collection of waste gases and liquids;
- Oxidation of the waste;
- Conditioning compatible with enrichment;
- Enrichment to high specific activity.

Dedicated pipework will transfer wastes to the oxidation system, which comprises thermal oxidation involving the combustion of the waste in the presence of an oxygen supply before being passed over a hot catalyst. Exhausts are recovered and conditioned by electrolysis and enriched using cryogenic distillation.

It is anticipated that the plant will become ready for operation at the end of 2005. It is, however, a very complex project, and timely inputs from a number of organizations will be necessary to complete the project on this timescale.

7.2.6 Comparison with performance of similar plants world-wide

The activities currently being undertaken at the Maynard Centre do not easily lend themselves to comparisons with other plants world wide. However GE Healthcare do maintain a watching brief on international best practice in this field. GE Healthcare do consider alternative processes used by other organisations during BPM deliberations, for example electrochemical oxidation as described in Section 8.2.5.

7.3 References

EA, EHS, FSA and SEPA (2004). Radioactivity in Food and the Environment, 2003. RIFE 9. Preston, Belfast, London and Stirling.

EA (2002). Certificate of Authorisation, Disposal of Radioactive Waste from Nuclear Site, Amersham plc, The Maynard Centre. Environment Agency, Bristol.

Nycomed Amersham plc (2001). Sources and Nature of Radioactive Waste Arisings from Nycomed Amersham Cardiff Laboratories, RSA 93/CL/RFI/0005.

Nycomed Amersham plc (2001). BPEO Study for Radioactive Discharges for the Application for Variation in Authorisation from the Environment Agency.

Nycomed Amersham plc (2001). Progress Review of Waste Recovery and Recycling Programme, Issue 2, RSA 93/CL/RFI/0022.

8. The Development and Application of BAT

The UK believes that its technology and techniques for managing liquid waste streams, and controlling discharges from nuclear installations, represents BAT. The regulatory controls require that BPM be used to limit the activity of waste discharged and that this discharge represents the BPEO, as described in Section 3. Furthermore, the way in which discharge authorisations are applied and reviewed places a continuing pressure to improve technologies. Thus, BPM and BPEO, together with the way in which these concepts are applied, are regarded as an alternative formulation of the concept of BAT as defined in the OSPAR Convention.

Since the last report, some changes have been made to the authorisation process, with the aim of ensuring, among other things, that the objectives of the OSPAR Strategy with regard to Radioactive Substances and the UK Strategy for Radioactive Discharges 2001-2020 are adhered to. The authorisations to dispose of radioactive substances are reviewed in a transparent, consultative and integrated approach on a cycle of around 4 years. Integrated multi-media authorisations are replacing the range of single medium authorizations in place at many sites. For example, the revised authorisation for the Sellafield site, which came into force on 1 October 2004, replaced a suite of 6 authorisations for discharge, transfers and disposals. The decision and explanatory documents associated with this authorisation also demonstrate the level of detail underlying the consideration of different abatement technologies and the corresponding discussions between the operator and authorising authority. The additional condition included in this authorisation, that the operators keep abreast of new abatement and treatment technologies (and report within stipulated timescales), is being applied to revised authorisations for other sites, and is designed to further improve the transparency of decision making.

The abatement technologies under development and in use in the UK are briefly summarized below, followed by a consideration of the way in which these compare with those identified in recent international reports on the subject.

8.1 Technologies in use or under development in the UK

8.1.1 Filtration

Techniques being used in UK nuclear installations employ the following main types of filter media, often in conjunction with decay storage and the application of suitable reagents and pH, to ensure precipitation of particular radionuclides.

- granular media such as sand or alumina of either fixed or varying grain size;
- cloth or paper;
- metal (or other rigid material) mesh; and
- carbon fibre, porous or sintered metal, and ceramic filters.

The choice of filter media depends on the characteristics (generally, the particle size) of the material to be removed and the operational constraints; there is invariably a balance between filter rating (DF – decontamination factor) and the required liquid throughput. Improved efficiencies are often achieved by placing filters of varying pore size in series. The principal area of development has been in regard to fine particulates (~0,001 to 0,1µm), filtration of which by fine pore media would normally require high pressure drops and low throughputs, and are therefore appropriate for removing low levels of activity from pre-treated liquid effluents.

Cross-flow filtration is receiving increasing attention, both for direct filtration of liquids and for the removal of solids formed by co-precipitation/flocculation treatments. The process stream is passed tangentially across the surface of the filter medium and a high cross-flow velocity is required if the formation of a filter cake is to be avoided. A clarified permeate passes through the filter and leaves a liquid with a greatly increased level of suspended solids/activity on the primary side of the filter – which can be removed as a separate mobile waste stream as required. An advantage of this technique is that it can operate on a 'bleed-and-feed' basis in a continuous loop; in this mode of operation, the primary side of the cross-flow filters works as a closed loop but is fed by new liquor at the same rate as the accumulated solid/active materials are bled off. It is possible to achieve a level of 10% solids in secondary waste bled from such a cross-flow loop and this is suitable for solidification in cement. The Enhanced Actinide Removal Plant (EARP) at Sellafield, remains the only full-scale plant in the world using this process.

For radionuclides in either soluble or microcolloidal form in liquid effluent, two options present themselves. The first is to adjust the pH to facilitate precipitation as the hydroxide; this will work for some elements but, for others, too high a pH may be necessary for convenient operation and some radioisotopes, such as ^{137}Cs, will not be removed by this process. The second option is to seed the liquor with a fine powdered material which absorbs the radionuclide and is then removed by the filter. A number of seed materials have been identified and are mostly inorganic substances with ion exchange properties and include compounds such as hexacyanoferrates which are able to absorb caesium, even in the presence of a large excess of sodium ions, but are of little or no value for other radionuclides. For example, the ion exchange resin IONSIV IE911 has been used for this purpose in fuel ponds and a number of Magnox stations and similar materials have been installed at a number of AGR sites. However, plant trials at Sellafield of the application of an ion-exchange pre-coating on existing filtration systems to reduce discharges of ^{60}Co proved unsuccessful.

The UK programme on ultrafiltration has sought to identify suitable seeds to provide not only high decontamination of radiologically important radioisotopes but also good overall beta-gamma decontamination. No single seed has been identified which can achieve this and development work has concentrated on the identification of cocktails of different seeds for this purpose. Co-precipitation and ultrafiltration form part of the EARP plant.

8.1.2 Caustic scrubbers

^{14}C is released as CO_2 and CO gas during fuel dissolution in the Magnox and THORP reprocessing plants. During the reprocessing of Magnox fuel, ^{14}C is released into the fuel dissolver off-gas ventilation system and is removed by sodium hydroxide (caustic) scrubbers. The design of the dissolver and its nitric acid feed and off-gas treatment systems allows a significant fraction of the ^{14}C present initially in the fuel to be carried forward in nitric acid solution into the chemical separation process. Here it is either released into the vessel ventilation system where it is removed by caustic scrubbers (with a residual fraction being discharged to air via B204 stack) or is carried forward into Highly Active Liquor Evaporation and Storage (HALES).

In contrast to the Magnox Reprocessing Plant, THORP is designed to drive-off ^{14}C into the dissolver off-gas (DOG) treatment system and to minimise the amount of the radionuclide that is transferred into the uranium chemical separation process. In the DOG system, ^{14}C passes through an acid recombination column, an iodine desorber column and finally through a caustic scrubber, where it is removed from the gas stream. ^{14}C is then removed from spent caustic scrubber liquor in a barium carbonate precipitate that is subsequently encapsulated in cement grout in the Waste Encapsulation Plant.

8.1.3 Ion exchange and adsorption

Ion exchange media used in treatment and abatement of active liquids in nuclear installations in the UK are:

- Organic resins – mostly crosslinked styrene-divinylbenzene copolymers or phenol formaldehydes which can carry various functional groups that provide the cation or anion exchange effect, and
- Inorganic ion exchangers – such as hydrated metal oxides (e.g. hydrous titanium oxide, hydrated iron oxide), insoluble salts of polyvalent metals (e.g. titanium phosphate, nickel hexacyanoferrate), insoluble salts of heteropolyacids (e.g. ammonium molybdo-phosphate), and synthetic and natural zeolites (alumino-silicates).

The Site Ion Exchange Effluent Treatment Plant (SIXEP) at Sellafield is a notable example of the use of an array of pressure filters and ion exchange columns containing an alumino-silicate zeolite, climopilolite, to remove caesium and strontium isotopes.

A wide variety of organic resins have been developed which will cater for specific cations or anions, for example with a gel or macroreticular structure that have a high specific surface area and therefore give improved efficiencies. However, organic resins can give rise to disposal problems and the inorganic alternatives may then be more appropriate. Some of the inorganic media act as adsorbers rather than ion-exchangers and, to make them more efficient, are fabricated into beads or microporous gels with a high surface area.

Research is in progress to identify media which will remove particular ions, or groups of ions, with high efficiency and which will produce lower volumes of solid waste, but this work has not progressed sufficiently to consider immediate application.

8.1.4 Hydrocyclone centrifuge

Hydrocyclone centrifuges remove solid radioactive materials by rapidly rotating the liquid effluent in a vortex, forcing particulate matter towards the wall of the centrifuge. The efficiency of this technique depends on particle size and the overall effectiveness of the technique may be enhanced by treating effluents by a number of hydrocyclones in series.

8.1.5 Electrochemical and electrophysical processes

Most of the techniques using an applied electric field to separate radionuclides from the waste stream on the basis of their electrical properties have been developed only on a pilot scale and then only in regard to specific waste streams arising from certain nuclear operations. More development is required to enable introduction for large-scale treatment of liquors. However, the system under development at the Maynard Centre, Cardiff, to recover ^{3}H and ^{14}C from its effluents will utilize a combination of thermal oxidation, conditioning using electrolysis and enrichment by cryogenic distillation.
The following is a selection of those being studied in the UK; others not included below are electrodialysis, electrodeposition and electroprecipitation all of which may find a use for waste streams of very specific character.

ELECTROFLOCCULATION

In this technique, ions are injected directly into the waste stream via dissolution of a sacrificial anode, usually iron or aluminium. The resulting high pH (from the OH^- ions generated at the cathode) ensures flocculent ions are formed in conditions of low solubility, so forming a co-precipitate which efficiently scavenges active species from the solution.

ELECTROFLOTATION

Bubbles of hydrogen and oxygen are generated in the waste stream by electrolysis and as these rise, they carry particulates to the surface – which can then be skimmed off. The main disadvantage of this approach is that large quantities of potentially explosive gases may be evolved in the process.

ELECTRO-OSMOTIC DEWATERING

This is a modification of standard cross-flow filtration used to dewater the sludges formed in co-precipitation for waste stream treatment. In this technique, an electric gradient is applied across the filter membrane with the result that levels of solids in the thickened waste stream can be increased to 40% or more (from 10-20%) and the frequency of filter blockage is reduced, thus decreasing the frequency of filter cleaning (by back-washing). This process was considered as an option for treating liquid effluents from Magnox fuel production, which represents the primary source of liquid discharges at Springfields. However, it was decided that, given that Magnox fuel production is expected to cease in 2006, that the likely overall costs would outweigh the corresponding benefits.

ELECTRICAL MEMBRANE CLEANING

The application of an electrical membrane cleaning technique can reduce the need for filter back-washing in order to maintain filtration rates and efficiency, particularly for cross-flow filtration. This technique uses an electric current to generate small bubbles within the filter membrane, so loosening and removing trapped particles as they appear and reducing the need for a high cross-flow velocity.

ELECTROCHEMICAL ION EXCHANGE

This is an advanced ion exchange process in which radioactive ions are transferred by electric current onto organic and inorganic ion exchange material bound onto electrodes. Its current state of development in the UK is at the pilot plant stage. The main advantages of this process are:

- Less dependence of the ion exchange process on the pH of the waste stream, thus removing the need for extensive chemical control,
- Increased migration of ionic components into the ion exchange medium, thus increasing the rate of ion exchange and realising the full ion exchange capacity thereby resulting in smaller plant for the same or better DF;
- Treatment of waste streams with higher salt loadings than is normal;
- Regeneration of ion exchange mediums is easier by reversal of the electrode polarity, thus decreasing the secondary waste arisings and dispensing with the need for regenerant chemicals; and
- Complexed species in the waste stream are broken down in the electric fields, so releasing nuclides as simple ions that are more amenable to removal by ion exchange.

Electrochemical ion exchange has been tested with a number of simulated radioactive waste streams including ones representative of Magnox and AGR ponds and PWR drains. The results have generally been very encouraging with high DFs for a wide range of species being obtained. A number of issues require attention (e.g. long term stability of the electrodes, industrial manufacture of the electrodes, process scale up) but this approach is the potential to become an effective waste management technique, not only for radioactive species but also for heavy metal pollutants.

8.2 International reports related to BAT

8.2.1 The NEA EGRO Report

The 2003 report by a NEA Expert Group on Effluent Release Options (OECD, 2003) provides a useful summary of currently available abatement techniques for liquid and gaseous wastes. The liquid abatement technologies identified are as follows.

- Chemical precipitation;
- Hydrocyclone centrifuging;
- Cross-flow filtration;
- Ion exchange;
- Reverse osmosis;
- Ultrafiltration;
- Evaporation.

This discussion is consistent with that above. Chemical precipitation is in use and under continuing development in the UK, as discussed above under the filtration heading. For example, this approach is used to remove caesium and plutonium dissolved in aqueous solution, often before the treated effluent before it is filtered and passed through an ion exchange column. This demonstrates a general point, also clear from the discussion above, that high decontamination factors can be achieved by combining a number of different techniques. As an example, as a combination, precipitation, filtration and ion exchange can achieve high decontamination factors of between 10^3 and 10^6.

The EGRO report notes that insoluble materials require removal by physical separation technologies, such as centrifuging and cross-flow filtration. Such techniques are in use and under development in the UK, as indicated above.

Reverse osmosis, ultrafiltration and evaporation are used to remove very low levels of contaminants from liquid effluents. As indicated above, reverse osmosis and ultrafiltration rely on passing clean effluents through a sensitive permeable membrane under pressure. The membrane removes particulates and allows dissolved salts to pass through. In combination with evaporation, extremely low discharges result. A system that uses this combination of techniques is under development in the UK by AWE Aldermaston to remove plutonium isotopes from effluents discharged into the River Thames.

8.2.2 IAEA-TECDOC 1336

This report was the result of an IAEA Co-ordinated Research Project on Combined Methods for Liquid Radioactive Waste Treatment, initiated in 1997 and published in 2003. This report acknowledges that, in the light of increasing pressure to reduce the release of radioactive and other materials into the environment, the treatment of radioactive liquid effluents often involves a number of steps (such as filtration, precipitation, sorption, ion exchange, evaporation and/or membrane separation) to prepare effluents for discharge and condition concentrated wastes for disposal. It identified research underway in 12 countries and focused on those techniques, which in combination, could prove valuable for full plant-scale waste treatment. The following areas were considered:

- Use of inorganic sorbents in combination with other treatment processes;
- Use of sorbent mixtures;
- Combined processes for treatment of solutions containing complexing agents and organics;
- Multiple processes for treatment and immobilization of organic wastes.

Most research and development involved the application of materials with combined properties (e.g. those that exhibit both photo-catalytic and ion exchange properties) and the application of different techniques within a single stage process (e.g. electro-sorption that combines migration of ions in an electrical field with sorption onto a suitable sorbent). These studies are generally extensions of academic studies and would need to be tested further in order to determine the extent to which they could find practical application in the nuclear industry. However, some of the features of these studies are identified below.

8.2.3 Materials with combined properties

Such materials include:

- A new class of specific sorbents or sorbtion-reagent materials for particular radionuclides (Cs, Sr, Co etc) from liquid wastes containing highly complexing agents. These have been tested on a pilot scale facility in the Russian Federation;
- Modified chitin-based biosorbents with fibrous structure with specific sorption properties for heavy metals and actinides. These address the removal of, for example cobalt and potassium, in colloidal form characteristic of stored wastes, for which ion exchange and sorption are not effective. This approach is under investigation at the Kurchatov Institute, Russian Federation;
- Tritium dioxide based sorbants with sorption properties and catalytic activity for photo- and chemical oxidation of organic components of liquid wastes. The degradation of organic complexants such as oxalic and citric acids and the removal of metal ions from alkaline solutions have been studied at the Czech Technical University in Prague.

8.2.4 Combined single-stage processes

The following techniques were considered:

- Electrosorption; involving the simultaneous migration of ions in an electric field and the sorption of radionuclides on a suitable sorbent. Model experiments were performed in the Russian Federation for the removal of ^{137}Cs, ^{90}Sr + ^{90}Y and $^{238}UO_2^{2+}$. Sorbents tested included nickel ferrocyanide precipitated on silica gel. The efficiency of the process could be compared with conventional sorption. For practical purposes, a multi-chamber devise was proposed.
- Photo-catalytic oxidation: the Czech Technical University undertook a study that used real and simulated liquid wastes from nuclear power stations in the Czech and Slovak Republics, in which metal ions were released onto the TiO_2 photo-catalyst-absorption. However, photo-catalysis was effective only under acidic conditions while sorption occurred only under alkaline conditions. Sequential pH conditioning would therefore be necessary to develop this approach further.
- Multi-layer sorption processes. A study was undertaken by the Paks power plant and the University of Veszprém, Hungary, using adsorption with ion exchange in a multiplayer column to treat waste streams containing complex organic compounds. The experiments indicated that this approach has potential to achieve favourable DFs and a mobile treatment unit has been commissioned for use at the Paks power station.

8.2.5 Combined multi-stage processes

Such processes allow treatment of wastes with varied composition by careful combination of treatment processes. Wastes with complex composition, including those from reprocessing, secondary wastes from decontamination operations, organic radioactive sludges and spent ion exchange resins are possible candidates for multi-stage processes. Examples include:

- Evaporation and fractional condensation treatment of boric acid solutions resulting from PWR operations. A small pilot plant is in operation at Doel power plant in Belgium;
- Thermal oxidation and catalytic oxidation of organic and sorption of tritiated water from tritiated organic solvents, under development at SCK-CEN, Belgium;
- Sorption/membrane filtration or sorption/centrifugation for colloid-containing waste streams: are under investigation by the Belorussian Academy of Sciences. The methods show potential when Fe(III) and Cr(III) concentrations are very low.

8.3 Conclusions

Progress in the application of BAT in the UK's nuclear facilities is clearly demonstrated in this report, specific examples of progress include:

- Abatement of ^{99}Tc discharges from current and future MAC arisings through diversion to vitrification;
- Abatement of ^{99}Tc discharges from treatment of stored MAC by use of TPP in EARP;
- The use and combination of SIXEP and EARP plants at Sellafield;
- The construction and commissioning of the new Low Level Liquid Effluent Treatment Plant at Dounreay;
- The development and use of Submersible Caesium Removal Units (IONSIV IE-911) in Magnox fuel storage ponds;
- The combination of techniques (segregation, collection, oxidation, isotopic enrichment) under development at GE Healthcare's Maynard Centre for the recycling, rather than discharge, of ^{3}H and ^{14}C;
- Diversion of high concentration radioactive aqueous effluents to cementation at Harwell.

The procedures and techniques applied in the UK nuclear industry are consistent with BAT, and measures are in place, as part of the authorisation review process, to ensure that technological developments continue to be reviewed and implemented where appropriate. Where the regulators believe it is justified and proportionate they can, and do, impose improvement conditions in the authorisation certificates, amongst which the regulators can include the requirement to review and report, periodically, on international best practice on the abatement of discharges. The approaches identified in recent international reports are consistent with those currently adopted or under development in the UK.

8.4 References

OECD (2003). Effluent Release Options from Nuclear Installations, Technical Background and Regulatory Aspects. ISBN-92-64-02146-9. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

International Atomic Energy Agency (2003), Combined Methods for Liquid Radioactive Waste Treatment, Final Report of a Co-ordinated Research Project 1997-2001, IAEA-TECDOC-1336, Vienna, Austria,

9. Acronyms

AETP	Active Effluent Treatment Plant
AGR	Advanced Gas-coded Reactor
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable (UK term equivalent to ALARA)
ALES	Active Liquid Effluent System
BAT	Best Available Technique

BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
BSS	Basic Safety Standards
Cm2919	Command 2919, Review of Radioactive Waste Management Policy, Final Conclusions (July 1995)
COS	Carbonyl Sulphide
CRU	Caesium Removal Unit
DEFRA	Department of the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (predecessor to DEFRA)
DF	Decontamination Factor
DOENI	Department of the Environment, Northern Ireland
DPAG	Dounreay Particles Advisory Group
EA	Environment Agency of England and Wales
EARP	Enhanced Actinide Removal Plant
EHS	Environment and Heritage Service Northern Ireland
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
FASSET	Framework for Assessment of Environmental Impact
FSA	Food Standards Agency
HEPA	High Efficiency Particulate Air
HLW	High Level Waste (waste containing >4 GBq α and/or 12 G Bq β/γ and with heat generating properties).
HSE	Health and Safety Executive
ICRP	International Commission for Radiological Protection
ILW	Intermediate Level Waste (as for HLW but not heat generating)
IPPC	Integrated Pollution Prevention and Control
ISO	International Standards Organisation
ISTA	Inter Site Transfer Authorisation
LCBL	Life Cycle Base Line
LETP	Liquid Effluent Treatment Plant
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low Level Waste (<4 GBq α and/or 12 G Bq β/γ)
LMU	Liabilities Management Unit
MAC	Medium Active Concentrate
MRP	Magnox Reprocessing Plant
MXD	Magnox Dissolution Plant
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NII	Nuclear Installations Inspectorate
NRPB	National Radiological Protection Board
NTWP	Near Term Work Plan
PFR	Prototype Fast Reactor

PIE	Post Irradiation Examination
POCO	Post Operational Clean-Out
PWR	Pressurised Water Reactor
RIFE	Radioactivity in Food and the Environment
RSA 93	Radioactive Substances Act (1993)
SCRU	Submersible Caesium Removal Unit
SDP	Sellafield Drypack Plant
SEC	Salt Evaporator Concentrate
SEPA	Scottish Environment Protection Agency
SETP	Segregated Effluent Treatment Plant
SGHWR	Steam Generating Heavy Water Reactor
SGHWR	Steam Generating Heavy Water Reactor
SIXEP	Site Ion Exchange Effluent Plant
SMP	Sellafield Mox Plant
STP	Solvent Treatment Plant
SWES	Site Wide Environmental Statement
THORP	Thermal Oxide Reprocessing Plant
TPP	Tetraphenylphosphonium bromide
UCL	Urenco Capenhurst Ltd
UKAEA	UK Atomic Energy Authority
UOC	Uranium Ore Concentrate
WAGR	Windscale Advanced Gas-cooled Reactor
WETP	Waste Encapsulation Treatment Plant
WVP	Waste Vitrification Plant

Table 8. BNFL/URENCO Capenhurst, Site Characteristics

Type of Facility	Uranium enrichment by centrifuge
Location	Cheshire, England, UK
Date commissioned	1954
Date ceased generation or commenced decommissioning	n/a
Tonnes U processed annually	Information not supplied by site operator
Receiving waters and catchment area	Rivacre Brook into Mersey Estuary (OSPAR Region III)
Volume of effluent discharged into the receiving waters	Information not supplied by site operator

Table 9. BNFL/URENCO Capenhurst, Discharge Data

	Authorised Annual Discharge Limits (TBq) for Liquid Effluents					
	1998	1999	2000	2001	2002	2003
Total U- alpha activity	0,02	0,02	0,02	0,02	0,02	0,02
U- daughters	0,02	0,02	0,02	0,02	0,02	0,02
Non-uranic alpha emitters	0,003	0,03	0,003	0,003	0,003	0,003
^{99}Tc	0,1	0,1	0,1	0,1	0,1	0,1
^{3}H				87,5	78	78
	Actual Site Annual Liquid Discharges (TBq)					
Total U- alpha activity	1,2E-3	2,3E-03	0,00116	0,0015	0,00124	9,2E-04
U- daughters	<0,0028	0,0019	0,0024	0,0022	0,0011	9,2E-04
Non-uranic alpha emitters	1,5E-05	2,1E-05	1,22E-04	2,1E-05	6,4E-06	6,7E-06
^{99}Tc	0,00134	0,00114	0,00151	0,0013	0,0011	0,102
^{3}H				0,124	0,125	9,2E-04
	Actual site annual emissions to air (TBq)					
^{3}H	5,09	<2,94	0,57	0,04	0,0097	1,05E-02
Uranium (BNFL)	6,15E-06	2,8E-05	4,7E-06	1E-06	4,8E-07	1,02E-05
Uranium (Urenco)						3,27E-07

Table 10. BNFL/URENCO Capenhurst, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
	1998	1999	2000	2001	2002	2003
^{3}H	-	<130	<25	<0,25	<25	<25
^{60}Co	<0,06	<0,06	<0,12	<0,13	<0,05	<0,05
^{99}Tc	1,0	2,9	4,9	-	16	3,6
^{137}Cs	3,3	2,5	2,6	1,7	2,2	1,9
^{155}Eu	-	<0,15	<0,34	-	-	<0,14
^{239}Pu + ^{240}Pu	-	-	-	-	<0,05	-
^{241}Am	<0,06	<0,17	<0,49	<0,24	-	<0,16
	Activity Concentration (Bq kg^{-1} wet wt) in Cockles**					
^{60}Co	0,17	0,30	0,36	0,23	0,14	0,17
^{99}Tc	36	35	33	-	16	13
^{137}Cs	1,1	1,3	2,1	1,7	1,5	1,9
^{155}Eu	-	<0,20	<0,15	-	-	<0,10
^{226}Ra	-	-	-	0,91	-	-
^{234}Th	<5,7	<8,0	12	4,8	-	11
^{238}Pu	-	-	-	-	0,11	0,16
^{239}Pu + ^{240}Pu	-	-	-	-	0,64	0,88
^{241}Am	1,5	2,1	2,7	2,3	1,8	2,3
	Activity concentration (Bq kg^{-1} wet wt) in *Elodea canadensis****					
^{60}Co	<0,06	<0,07	<0,11	<0,05	<0,05	<0,08
^{99}Tc	7,2	17	3,6	75	15	8,6
^{137}Cs	<0,31	0,25	0,13	0,62	0,39	0,48
^{155}Eu	-	<0,32	<0,17	-	-	<0,25
^{233}Pa	1,2	0,97	-	-	-	0,12
^{234}Th	2,1	180	3,9	40	20	13
^{234}U	5,4	28	4,9	33	7,9	8,8
^{235}U + ^{236}U	0,30	1,2	0,25	1,9	0,29	-
^{238}U	5,3	2,4	2,5	25	5,0	5,0
^{237}Np	0,24	0,099	0,10	8,8	0,50	0,19
	Activity concentration (Bq kg^{-1} wet wt) in *Elodea canadensis****					
^{241}Am	<0,09	<0,08	<0,09	<0,18	<0,23	<0,28
	Activity concentration (Bq kg^{-1} wet wt) in *Cladophora****					
^{60}Co	-	-	-	<0,04	-	-

^{99}Tc	-	-	-	44	-	-
^{137}Cs	-	-	-	0,51	-	-
^{234}Th	-	-	-	77	-	-
^{234}U	-	-	-	11	-	-
^{235}U + ^{236}U	-	-	-	0,58	-	-
^{238}U	-	-	-	6,9	-	-
^{237}Np	-	-	-	1,7	-	-
^{241}Am	-	-	-	<0,06	-	-

Sample locations: * Hoylake (1998, 1999, 2000), Wirral (2001, 2002, 2003); ** Dee Estuary (1998, 1999, 2001, 2002, 2003), Wirral (2000); *** Rivacre Brook.

Table 11. BNFL/URENCO Capenhurst, Radiation Doses to the Public

Reference Group	Dose (μSv a^{-1})					
	1998	1999	2000	2001	2002	2003
Local children due to inadvertent ingestion of water and sediment from Rivacre Brook	<1	<1	<1	<1	<1	<1

Table 12. BNFL Springfields, Site Characteristics

Type of Facility	Production of fuel and intermediates
Location	Salwick, Preston, Lancs
Date commissioned	From 1949
Date ceased generation or commenced decommissioning	n/a
Tonnes U processed annually	Approximately 5 000 (varies)
Receiving waters and catchment area	River Ribble (OSPAR Region III)
Volume of effluent discharged into the receiving waters	~1x10^{6} m^{-3} 2003 (site total including storm drainage – common discharge point)

Table 13. BNFL Springfields, Discharge and Emission Data

	Authorised Annual Discharge Limits (TBq) for Liquid Effluents					
	1998	1999	2000	2001	2002	2003
Total beta	240	240	240	240	240	240
Total alpha	4	4	4	4	4	4
^{230}Th	2	2	2	2	2	2
^{232}Th	0,2	0,2	0,2	0,2	0,2	0,2
U-α	0,15	0,15	0,15	0,15	0,15	0,15
^{237}Np	0,04	0,04	0,04	0,04	0,04	0,04
^{99}Tc	0,6	0,6	0,6	0,6	0,6	0,6
	Actual Site Annual Liquid Discharges (TBq)					
Total beta	150	128	71,3	85,1	106	97
Total alpha	0,195	0,239	0,173	0,16	0,221	0,18
^{230}Th	8,50E-02	0,146	6,93E-02	6,94E-02	0,102	6,70E-02
^{232}Th	1,20E-03	4,70E-03	9,00E-04	4,70E-03	2,50E-03	6,00E-04
U-α	4,70E-02	4,98E-02	5,87E-02	4,78E-02	4,96E-02	5,60E-02
^{237}Np	2,00E-04	0,0012	5,00E-04	3,00E-04	0,0014	1,80E-03
^{99}Tc	2,73E-02	3,87E-02	3,49E-02	1,77E-02	0,0167	5,20E-02
	Actual site annual emissions to air (TBq)					
U-α	1,54E-03	1,6E-03	3,57E-04	4,21E-04	8,6E-04	0,9

Table 14. BNFL Springfields, Environmental Impact

	Activity Concentration (Bq kg^{-1} wet wt) in Flounder					
	1998	1999	2000	2001	2002	2003
^{60}Co	<0,09	<0,07	<0,17	<0,09	<0,07	<0,06
^{125}Sb	<0,24	-	-	-	<0,18	<0,18
^{137}Cs	9,2	8,4	7,8	5,9	5,2	4,6
^{154}Eu	<0,29	-	-	-	-	-
^{241}Am	<0,29	<0,08	<0,62	<0,39	<0,08	<0,17
	Activity Concentration (Bq kg^{-1} wet wt) in Salmon					
^{60}Co	<0,09	<0,11	<0,06	<0,12	<0,15	<0,11
^{125}Sb	<0,26	-	-	-	<0,35	<0,25
^{137}Cs	0,43	0,27	0,39	0,32	0,26	0,22
^{154}Eu	<0,28	-	-	-	-	-
^{241}Am	<0,24	<0,55	<0,18	<0,33	<0,62	<0,32

	Activity Concentration (Bq kg^{-1} wet wt) in Sea trout					
^{60}Co	<0,11	<0,09	<0,14	<0,13	<0,09	<0,07
^{125}Sb	<0,29	-	-	-	<0,26	<0,20
^{137}Cs	6,0	15	5,4	2,5	3,5	6,7
^{154}Eu	<0,35	-	-	-	-	-
^{241}Am	<0,23	<0,08	<0,37	<0,33	<0,25	<0,19
	Activity Concentration (Bq kg^{-1} wet wt) in Grey mullet					
^{60}Co	<0,19	-	<0,17	<0,14	-	<0,16
^{99}Tc	-	-	-	1,4	-	-
^{125}Sb	<0,46	-	-	-	-	<0,41
^{137}Cs	4,7	-	5,4	1,2	-	2,4
^{154}Eu	<0,62	-	-	-	-	-
^{241}Am	<0,85	-	<0,24	<0,31	-	<0,34
	Activity Concentration (Bq kg^{-1} wet wt) in Bass					
^{60}Co	-	<0,07	<0,12	<0,11	<0,13	<0,07
	Activity Concentration (Bq kg^{-1} wet wt) in Bass					
^{125}Sb	-	-	-	-	<0,29	<0,17
^{137}Cs	-	12	14	18	6,8	7,7
^{241}Am	-	<0,06	<0,30	<0,09	<0,30	<0,08
	Activity Concentration (Bq kg^{-1} wet wt) in Shrimps					
^{14}C	56	47	-	-	56	59
^{60}Co	<0,05	<0,06	<0,06	<0,07	<0,07	<0,07
^{99}Tc	-	1,5	4,1	6,9	3,2	3,0
^{125}Sb	<0,15	-	-	-	<0,16	<0,15
^{137}Cs	4,4	3,8	3,3	2,2	2,6	2,5
^{154}Eu	<0,15	-	-	-	-	-
^{226}Ra	0,033	0,067	0,016	0,045	0,018	-
^{228}Th	0,0078	0,012	0,013	0,0099	0,0064	5,9E-03
^{230}Th	0,010	0,022	0,014	0,014	0,00098	7,6E-03
^{232}Th	0,0041	0,0052	0,0054	0,0044	0,0023	2,2E-03
^{234}Th	3,8	-	-	-	-	-
^{238}Pu	0,0034	0,0025	0,0043	0,0019	0,0016	1,5E-03
^{239}Pu + ^{240}Pu	0,017	0,012	0,021	0,011	0,0095	8,8E-03
^{241}Am	0,028	0,023	0,034	0,020	0,018	1,5E-02
^{243}Cm + ^{244}Cm	0,000072	0,000048	0,000052	-	0,000059	-
	Activity Concentration (Bq kg^{-1} wet wt) in Cockles					
^{60}Co	0,67	1,1	1,6	1,0	0,51	0,57
^{125}Sb	<0,25	-	-	-	<0,22	<0,28
^{137}Cs	4,3	5,3	4,3	2,1	2,4	2,4
^{154}Eu	<0,24	-	-	-	-	-
^{226}Ra	0,069	-	0,020	0,012	0,022	-
^{228}Th	0,44	-	0,37	0,32	0,35	0,45
^{230}Th	0,63	-	0,58	0,37	0,59	0,44
^{232}Th	0,24	-	0,23	0,14	0,19	0,20
^{234}Th	33	47	9,7	16	-	20
^{238}Pu	0,38	-	0,23	0,16	0,19	0,20
^{239}Pu + ^{240}Pu	2,0	-	1,3	0,87	1,1	1,1
^{241}Am	5,1	7,8	3,3	2,5	2,8	3,4
^{242}Cm	-	-	-	-	0,0022	4,2E-03
^{243}Cm + ^{244}Cm	0,011	-	0,012	0,0043	0,0034	6,0E-03
	Activity Concentration (Bq kg^{-1} wet wt) in Mussels					
^{60}Co	-	-	-	0,33	0,25	0,18
^{125}Sb	-	-	-	-	0,25	0,38
^{137}Cs	-	-	-	1,9	2,5	1,3
^{226}Ra	-	-	-	-	0,10	-
^{228}Th	-	-	-	-	0,27	0,18
^{230}Th	-	-	-	-	0,49	0,31
^{232}Th	-	-	-	-	0,16	8,0E-02
^{234}Th	-	-	-	18	-	36
^{241}Am	-	-	-	1,7	2,4	0,74

All samples from the Ribble estuary.

Table 15. BNFL Springfields, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group*	1998	1999	2000	2001	2002	2003
River Ribble houseboat dweller due mainly to external radiation from activity in river bed due to past disposals	15	10	11	18**	19**	23
Local fishing community due to fish and shellfish consumption and external radiation***	5	5	5	5	5	5

* Doses are estimated using a combination of measurements and modelling. Generally speaking, the dose does not include a historical component, as the principal contributing nuclides discharged from Springfields are short lived. ** Average of range. *** Typical dose rate.

Table 16. BNFL Magnox Berkeley, Site Characteristics

Type of Facility	Decommissioning station
Location	Gloucestershire
Date commissioned	1962
Date ceased generation or commenced decommissioning	1989
Installed generating capacity	n/a
Receiving waters and catchment area	River Severn (OSPAR Region II)
Volume of effluent discharged into the receiving waters	Information not supplied by site operator

Table 17. BNFL Magnox Berkeley, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluent					
	1998	1999	2000	2001	2002	2003
Tritium	8	8	8	8	8	2
^{137}Cs	0,2	0,2	0,2	0,2	0,2	0,2
"Other activity"	0,4	0,4	0,4	0,4	0,4	0,4
	Actual site annual liquid discharges (TBq)					
^{3}H	3,4E-02	6,38E-03	6,39E-03	7,4E-04	6,2E-04	3,0E-04
Total beta*	8,8E-02	2,6E-02	3,9E-02	6,2E-03	3,4E-04	3,6E-04
Total alpha**	2,4E-05	4,7E-05	2,8E-05	1,3E-05	4,4E-06	3,1E-06
^{58}Co	<7,E-06	<2,E-05	<2,E-05	<1,E-05	<6,E-06	<6,E-06
^{60}Co	1,5E-04	6,8E-05	6,4E-05	3,6E-05	<3,E-06	1,8E-05
^{65}Zn	<2,E-04	<6,E-05	<4,E-05	<3,E-05	<1,E-05	<2,E-05
^{90}Sr	3,2E-02	9,0E-03	1,9E-02	2,0E-03	9,6E-05	6,2E-05
^{95}Zr + ^{95}Nb	<6,E-05	<1,E-04	<8,E-05	<6,E-05	<2,E-05	<3,E-05
^{106}Ru	<4,E-04	<3,E-04	<2,E-04	<7,E-05	<3,E-05	<4,E-05
^{110}mAg	<5,E-05	<3,E-05	<3,E-05	<2,E-05	<6,E-06	<9,E-06
^{125}Sb	<2,E-04	<7,E-05	<7,E-05	<4,E-05	<9,E-06	<8,E-06
^{134}Cs	1,8E-04	5,5E-05	4,3E-05	<1,E-05	2,3E-05	<6,E-06
^{137}Cs	1,43E-02	7,68E-03	1,75E-02	2,29E-03	2,1E-04	1,57E-04
^{144}Ce	<3,E-04	<2,E-04	<2,E-04	<6,E-05	<2,E-05	<2,E-05
Other radionuclides	0,0734	1,78E-03	2,2E-02	3,92E-03	1,3E-04	1,11E-04
	Actual site annual emissions to air (TBq)					
^{3}H	1,3E-02	3,87E-03	4,78E-03	4,3E-03	4,21E-03	3,71E-03
^{14}C	2,31E-04	1,22E-04	1,86E-04	2,0E-04	2,64E-04	2,51E-04
Alpha and beta activity assoc' with particulate matter	1,87E-06	1,54E-06	5,3E-07	5,8E-07	3,68E-07	3,81E-07

* Analytical Methods for Gross Beta in Liquid Effluent. Hunterston and Chapelcross, direct measurement. Other stations, sample evaporated to dryness to remove tritium, then the residue is taken up in nitric acid. Solution analysed by liquid scintillation against ^{14}C and ^{137}Cs standards (except Wylfa, which is analysed against ^{3}H and ^{14}C standards) to best represent the dominant radionuclides in the sample (^{14}C is used as a surrogate for ^{35}S).

** Analytical Methods for Gross Alpha in Liquid Effluent. Hunterston and Chapelcross, direct measurement. Other stations, sum of ^{238}Pu, ^{239}Pu &^{240}Pu, ^{241}Am, ^{242}Cm and ^{243}Cm &^{244}Cm determined on a representative bulked sample of the effluent discharged each calendar year.

Table 18. BNFL Magnox Berkley, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Fish					
	1998	1999	2000	2001	2002	2003
Total beta	86	-	-	-	-	-
^{60}Co	<0,5	<0,1 - <2	<0,2 - <0,3	<0,2 - <0,4	<0,2 - <0,6	<0,4

^{65}Zn	<0,3	<0,2 - <0,6	< 0,2 - <0,5	<0,3 - <0,6	<0,2 - <2	-
^{134}Cs	<0,2	< 0,1 - <0,3	< 0,1 - <0,2	<0,1 - <0,2	<0,1 - <0,4	<0,3 - <0,4
^{137}Cs	0,94	<0,2 - 0,80	<0,2 - 0,6	<0,2 - 0,70	<0,2 - 1,2	<0,5 - 0,83
^{241}Am	<0,4	<0,1 - <0,6	<0,3 - <0,7	<0,3 - <0,7	<0,3 - <2	-
	Activity concentration (Bq kg^{-1} wet wt) in Crustaceans					
^{60}Co	-	<0,1	<0,2	<0,2	-	-
^{65}Zn	-	<0,3	<0,3	<0,3	-	-
^{134}Cs	-	<0,1	<0,1	<0,1	-	-
^{137}Cs	-	<0,1	<0,2	<0,5	-	<0,3
^{241}Am	-	<0,3	<0,3	<0,6	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{60}Co	-	<0,9	<0,4	<0,3	<0,3	<0,4
^{65}Zn	-	<1,1	<0,6	<0,6	0,49	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{134}Cs	-	0,54	<0,3	<0,2	0,25	0,30
^{137}Cs	-	1,1	0,35	<0,4	0,70	0,98
^{241}Am	-	<1	<0,7	<0,8	<0,7	-

Table 19. BNFL Magnox Berkeley, Radiation Doses to the Public

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
External exposure + consumption of fish	10	12	5,8	9,8	3,3	

Doses all derived from environmental monitoring results.

Table 20. BNFL Magnox Bradwell, Site Characteristics

Type of Facility	Defuelling station
Location	Essex
Date commissioned	1962
Date ceased generation or commenced decommissioning	2002
Installed generating capacity	Currently 0, design 246 MW
Receiving waters and catchment area	Blackwater Estuary (OSPAR Region II)
Volume of effluent discharged into the receiving waters	Information not supplied by site operator

Table 21. BNFL Magnox Bradwell, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	30	30	30	30	30	7
^{137}Cs	0,75	0,75	0,75	0,75	0,75	0,2
"Other activity"	1	1	1	1	1	0,4
	Actual site annual liquid discharges (TBq) for 1998-2003					
^{3}H	1,8	5,25E-01	6,49E-01	1,8E	1,93E	0,127
Total beta	6,8E-01	6,4E-01	6,6E-01	7,8E-01	4,4E-01	6,5E-01
Total alpha	5,2E-04	3,7E-04	1,7E-04	3,1E-04	7,4E-04	1,0E-03
^{58}Co	<2,E-04	<2,E-04	<2,E-04	<2,E-04	<1,E-04	<1,E-04
^{60}Co	1,5E-03	1,1E-03	3,5E-04	4,0E-04	4,5E-04	3,5E-04
^{65}Zn	9,8E-04	5,7E-04	<3,E-04	<3,E-04	<3,E-04	<3,E-04
^{90}Sr	2,9E-02	2,6E-03	2,9E-02	3,1E-02	3,1E-02	1,1E-01
^{95}Zr + ^{95}Nb	<1,E-03	<1,E-03	<8,E-04	<9,E-04	<6,E-04	<8,E-04
^{106}Ru	<4,E-03	<2,E-03	<3,E-03	<2,E-03	<2,E-03	<2,E-03
^{110}mAg	<4,E-04	<2,E-04	<2,E-04	<2,E-04	<2,E-04	<2,E-04
^{125}Sb	<9,E-04	<8,E-04	6,5E-03	8,9E-03	<8,E-04	1,8E-03
^{134}Cs	8,5E-02	9,4E-02	9,1E-02	5,9E-02	4,7E-02	3,8E-02
^{137}Cs	3,23E-01	3,37E-01	4,87E-01	4,69E-01	3,06E-01	0,373
^{144}Ce	<3,E-03	<2,E-03	<2,E-03	<1,E-03	<2,E-03	<2,E-03
Other radionuclides	3,59E-01	0,3	0,17	3,1E-01	0,194	0,285
	Actual site annual emissions to air (TBq)					
^{3}H	8,4E-01	7,81E-01	5,58E-01	9,01E-01	6,47E-01	8,5E-02
^{14}C	3,8E-01	0,199	1,96E-01	4,64E-01	1,58E-01	0,00376
^{35}S	5,8E-02	3,7E-02	2,76E-02	8,3E-02	4,85E-02	8,5E-05
^{41}Ar	7,2E+02	2,79E+02	2,41E+02	6,22E+02	1,37E+02	-
Beta activity associated with particulate matter	2,6E-04	2,25E-04	1,77E-04	3,26E-04	1,43E-04	2,01E-05

Table 22. BNFL Magnox Bradwell, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Fish					
	1998	1999	2000	2001	2002	2003
Total beta	130	-	-	-	-	-
^{60}Co	<0,4	<0,6	<0,4	0,60	1,2	<0,7
^{65}Zn	<0,4	<0,8	< 0,9	<0,9	<3	<2
^{110}mAg	<0,4	<0,5	<0,4	<0,4	<2	<0,8
^{134}Cs	<0,4	<0,4	0,47	0,50	<1	<0,7
^{137}Cs	1,2	0,85	1,8	2,1	1,5	1,4
^{241}Am	<0,8	<2	<2	<2	<3	<2
	Activity concentration (Bq kg^{-1} wet wt) in Molluscs					
Total beta	120	-	-	-	-	-
^{60}Co	<0,4	0,25 - 0,26	<0,4 - 0,12	<0,2 - 0,77	<0,5 - 0,57	0,46 - 0,78
^{65}Zn	1,8	0,90 - 2,0	0,35 - 0,80	0,23 - 0,37	0,90 - 1,2	0,88 - 1,4
^{110}mAg	<0,2	<0,2 - <0,3	<0,1 - <0,2	<0,2	<0,4	<0,4 - <0,8
^{134}Cs	<0,2	0,25 - 0,26	0,15 - 0,17	0,16 - 0,19	0,38 - <0,4	<0,4 - <0,7
^{137}Cs	0,67	0,69 - 0,74	0,78 - 0,82	0,64 - 0,72	1,4 - 1,9	0,65 - 1,2
^{241}Am	<0,5	<0,4 - <0,5	<0,7 - 0,42	<0,4 - <0,6	<0,9 - <2	<1 - <4
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{60}Co	-	0,90	< 0,3	0,25	0,79	< 0,7
^{65}Zn	-	< 0,6	< 0,4	< 0,5	1,9	< 2
^{110}mAg	-	< 0,8	< 0,2	< 0,2	< 0,9	< 0,9
^{134}Cs	-	1,3	0,85	0,51	0,71	0,65
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{137}Cs	-	5,6	4,9	3,7	5,1	4,5
^{241}Am	-	< 2	< 0,7	< 2	< 3	< 2

Table 23. BNFL Magnox Bradwell, Radiation Doses to the Public

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
External exposure + consumption of fish	20	45	17	15	29	

Doses all derived from environmental monitoring results.

Table 24. BNFL Magnox Chapelcross, Site Characteristics

Type of Facility	Defuelling station
Location	Dumfriesshire
Date commissioned	1959
Date ceased generation or commenced decommissioning	2004
Installed generating capacity	Currently 0, design 196 MW
Receiving waters and catchment area	Solway Firth (OSPAR Region III)
Volume of effluent discharged into the receiving waters	

Table 25. BNFL Magnox Chapelcross, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluent					
	1998	1999	2000	2001	2002	2003
^{3}H	5,5	5,5	5,5	5,5	5,5	5,5
Total beta	25	25	25	25	25	25
Total alpha	0,1	0,1	0,1	0,1	0,1	0,1
	Actual site annual liquid discharges (TBq)					
^{3}H	2,2E-01	7,08E-01	5,46E-01	1,67E-01	2,80E-01	0,249
Total beta	4,0E-02	0,0675	1,93E-01	2,6E-02	1,23E-01	0,178
Total alpha	4,2E-04	1,78E-04	6,29E-04	7,3E-05	1,05E-04	8,01E-04
^{60}Co	1,7E-03	4,0E-04	7,0E-04	3,0E-04	3,0E-04	1,6E-03
^{65}Zn	<1,E-04	<2,E-04	<1,E-04	<2,E-05	<1,E-05	<5,E-05
^{90}Sr	1,5E-02	2,4E-02	8,8E-02	8,0E-03	5,3E-02	8,1E-02
^{106}Ru	<9,E-04	<4,E-04	<6,E-04	<1,E-04	<1,E-04	<6,E-04
^{125}Sb	<3,E-04	<5,E-04	<4,E-04	<5,E-05	<2,E-04	<4,E-04
^{134}Cs	4,0E-04	3,0E-04	1,3E-03	3,0E-04	2,1E-03	3,2E-03
^{137}Cs	4,9E-03	3,8E-03	1,7E-02	4,2E-03	2,0E-02	3,6E-02
^{144}Ce	<5,E-04	<2,E-04	<2,E-04	<5,E-05	<1,E-04	<3,E-04
Other radionuclides	1,8E-02	4,2E-02	8,3E-02	1,3E-02	4,5E-02	5,8E-02

	Actual site annual emissions to air (TBq)					
^{3}H	1,3E+03	1,42E+03	1,5E+03	8,44E+02	7,63E+02	4,1E+02
^{35}S	2,2E-02	2,65E-02	2,43E-02	1,95E-02	7,33E-03	3,7E-03
^{41}Ar	2,8E+03	2,81E+03	2,55E+03	2,14E+03	1,16E+03	748

Table 26. BNFL Magnox Chapelcross, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Fish					
	1998	1999	2000	2001	2002	2003
^{60}Co	-	0,1	-	<0,1	-	-
^{90}Sr	0,1 - 0,2	0,1	0,1 - 0,2	<0,1	0,1	< 0,1
^{99}Tc	-	-	-	-	<0,9 - <1,2	<0,6 - <1
^{110}mAg	-	-	-	-	-	<0,1
^{134}Cs	<0,1	<0,1	<0,1	<0,1	<0,1 - <0,2	<0,1
^{137}Cs	0,6 - 25	0,40 - 23	0,4 - 20	0,3	0,4 - 12	0,2 - 12
^{241}Am	-	-	-	-	-	< 0,1
	Activity concentration (Bq kg^{-1} wet wt) in Crustaceans					
^{60}Co	-	0,1	0,1	<0,1	-	-
^{90}Sr	0,4	0,3	0,3	<0,1	0,25	-
^{99}Tc	-	-	-	-	7,5	-
^{134}Cs	<0,1	<0,1	<0,1	<0,1	<0,1	-
^{137}Cs	5,5	7,1	5,8	4,5	4,0	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{60}Co	-	0,90	0,7	0,6	0,6	0,5
^{99}Tc	-	-	-	-	5100	3200
^{134}Cs	-	-	-	-	-	< 0,1
^{137}Cs	-	10	8,0	7,1	5,5	8
^{241}Am	-	-	-	-	-	4,5

Table 27. BNFL Magnox Chapelcross, Radiation Doses to the Public

Reference Group	**Dose (µSv a^{-1})** derived from environmental monitoring results					
External exposure + consumption of fish & shrimp	1998	1999	2000	2001	2002	2003
	26	34	37	38	21	

Table 28. BNFL Magnox Dungeness A, Site Characteristics

Type of Facility	Generating station
Location	Kent
Date commissioned	1965
Date ceased generation or commenced decommissioning (if applicable)	n/a
Installed generating capacity	450 MW
Receiving waters and catchment area	English Channel (OSPAR Region II)
Volume of effluent discharged into the receiving waters	

Table 29. BNFL Magnox Dungeness A, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	35	35	35	35	35	8
^{137}Cs	1,2	1,2	1,2	1,2	1,2	1,1
"Other activity"	1,4	1,4	1,4	1,4	1,4	0,8
	Actual site annual liquid discharges (TBq)					
^{3}H	4,2E-01	2,12	1,09	2,42	3,45	0,335
Total beta	1,1	7,7E-01	5,7E-01	3,2E-01	5,0E-01	4,8E-01
Total alpha	3,1E-04	2,8E-03	2,6E-03	9,2E-04	2,8E-04	1,3E-04
^{58}Co	<4,E-04	<3,E-04	<2,E-04	<2,E-04	<3,E-04	<3,E-04
^{60}Co	2,9E-04	3,3E-04	8,1E-04	4,4E-04	7,2E-05	2,7E-04
^{65}Zn	<1,E-03	<4,E-04	<4,E-04	<3,E-04	<3,E-04	<3,E-04
^{90}Sr	1,4E-02	3,9E-03	5,1E-03	7,4E-03	7,5E-03	1,2E-02
$^{95}Zr + {}^{95}Nb$	1,2E-02	1,4E-01	7,1E-02	<6,E-03	<2,E-03	<1,E-03
^{106}Ru	<5,E-03	2,1E-02	4,5E-02	1,2E-02	5,9E-03	<3,E-03
^{110}mAg	<6,E-04	<2,E-04	<2,E-04	<1,E-04	<2,E-04	<2,E-04
^{125}Sb	9,1E-03	3,9E-02	1,0E-01	6,1E-02	2,2E-02	2,8E-03
^{134}Cs	2,5E-01	1,1E-01	3,9E-02	3,0E-02	8,4E-02	9,8E-02
^{137}Cs	7,1E-01	3,3E-01	1,3E-01	1,18E-01	3,06E-01	0,308

^{144}Ce	5,1E-03	4,8E-02	5,9E-02	1,2E-02	1,5E-03	<1,E-03
Other radionuclides	3,9E-01	0,441	0,438	0,212	0,132	0,166
	Actual site annual emissions to air (TBq)					
^{3}H	5,8E-01	5,07E-01	5,52E-01	6,9E-01	4,6E-01	0,478
^{14}C	3,3	3,56	3,27	3,0	3,5	3,4
^{35}S	6,3E-02	5,2E-02	5,23E-02	3,6E-02	3,9E-02	0,0356
^{41}Ar	1,3E+03	1,25E+03	1,1E+03	8,6E+02	1,2E+03	1050
Beta activity associated with particulate matter	3,6E-04	3,11E-04	2,82E-04	2,2E-04	2,5E-04	2,25E-04

Dungeness A and Dungeness B are on contiguous sites. Environmental input data are indistinguishable in routine surveillance programmes. All environmental concentration data, and assessed radiation exposures, are presented for the two stations in Tables 80 and 81.

Table 30. BNFL Magnox Hinkley Point A, Site Characteristics

Type of Facility	Defuelling station
Location	Somerset
Date commissioned	1964
Date ceased generation or commenced decommissioning	2000
Installed generating capacity	Currently 0, design 470 MW
Receiving waters and catchment area	Bristol Channel (OSPAR Region III)
Volume of effluent discharged into the receiving waters	Information not supplied by site operator

Table 31. BNFL Magnox Hinkley Point A, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	25	25	25	25	25	1,8
^{137}Cs	1,5	1,5	1,5	1,5	1,5	1
"Other activity"	1	1	1	1	1	0,7
	Actual site annual liquid discharges (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	7,1E-01	0,836	1,27	1,09	7,11E-01	0,536
Total beta	7,3E-01	8,8E-01	4,2E-01	5,8E-01	4,0E-01	6,2E-01
Total alpha	2,0E-03	2,2E-03	1,3E-03	3,5E-03	2,2E-03	1,4E-03
^{58}Co	<2,E-04	<3,E-04	<2,E-04	<2,E-04	<2,E-04	<2,E-04
^{60}Co	1,1E-03	1,5E-03	8,1E-04	8,6-04	5,1E-04	4,3E-04
^{65}Zn	<7,E-04	<4,E-04	<3,E-04	<3,E-04	<2,E-04	<3,E-04
^{90}Sr	8,6E-03	6,0E-03	8,3E-03	1,3E-02	1,7E-02	7,5E-02
^{95}Zr + ^{95}Nb	3,1E-03	<2,E-03	<1,E-03	<1,E-03	<3,E-04	<7,E-04
^{106}Ru	<5,E-03	<3,E-03	<2,E-03	3,7E-03	<2,E-03	<2,E-03
^{110}mAg	<5,E-04	<2,E-04	<2,E-04	<2,E-04	<1,E-04	<2,E-04
^{125}Sb	5,7E-03	4,6E-03	5,6E-03	2,6E-02	2,4E-02	3,2E-03
^{134}Cs	1,2E-01	1,2E-01	6,2E-02	6,8E-02	3,5E-02	3,3E-02
^{137}Cs	4,9E-01	4,39E-01	1,3E-01	4,28E-01	3,32E-01	0,486
^{144}Ce	8,1E-03	5,5E-03	2,0E-03	6,5E-03	2,0E-03	<2,E-03
Other radionuclides	2,8E-01	2,73E-01	0,1	0,15	0,0757	0,0134
	Actual site annual emissions to air (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	2,6	3,3	7,86E-02	6,32E-01	3,57E-02	0,0126
^{14}C	1,4	1,6	5,6E-02	2,06E-03	2,56E-03	0,00263
^{35}S	5,8E-02	4,9E-02	1,11E-03	4,86E-04	2,55E-06	-
^{41}Ar	2,7E+03	1,1E+03	Nil	Nil	Nil	-
Beta activity associated with particulate matter	1,1E-04	4,9E-05	1,16E-06	2,15E-06	2,63E-06	3,04E-06

Hinkley Point A and Hinkley Point B are on contiguous sites. Environmental input data are indistinguishable in routine surveillance programmes. All environmental concentration data, and assessed radiation exposures, are presented for the two stations in Tables 78 and 79.

Table 32. BNFL Magnox Hunterston A, Site Characteristics

Type of Facility	Decommissioning station
Location	Ayrshire
Date commissioned	1964
Date ceased generation or commenced decommissioning (if applicable)	1990
Installed generating capacity	Currently 0
Receiving waters and catchment area	Firth of Clyde (OSPAR Region III)
Volume of effluent discharged into the receiving waters	

Table 33. BNFL Magnox Hunterston A, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	5	5	5	0,7	0,7	0,7
Total alpha	-	-	-	0,04	0,04	0,04
^{241}Pu	-	-	-	1	1	1
Total activity (excl ^{3}H)	2	2	2	-	-	-
"Other beta activity"	-	-	-	0,6	0,6	0,6
	Actual site annual liquid discharges (TBq)					
^{3}H	6,7E-03	2,18E-02	2,8E-03	4,05E-03	8,17E-04	9,4E-04
Total beta	2,4E-01	2,0E-01	1,4E-01	2,46E-02	2,87E-02	0,0498
Total alpha	6,6E-04	5,3E-04	1,9E-04	1,4E-04	1,47E-04	1,79E-04
^{137}Cs	1,8E-01	1,7E-01	1,2E-01	1,3E-02	1,6E-02	-
^{241}Pu	-	-	-	8,25E-04	2,19E-04	-
Other radionuclides	6,0E-02	3,0E-02	2,0E-02	Nil	1,3E-02	-
Total Activity (excl ^{3}H)	0,242	0,197	0,138	-	-	-
	Actual site annual emissions to air (TBq)					
^{3}H	Nil	Nil	Nil	Nil	1,45E-03	0,00159
^{14}C	Nil	Nil	Nil	Nil	1,8E-04	1,88E-04
Beta activity associated with particulate matter	1,3E-07	4,7E-07	4,6E-07	3,6E-07	2,6E-07	4,5E-07

Hunterston A and Hunterston B are on contiguous sites. Environmental input data are indistinguishable in routine surveillance programmes. All environmental concentration data, and assessed radiation exposures, are presented for the two stations in Tables 85 and 86.

Table 34. BNFL Magnox Oldbury, Site Characteristics

Type of Facility	Generating station
Location	Gloucestershire
Date commissioned	1967
Date ceased generation or commenced decommissioning	N/A
Installed generating capacity	434 MW
Receiving waters and catchment area	Severn Estuary (OSPAR Region III)
Volume of effluent discharged into the receiving waters	

Table 35. BNFL Magnox Oldbury, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	25	25	25	25	25	1
^{137}Cs	0,7	0,7	0,7	0,7	0,7	0,7
"Other activity"	1,3	1,3	1,3	1,3	1,3	0,7
	Actual site annual liquid discharges (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	1,7E-01	2,14E-01	3,54E-01	3,44E-01	4,19E-01	0,334
Total beta	2,4E-01	2,4E-01	2,1E-01	8,0E-01	8,5E-01	6,7E-01
Total alpha	1,6E-04	1,4E-04	1,8E-04	9,3E-05	9,5E-05	5,7E-05
^{58}Co	<2,E-04	<1,E-04	<8,E-05	<2,E-04	<2,E-04	<2,E-04
^{60}Co	2,6E-04	2,1E-04	2,1E-04	1,9E-04	2,7E-04	1,8E-04
^{65}Zn	3,9E-04	3,1E-04	2,0E-04	<6,E-04	<6,E-04	<3,E-04
^{90}Sr	2,5E-02	3,5E-02	2,3E-02	5,7E-02	<7,0E-02	5,5E-02
$^{95}Zr + {}^{95}Nb$	<8,E-04	<1,E-03	<6,E-04	<1,E-03	<1,E-03	<1,E-03
^{106}Ru	<2,E-03	<2,E-03	<1,E-03	<3,E-03	<3,E-03	<3,E-03
^{110}mAg	<2,E-04	<1,E-04	<1,E-04	<2,E-04	<2,E-04	<2,E-04

^{125}Sb	<5,E-04	<4,E-04	<4,E-04	<9,E-04	<1,E-03	<8,E-04
^{134}Cs	1,0E-02	1,0E-02	1,0E-02	1,3E-01	1,4E-01	1,2E-01
^{137}Cs	6,3E-02	6,6E-02	6,4E-02	4,82E-01	5,43E-01	0,449
^{144}Ce	<8,E-04	<8,E-04	<5,E-04	<2,E-03	<2,E-03	<2,E-03
Other radionuclides	1,8E-01	0,172	1,5E-01	3,2E-01	3,09E-01	0,224
	Actual site annual emissions to air (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	2,4	2,42	1,63	2,13	2,79	3,29
^{14}C	3,7	3,93	3,69	4,73	4,48	1,91
^{35}S	3,1E-01	3,33E-01	3,29E-01	3,34E-01	3,43E-01	0,168
^{41}Ar	1,8E+02	1,91E+02	1,57E+02	2,24E+02	2,84E+02	7,5,7
Beta activity associated with particulate matter	1,0E-04	1,08E-04	1,87E-04	1,44E-04	1,2E-04	4,85E-05

Table 36. BNFL Magnox Oldbury Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Fish					
	1998	1999	2000	2001	2002	2003
Total beta	86	-	-	-	-	-
^{60}Co	< 0,5	< 0,1 - < 2	< 0,2 - < 0,3	< 0,2 - < 0,4	< 0,2 - < 0,6	< 0,4
^{65}Zn	< 0,3	< 0,2 - < 0,6	< 0,2 - < 0,5	< 0,3 - < 0,6	< 0,2 - < 2	-
^{134}Cs	< 0,2	< 0,1 - < 0,3	< 0,1 - < 0,2	< 0,1 - < 0,2	< 0,1 - < 0,4	< 0,3 - < 0,4
^{137}Cs	0,94	< 0,2 - 0,80	< 0,2 - 0,6	< 0,2 - 0,70	< 0,2 - 1,2	< 0,5 - 0,83
^{241}Am	< 0,4	< 0,1 - < 0,6	< 0,3 - < 0,7	< 0,3 - < 0,7	< 0,3 - < 2	-
	Activity concentration (Bq kg^{-1} wet wt) in Crustaceans					
^{60}Co	-	< 0,1	< 0,2	< 0,2	-	-
^{65}Zn	-	< 0,3	< 0,3	< 0,3	-	-
^{134}Cs	-	< 0,1	< 0,1	< 0,1	-	-
^{137}Cs	-	< 0,1	< 0,2	< 0,5	-	< 0,3
^{241}Am	-	< 0,3	< 0,3	< 0,6	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{60}Co	-	< 0,9	< 0,4	< 0,3	< 0,3	< 0,4
^{65}Zn	-	< 1,1	< 0,6	< 0,6	0,49	-
^{134}Cs	-	0,54	< 0,3	< 0,2	0,25	0,30
^{137}Cs	-	1,1	0,35	< 0,4	0,70	0,98
^{241}Am	-	< 1	< 0,7	< 0,8	< 0,7	-

Table 37. BNFL Magnox Oldbury Radiation Doses to the Public

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
External exposure + consumption of fish	10	12	5,8	9,8	3,3	

Doses all derived from environmental monitoring results.

Table 38. BNFL Magnox Sizewell A, Site Characteristics

Type of Facility	Generating station
Location	Suffolk
Date commissioned	1965
Date ceased generation or commenced decommissioning	N/A
Installed generating capacity	420 MW
Receiving waters and catchment area	North Sea (OSPAR Region II)
Volume of effluent discharged into the receiving waters	

Table 39. BNFL Magnox Sizewell A, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	35	35	35	35	35	11
^{137}Cs	1	1	1	1	1	1
"Other activity"	0,7	0,7	0,7	0,7	0,7	0,7
	Actual site annual liquid discharges (TBq)					
^{3}H	2,9	6,65E-01	1,582	2,01	3,41E-01	2,83
Total beta	2,2E-01	1,9E-01	3,1E-01	1,1	8,2E-01	8,9E-01
Total alpha	2,4E-05	2,3E-05	2,3E-05	1,7E-04	1,9E-04	1,9E-04
^{58}Co	<7,E-05	<5,E-05	<2,E-04	<2,E-04	<2,E-04	<2,E-04
^{60}Co		1,2E-04	1,0E-04	5,2E-04	3,6E-04	3,8E-04

^{65}Zn	<3,E-04	1,5E-04	<2,E-04	<3,E-04	<2,E-04	<3,E-04
^{90}Sr	3,6E-02	3,7E-02	8,2E-02	9,0E-02	7,2E-02	8,5E-02
^{95}Zr + ^{95}Nb	<4,E-04	<4,E-04	<4,E-04	<1,E-03	<1,E-03	<1,E-03
^{106}Ru	<9,E-04	<7,E-04	<9,E-04	<3,E-03	<2,E-03	<3,E-03
^{110}mAg	<1,E-04	<6,E-05	<7,E-05	-	<2,E-04	<2,E-04
^{125}Sb	<4,E-05	<3,E-04	<4,E-04	<1,E-03	<7,E-04	<9,E-04
^{134}Cs	6,3E-03	4,7E-03	2,2E-02	1,7E-01	1,1E-01	1,1E-01
^{137}Cs	7,1E-02	6,87E-02	1,44E-01	7,59E-01	5,36E-01	0,558
^{144}Ce	<9,E-04	<5,E-04	<6,E-04	<2,E-03	<2,E-03	<2,E-03
Other radionuclides	1,1E-01	0,116	0,172	0,317	2,82E-01	0,334
	Actual site annual emissions to air (TBq)					
^{3}H	5,2E-01	1,41	9,16E-01	2,06	2,63	1,93
^{14}C	4,7E-01	1,09	1,07	1,02	1,17	1,26
^{35}S	1,9E-02	1,23E-01	1,59E-01	1,64E-01	1,33E-01	0,179
^{41}Ar	8,4E+02	1,68E+03	1,73E+03	1,84E+03	1,85E+03	2030
Beta activity associated with particulate matter	5,6E-05	1,47E-04	1,52E-04	1,9E-04	1,87E-04	2,05E-04

Sizewell A and Sizewell B are on contiguous sites. Environmental input data are indistinguishable in routine surveillance programmes. All environmental concentration data, and assessed radiation exposures, are presented for the two stations in Tables 92 and 93.

Table 40. BNFL Magnox Trawsfynydd, Site Characteristics

Type of Facility	Decommissioning station
Location	Gwynedd
Date commissioned	1965
Date ceased generation or commenced decommissioning	1993
Installed generating capacity	
Receiving waters and catchment area	Lake Trawsfynydd
Volume of effluent discharged into the receiving waters	

Table 41. BNFL Magnox Trawsfynydd, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	12	12	12	12	12	0,5
^{137}Cs	0,05	0,05	0,05	0,05	0,05	0,03
^{90}Sr	0,08	0,08	0,08	0,08	0,08	0,05
"Total activity"	0,72	0,72	0,72	0,72	0,72	-
"Other activity (inc ^{90}Sr)"	-	-	-	-	-	0,17
	Actual site annual liquid discharges (TBq)					
^{3}H	6,3E-02	4,02E-02	5,3E-03	2,92E-02	1,55E-01	0,0358
Total beta	3,4E-02	6,0E-02	6,0E-03	4,6E-03	7,9E-03	3,9E-03
Total alpha	2,3E-04	1,3E-04	3,1E-05	5,2E-05	6,7E-05	9,1E-05
^{58}Co	<5,E-05	<6,E-05	<4,E-05	<4,E-05	<3,E-05	<3,E-05
^{60}Co	<5,E-05	1,3E-04	<2,E-05	<1,E-05	9,1E-05	1,1E-04
^{65}Zn	<4,E-04	<2,E-04	<7,E-05	<7,E-05	<7,E-05	<8,E-05
^{90}Sr	1,0E-02	2,32E-02	1,5E-03	9,2E-04	0,00158	2,2E-03
^{95}Zr + ^{95}Nb	<4,E-04	<4,E-04	<2,E-04	<3,E-04	<2,E-04	<2,E-04
^{106}Ru	<7,E-04	<4,E-04	<2,E-04	<1,E-04	<1,E-04	<7,E-05
^{110}mAg	<6,E-05	<6,E-05	<4,E-05	<4,E-05	<4,E-05	<4,E-05
^{125}Sb	3,7E-04	4,0E-04	<5,E-05	<4,E-05	<6,E-05	<5,E-05
^{134}Cs	1,5E-04	<3,E-05	<3,E-05	<2,E-05	1,6E-04	<2,E-05
^{137}Cs	6,5E-03	4,3E-03	1,8E-03	1,85E-03	1,95E-03	0,00193
^{144}Ce	<4,E-04	<2,E-04	<2,E-04	<1,E-04	<1,E-04	<1,E-04
Other radionuclides(excl ^{3}H, ^{90}Sr, ^{137}Cs)	1,8E-02	0,0303	0,0271	0,00179	0,00215	0,0042
	Actual site annual emissions to air (TBq)					
^{3}H	1,4E-01	9,0E-02	1,73E-01	1,18E-01	4,83E-02	0,0555
^{14}C	1,6E-03	8,77E-04	1,15E-03	2,87E-03	9,0E-04	1,4E-03
Beta activity associated with particulate matter	1,5E-06	2,07E-06	1,58E-06	1,76E-06	4,63E-07	4,77E-07

Note: Trawsfynydd discharges into an inland lake. Marine environmental impact and radiation dose estimates are not applicable at this site.

Table 42. BNFL Magnox Wylfa, Site Characteristics

Type of Facility	Generating station
Location	Anglesey
Date commissioned	1971
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	980 MW
Receiving waters and catchment area	Irish Sea (OSPAR Region III)
Volume of effluent discharged into the receiving waters	

Table 43. BNFL Magnox Wylfa, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	40	40	40	40	40	15
Other activity	0,15	0,15	0,15	0,15	0,15	0,11
	Actual site annual liquid discharges (TBq)					
^{3}H	9,6	4,59	4,02	6,43	4,93	8,6
Total beta	7,0E-02	1,9E-02	2,9E-02	5,5E-02	6,8E-02	5,8E-02
Total alpha	7,9E-06	2,9E-06	2,5E-06	5,8E-06	6,1E-06	1,3E-05
^{58}Co	<9,E-05	<8,E-05	<7,E-05	<8,E-05	<9,E-05	<2,E-04
^{60}Co	1,4E-03	1,3E-03	1,4E-03	1,5E-03	1,9E-03	1,8E-03
^{65}Zn	<4,E-04	<2,E-04	<2,E-04	<2,E-04	<2,E-04	<3,E-04
^{90}Sr	1,4E-04	2,5E-04	3,9E-04	5,4E-04	7,0E-04	3,7E-04
$^{95}Zr + {}^{95}Nb$	<5,E-04	<4,E-04	<4,E-04	<5,E-04	<5,E-04	<6,E-04
^{106}Ru	<5,E-04	<3,E-04	<3,E-04	<5,E-04	<7,E-04	<7,E-04
^{110}mAg	<3,E-04	<9,E-05	<4,E-05	<8,E-05	<2,E-04	<2,E-04
^{125}Sb	<2,E-04	<6,E-05	<2,E-04	<2,E-04	<2,E-04	<3,E-04
^{134}Cs	1,2E-03	2,5E-04	2,3E-03	4,9E-03	6,3E-03	2,0E-03
^{137}Cs	1,2E-03	1,3E-03	1,0E-02	1,8E-02	3,0E-02	1,5E-02
^{144}Ce	<5,E-04	2,3E-04	<2,E-04	<3,E-04	<4,E-04	<4,E-04
Other radionuclides	7,0E-02	0,0185	0,029	0,0553	6,82E-02	0,0584
	Actual site annual emissions to air (TBq)					
^{3}H	8,3	4,84	6,0	1,61	3,81	4,5
^{14}C	1,5	1,48	5,22E-01	4,04E-01	1,54	1,4
^{35}S	3,0E-01	3,0E-01	7,75E-02	3,5E-02	2,03E-01	1,8E-01
^{41}Ar	6,1E+01	3,65E+01	7,45	1,27E+01	3,19E+01	41,1
Beta activity associated with particulate matter	6,4E-05	7,8E-05	9,56E-05	2,27E-05	2,93E-05	3,01E-05

Table 44. BNFL Magnox Wylfa, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Fish					
	1998	1999	2000	2001	2002	2003
^{60}Co	< 0,2	< 0,09 - < 0,2	< 0,05 - < 0,1	< 0,06 - 0,34	< 0,3	< 0,5 - < 0,6
^{65}Zn	< 0,4	< 0,2 - < 0,4	< 0,2 - < 0,3	< 0,3 - < 0,4	< 0,1 - < 0,8	-
^{134}Cs	< 0,2	< 0,1 - < 0,2	< 0,1	< 0,1	< 0,1 - < 0,2	-
^{137}Cs	3,0	1,1 - 1,9	1,8 - 1,9	1,0 - 1,8	0,83 - 0,90	0,4 - 1,2
^{241}Am	< 0,5	< 0,4 - < 0,5	< 0,3 - < 0,4	< 0,4 - < 0,5	< 0,5	-
	Activity concentration (Bq kg^{-1} wet wt) in Crustaceans					
^{60}Co	< 0,2	< 0,2	< 0,2	0,20 - 0,45	< 0,2 - 0,62	< 0,6
^{65}Zn	< 0,3	< 0,3	< 0,3	< 0,3 - < 0,4	< 0,3 - < 0,5	-
^{134}Cs	< 0,2	< 0,1	< 0,1 - < 0,2	< 0,1 - < 0,2	< 0,2	-
^{137}Cs	< 0,7	0,65 - 0,93	0,60 - 0,85	0,43 - 0,48	0,33 - 0,43	0,37 - 0,51
^{241}Am	< 0,5	< 0,4 - < 0,6	< 0,4 - < 0,6	< 0,5 - < 0,6	< 0,8 - < 2	-
	Activity concentration (Bq kg^{-1} wet wt) in Molluscs					
^{60}Co	< 0,3	< 0,2	< 0,2	< 0,4	< 0,7	< 0,6
^{65}Zn	< 0,5	< 0,5	< 0,3	< 0,6	< 0,5	-
^{134}Cs	< 0,2	< 0,2	< 0,1	< 0,2	< 0,2	-
^{137}Cs	1,4	1,7	1,3	0,93	0,60	0,83
^{241}Am	< 0,9	< 0,8	< 0,7	< 0,8	< 2	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					
^{60}Co	-	< 0,08 - 0,38	< 0,2 - 0,36	< 0,2 - 0,84	< 0,3 - 0,69	< 0,7 - 0,82
^{65}Zn	-	< 0,3	< 0,3	< 0,3 - < 0,5	< 0,4 - < 0,6	-
^{134}Cs	-	< 0,1 - < 0,2	< 0,1	< 0,1 - 0,15	< 0,2	-
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed					

^{137}Cs	-	0,75 - 1,3	0,70 - 1,5	0,80 - 1,4	0,50 - 1,0	0,35 - 0,60
^{241}Am	-	< 0,5 - < 0,6	< 0,4 - < 0,5	< 0,3 - < 0,5	< 0,8 - < 0,2	-

Table 45. BNFL Magnox Wylfa, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
External exposure + consumption of fish	20	11	13	7,7	11	

Doses all derived from environmental monitoring results.

Table 46. British Energy Dungeness B, Site Characteristics

Type of Facility:	Power Station, 2 Advanced Gas Cooled Reactors
Location:	Kent
Date commissioned:	1983
Date ceased generation or commenced decommissioning:	n/a
Installed generating capacity	See Table below
Receiving waters and catchment area	English Channel (OSPAR Region II)
Volume of effluent discharged into the receiving waters	25 000 cubic metres per year (before dilution in cooling water)

Table 47. British Energy Dungeness B, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1110	1110	1110	1110	1110	1110
Annual electricity generation, GWh(e)	4191	3622	2250	5900	4640	6150

Table 48. British Energy Dungeness B, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	650	650	650	650	650	650
^{35}S	2	2	2	2	2	2
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	0,25	0,25	0,25	0,25	0,25	0,25
	Actual site annual liquid discharges (TBq)					
^{3}H	172	122	119	356	290	446
Total beta*	0,22	0,27	0,14	0,61	0,39	0,78
Total alpha**	5E-06	8E-06	9E-06	9E-06	1,6E-05	-
^{35}S	0,20	0,242	0,117	0,58	0,359	0,79
^{60}Co	1,3E-03	2,0E-03	1,54E-03	2,41E-03	1,56E-03	1,7E-03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	1,7E-02	2,47E-02	1,71E-02	2,71E-02	2,74E-02	0,0252
^{45}Ca	1,1E-02	6,6E-03	6,0E-03	3,1E-03	0,9E-03	-
^{54}Mn	3,7E-04	6,7E-04	2,4E-04	5,7E-04	3,1E-04	-
^{55}Fe	2,3E-04	1,6E-04	1,2E-04	3,2E-04	2,3E-04	-
^{124}Sb	-	8,8E-04	-	-	8,2E-04	-
^{134}Cs	1,5E-03	0,3E-03	1,5E-03	1,8E-03	2,7E-03	-
^{137}Cs	1,6E-03	3,7E-03	2,2E-03	4,2E-03	7,1E-03	-
^{241}Pu	-	-	4,1E-04	3,5E-04	1,9E-04	-

* Total beta calculated as sum of ^{35}S, ^{60}Co and "Total activity excluding ^{3}H, ^{35}S & ^{60}Co"; ** Total alpha calculated as sum of measured alpha emitters.

Table 49. British Energy Dungeness B, Normalised Liquid Discharge Data

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	4,191	3,622	2,250	5,900	4,640	6,150
^{3}H	41	34	53	60	63	72
Total beta	0,05	0,07	0,06	0,10	0,08	0,13
Total alpha	1,2E-06	2,3E-06	4,0E-06	1,5E-06	3,4E-06	-
^{35}S	4,80E-02	6,70E-02	5,20E-02	9,90E-02	7,70E-02	1,22E-01
^{60}Co	3,00E-04	5,50E-04	6,90E-04	4,10E-04	3,40E-04	2,80E-04
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	3,90E-03	6,90E-03	7,50E-03	4,60E-03	5,90E-03	4,10E-03

^{45}Ca	2,60E-03	1,80E-03	2,70E-03	5,30E-04	1,90E-04	-
^{54}Mn	8,80E-05	1,85E-04	1,07E-04	9,70E-05	6,70E-05	-
^{55}Fe	5,50E-05	4,40E-05	5,30E-05	5,40E-05	5,00E-05	-
^{124}Sb	-	2,43E-04	-	-	1,77E-04	-
^{134}Cs	3,58E-04	8,28E-04	6,67E-04	3,05E-04	5,82E-04	-
^{137}Cs	3,82E-04	1,02E-03	9,78E-04	7,12E-04	1,53E-03	-
^{241}Pu	-	-	1,82E-04	5,90E-05	4,10E-05	-

Table 50. British Energy Dungeness B, Aerial Discharge Data

	Actual site annual emissions to air (TBq) for 1998-2003					
	1998	1999	2000	2001	2002	2003
^{3}H	3,3	1,2	2,65	0,809	4,9	11,0
^{14}C	0,41	0,470	0,277	0,523	0,638	0,714
^{35}S	2,30E-02	1,01E-02	5,44E-03	9,98E-03	4,63E-02	0,0889
Particulate beta	1,6E-05	1,15E-05	6,64E-06	8,85E-06	9,25E-06	7,84E-06

Table 51. British Energy Dungeness B, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Plaice*					
	1998	1999	2000	2001	2002	2003
Organic ^{3}H	-	-	-	-	<25	<25
^{3}H	<120	<25	<25	<25	<25	<25
^{60}Co	<0,07	<0,05	<0,05	<0,09	<0,04	<0,04
^{134}Cs	<0,07	<0,05	-	-	-	-
^{137}Cs	0,18	0,12	0,12	<0,16	0,11	0,10
^{155}Eu	<0,13	-	<0,11	<0,19	<0,12	-
^{241}Am	<0,11	<0,08	<0,12	<0,20	<0,11	<0,10
	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
^{3}H	<120	<25	<25	<25	<25	<25
^{60}Co	<0,06	<0,06	<0,11	<0,04	<0,04	<0,04
^{134}Cs	<0,06	<0,06	-	-	-	-
^{137}Cs	0,37	0,30	0,23	0,23	0,21	0,24
^{155}Eu	<0,14	-	<0,23	<0,11	<0,09	-
^{241}Am	<0,16	<0,10	<0,28	<0,14	<0,08	<0,04
	Activity concentration (Bq kg^{-1} wet wt) in Bass*					
^{3}H	<130	<25	<25	<25	<25	<25
^{60}Co	<0,05	<0,22	<0,11	<0,04	<0,06	<0,05
^{134}Cs	<0,05	<0,23	-	-	-	-
^{137}Cs	0,76	0,83	0,24	0,37	0,63	0,72
^{155}Eu	<0,12	-	<0,17	<0,09	<0,18	-
^{241}Am	<0,12	<0,46	<0,09	<0,05	<0,28	<0,05
	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
Organic ^{3}H	-	-	-	-	<32	<25
^{3}H	-	-	-	<25	<25	<25
^{60}Co	<0,08	<0,05	<0,07	<0,20	<0,06	<0,08
^{134}Cs	<0,14	<0,07	-	-	-	-
^{137}Cs	0,45	0,24	0,16	<0,18	0,25	0,21
^{155}Eu	<0,13	-	<0,14	<0,35	<0,14	-
^{241}Am	<0,08	<0,10	<0,10	<0,24	<0,11	<0,19
	Activity concentration (Bq kg^{-1} wet wt) in Whelks*					
^{60}Co	0,34	<0,23	<0,10	<0,14	<0,11	<0,13
^{134}Cs	<0,06	<0,13	-	-	-	-
^{137}Cs	<0,05	<0,12	<0,11	<0,10	<0,05	<0,08
^{155}Eu	<0,14	-	<0,22	<0,19	<0,11	-
^{238}Pu	1,10E-03	3,20E-04	6,50E-04	7,70E-04	-	5,4E-04
^{239}Pu + ^{240}Pu	3,90E-03	2,20E-03	2,70E-03	2,60E-03	-	2,5E-03
^{241}Am	5,30E-03	2,60E-03	2,30E-03	2,30E-03	4,10E-03	2,3E-03
^{242}Cm	2,10E-04	2,90E-04	2,50E-04	1,20E-04	-	-
^{243}Cm + ^{244}Cm	4,50E-04	2,20E-04	1,70E-04	1,40E-04	-	1,6E-04
	Activity concentration (Bq kg^{-1} wet wt) in Crabs**					
^{60}Co	0,45	0,89	0,12	<0,07	<0,05	<0,05
^{134}Cs	<0,19	<0,06	-	-	-	-
^{137}Cs	<0,17	<0,05	0,06	<0,06	<0,05	<0,04
^{155}Eu	<0,36	-	<0,15	<0,20	<0,13	-
^{241}Am	<0,42	<0,26	<0,14	<0,27	<0,12	<0,04

	Activity concentration (Bq kg^{-1} wet wt) in Cuttlefish**					
^{60}Co	-	-	<0,03	<0,04	<0,05	<0,02
^{137}Cs	-	-	0,02	<0,04	<0,05	0,02
^{155}Eu	-	-	<0,06	<0,11	<0,17	-
^{241}Am	-	-	<0,04	<0,10	<0,26	<0,03
	Activity concentration (Bq kg^{-1} wet wt) in Cockles***					
^{60}Co	-	-	-	-	0,50	-
^{137}Cs	-	-	-	-	0,10	-
^{155}Eu	-	-	-	-	<0,14	-
^{241}Am	-	-	-	-	<0,07	-
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus vesiculosus*+					
^{60}Co	0,43	0,26	-	-	-	-
^{99}Tc	-	-	4,9	3,2	7,6	5,2
^{134}Cs	<0,07	<0,06	-	-	-	-
^{137}Cs	0,17	<0,10	-	-	-	-
^{241}Am	<0,22	<0,11	-	-	-	-

* Pipeline outfall. **Hastings. *** Greatstone-on-sea. + Copt Point.

Table 52. British Energy Dungeness B, Radiation Doses to the Public

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Bait diggers due to fish and shellfish consumption and external radiation	14	10	5	7	7	*

The doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites, including Dungeness A. * 2003 data not yet available.

Table 53. British Energy Hartlepool, Site Characteristics

Type of Facility:	Power Station, 2 Advanced Gas Cooled Reactors
Location:	Cleveland
Date commissioned:	1984
Date ceased generation or commenced decommissioning:	n/a
Installed generating capacity	See Table below
Receiving waters and catchment area	North Sea
Volume of effluent discharged into the receiving waters	20 000 m^3 yr^{-1} (before dilution in cooling water)

Table 54. British Energy Hartlepool, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1210	1210	1210	1210	1210	1210
Annual electricity generation, GWh(e)	8089	9283	8990	8910	9520	8050

Table 55. British Energy Hartlepool, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	1200	1200	1200	1200	1200	1200
Total beta *	3,33	-	-	-	-	-
^{35}S	3	3	3	3	3	3
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	0,3	0,3	0,3	0,3	0,3	0,3
	Actual site annual liquid discharges (TBq)					
^{3}H	329	409	411	386	411	360
Total beta*	0,332	0,870	1,221	1,725	1,576	1,307
Total alpha**	4,10E-06	3,50E-06	2,90E-06	4,80E-06	1,20E-05	-
^{35}S	0,33	0,864	1,22	1,72	1,56	1,30
^{60}Co	3,30E-03	3,11E-03	3,27E-03	1,96E-03	4,80E-03	1,70E-03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	2,50E-03	3,15E-03	1,93E-03	8,63E-03	1,57E-02	0,013
^{45}Ca	-	-	7,70E-03	7,00E-04	-	-
^{54}Mn	1,00E-03	1,20E-03	8,60E-04	1,50E-03	4,60E-03	-
^{55}Fe	1,50E-04	5,80E-05	4,70E-05	4,20E-05	7,50E-05	-
^{134}Cs	2,70E-04	2,50E-04	1,30E-04	2,20E-04	3,60E-03	-
^{137}Cs	3,70E-04	3,90E-04	3,50E-04	6,70E-04	5,50E-03	-
^{241}Pu	-	-	1,60E-04	2,10E-04	2,00E-04	-

*Total beta calculated as sum of ^{35}S, ^{60}Co and "Total activity excluding ^{3}H, ^{35}S & ^{60}Co".

**Total alpha calculated as sum of measured alpha emitters.

Table 56. British Energy Hartlepool, Normalised Liquid Discharge Data

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	8,089	9,283	8,990	8,910	9,520	8,050
^{3}H	41	44	46	43	43	45
Total beta	0,04	0,09	0,14	0,19	0,17	0,16
Total alpha	5,1E-07	3,8E-07	3,2E-07	5,4E-07	1,3E-06	-
^{35}S	0,04	0,09	0,14	0,19	0,16	0,16
^{60}Co	4,00E-04	3,40E-04	3,60E-04	2,10E-04	5,00E-04	2,10E-04
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	3,10E-04	3,40E-04	2,10E-04	9,40E-04	1,65E-03	1,56E-03
^{45}Ca	-	-	8,57E-04	8,30E-05	-	-
^{54}Mn	1,20E-04	1,30E-04	1,00E-04	1,70E-04	4,80E-04	-
^{55}Fe	1,90E-05	6,20E-06	5,20E-06	4,70E-06	7,878E-06	-
^{134}Cs	3,30E-05	2,70E-05	1,40E-05	2,50E-05	3,782E-04	-
^{137}Cs	4,60E-05	4,20E-05	3,90E-05	7,50E-05	5,777E-04	-
^{241}Pu	-	-	1,80E-05	2,40E-05	2,101E-05	-

Table 57. British Energy Hartlepool, Aerial Discharge Data

	Actual site annual emissions to air (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	1,50	1,41	1,86	1,82	1,56	2,54
^{14}C	1,91	1,74	1,47	2,09	1,78	1,80
^{35}S	2,20E-02	5,48E-02	7,22E-02	6,37E-02	1,10E-01	1,21E-01
Particulate beta	4,3E-06	4,3E-06	4,31E-06	4,72E-06	5,37E-06	8,76E-06

Table 58. British Energy Hartlepool, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Plaice*					
	1998	1999	2000	2001	2002	2003
Organic ^{3}H	-	-	<25	<25	<26	<25
^{3}H	-	-	<25	<25	<25	<26
^{14}C	46	24	36	17	-	33
^{54}Mn	-	-	-	-	<0,04	-
^{60}Co	<0,05	<0,12	<0,05	<0,10	<0,05	<0,11
^{131}I	-	<1,2	-	-	-	-
^{137}Cs	0,41	0,44	0,35	0,29	0,34	0,23
^{155}Eu	-	<0,16	-	-	-	-
^{241}Am	<0,11	<0,09	<0,11	<0,37	<0,15	<0,18
	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
^{54}Mn	-	-	-	-	<0,05	-
^{60}Co	<0,05	<0,04	<0,04	<0,06	<0,05	<0,04
^{131}I	-	<0,23	-	-	<0,33	-
^{137}Cs	0,65	0,60	0,46	0,56	0,57	0,44
^{155}Eu	-	<0,09	-	-	-	-
^{241}Am	<0,13	<0,07	<0,17	<0,17	<0,21	<0,15
	Activity concentration (Bq kg^{-1} wet wt) in Crabs*					
Organic ^{3}H	-	-	-	-	47	-
^{14}C	57	44	40	25	-	27
^{54}Mn	-	-	-	-	<0,06	-
^{60}Co	<0,07	<0,07	<0,05	<0,04	<0,06	<0,05
^{137}Cs	0,19	<0,14	<0,09	0,09	0,14	<0,09
^{155}Eu	-	<0,22	-	-	-	-
^{238}Pu	1,70E-03	4,20E-04	3,60E-04	6,80E-04	-	3,4E-04
^{239}Pu + ^{240}Pu	8,70E-03	2,30E-03	2,30E-03	3,50E-03	-	2,2E-03
^{241}Am	1,50E-02	2,20E-03	1,80E-03	6,20E-03	1,90E-03	1,8E-03
^{243}Cm + ^{244}Cm	2,40E-03	-	-	1,20E-05	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Winkles**					
Organic ^{3}H	-	-	95	68	38	<31
^{3}H	-	-	110	71	42	38
^{14}C	-	-	-	-	-	-
^{54}Mn	-	-	-	-	<0,07	-
^{60}Co	<0,07	<0,06	<0,07	<0,06	<0,06	<0,04

^{131}I	-	<0,19	-	-	<0,67	-
^{137}Cs	0,54	0,48	0,44	0,44	0,43	0,38
^{155}Eu	-	<0,16	-	-	-	-
^{238}Pu	9,00E-03	7,30E-03	1,00E-02	9,70E-03	-	1,2E-02
^{239}Pu + ^{240}Pu	5,20E-02	4,90E-02	6,20E-02	6,30E-02	-	7,9E-02
^{241}Am	2,60E-02	2,00E-02	2,90E-02	2,50E-02	3,10E-02	3,5E-02
^{243}Cm + ^{244}Cm	-	3,10E-05	1,10E-03	-	-	9,3E-05
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus vesiculosus****					
^{54}Mn	-	-	-	-	<0,15	-
^{60}Co	<0,04	<0,04	<0,05	<0,05	<0,06	<0,10
^{99}Tc	110	58	44	-	110	24
^{131}I	-	<2,8	-	-	<1,4	-
^{137}Cs	0,23	0,22	0,19	0,12	0,21	0,16
^{155}Eu	-	<0,08	-	-	-	-
^{241}Am	<0,09	<0,05	<0,21	<0,13	<0,07	<0,16

* Pipeline outfall area. **Paddy's Hole. ***Pilot Station.

Table 59. British Energy Hartlepool, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishing community due to fish and shellfish consumption and external radiation	5	<5	<5	<5	<5	*

The doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites. *2003 data not yet available.

Table 60. British Energy Heysham 1, Site Characteristics

Type of Facility	Power Station, 2 Advanced Gas Cooled Reactors
Location	Lancashire
Date commissioned	1984
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	1150 MW(e) see Table below
Receiving waters and catchment area	Morecambe Bay and Irish Sea (OSPAR Region III)
Volume of effluent discharged into the receiving waters	5 000 – 10 000 m^3 y^{-1} (before dilution in cooling water)

Table 61. British Energy Heysham 1, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1150	1150	1150	1150	1150	1150
Annual electricity generation, GWh(e)	9144	8069	8990	8390	7840	7390

Table 62. British Energy Heysham 1, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents.					
	1998	1999	2000	2001	2002	2003
^{3}H	1200	1200	1200	1200	1200	1200
^{35}S	2,8	2,8	2,8	2,8	2,8	2,8
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	0,3	0,3	0,3	0,3	0,3	0,3
	Actual site annual liquid discharges (TBq)					
^{3}H	396	395	441	399	402	360
Total beta*	0,25	0,16	0,14	0,20	0,30	0,41
Total alpha**	3,00E-06	4,00E-06	7,00E-06	3,00E-05	3,00E-05	-
^{35}S	0,24	0,144	0,121	0,179	0,278	0,37
^{60}Co	1,00E-03	3,00E-04	1,05E-03	7,90E-04	9,23E-04	8,4E-04
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	9,00E-03	0,0116	1,42E-02	2,11E-02	2,32E-02	4,30E-02
^{45}Ca	1,90E-03	-	1,10E-03	1,50E-03	9,00E-04	-
^{54}Mn	1,20E-03	1,00E-03	2,20E-03	8,30E-03	7,00E-03	-
^{55}Fe	1,20E-04	6,60E-05	8,00E-05	3,00E-04	7,00E-04	-
^{58}Co	-	-	-	2,80E-04	4,30E-04	-
^{124}Sb	-	-	-	1,90E-04	2,10E-04	-
^{134}Cs	5,70E-04	4,30E-04	7,10E-04	1,20E-03	2,50E-03	-
^{137}Cs	9,80E-04	1,00E-03	1,50E-03	4,40E-03	6,40E-03	-
^{241}Pu	-	-	1,80E-04	4,60E-04	5,00E-04	-

*Total beta calculated as sum of ^{35}S, ^{60}Co and "Total activity excluding ^{3}H, ^{35}S & ^{60}Co".
**Total alpha calculated as sum of measured alpha emitters.

Table 63. British Energy Heysham 1, Normalised Liquid Discharge

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	9,144	8,069	8,990	8,390	7,840	7,390
^{3}H	43	49	49	48	51	49
Total beta	0,03	0,02	0,02	0,02	0,04	0,06
Total alpha	3,3E-07	5,0E-07	7,8E-07	3,6E-06	3,8E-06	-
^{35}S	0,03	0,02	0,01	0,02	0,04	0,05
^{60}Co	1,10E-04	3,00E-05	1,20E-04	9,00E-05	1,20E-04	1,10E-04
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	1,00E-03	1,44E-03	1,58E-03	2,51E-03	2,96E-03	5,88E-03
^{45}Ca	2,10E-04	-	1,20E-04	1,80E-04	1,10E-04	-
^{54}Mn	1,30E-04	1,20E-04	2,40E-04	9,90E-04	8,90E-04	-
^{55}Fe	1,00E-05	1,00E-05	1,00E-05	4,00E-05	9,00E-05	-
^{58}Co	-	-	-	3,00E-05	5,00E-05	-
^{124}Sb	-	-	-	2,00E-05	3,00E-05	-
^{134}Cs	6,00E-05	5,00E-05	8,00E-05	1,40E-04	3,20E-04	-
^{137}Cs	1,10E-04	1,20E-04	1,70E-04	5,20E-04	8,20E-04	-
^{241}Pu	-	-	2,00E-05	5,00E-05	6,00E-05	-

Table 64. British Energy Heysham 1, Aerial Discharge Data

	Actual Site Annual Aerial Discharges (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	1,42	0,978	0,952	1,39	2,15	1,36
^{14}C	1,16	0,688	1,38	1,23	1,32	1,67
^{35}S	1,40E-02	0,0185	1,62E-02	2,12E-02	2,28E-02	2,62E-02
particulate beta	3,60E-05	6,42E-06	7,66E-06	7,72E-06	8,34E-06	7,89E-06

Table 65. British Energy Heysham 1, Environmental Impact

	Activity Concentration (Bq kg^{-1} wet wt) in Flounder*					
	1998	1999	2000	2001	2002	2003
^{14}C	98	77	57	41	97	120
^{54}Mn	-	<0,08	-	-	<0,12	<0,09
^{60}Co	<0,15	<0,09	<0,11	<0,12	<0,12	<0,10
^{106}Ru	<1,6	<0,85	<1,0	<1,1	<1,3	<0,92
^{125}Sb	<0,43	<0,24	<0,27	<0,31	<0,36	<0,27
^{134}Cs	<0,15	-	<0,11	<0,11	<0,13	<0,10
^{137}Cs	17	17	14	14	11	10
^{144}Ce	-	<0,37	-	-	<0,83	<0,52
^{154}Eu	<0,46	<0,28	<0,32	<0,36	-	-
^{155}Eu	-	<0,18	<0,21	<0,20	<0,38	-
^{238}Pu	3,10E-04	1,20E-03	3,10E-04	3,40E-04	4,40E-04	1,6E-03
$^{239}Pu + ^{240}Pu$	1,90E-03	6,30E-03	1,70E-03	1,80E-03	2,50E-03	9,4E-03
^{241}Am	3,40E-03	1,20E-02	3,40E-03	4,00E-03	4,70E-03	1,7E-02
$^{243}Cm + ^{244}Cm$	-	2,10E-05	-	-	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
^{14}C	77	75	75	45	110	120
^{54}Mn	-	<0,07	-	-	<0,07	<0,08
^{60}Co	<0,09	<0,11	<0,10	<0,08	<0,07	<0,11
^{99}Tc	11	3,8	4,7	6,2	6,6	12
^{106}Ru	<0,83	<0,74	<0,48	<0,60	<0,67	<0,81
^{125}Sb	<0,22	<0,20	<0,13	<0,15	<0,19	<0,22
^{134}Cs	<0,09	-	<0,05	<0,06	<0,07	<0,09
^{137}Cs	6,8	6,2	6,1	4,3	4,5	5,1
^{144}Ce	-	<0,42	-	-	<0,40	<0,39
^{154}Eu	<0,24	<0,21	<0,15	<0,19	-	-
^{155}Eu	-	<0,19	<0,13	<0,13	<0,19	-
^{238}Pu	5,70E-03	4,60E-03	4,80E-03	5,00E-03	2,40E-03	4,4E-03
$^{239}Pu + ^{240}Pu$	3,10E-02	2,70E-02	2,70E-02	2,90E-02	1,60E-02	2,4E-02
^{241}Pu	0,37	7,00E-01	5,20E-01	<0,31	8,60E-02	0,27
^{241}Am	5,20E-02	4,60E-02	4,00E-02	4,60E-02	2,10E-02	3,7E-02

$^{243}Cm + ^{244}Cm$	1,90E-04	1,30E-04	-	8,10E-05	-	5,3E-05
	Activity concentration (Bq kg^{-1} wet wt) in Cockles*					
^{14}C	84	63	87	52	100	110
^{54}Mn	-	<0,05	-	-	<0,06	<0,06
^{60}Co	1,4	2,2	3,8	2,3	1,4	1,2
^{90}Sr	0,44	0,49	0,31	0,28	0,31	0,60
^{99}Tc	25	37	74	41	87	37
^{106}Ru	1,5	<0,96	<0,70	<0,64	<1,1	2,8
^{125}Sb	<0,16	<0,18	<0,18	<0,19	0,46	0,59
^{134}Cs	<0,06	-	<0,07	<0,07	<0,07	<0,06
^{137}Cs	5,7	5,2	4,5	3,7	3,7	4,6
^{144}Ce	-	<0,25	-	-	<0,31	<0,28
^{154}Eu	<0,16	<0,13	<0,18	<0,18	-	-
^{155}Eu	-	<0,11	<0,15	<0,15	<0,15	-
^{238}Pu	0,43	0,48	0,42	0,40	0,45	0,48
$^{239}Pu + ^{240}Pu$	2,4	2,5	2,3	2,2	2,5	2,6
^{241}Pu	25	27	22	20	22	24
^{241}Am	6,0	6,9	6,1	6,0	6,6	6,8
^{242}Cm	-	1,30E-02	-	-	-	-
$^{243}Cm + ^{244}Cm$	9,40E-03	1,70E-03	-	7,10E-03	1,00E-02	1,4E-02
	Activity concentration (Bq kg^{-1} wet wt) in Plaice**					
	1998	1999	2000	2001	2002	2003
Organic ^{3}H	-	-	-	-	32	<37
^{3}H	<120	37	52	<35	32	<45
	Activity concentration (Bq kg^{-1} wet wt) in Plaice**					
^{54}Mn	-	<0,07	-	-	<0,08	<0,10
^{60}Co	<0,11	<0,08	<0,09	<0,09	<0,09	<0,11
^{90}Sr	0,039	4,20E-02	3,90E-02	2,30E-02	3,00E-02	3,3E-02
^{99}Tc	1,6	16	12	2,2	7,4	2,0
^{106}Ru	<0,98	<0,75	<0,81	<0,86	<0,84	<0,99
^{125}Sb	<0,25	<0,20	<0,20	<0,20	<0,23	<0,26
^{134}Cs	<0,10	-	<0,08	<0,09	<0,09	<0,11
^{137}Cs	6,6	7,1	6,3	4,3	5,1	5,1
^{144}Ce	-	<0,38	-	-	<0,49	<0,45
^{154}Eu	<0,31	<0,23	<0,26	<0,27	-	-
^{155}Eu	-	<0,18	<0,16	<0,17	<0,22	-
^{238}Pu	-	2,30E-04	-	-	-	-
$^{239}Pu + ^{240}Pu$	-	1,20E-03	-	-	-	-
^{241}Am	<0,29	2,20E-03	<0,11	<0,15	<0,23	<0,17
	Activity concentration (Bq kg^{-1} wet wt) in Bass**					
^{54}Mn	-	<0,11	-	-	<0,09	<0,07
^{60}Co	<0,15	<0,12	<0,10	<0,10	<0,10	<0,07
^{106}Ru	<1,5	<1,2	<1,0	<1,1	<0,90	<0,75
^{125}Sb	<0,42	<0,3	<0,28	<0,28	<0,26	<0,21
^{134}Cs	<0,16	-	<0,11	<0,11	<0,10	<0,08
^{137}Cs	18	15	15	15	14	14
^{144}Ce	-	<0,49	-	-	<0,45	<0,47
^{154}Eu	<0,46	<0,36	<0,32	<0,29	-	-
^{155}Eu	-	<0,21	<0,23	<0,22	<0,21	-
^{241}Am	<0,25	<0,15	<0,27	<0,16	<0,21	<0,15
	Activity concentration (Bq kg^{-1} wet wt) in Mussels**					
Organic ^{3}H	-	-	-	-	<35	<38
^{3}H	-	87	75	79	53	<32
^{14}C	87	72	70	45	77	120
^{54}Mn	-	<0,09	-	-	<0,07	<0,05
^{60}Co	0,66	0,81	0,89	0,50	0,57	0,82
^{99}Tc	250	190	150	610	710	900
^{106}Ru	1,6	<1,0	<0,94	<0,83	1,7	4,6
^{125}Sb	<0,16	<0,33	<0,23	<0,30	0,60	0,92
^{134}Cs	<0,06	-	<0,06	<0,08	<0,07	<0,05
^{137}Cs	3,3	4,8	3,5	3,7	3,5	3,7
^{144}Ce	-	<0,4	-	-	<0,36	<0,27
^{154}Eu	<0,14	<0,24	<0,16	<0,21	-	-
^{155}Eu	-	<0,19	<0,14	<0,16	<0,18	-
^{238}Pu	0,33	0,36	0,27	0,30	0,30	0,48
$^{239}Pu + ^{240}Pu$	1,8	2,0	1,5	1,7	1,7	2,6

^{241}Am	3,1	3,6	2,6	2,8	3,0	4,3
^{242}Cm	-	-	-	5,10E-03	-	-
^{243}Cm + ^{244}Cm	4,20E-03	3,80E-03	-	6,90E-03	2,40E-03	8,5E-02
	Activity concentration (Bq kg^{-1} wet wt) in Whitebait* **					
^{54}Mn	-	<0,05	-	-	<0,06	<0,08
^{60}Co	<0,08	0,30	<0,07	<0,07	<0,07	<0,09
^{90}Sr	0,20	0,15	0,17	0,15	0,17	0,13
^{106}Ru	<0,67	<0,44	<0,54	<0,56	<0,54	<0,87
^{125}Sb	<0,12	<0,12	<0,15	<0,14	<0,16	<0,24
^{134}Cs	<0,08	-	<0,06	<0,06	<0,07	<0,10
^{137}Cs	5,8	6,4	6,9	6,8	4,5	5,1
^{144}Ce	-	<0,23	-	-	<0,28	<0,55
^{154}Eu	<0,20	<0,14	<0,18	<0,19	-	-
^{155}Eu	-	<0,10	<0,18	<0,10	<0,12	-
^{238}Pu	0,048	6,60E-02	5,80E-02	5,10E-02	5,40E-02	3,3E-02
^{239}Pu + ^{240}Pu	0,26	0,35	0,33	0,29	0,30	0,21
^{241}Pu	2,8	3,6	3,3	2,6	2,7	1,6
^{241}Am	0,41	0,59	0,51	0,48	0,51	0,35
^{243}Cm + ^{244}Cm	6,70E-04	8,30E-04	1,0E-03	-	7,20E-04	9,2E-04
	Activity concentration (Bq kg^{-1} wet wt) in Cockles+					
^{54}Mn	-	<0,05	-	-	<0,05	<0,05
^{60}Co	1,7	2,5	4,4	3,5	2,0	1,3
^{106}Ru	<1,2	<0,95	<0,61	<0,64	2,1	1,1
^{125}Sb	<0,17	<0,15	<0,16	<0,17	0,40	0,56
^{134}Cs	<0,07	-	<0,07	<0,07	<0,07	<0,05
	Activity concentration (Bq kg^{-1} wet wt) in Cockles+					
^{137}Cs	4,0	4,6	3,9	4,6	4,0	3,3
^{144}Ce	-	<0,25	-	-	<0,26	<0,26
^{154}Eu	<0,19	<0,17	<0,18	<0,18	-	-
^{155}Eu	-	<0,13	<0,14	<0,14	<0,15	-
^{238}Pu	0,35	0,39	0,36	0,37	0,52	0,35
^{239}Pu + ^{240}Pu	1,9	2,2	2,0	2,0	3,0	1,9
^{241}Am	4,9	5,1	5,3	6,6	6,7	5,3
^{243}Cm + ^{244}Cm	6,50E-03	7,30E-03	1,2E-02	1,40E-02	1,10E-02	6,5E-03
	Activity concentration (Bq kg^{-1} wet wt) in Winkles++					
^{54}Mn	-	<0,13	-	-	<0,16	<0,10
^{60}Co	0,91	1,4	1,6	0,96	0,91	0,99
^{106}Ru	2,0	<1,3	<1,0	<0,91	2,2	3,9
^{125}Sb	<0,25	0,34	<0,38	<0,44	0,97	1,3
^{134}Cs	<0,08	-	<0,08	<0,08	<0,07	<0,07
^{137}Cs	5,3	6,6	4,7	3,7	5,0	5,0
^{144}Ce	-	<0,35	-	-	<0,30	<0,34
^{154}Eu	<0,23	<0,24	<0,21	<0,21	-	-
^{155}Eu	-	<0,20	<0,18	<0,21	<0,15	-
^{238}Pu	0,30	0,42	0,27	0,25	0,35	0,42
^{239}Pu + ^{240}Pu	1,6	2,3	1,4	1,4	1,9	2,2
^{241}Am	3,0	4,1	2,7	2,5	3,5	4,0
^{243}Cm + ^{244}Cm	3,80E-03	1,30E-02	1,9E-03	4,90E-03	4,80E-03	5,3E-03
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus Vesiculosus*+++					
^{54}Mn	-	<0,07	-	-	<0,19	<0,10
^{60}Co	0,91	1,1	1,3	0,72	<0,43	0,58
^{99}Tc	3600	2800	2900	2900	4700	5100
^{106}Ru	<0,77	<0,56	<0,58	<0,73	<0,67	<0,90
^{125}Sb	<0,21	<0,32	<0,40	<0,49	0,73	1,1
^{134}Cs	<0,10	-	<0,07	<0,09	<0,09	<0,11
^{137}Cs	5,9	6,2	5,9	5,0	3,9	5,0
^{144}Ce	-	<0,29	-	-	<0,36	<0,45
^{154}Eu	<0,27	<0,21	<0,21	<0,28	-	-
^{155}Eu	-	<0,15	<0,17	<0,19	<0,20	-
^{241}Am	0,81	0,82	0,72	0,84	0,68	0,78

* Flookburgh. ** Morecambe. *** Sunderland Point. + Middleton Sands. ++Reb Nab Point. +++ Half Moon Bay.
Note: At Heysham there are two separate nuclear power stations. Authorised disposals of radioactive waste from both stations are made via adjacent outfalls in Morecombe Bay and stacks. For the purposes of environmental monitoring both stations are considered together.

Table 66. British Energy Heysham 1, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishermen due to consumption of fish and shellfish and external radiation	0,074	0,071	0,066	0,059	0,066	n/a

The doses are taken from RIFE reports and are assessed from measured activity concentrations which are dominated by the effects of historical discharges from Sellafield. There is no reason to believe that doses due to Heysham 1 discharges should be significantly different from other AGRs (<5μSv).

Table 67. British Energy Heysham 2, Site Characteristics

Type of Facility	Power Station, 2 Advanced Gas Cooled Reactors
Location	Lancashire
Date commissioned	1988
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	See below
Receiving waters and catchment area	Morecambe Bay and Irish Sea (OSPAR Region III)
Volume of effluent discharged into the receiving waters	3 000 – 5 000 cubic metres per year (before dilution in cooling water)

Table 68. British Energy Heysham 2, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1250	1250	1250	1250	1250	1250
Annual electricity generation, GWh(e)	9031	7153	9780	9030	9430	9630

Table 69. British Energy Heysham 2, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	1200	1200	1200	1200	1200	1200
^{35}S	2,3	2,3	2,3	2,3	2,3	2,3
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	0,3	0,3	0,3	0,3	0,3	0,3
	Actual site annual liquid discharges (TBq)					
^{3}H	307	255	337	330	334	390
Total beta	0,05	0,04	0,05	0,07	0,11	0,14
Total alpha	2,80E-06	5,70E-06	8,70E-06	1,00E-05	2,00E-05	-
^{35}S	3,40E-02	2,41E-02	3,75E-02	5,58E-02	9,06E-02	1,30E-01
^{60}Co	1,09E-03	1,01E-03	3,66E-04	2,29E-04	3,85E-04	2,80E-04
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	1,70E-02	1,75E-02	1,48E-02	1,59E-02	1,88E-02	1,60E-02
^{45}Ca	1,60E-03	1,20E-03	4,00E-04	7,00E-04	1,90E-03	-
^{54}Mn	7,20E-04	3,20E-04	2,70E-04	1,60E-04	5,50E-04	-
^{55}Fe	7,90E-04	5,60E-04	3,90E-04	3,10E-04	6,80E-04	-
^{58}Co	8,80E-05	-	-	-	5,60E-05	-
^{90}Sr	1,60E-03	2,90E-03	1,40E-03	1,50E-03	1,30E-03	-
^{134}Cs	1,60E-04	1,40E-04	1,80E-04	8,20E-04	3,90E-04	-
^{137}Cs	4,40E-04	6,30E-04	7,00E-04	2,60E-03	2,40E-03	-
^{144}Ce	-	-	7,50E-05	-	8,60E-05	-
^{241}Pu	-	8,10E-05	1,90E-04	1,90E-04	2,70E-04	-

Total beta calculated as sum of ^{35}S, ^{60}Co and "Total activity excluding ^{3}H, ^{35}S & ^{60}Co"; Total alpha calculated as sum of measured alpha emitters.

Table 70. British Energy Heysham 2, Liquid Discharges Normalised to Output

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	9,031	7,153	9,780	9,030	9,430	9,630
^{3}H	34	36	34	37	35	41
Total beta	0,01	0,01	0,01	0,01	0,01	0,01
Total alpha	3,1E-07	8,0E-07	8,9E-07	1,1E-06	2,1E-06	-
^{35}S	3,70E-03	3,40E-03	3,80E-03	6,20E-03	9,60E-03	1,30E-02

	Normalised to output - TBq/TWh					
^{60}Co	1,20E-04	1,40E-04	4,00E-05	3,00E-05	4,00E-05	3,00E-05
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	1,89E-03	2,45E-03	1,52E-03	1,76E-03	2,00E-03	1,65E-03
^{45}Ca	1,77E-04	1,68E-04	4,20E-05	7,80E-05	2,01E-04	-
^{54}Mn	8,00E-05	4,50E-05	2,80E-05	1,80E-05	5,80E-05	-
^{55}Fe	8,70E-05	7,80E-05	4,00E-05	3,40E-05	7,20E-05	-
^{58}Co	1,00E-05	-	-	-	6,00E-06	-
^{90}Sr	1,77E-04	4,05E-04	1,43E-04	1,66E-04	1,38E-04	-
^{134}Cs	1,80E-05	2,00E-05	1,80E-05	9,10E-05	4,10E-05	-
^{137}Cs	4,90E-05	8,80E-05	7,20E-05	2,88E-04	2,55E-04	-
^{144}Ce	-	-	8,00E-06	-	9,00E-06	-
^{241}Pu	-	1,10E-05	1,90E-05	2,10E-05	2,90E-05	-

Table 71. British Energy Heysham 2, Aerial Discharge Data

	(TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	2,2	1,21	1,06	1,7	1,3	1,13
^{14}C	1,1	1,09	0,94	1,16	1,28	1,21
^{35}S	0,015	0,079	0,0196	0,0185	0,0158	0,016
particulate beta	1,5E-05	8,1E-06	9,51E-06	1,11E-05	9,38E-06	1,37E-05

For Environmental data, see Table 65 for Heysham 1.

Table 72. British Energy Heysham 2, Radiation Doses to the Public

Reference Group	Dose (μSv a^{-1})					
Local fishermen due to fish and shellfish consumption and external radiation, (OSPAR, 2000)	1998	1999	2000	2001	2002	2003
	0,074	0,071	0,066	0,059	0,066	n/a

The doses are taken from RIFE reports and are assessed from measured activity concentrations which are dominated by the effects of historical discharges from Sellafield. There is no reason to believe that doses due to Heysham 2 discharges should be significantly different from other AGRs (<5μSv).

Table 73. British Energy Hinkley Point B, Site Characteristics

Type of Facility	Power Station, 2 Advanced Gas Cooled Reactors
Location	Somerset
Date commissioned	1976
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	See below
Receiving waters and catchment area	Bristol Channel (OSPAR Region III)
Volume of effluent into the receiving waters	5 000 – 15 000 m^{3} yr^{-1} (before dilution in cooling water)

Table 74. British Energy Hinkley Point B, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1220	1220	1220	1220	1220	1220
Annual electricity generation, GWh(e)	8349	8074	8340	9170	7800	8690

Table 75. British Energy Hinkley Point B, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	620	620	620	620	620	620
^{35}S	5	5	5	5	5	5
^{60}Co	3,30E-02	3,30E-02	3,30E-02	3,30E-02	3,30E-02	3,30E-02
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	0,235	0,235	0,235	0,235	0,235	0,235
	Actual site annual liquid discharges (TBq)					
^{3}H	387	355	352	419	381	400
Total beta	0,60	0,61	0,36	0,50	0,54	0,45
Total alpha	1,70E-05	4,50E-05	4,00E-05	4,50E-05	2,20E-05	-
^{35}S	0,58	0,591	0,347	0,483	0,53	0,431
^{60}Co	4,40E-04	4,20E-04	3,00E-04	4,50E-04	1,50E-04	7,20E-04

Total activity excluding ^{3}H, ^{35}S & ^{60}Co	2,00E-02	1,90E-02	1,73E-02	1,88E-02	1,30E-02	0,0146
^{45}Ca	9,00E-04	-	-	-	-	-
^{54}Mn	2,10E-03	1,10E-03	1,30E-03	1,60E-03	1,10E-03	-
^{55}Fe	4,50E-03	2,00E-03	2,50E-03	2,10E-03	9,10E-04	-
^{58}Co	1,80E-04	-	-	-	-	-
^{90}Sr	1,60E-04	-	-	-	-	-
^{124}Sb	3,20E-04	-	3,30E-04	3,60E-04	-	-
^{134}Cs	6,40E-04	3,10E-04	5,80E-04	5,80E-04	3,70E-04	-
^{137}Cs	1,30E-03	8,30E-04	1,70E-03	2,40E-03	1,40E-03	-
^{241}Pu	1,90E-04	6,90E-04	9,30E-04	6,50E-04	4,80E-04	-

Total beta calculated as sum of ^{35}S, ^{60}Co and "Total activity excluding ^{3}H, ^{35}S & ^{60}Co"; Total alpha calculated as sum of measured alpha emitters.

Table 76. British Energy Hinkley Point B, Liquid Discharges Normalised to Output

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	8,349	8,074	8,340	9,170	7,800	8,690
^{3}H	46	44	42	46	49	46
Total beta	0,07	0,08	0,04	0,05	0,07	0,05
Total alpha	2,0E-06	5,6E-06	4,8E-06	4,9E-06	2,8E-06	na
^{35}S	6,93E-02	7,32E-02	4,16E-02	5,27E-02	6,76E-02	4,96E-02
^{60}Co	5,00E-05	5,00E-05	4,00E-05	5,00E-05	2,00E-05	8,00E-05
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	2,36E-03	2,35E-03	2,07E-03	2,05E-03	1,65E-03	1,68E-03
^{45}Ca	1,04E-04	-	-	-	-	-
^{54}Mn	2,52E-04	1,36E-04	1,56E-04	1,74E-04	1,41E-04	-
^{55}Fe	5,39E-04	2,48E-04	3,00E-04	2,29E-04	1,17E-04	-
^{58}Co	2,20E-05	-	-	-	-	-
^{90}Sr	1,90E-05	-	-	-	-	-
^{124}Sb	3,80E-05	-	4,00E-05	3,90E-05	-	-
^{134}Cs	7,70E-05	3,80E-05	7,00E-05	6,30E-05	4,70E-05	-
^{137}Cs	1,56E-04	1,03E-04	2,04E-04	2,62E-04	1,79E-04	-
^{241}Pu	2,30E-05	8,50E-05	1,12E-04	7,10E-05	6,20E-05	-

Table 77. British Energy Hinkley Point B, Actual Site Annual Emissions to Air

	(TBq) for 1998-2003					
	1998	1999	2000	2001	2002	2003
^{3}H	1,7	2,2	3,06	5,04	5,02	7,18
^{14}C	1,9	1,21	1,00	1,14	1,07	1,22
^{35}S	0,10	0,020	0,132	0,136	0,124	0,193
particulate beta	5,2E-05	5,56E-05	3,17E-05	3,32E-05	3,18E-05	3,88E-05

Table 78. British Energy Hinkley Point B, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Flounder*					
	1998	1999	2000	2001	2002	2003
^{3}H	3200	-	-	5300	-	-
^{14}C	110	95	99	88	-	-
^{54}Mn	<0,03	<0,05	<0,06	<0,10	-	-
^{60}Co	<0,03	<0,06	<0,07	<0,10	-	-
^{65}Zn	-	<0,13	-	-	-	-
^{125}Sb	-	-	-	<0,20	-	-
^{134}Cs	0,06	<0,12	<0,07	<0,10	-	-
^{137}Cs	0,54	0,80	0,74	0,40	-	-
^{144}Ce	-	<0,22	-	<0,38	-	-
^{155}Eu	<0,09	<0,11	<0,11	<0,15	-	-
^{241}Am	<0,10	<0,10	<0,08	<0,08	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
Organic ^{3}H	-	-	-	580	950	880
^{3}H	-	-	-	690	1100	880
^{14}C	-	-	-	36	37	38
^{54}Mn	-	-	-	<0,07	<0,05	<0,04
^{60}Co	-	-	-	<0,07	<0,06	<0,04
^{125}Sb	-	-	-	<0,16	-	-

^{134}Cs	-	-	-	<0,08	0,08	0,11
^{137}Cs	-	-	-	0,71	0,70	1,0
^{144}Ce	-	-	-	<0,34	-	-
^{155}Eu	-	-	-	<0,15	-	-
^{241}Am	-	-	-	<0,15	<0,15	<0,05
	Activity concentration (Bq kg^{-1} wet wt) in Grey Mullet*					
Organic ^{3}H	-	-	-	26	150	-
^{3}H	-	-	-	40	180	-
^{14}C	-	-	-	32	50	-
^{54}Mn	-	-	-	<0,12	<0,05	-
^{60}Co	-	-	-	<0,14	<0,05	-
^{125}Sb	-	-	-	<0,29	-	-
^{134}Cs	-	-	-	<0,14	0,08	-
^{137}Cs	-	-	-	1,5	1,1	-
^{144}Ce	-	-	-	<0,47	-	-
^{155}Eu	-	-	-	<0,19	-	-
^{241}Am	-	-	-	<0,10	<0,05	-
	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
Organic ^{3}H	-	-	-	2000	970	770
^{3}H	1900	1400	1300	2100	980	810
^{14}C	110	88	92	57	43	33
^{54}Mn	<0,07	<0,06	<0,12	<0,15	<0,04	<0,05
^{60}Co	<0,06	<0,07	<0,11	<0,14	<0,04	<0,05
^{65}Zn	-	<0,16	-	-	-	-
^{125}Sb	-	-	-	<0,33	-	-
^{134}Cs	<0,09	0,17	<0,26	<0,17	<0,05	<0,06
^{137}Cs	0,55	0,74	1,0	0,68	0,48	0,56
^{144}Ce	-	<0,34	-	<0,65	-	-
^{155}Eu	<0,19	<0,16	<0,28	<0,28	-	-
^{238}Pu	2,50E-04	1,70E-04	5,10E-04	-	-	1,7E-04
	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
^{239}Pu + ^{240}Pu	7,80E-04	7,30E-04	2,40E-03	-	-	6,4E-04
^{241}Am	1,20E-03	6,00E-04	1,60E-03	4,50E-03	8,10E-04	6,0E-04
^{242}Cm	7,80E-05	-	1,40E-04	-	-	-
^{243}Cm + ^{244}Cm	4,20E-05	8,00E-05	5,80E-05	-	-	1,7E-05
	Activity concentration (Bq kg^{-1} wet wt) in Whelks*					
^{3}H	-	-	-	3000	1400	2400
^{14}C	-	-	-	73	-	61
^{54}Mn	-	-	-	<0,18	-	<0,05
^{60}Co	-	-	-	<0,19	-	<0,05
^{125}Sb	-	-	-	<0,40	-	-
^{134}Cs	-	-	-	<0,18	-	<0,06
^{137}Cs	-	-	-	0,47	-	0,38
^{144}Ce	-	-	-	<0,68	-	-
^{155}Eu	-	-	-	<0,30	-	-
^{241}Am	-	-	-	<0,35	-	<0,15
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus vesiculosus***					
	1998	1999	2000	2001	2002	2003
^{54}Mn	0,54	<0,77	<0,57	1,6	<1,3	1,2
^{60}Co	1,1	2,7	<0,25	2,4	<0,32	0,48
^{65}Zn	-	<0,27	-	-	-	-
^{125}Sb	-	-	-	0,48	-	-
^{134}Cs	3,9	5,8	0,55	4,1	<0,70	0,58
^{137}Cs	14	21	2,6	29	6,4	7,6
^{144}Ce	-	<0,70	-	<0,37	-	-
^{155}Eu	<0,19	<0,14	<0,16	0,15	-	-
^{241}Am	<0,25	<0,32	<0,13	0,13	<0,35	<0,19

* Stolford. **Pipeline.
There are two separate nuclear power stations at this site. Environmental monitoring covers the effects of both together.

Table 79. British Energy Hinkley Point B, Radiation Doses to the Public

Reference Group	Dose (μSv a^{-1})					
Local fishing community due to fish and shellfish consumption and external radiation, (OSPAR, 2000)	1998	1999	2000	2001	2002	2003
	0,013	0,011	0,012	0,014	0,015	n/a

The doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites, including Hinkley Point A.

Table 80. British Energy Hunterston B, Site Characteristics

Type of Facility	Power Station, Advanced Gas Cooled Reactor
Location	Near West Kilbride, Ayrshire
Date commissioned	1976
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	See below
Receiving waters and catchment area	Firth of Clyde (OSPAR Region III)
Volume of effluent discharged into the receiving waters	Approximately 10 000 m^3 y^{-1} (before dilution in cooling water)

Table 81. British Energy Hunterston B, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1190	1190	1190	1190	1190	1190
Annual electricity generation, GWh(e)	9378	8993	7350	8610	9080	8560

Table 82. British Energy Hunterston B, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	800	800	800	800	800	800
Total beta	0,45	0,45	0,45	-	-	0,45
Total alpha	1,00E-03	1,00E-03	1,00E-03	1,00E-03	1,00E-03	1,00E-03
^{35}S	10	10	10	10	10	10
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
	Actual site annual liquid discharges (TBq)					
^{3}H	442	416	326	478	448	446
Total beta	0,01	0,00867	0,00361	0,0058	0,00593	1,46E-2
Total alpha	9,00E-05	1,10E-04	6,00E-05	6,09E-05	6,79E-05	1,14E-04
^{35}S	2,4	2,62	1,64	2,31	2,02	1,5
^{60}Co	1,93E-03	9,80E-04	4,60E-04	4,10E-04	4,00E-04	6,00E-04

Total beta calculated as sum of ^{35}S, ^{60}Co and "Total beta activity excluding ^{3}H, ^{35}S & ^{60}Co".
Total alpha is result of gross alpha measurement.

Table 83. British Energy Hunterston B, Liquid Discharges Normalised to Output

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	9,378	8,993	7,350	8,610	9,080	8,560
^{3}H	47	46	44	55	49	52
Total beta	0,25	0,29	0,22	0,27	0,22	0,17
Total alpha	1,00E-05	1,20E-05	8,00E-06	7,00E-06	7,00E-06	1,30E-05
^{35}S	0,25	0,29	0,22	0,27	0,22	0,17
^{60}Co	2,06E-04	1,09E-04	6,30E-05	4,80E-05	4,40E-05	7,00E-05
Total activity excluding ^{3}H, ^{35}S & ^{60}Co	1,09E-03	9,70E-04	5,00E-04	6,80E-04	6,60E-04	1,70E-03

Table 84. British Energy Hunterston B, Aerial Discharge Data

	Actual site annual aerial discharge (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	2,2	3,52	5,28	7,34	6,8	6,07
^{14}C	1,9	2,0	1,82	1,9	2,23	1,67
^{35}S	8,00E-02	7,14E-02	2,76E-01	5,82E-02	6,92E-02	0,0675
particulate beta	4,48E-05	6,78E-05	9,63E-05	4,84E-05	5,43E-05	9,00E-05

Note: Liquid effluent is discharge to a point off shore from Hunterston through an undersea pipeline. Survey sites range from the closest land to the discharge point and include location points along the Hunterston peninsula as well as local islands.

Table 85. British Energy Hunterston B, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
	1998	1999	2000	2001	2002	2003
^{54}Mn	<0,10	<0,10	<0,10	<0,10	<0,10	-
^{58}Co	-	-	-	-	<0,11	-
^{60}Co	<0,10	<0,10	<0,10	<0,10	<0,10	-
^{65}Zn	<0,20	-	<0,16	-	-	-
^{95}Nb	-	<0,14	<0,34	<0,17	-	-
^{106}Ru	<0,67	-	-	<0,34	-	-
^{110}mAg	<0,10	<0,10	<0,11	<0,10	<0,10	-
^{125}Sb	-	-	-	-	<0,13	-
^{137}Cs	2,7	2,7	2,0	2,4	2,9	-
^{144}Ce	<0,35	<0,33	<0,26	<0,23	-	-
^{155}Ce	-	-	<0,12	-	-	-
^{155}Eu	<0,30	-	-	<0,11	<0,14	-
^{241}Am	<0,30	<0,18	<0,10	<0,10	<0,13	-
	Activity concentration (Bq kg^{-1} wet wt) in Hake*					
^{54}Mn	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,10	<0,14
^{60}Co	<0,10	<0,11	<0,10	<0,10	<0,10	<0,10
^{65}Zn	0,17	-	<0,21	-	-	<0,16
^{95}Nb	-	<0,13	<2,4	<0,10	-	-
^{106}Ru	<0,71	-	-	<0,64	-	<0,46
^{110}mAg	<0,10	<0,10	<0,11	<0,10	<0,10	<0,10
^{125}Sb	-	-	-	-	<0,13	<0,13
^{137}Cs	2,8	3,3	3,2	3,1	2,4	1,3
^{144}Ce	<0,35	<0,47	<0,38	<0,34	-	<0,32
^{155}Ce	-	-	<0,15	-	-	-
^{155}Eu	<0,30	-	-	<0,16	<0,14	<0,14
^{241}Am	<0,37	<0,25	<0,11	<0,10	<0,12	<0,11
	Activity concentration (Bq kg^{-1} wet wt) in Crabs*					
^{14}C	-	-	-	-	33	42
^{54}Mn	<0,10	<0,11	<0,10	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,10	<0,11
^{60}Co	<0,10	<0,11	<0,10	<0,10	<0,10	<0,10
^{65}Zn	<0,20	-	<0,16	-	-	<0,11
^{95}Nb	-	<0,13	<0,17	<0,12	-	-
^{99}Tc	-	-	9,1	-	-	2,7
^{106}Ru	<1,0	-	-	<0,21	-	<0,27
^{110}mAg	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
^{125}Sb	-	-	-	-	<0,10	<0,10
^{137}Cs	<0,50	0,66	0,44	0,41	0,35	0,33
^{144}Ce	<0,50	<0,48	<0,32	<0,16	-	<0,21
^{155}Ce	-	-	<0,14	-	-	-
^{155}Eu	<0,50	-	-	<0,10	<0,10	<0,10
^{238}Pu	6,20E-03	0,27	4,00E-03	3,20E-03	8,70E-02	2,3E-03
^{239}Pu + ^{240}Pu	1,60E-02	0,53	2,50E-02	2,40E-02	0,51	7,4E-03
^{241}Am	2,50E-02	8,50E-02	4,00E-02	3,10E-02	3,00E-02	8,2E-03
	Activity concentration (Bq kg^{-1} wet wt) in Nephrops*					
^{54}Mn	<0,12	<0,16	<0,10	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,10	<0,17
^{60}Co	<0,12	<0,16	<0,10	<0,10	<0,10	<0,10
^{65}Zn	<0,20	-	<0,13	-	-	<0,19
^{95}Nb	-	<0,66	<0,12	<0,10	-	-
^{99}Tc	-	-	5,7	320	320	120
^{106}Ru	<1,1	-	-	<0,20	-	<0,53
^{110}mAg	<0,12	<0,15	<0,10	<0,10	<0,10	<0,10
^{125}Sb	-	-	-	-	<0,10	<0,13
^{137}Cs	5,7	1,6	1,4	1,4	1,1	0,44
^{144}Ce	<0,54	<0,66	<0,20	<0,16	-	<0,41
^{155}Ce	-	-	<0,12	-	-	-
^{155}Eu	<0,39	-	-	<0,10	<0,10	<0,16
^{241}Am	<0,53	<0,36	<0,10	<0,11	<0,11	<0,12
	Activity concentration (Bq kg^{-1} wet wt) in Lobsters**					

^{54}Mn	<0,10	<0,11	<0,09	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,10	<0,10
^{60}Co	<0,10	<0,11	<0,08	<0,10	<0,10	<0,10
^{65}Zn	<0,20	-	<0,27	-	-	<0,11
^{95}Nb	-	<0,24	<1,1	<0,10	-	-
^{99}Tc	-	-	280	220	310	140
^{106}Ru	<0,10	-	-	<0,17	-	<0,33
^{110}mAg	<0,10	<0,10	<0,14	<0,10	<0,10	<0,10
^{125}Sb	-	-	-	-	<0,11	<0,10
^{137}Cs	1,6	1,8	0,57	0,42	0,66	<0,10
^{144}Ce	<0,32	<0,63	<0,46	<0,13	-	<0,24
^{155}Ce	-	-	<0,20	-	-	-
^{155}Eu	<0,11	-	-	<0,10	<0,12	<0,11
^{241}Am	0,22	0,46	<0,32	<0,10	<0,10	<0,10
	Activity concentration (Bq kg^{-1} wet wt) in Squat Lobsters**					
^{54}Mn	<0,10	<0,11	<0,10	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,11	<0,13
^{60}Co	<0,10	<0,11	<0,10	<0,10	<0,10	<0,10
^{65}Zn	<0,20	-	<0,17	-	-	<0,17
^{95}Nb	-	<0,21	<0,23	<0,12	-	-
^{99}Tc	-	-	<1,6	17	95	83
^{106}Ru	<0,68	-	-	<0,27	-	<0,51
^{110}mAg	<0,10	<0,11	<0,10	<0,10	<0,10	<0,11
^{125}Sb	-	-	-	-	<0,12	<0,15
^{137}Cs	0,47	0,56	0,55	0,42	0,44	0,48
^{144}Ce	<0,43	<0,35	<0,34	<0,17	-	<0,34
^{155}Ce	-	-	<0,17	-	-	-
^{155}Eu	<0,33	-	-	<0,11	<0,11	<0,16
^{238}Pu	5,90E-03	5,80E-03	9,20E-03	1,10E-03	5,30E-03	6,9E-03
^{239}Pu + ^{240}Pu	3,20E-02	2,90E-02	3,70E-02	3,80E-02	2,20E-02	2,9E-02
^{241}Am	1,80E-02	1,90E-02	1,60E-02	2,20E-02	2,70E-02	2,4E-02
	Activity concentration (Bq kg^{-1} wet wt) in Scallops**					
	1998	1999	2000	2001	2002	2003
^{54}Mn	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
^{58}Co	-	-	-	-	<0,10	<0,12
^{60}Co	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
^{65}Zn	<0,20	-	<0,13	-	-	<0,15
^{95}Nb	-	<0,13	<0,33	<0,11	-	-
^{106}Ru	<0,66	-	-	<0,19	-	<0,42
^{110}mAg	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
^{125}Sb	-	-	-	-	<0,11	<0,11
^{137}Cs	0,70	0,63	0,55	0,34	0,50	0,48
^{144}Ce	<0,41	<0,26	<0,27	<0,15	-	<0,29
^{155}Ce	-	-	<0,13	-	-	-
^{155}Eu	<0,31	-	-	<0,10	<0,12	<0,13
^{238}Pu	5,20E-03	8,70E-03	9,30E-03	2,90E-03	<0,0012	2,5E-03
^{239}Pu + ^{240}Pu	2,40E-02	3,00E-02	3,70E-02	2,80E-02	8,50E-03	1,1E-02
^{241}Am	4,10E-03	6,40E-02	1,40E-02	0,13	7,10E-03	4,2E-03
	Activity concentration (Bq kg^{-1} wet wt) in Oysters***					
	1998	1999	2000	2001	2002	2003
^{54}Mn	0,12	0,12	<0,10	-	0,15	0,12
^{58}Co	-	-	-	-	<0,10	<0,10
^{60}Co	<0,10	<0,10	<0,10	-	<0,10	<0,10
^{65}Zn	<0,20	-	<0,22	-	-	<0,10
^{95}Nb	-	<0,10	<1,7	-	-	-
^{106}Ru	<0,10	-	-	-	-	<0,29
^{110}mAg	<0,10	0,33	0,22	-	<0,10	0,42
^{125}Sb	-	-	-	-	<0,10	<0,10
^{137}Cs	0,28	0,38	0,39	-	0,29	0,26
^{144}Ce	<0,26	<0,15	<0,37	-	-	<0,19
^{155}Ce	-	-	<0,13	-	-	-
^{155}Eu	<0,10	-	-	-	<0,10	<0,10
^{238}Pu	-	-	-	-	-	-
^{239}Pu + ^{240}Pu	-	-	-	-	-	-
^{241}Am	<0,10	<0,10	<0,10	-	<0,10	<0,10

	Activity concentration (Bq kg^{-1} wet wt) in Winkles+					
^{54}Mn	3,3	2,5	0,41	0,68	1,1	3,1
^{58}Co	-	-	-	-	<0,10	<0,36
^{60}Co	0,89	0,97	0,48	0,37	<0,26	6,3
^{65}Zn	<0,20	-	<0,30	-	-	<0,52
^{95}Nb	-	<0,22	<0,29	<0,27	-	-
^{106}Ru	<1,2	-	-	<0,76	-	<3,7
^{110}mAg	<0,46	1,4	<0,41	0,67	0,55	0,75
^{125}Sb	-	-	-	-	<0,18	<0,41
^{137}Cs	1,0	1,0	0,78	0,81	0,49	3,1
^{144}Ce	<0,55	<0,54	<0,56	<0,51	-	<1,5
^{155}Ce	-	-	<0,25	-	-	-
^{155}Eu	<0,40	-	-	<0,23	<0,17	<0,51
^{238}Pu	3,60E-02	3,40E-02	1,70E-02	5,40E-02	2,40E-02	0,33
^{239}Pu + ^{240}Pu	0,13	0,13	3,60E-02	0,29	0,11	0,64
^{241}Am	4,60E-02	0,39	6,50E-02	0,53	5,00E-02	0,47
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus vesiculosus*+					
^{54}Mn	8,2	2,6	-	-	3,0	-
^{58}Co	-	-	-	-	<0,10	-
^{60}Co	<0,85	0,62	-	-	0,37	-
^{65}Zn	0,14					-
^{95}Nb	-	<0,10	-	-	-	-
^{106}Ru	1,5					-
^{110}mAg	<0,10	<0,10	-	-	<0,10	-
^{125}Sb	-	-	-	-	<0,11	-
^{137}Cs	2,0	1,8	-	-	0,98	-
^{144}Ce	<0,40	<0,24	-	-	-	-
^{155}Eu	<0,30	-	-	-	<0,14	-
^{241}Am	<0,11	<0,17	-	-	<0,14	-

* Millport. ** Largs. *** Fairlie. + Pipeline.

Marine environmental samples collect by Hunterston staff are monitored for a wide range of radionuclides by gamma spectrometry, Radioactive contamination in such samples can result from discharges by Hunterston B, but also Hunterston A Power Station (decommissioned), past and present Sellafield discharges, and possible discharges from the Faslane Nuclear Submarine base or nuclear submarines that use the Firth of Clyde.

Trace quantities of ^{51}Cr and ^{54}Mn at up to a few tens of Bq kg^{-1} are sometimes detectable in seaweed local to the discharge point and are presumed to originate from Hunterston. Traces of nuclides such as ^{106}Ru and ^{137}Cs are thought to originate from other nuclear facilities.

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Table 86. British Energy Hunterston B, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishing community due to fish and shellfish consumption and external radiation, (OSPAR, 2000)	2,50E-02	1,50E-02	9,00E-03	<0,005	0,17	n/a

The doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites, including Hunterston A.

Table 87. British Energy Sizewell B, Site Characteristics

Type of Facility	PWR Power Station
Location	Suffolk
Date commissioned	1995
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	See below
Receiving waters and catchment area	North Sea (OSPAR Region II)
Volume of effluent discharged into the receiving waters	12 000 cubic metres per year (including secondary liquid waste and before dilution in cooling water)

Table 88. British Energy Sizewell B, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1188	1188	1188	1188	1188	1188
Annual electricity generation, GWh(e)	10166	8211	8550	9200	9210	8890

Table 89. British Energy Sizewell B, Liquid Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	80	80	80	80	80	80
Total activity excluding ^{3}H	0,2	0,2	0,2	0,2	0,2	0,2
	Actual site annual liquid discharges (TBq) for 1998-2003					
^{3}H	48	55,7	53,1	64,1	65,1	68,9
Total beta	1,80E-02	4,60E-02	6,00E-02	5,30E-02	5,00E-02	4,40E-02
Total alpha	1,00E-06	1,60E-06	1,00E-05	3,10E-06	2,00E-05	-
Total activity excluding ^{3}H	1,80E-02	4,58E-02	6,04E-02	5,29E-02	5,00E-02	4,42E-02
^{54}Mn	4,90E-04	5,80E-04	5,10E-04	7,30E-04	3,20E-04	-
^{55}Fe	7,00E-03	1,90E-02	3,00E-02	2,40E-02	1,40E-02	-
^{58}Co	3,20E-03	7,20E-03	2,90E-03	4,00E-03	1,00E-03	-
^{60}Co	4,40E-04	1,20E-03	1,60E-03	2,40E-03	1,60E-03	-
^{95}Zr	-	5,00E-04	7,30E-04	4,30E-04	-	-
^{95}Nb	-	2,10E-03	2,40E-03	1,50E-03	5,30E-04	-
^{124}Sb	-	-	1,60E-04	3,80E-04	-	-
^{125}Sb	-	2,70E-04	7,70E-04	1,50E-03	5,70E-04	-
^{125}mTe	-	6,30E-05	1,80E-04	3,50E-04	1,30E-04	-
^{134}Cs	7,00E-04	1,90E-03	5,30E-03	1,00E-02	1,10E-02	-
^{137}Cs	1,60E-03	2,40E-03	6,00E-03	1,00E-02	1,30E-02	-
^{144}Ce	-	-	4,10E-04	-	-	-
^{144}Pr	-	-	4,10E-04	-	-	-
^{144}Pu	-	-	1,30E-04	1,40E-04	1,40E-04	-

Total beta interpreted as "Total activity excluding ^{3}H"; Total alpha calculated as sum of measured alpha emitters.

Table 90. British Energy Sizewell B, Liquid Discharges Normalised to Output

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	10,166	8,211	8,550	9,200	9,210	8,890
^{3}H	4,7	6,8	6,2	7,0	7,1	7,8
Total beta	1,80E-03	5,60E-03	7,10E-03	5,70E-03	5,40E-03	5,00E-03
Total alpha	9,80E-08	1,90E-07	1,20E-06	3,40E-07	2,20E-06	-
Total activity excluding ^{3}H	1,75E-03	5,58E-03	7,06E-03	5,75E-03	5,43E-03	4,96E-03
^{54}Mn	5,00E-05	7,00E-05	6,00E-05	8,00E-05	3,00E-05	-
^{55}Fe	6,90E-04	2,31E-03	3,51E-03	2,61E-03	1,52E-03	-
^{58}Co	3,10E-04	8,80E-04	3,40E-04	4,30E-04	1,10E-04	-
^{60}Co	4,00E-05	1,50E-04	1,90E-04	2,60E-04	1,70E-04	-
^{95}Zr	-	6,00E-05	9,00E-05	5,00E-05	-	-
^{95}Nb	-	2,60E-04	2,80E-04	1,60E-04	6,00E-05	-
^{124}Sb	-	-	2,00E-05	4,00E-05	-	-
^{125}Sb	-	3,00E-05	9,00E-05	1,60E-04	6,00E-05	-
^{125}mTe	-	1,00E-05	2,00E-05	4,00E-05	1,00E-05	-
^{134}Cs	7,00E-05	2,30E-04	6,20E-04	1,09E-03	1,19E-03	-
^{137}Cs	1,60E-04	2,90E-04	7,00E-04	1,09E-03	1,41E-03	-
^{144}Ce	-	-	5,00E-05	-	-	-
^{144}Pr	-	-	5,00E-05	-	-	-
^{144}Pu	-	-	2,00E-05	2,00E-05	2,00E-05	-

Table 91. British Energy Sizewell B, Aerial Discharge Data

	Actual site annual aerial discharges (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	1,39	0,686	0,572	1,82	0,858	0,88
^{14}C	0,23	0,232	0,176	0,179	0,194	0,28
Noble gases	15,7	7,29	12,5	4,93	5,14	4,3
Particulate beta	1,1E-05	3,54E-06	1,81E-05	7,34E-06	7,14E-06	1,15E-05

Table 92. British Energy Sizewell B, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
	1998	1999	2000	2001	2002	2003

^{3}H	<120	130	<25	<25	<25	<25
^{60}Co	<0,04	<0,05	-	-	-	-
^{110m}Ag	-	-	-	<0,06	-	-
^{134}Cs	-	-	-	<0,03	-	<0,06
^{137}Cs	0,63	0,42	0,61	0,43	0,63	0,54
^{155}Eu	<0,11	<0,13	-	-	-	-
^{241}Am	<0,11	<0,21	<0,25	<0,09	<0,11	<0,06
	Activity concentration (Bq kg^{-1} wet wt) in Sole*					
Organic ^{3}H	-	-	-	<25	<25	-
^{3}H	<130	<25	<25	<25	<25	<25
^{60}Co	<0,15	<0,18	-	-	-	-
^{110m}Ag	-	-	-	<0,17	-	-
^{134}Cs	-	-	-	<0,09	-	0,09
^{137}Cs	0,40	0,29	0,33	0,25	0,20	0,61
^{155}Eu	<0,22	<0,31	-	-	-	-
^{241}Am	<0,11	<0,36	<0,27	<0,07	<0,11	<0,13
	Activity concentration (Bq kg^{-1} wet wt) in Crabs*					
^{3}H	<120					-
^{14}C	46	37	33	9,9	37	24
^{60}Co	<0,15	<0,06	-	-	-	-
^{110m}Ag	-	-	-	<0,28	-	-
^{134}Cs	-	-	-	<0,15	-	<0,06
^{137}Cs	<0,20	0,16	<0,14	0,17	0,25	0,35
^{155}Eu	<0,34	<0,09	-	-	-	-
^{238}Pu	9,60E-04	1,30E-04	7,30E-05	7,30E-05	1,10E-04	8,1E-05
$^{239}Pu + ^{240}Pu$	5,30E-03	7,00E-04	3,40E-04	4,00E-04	6,20E-04	4,7E-04
^{241}Am	9,40E-03	1,20E-03	6,70E-04	1,00E-03	1,20E-03	9,8E-04
^{242}Cm	-	-	-	-	4,90E-05	2,9E-04
$^{243}Cm + ^{244}Cm$	4,90E-05	5,20E-05	-	5,40E-05	2,30E-05	2,8E-05
	Activity concentration (Bq kg^{-1} wet wt) in Shrimps*					
Organic ^{3}H	-	-	-	<25	-	-
^{3}H	-	-	-	<25	-	-
^{60}Co	-	<0,25	-	-	-	-
^{110}mAg	-	-	-	<0,13	-	-
^{134}Cs	-	-	-	0,29	-	<0,04
^{137}Cs	-	0,43	-	1,6	-	0,28
^{155}Eu	-	<0,45	-	-	-	-
^{238}Pu	-	5,90E-04	-	5,50E-05	-	2,6E-04
$^{239}Pu + ^{240}Pu$	-	3,50E-03	-	2,50E-04	-	1,2E-03
^{241}Am	-	5,00E-03	-	2,70E-04	-	7,4E-04
	Activity concentration (Bq kg^{-1} wet wt) in Pacific Oyster**					
^{60}Co	<0,03	<0,02	-	-	-	-
^{110m}Ag	-	-	-	0,09	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Pacific Oyster**					
^{134}Cs	-	-	-	<0,03	-	<0,03
^{137}Cs	0,08	0,07	0,06	0,03	0,15	0,08
^{155}Eu	<0,07	<0,04		-	-	-
^{241}Am	<0,10	<0,03	<0,08	<0,11	<0,03	<0,04
	Activity concentration (Bq kg^{-1} wet wt) in Whelks***					
^{60}Co	<0,17	<0,18	-	-	-	-
^{110m}Ag	-	-	-	<0,09	-	-
^{134}Cs	-	-	-	<0,05	-	<0,13
^{137}Cs	<0,14	0,25	0,11	0,10	0,16	0,24
^{155}Eu	<0,23	<0,24	-	-	-	-
^{241}Am	<0,11	<0,12	<0,07	<0,06	<0,09	<0,10
	Activity concentration (Bq kg^{-1} wet wt) in Mussels+					
Organic ^{3}H	-	-	-	<25	-	-
^{3}H	-	-	-	<25	<25	<25
^{110m}Ag	-	-	-	<0,33	-	-
^{134}Cs	-	-	-	<0,19	-	<0,12
^{137}Cs	-	-	-	<0,16	<0,12	<0,11
^{241}Am	-	-	-	<0,37	<0,10	<0,09

* Sizewell. ** Blyth estuary. ***Dunwich. +River Alde

At Sizewell there are two power stations. Authorised discharges of radioactive liquid effluent from both power stations are made via adjacent outfalls to the North Sea. Gaseous wastes are discharged via separate stacks to the local

environment. Environmental monitoring for the power stations is considered in a single programme covering the area likely to be affected.

Table 93. British Energy Sizewell B, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishing community due to consumption of fish and shellfish and external radiation,	<5	<5	<5	<5	<5	n/a

The doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites, including Sizewell.

Table 94. British Energy Torness, Site Characteristics

Type of Facility	AGR Power Station
Location	East Lothian
Date commissioned	1988
Date ceased generation or commenced decommissioning	n/a
Installed generating capacity	See below
Receiving waters and catchment area	North Sea (OSPAR Region II)
Volume of effluent discharged into the receiving waters:	6 000 cubic metres per year (before dilution in cooling water)

Table 95. British Energy Torness, Annual Electricity Generation

	1998	1999	2000	2001	2002	2003
Installed electrical generation capacity, MW(e)	1250	1250	1250	1250	1250	1250
Annual electricity generation, GWh(e)	9422	10238	8310	8020	5670	8470

Table 96. British Energy Torness, Liquid Discharges

	Authorised annual discharge limits (TBq) for liquid effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	800	800	800	800	800	800
Total alpha	1,00E-03	1,00E-03	1,00E-03	1,00E-03	1,00E-03	1,00E-03
Total Beta (excl ^{3}H, ^{35}S, ^{60}C)	0,45	0,45	0,45	0,45	0,45	0,45
^{35}S	10	10	10	10	10	10
^{60}Co	0,03	0,03	0,03	0,03	0,03	0,03
	Actual annual liquid discharges (TBq) for 1998-2003					
^{3}H	355	335	234	274	250	314
Total beta	3,4E-03	0,00218	2,78E-03	1,19E-03	4,19E-03	2,40E-02
Total alpha	7,00E-06	6,57E-06	1,25E-05	6,01E-06	7,42E-06	5,18E-06
^{35}S	4,80E-02	4,51E-02	1,89E-02	1,85E-02	1,84E-02	2,16E-02
^{60}Co	4,50E-04	4,23E-04	3,46E-04	1,48E-04	2,57E-04	1,42E-04
^{54}Mn	9,30E-04	5,60E-04	2,37E-03	3,80E-04	1,02E-03	8,00E-05
^{134}Cs	1,30E-04	2,00E-04	5,70E-04	6,00E-05	2,40E-04	8,00E-05
^{137}Cs	2,10E-04	3,90E-04	1,18E-03	2,10E-04	1,13E-03	4,20E-04

Total beta calculated as sum of ^{35}S, ^{60}Co and "Total beta activity excluding ^{3}H, ^{35}S & ^{60}Co". Total beta is not an authorised limit within the current Certificate of Authorisation held by Torness. Total alpha is result of gross alpha measurement.
^{54}Mn, ^{134}Cs and ^{137}Cs are not included in the Certificate of Authorisation for Torness.

Table 97. British Energy Torness, Liquid Discharges Normalised to Output

	Normalised to output - TBq/TWh					
	1998	1999	2000	2001	2002	2003
Output (TWh)	9,4	10,2	8,3	8,0	5,7	8,5
^{3}H	38	33	28	34	38	37
Total beta	5,50E-03	4,70E-03	2,70E-03	2,50E-03	3,60E-03	2,80E-03
Total alpha	7,00E-07	6,00E-07	1,50E-06	7,00E-07	1,40E-06	6,00E-07
^{35}S	5,10E-03	4,40E-03	2,30E-03	2,30E-03	2,80E-03	2,50E-03
^{60}Co	4,80E-05	4,10E-05	4,20E-05	1,80E-05	6,80E-05	1,70E-05
Total activity excluding ^{3}H, ^{35}S	3,70E-04	2,10E-04	3,50E-04	1,50E-04	7,20E-04	2,10E-04

& ^{60}Co						
^{54}Mn	9,90E-05	5,50E-05	2,85E-04	4,70E-05	1,80E-04	1,00E-05
^{134}Cs	1,30E-05	2,00E-05	6,80E-05	8,00E-06	4,30E-05	9,00E-06
^{137}Cs	2,20E-05	3,80E-05	1,42E-04	2,70E-05	1,99E-04	4,90E-05

Table 98. British Energy Torness, Aerial Discharges

	Actual site annual aerial discharges(TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	2,1	1,31	1,69	2,4	3,25	2,35
^{14}C	0,77	0,575	0,575	0,561	0,511	0,652
^{35}S	3,90E-02	2,18E-02	1,85E-02	2,83E-02	2,08E-02	2,12E-02
Particulate beta	1,6E-05	4,59E-06	7,61E-06	1,13E-05	1,81E-05	4,49E-06

Table 99. British Energy Torness, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Cod*					
	1998	1999	2000	2001	2002	2003
^{54}Mn	<0,10	<0,10	<0,10	<0,10	-	-
^{60}Co	<0,10	<0,10	<0,10	<0,10	-	-
^{106}Ru	-	<0,43	-	-	-	-
^{110m}Ag	-	<0,10	<0,10	<0,10	-	-
^{137}Cs	0,92	0,86	0,74	0,56	-	-
^{155}Eu	<0,31	<0,15	<0,12	<0,10	-	-
^{241}Am	<0,31	<0,10	<0,10	<0,10	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Winkles*					
^{54}Mn	0,22	<0,20	<0,23	<0,10	<0,48	<0,10
^{60}Co	<0,18	<0,34	<0,28	<0,17	<0,23	0,15
^{65}Zn	-	-	-	-	<0,29	-
^{106}Ru	-	<0,75	-	-	-	-
^{110m}Ag	-	0,37	0,18	0,14	-	-
^{137}Cs	0,31	0,18	0,18	<0,29	<0,14	0,26
^{155}Eu	<0,39	<0,24	<0,13	<0,14	<0,28	0,24
^{241}Am	<0,35	<0,16	<0,13	<0,10	<0,18	0,11
	Activity concentration (Bq kg^{-1} wet wt) in *Fucus vesiculosus**					
^{54}Mn	0,60	0,80	-	-	<0,69	0,11
^{60}Co	0,29	0,95	-	-	<0,14	<0,11
^{65}Zn	-	-	-	-	<0,15	-
^{99}Tc	-	-	-	-	8,8	45
^{106}Ru	-	<0,45	-	-	-	-
^{110m}Ag	-	<0,10	-	-	-	-
^{137}Cs	0,80	0,33	-	-	0,20	<0,22
^{155}Eu	<0,33	<0,15	-	-	<0,12	<0,33
^{241}Am	<0,15	<0,17	-	-	<0,11	<0,31
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed*					
^{54}Mn	-	-	1,4	<0,30	-	-
^{60}Co	-	-	<0,44	<0,27	-	-
^{99}Tc	-	-	150	-	-	-
^{110m}Ag	-	-	<0,08	<0,10	-	-
^{137}Cs	-	-	0,18	0,37	-	-
^{155}Eu	-	-	<0,14	<0,14	-	-
^{241}Am	-	-	<0,16	<0,12	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Cod**					
^{54}Mn	-	-	<0,10	<0,10	<0,10	-
^{60}Co	-	-	<0,36	<0,10	<0,10	-
^{65}Zn	-	-	-	-	<0,14	-
^{110m}Ag	-	-	<0,12	<0,10	-	-
^{137}Cs	-	-	0,53	0,44	0,48	-
^{155}Eu	-	-	<0,15	<0,11	<0,15	-
^{241}Am	-	-	<0,11	<0,10	<0,14	-
	Activity concentration (Bq kg^{-1} wet wt) in Crabs***					
^{54}Mn	<0,10	<0,10	<0,10	<0,10	<0,11	-
^{60}Co	<0,10	<0,10	<0,10	<0,10	<0,10	-
^{65}Zn	-	-	-	-	<0,24	-
^{99}Tc	-	-	5,2	-	<1,6	8,8
^{106}Ru	-	<0,62	-	-	-	-

^{110m}Ag	-	<0,10	<0,10	<0,10	-	-
^{137}Cs	<0,11	<0,13	<0,13	0,15	<0,13	-
^{155}Eu	<0,30	<0,23	<0,13	<0,18	<0,24	-
^{241}Am	<0,30	<0,14	<0,10	<0,11	<0,14	-
	Activity concentration (Bq kg^{-1} wet wt) in Lobsters* **					
^{54}Mn	<0,10	<0,10	<0,11	<0,10	<0,10	<0,10
^{60}Co	<0,31	<0,10	<0,10	<0,11	<0,10	<0,10
^{65}Zn	-	-	-	-	<0,17	-
^{99}Tc	26	54	67	-	56	34
^{106}Ru	-	<0,73	-	-	-	-
^{110m}Ag	-	<0,10	<0,12	<0,10	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Lobsters* **					
^{137}Cs	<0,28	0,48	0,13	0,17	0,21	<0,10
^{155}Eu	<0,50	<0,23	<0,20	<0,21	<0,18	<0,26
^{241}Am	<0,50	<0,11	<0,11	<0,11	<0,11	0,11
	Activity concentration (Bq kg^{-1} wet wt) in Nephrops+					
^{54}Mn	<0,11	<0,12	<0,11	<0,13	<0,10	<0,14
^{60}Co	<0,11	<0,12	<0,13	<0,13	<0,10	<0,14
^{65}Zn	-	-	-	-	<0,18	-
^{106}Ru	-	<1,0	-	-	-	-
^{110m}Ag	-	<0,12	<0,11	<0,13	-	-
^{137}Cs	0,62	<0,38	0,33	0,39	0,22	<0,26
^{155}Eu	<0,34	<0,31	<0,15	<0,24	<0,21	<0,33
^{238}Pu	1,90E-03	2,50E-03	1,20E-03	9,90E-04	-	<1,1E-03
^{239}Pu + ^{240}Pu	6,70E-03	8,10E-03	6,70E-03	6,10E-03	-	4,2E-03
^{241}Am	6,20E-03	6,50E-03	6,80E-03	5,20E-03	1,30E-03	4,9E-03
	Activity concentration (Bq kg^{-1} wet wt) in Seaweed++					
^{54}Mn	-	-	-	0,77	-	-
^{60}Co	-	-	-	0,32	-	-
^{110m}Ag	-	-	-	<0,10	-	-
^{137}Cs	-	-	-	0,32	-	-
^{155}Eu	-	-	-	<0,14	-	-
^{241}Am	-	-	-	<0,13	-	-
	Activity concentration (Bq kg^{-1} wet wt) in Crabs**					
^{54}Mn	-	-	<0,10		-	-
^{60}Co	-	-	<0,10		-	-
^{110m}Ag	-	-	<0,10		-	-
^{137}Cs	-	-	0,19		-	-
^{155}Eu	-	-	<0,17		-	-
^{241}Am	-	-	<0,10		-	-

* Pipeline. ** White Sands. ***Cove. + Dunbar. ++ Thornton Loch Beach.

Table 100. British Energy Torness, Radiation Doses to the Local Critical Group

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishing community due to fish and shellfish consumption,	6	<5	<5	<5	5	<5

Note: The above doses are taken from RIFE reports and are assessed from measured activity concentrations which include the effects of historical discharges from this and other sites.

Table 101. BNFL Sellafield, Site Characteristics

Type of Facility	Reprocessing Magnox and Oxide fuels Manufacture of Mixed Oxide fuels Management of stored wastes & clean-up of historical facilities Decommissioning Calder Hall NPS
Location	Cumbria
Date commissioned	Windscale Piles (first site operation) to B205 Magnox reprocessing – 1951 to 1964 THORP - 1991 MOX - 2001 Calder Hall - 1956
Date ceased generation or commenced decommissioning	B205 Magnox reprocessing – in operation THORP – in operation MOX – in operation

	Calder Hall - 2003
Tonnes of U processed annually	1998 1999 2000 2001 2002 2003 1125 1102 1176 1266 1580
OSPAR receiving waters and catchment area	Irish Sea (OSPAR Region II)
Volume of effluent discharged into the receiving waters	3,76 E+6 m^3 (2003) Range 3 to 4E+6 m^3

Table 102. BNFL Sellafield, Liquid Discharges

	Annual discharge limit (TBq) main pipeline					
	1998*	1999**	2000†	2001††	2002‡	2003***
^{3}H	25 000	31 000	30 000	30 000	25 000	25 000
^{14}C	20,8	20,8	20,8	20,8	20,8	20,8
^{60}Co	13	13	13	13	13	13
^{90}Sr	48	48	48	48	48	48
$^{95}Zr + {}^{95}Nb$	9	9	9	9	9	9
^{99}Tc	200	200	90	90	90	90
^{106}Ru	63	63	63	63	63	63
^{129}I	1,6	2	1,6	2	1,6	1,6
^{134}Cs	6,6	6,6	6,6	6,6	6,6	6,6
^{137}Cs	75	75	75	75	75	75
^{144}Ce	8	8	8	8	8	8
Pu-α	0,7	0,7	0,7	0,7	0,7	0,7
^{241}Pu	27	27	27	27	27	27
^{241}Am	0,3	0,3	0,3	0,3	0,3	0,3
Total beta	400	400	400	400	400	400
Total alpha	1	1	1	1	1	1
Uranium (kg)	2040	2040	2040	2040	2040	2040
	Annual discharge limit (TBq) Seaburn Sewer					
^{3}H	0,132	0,132	0,132	0,132	0,132	0,132
Total beta	0,0135	0,0135	0,0135	0,0135	0,0135	0,0135
Total alpha	3,30E-03	3,30E-03	3,30E-03	3,30E-03	3,30E-03	3,30E-03
	Actual Site Discharge (TBq per year) Main Pipeline					
^{3}H	2310	2520	2260	2560	3320	3900
^{14}C	3,70	5,76	4,61	9,47	13,00	17,00
^{35}S	0,43	0,32	0,36	0,16	0,17	-
^{54}Mn	7,00E-02	4,00E-02	1,00E-02	3,00E-02	2,00E-02	-
^{55}Fe	1,00E-02	2,00E-02	4,00E-02	2,00E-02	3,00E-02	-
^{60}Co	2,40	0,89	1,20	1,23	0,90	0,43
^{63}Ni	0,40	0,58	0,43	0,27	0,46	-
^{65}Zn	0,14	7,00E-02	3,00E-02	5,00E-02	3,00E-02	-
^{89}Sr	0,88	0,60	0,64	0,76	0,52	-
^{90}Sr	17,7	31,20	19,70	26,10	19,8	14,00
$^{95}Zr + {}^{95}Nb$	0,65	0,182	0,18	0,272	0,41	0,306
^{99}Tc	52,7	68,80	44,40	79,40	85,40	37,00
^{103}Ru	0,15	0,13	0,11	0,15	-	-
^{106}Ru	5,60	2,72	2,68	3,89	6,02	11,50
^{110m}Ag	0,12	9,00E-02	8,00E-02	0,10	-	-
^{125}Sb	4,80	7,90	7,80	13,00	17,00	-
^{129}I	0,55	0,485	0,47	0,629	0,73	0,554
	Actual Site Discharge (TBq per year) Main Pipeline					
^{134}Cs	0,32	0,34	0,23	0,483	0,49	0,39
^{137}Cs	7,50	9,12	6,91	9,57	7,69	6,24
^{144}Ce	0,76	0,602	0,55	0,789	0,97	0,885
^{147}Pm	0,39	0,41	0,35	0,42	0,79	-
^{152}Eu	0,16	0,11	7,00E-02	0,11	0,13	-
^{154}Eu	0,10	5,00E-02	6,00E-02	8,00E-02	0,13	-
^{155}Eu	9,00E-02	4,00E-02	5,00E-02	7,00E-02	0,10	-
^{237}Np	4,00E-02	4,00E-02	3,00E-02	4,00E-02	6,00E-02	-
Pu-α	0,14	0,115	0,12	0,155	0,34	0,358
^{241}Pu	3,50	2,87	3,20	4,58	10,50	10,10
^{241}Am	4,70E-02	3,5E-02	3,00E-02	3,80E-02	4,00E-02	5,90E-02
^{242}Cm	6,00E-03	3,00E-03	3,00E-03	6,00E-03	2,00E-02	-
$^{243}Cm + {}^{244}Cm$	3,00E-03	2,00E-03	3,00E-03	3,00E-03	3,00E-03	-
Total beta	86	110,00	76,60	123,00	112,00	83,30
Total alpha	0,17	0,133	0,12	0,196	0,35	0,407
Uranium (kg)	550	536	610	387	440	484

	Actual Discharge (TBq per year) Seaburn Sewer					
^{3}H	1,70E-02	1,48E-02	1,10E-02	2,53E-02	2,60E-02	2,68E-02
Total beta	4,90E-04	4,50E-04	4,90E-04	3,80E-03	4,40E-04	4,64E-04
Total alpha	3,20E-05	3,90E-05	3,50E-05	3,10E-05	5,40E-05	7,01E-05

* BNFL (1999) Annual report; ** BNFL (2000) Annual report; † BNFL (2001) Annual report; †† BNFL (2002) Annual report;
‡ BNFL (2003) Annual report; *** RIFE 9 (2004).
^{3}H & ^{129}I discharge limits are proportional to the throughput of uranium oxide fuel reprocessed.
Discharge, environmental monitoring and dose data for the Calder Hall reactors are included, as the data relating to them cannot be practically separated from those relating to the rest of the site.

Table 103. BNFL Sellafield, Aerial Discharges

	Total Discharge (TBq per year) to atmosphere					
Summary	1998	1999	2000	2001	2002	2003
^{3}H	250	236	213,0	241	253	373
^{14}C	2,62	2,65	2,58	0,953	0,829	0,71
^{41}Ar	2530	2590	2510	1930	325	153
^{85}Kr	99000	9,07E-04	73600	14000	101000	120000
^{35}S	0,15	0,1	0,10	0,115	0,0121	6,51E-03
^{60}Co	5,00E-05	3,95E-05	3,27E-05	3,00E-05	6,01E-06	1,89E-06
^{90}Sr	6,00E-05	6,33E-05	5,38E-05	5,30E-05	4,68E-05	5,26E-05
^{106}Ru	1,10E-03	9,60E-04	1,08E-03	1,02E-03	1,31E-03	1,43E-03
^{125}Sb	1,90E-04	2,53E-04	1,76E-04	5,40E-04	3,79E-04	1,06E-03
^{129}I	2,68E-02	2,53E-02	2,52E-02	1,99E-02	2,60E-02	1,70E-02
^{131}I	3,17E-03	4,02E-03	2,79E-03	2,28E-03	4,46E-04	6,00E-04
^{137}Cs	4,41E-04	5,83E-04	5,70E-04	3,34E-04	4,26E-04	4,95E-04
Pu-α	3,4E-05	1,07E-04	4,40E-05	3,27E-05	1,89E-05	6,51E-5
^{241}Pu	2,67E-04	8,31E-04	2,68E-04	1,78E-04	9,73E-05	3,94E-04
^{241}Am + ^{242}Cm	4,98E-05	7,67E-05	4,48E-05	3,56E-05	1,96E-05	3,82E-05
Total-alpha	1,1E-04	1,62E-04	7,77E-05	6,70E-05	4,62E-05	1,18E-04
Total-beta	1,54E-03	7,83E-04	7,18E-04	5,55E-04	9,24E-04	1,19E-03

Note: Atmospheric discharges are made from high, intermediate and low stacks, Calder Hall, THORP and other approved locations. Detail can be obtained from BNFL reports.

Table 104. BNFL Sellafield, Environmental Impact

Cod*							Plaice*						
	Activity concentration (Bq per kg fw, edible parts)							Activity concentration (Bq per kg fw, edible parts)					
	1998	1999	2000	2001	2002	2003		1998	1999	2000	2001	2002	2003
^{3}H	-	-	66	38	51	41	^{3}H	-	-	58	62	63	86
^{14}C	79	65	75	81	100	130	^{14}C	120	120	97	110	95	120
^{60}Co	0,26	0,29	0,34	0,30	0,21	0,26	^{60}Co	0,24	0,26	0,27	0,33	0,25	<0,22
^{90}Sr	0,33	0,14	0,18	0,45	0,14	<0,13	^{90}Sr	0,31	0,19	0,15	0,14	0,13	<0,13
^{95}Zr	0,005	0,04	0,40	0,42	0,27	-	^{95}Zr	0,35	0,46	0,42	0,39	0,30	-
^{95}Nb	0,001	0,10	0,13	0,12	0,11	-	^{95}Nb	0,11	0,11	0,12	0,11	0,12	-
^{99}Tc	5,80	2,10	1,60	1,60	1,50	<1	^{99}Tc	12,00	6,10	10	15	11	13
^{106}Ru	1,60	1,60	1,90	2,00	0,40	<1,6	^{106}Ru	1,40	1,70	0,19	1,80	1,50	<1,5
^{129}I	-	-	0,14	0,13	0,36	-	^{129}I	-	-	0,01	0,01	0,02	-
^{134}Cs	0,05	0,24	0,28	0,27	0,22	<0,24	^{134}Cs	0,18	0,24	0,24	0,26	0,19	<0,22
^{137}Cs	8,40	7,30	7,50	5,90	6,30	6	^{137}Cs	5,70	5,50	5,05	5,20	4,50	4,1
Pu-α	0,02	0,02	0,03	0,02	0,03	<0,02	Pu-α	0,02	0,04	0,03	0,02	0,05	0,03
^{241}Pu	-	-	-	-	-	-	^{241}Pu	-	-	-	-	-	-
^{241}Am	0,02	0,02	0,04	0,02	0,04	<0,01	^{241}Am	0,03	0,04	0,04	0,04	0,08	0,04
Winkles*							**Mussels***						
	Activity concentration (Bq per kg fw, edible parts)							Activity concentration (Bq per kg fw, edible parts)					
	1998	1999	2000	2001	2002	2003		1998	1999	2000	2001	2002	2003
^{3}H	-	-	22	16	-	-	^{3}H	-	-	67	73	-	-
^{14}C	140	120	140	200	220	280	^{14}C	200	170	190	230	260	370
^{60}Co	25	23	33	13	11	12	^{60}Co	15	14	160	10	7,6	7,5
^{90}Sr	5,5	4,8	3,4	2,4	1,4	2,9	^{90}Sr	3,60	3,60	1,8	1,4	1,6	1,1
^{95}Zr	1,5	1,8	1,8	1,4	1,3	-	^{95}Zr	1,70	1,30	0,9	1,4	0,75	-
^{95}Nb	1,5	0,69	1,2	-	0,5	-	^{95}Nb	4,20	-	0,1	-	0,30	-
^{99}Tc	1300	630	850	910	1300	1500	^{99}Tc	1400	1300	1100	1600	2800	2600
^{106}Ru	63	20	25	16	33	71	^{106}Ru	53	19	16	16	21	47
^{110m}Ag	12	7,70	3,80	2,1	4	3,9	^{110m}Ag	0,64	0,67	0,7	0,8	0,6	<0,47

^{137}Cs	12	11	10	5,7	6,80	7,3	^{137}Cs	4	3,7	3	2,5	2,4	2,3
^{237}Np	0,04	0,04	0,04	0,03	0,02	0,03	^{237}Np	0,10	0,07	0,05	0,04	0,05	0,04
Pu-α	1	15	16	11	13	14	Pu-α	11	11	9	8,3	10	10
^{241}Pu	130	130	120	82	95	100	^{241}Pu	110	99	80	69	81	83
^{241}Am	22	20	27	18	20	23	^{241}Am	17	17	17	15	18	17
U-α	-	-	2	1,50	1,50	1,8	U-α	-	-		1,7	2,2	2,1
Crab*							**Lobster***						
	Activity concentration (Bq per kg fw)							Activity concentration (Bq per kg fw)					
	1998	1999	2000	2001	2002	2003		1998	1999	2000	2001	2002	2003
^{3}H	-	-	69	54	-	-	^{3}H	-	-	130	88	-	-
^{14}C	170	140	120	130	130	-	^{14}C	190	180	160	170	200	-
^{60}Co	3	7,7	4,5	3,5	3,5	-	^{60}Co	4,6	6	4,1	3,5	2,5	-
^{90}Sr	1,2	1,2	1,5	0,8	1,00	-	^{90}Sr	0,38	0,32	0,42	0,4	0,43	-
^{95}Zr	0,5	0,72	0,008	0,4	0,51	-	^{95}Zr	0,8	0,92	0,8	0,8	0,48	-
^{95}Nb	0,3	0,48	0,001	0,1	0,18	-	^{95}Nb	-	-	0,3	-	-	-
^{99}Tc	280	95	79	92	110	-	^{99}Tc	8000	4400	3700	4500	5000	-
^{106}Ru	-	0,39	3	2,4	2,9	-	^{106}Ru	2,8	2,8	4	2,8	1,9	-
^{110m}Ag	3,5	3,4	-	1,1	-	-	^{110m}Ag	7,7	5,40	-	1,3		-
^{137}Cs	2,9	2,7	0,4	1,9	1,6	-	^{137}Cs	3,4	1,2	2,90	1,8	1,6	-
^{237}Np	0,008	0,009	0,007	0,01	0,01	-	^{237}Np	0,03	0,04	0,02	0,02	0,02	-
Pu-α	0,54	0,7	0,58	0,6	0,38	-	Pu-α	0,54	0,47	0,35	0,3	0,31	-
^{241}Pu	6,8	4,9	4	4,5	3,20	-	^{241}Pu	5,4	4,2	2,5	2	2,6	-
^{241}Am	1,3	1,6	1,8	1,7	1,60	-	^{241}Am	8,7	7,4	6,1	4,8	4,6	-
U-α	-	-	0,15	0,2	0,28	-	U-α	-	-	0,04	0,07	0,07	-
Porphyra*							***Fucus***						
	Activity concentration (Bq per kg fw, edible parts)							Activity concentration (Bq per kg fw, edible parts)					
	1998	1999	2000	2001	2002	2003		1998	1999	2000	2001	2002	2003
^{3}H	-	-	7	4,1	7,3	4,5	^{3}H	-	-	5	13	9,9	17
^{14}C	82	74	79	83	97	-	^{14}C	48	38	65	36	45	-
^{60}Co	-	-	4	3	1,6	2,1	^{60}Co	-	-	21	14	14	6,9
^{90}Sr	7,7	8,1	7	7	8,7	<5,9	^{90}Sr	9,6	8,8	11	8	8,9	<10
^{95}Zr	-	-	1	0,50	0,68	-	^{95}Zr	-	-	1	0,7	0,79	-
^{95}Nb	-	-	0,22	0,20	0,27	-	^{95}Nb	-	-	0,17	0,2	0,29	-
^{99}Tc	120	63	96	86	200	75	^{99}Tc	22000	31000	17000	13000	38200	25700
^{106}Ru	50	13	15	12	18	64	^{106}Ru	10	4,5	4,2	3,4	4	6,4
^{129}I	-	-	1,30	0,8	1,3	-	^{129}I	-	-	14	6	15	-
^{134}Cs	-	-	0,48	0,3	0,46	<0,34	^{134}Cs	-	-	0,67	0,4	0,48	<0,56
^{137}Cs	6,2	6,2	4,5	3,8	3,6	3,5	^{137}Cs	7,3	5,1	6,7	5,6	4,8	4,8
Pu-α	7,4	6,8	7,3	6	7,2	7,9	Pu-α	21	12	14	8,8	14	12
^{241}Pu	-	-	-	-	-	-	^{241}Pu	-	-	-	-	-	-
^{241}Am	11	11	12	9,4	12	12	^{241}Am	6,3	4,5	6	4,2	2,6	8,3
U-α	-	-	0,64	0,4	0,44	0,46	U-α	-	-	3,2	-	2	2,10

* Samples from St Bees – Selker. ** Samples from Seascale.

Table 105. BNFL Sellafield, Doses to marine reference organisms

Reference organism		Radionuclide										Total
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{239}Pu	^{241}Am	
Benthic mollusc	unweighted	2,37E-5	9,77E-3	0,0377	1,94E-3	0,0107	7,00E-3	6,90E-7	0,0107	0,0203	0,0572	0,155
	weighted	7,10E-5	9,77E-3	0,0377	1,94E-3	0,0107	7,00E-3	8,34E-7	0,0107	0,406	1,03	1,51
Large benthic crustacean	unweighted	2,37E-5	9,77E-3	0,0376	1,60E-3	0,0859	6,54E-4	6,92E-7	0,0106	2,04E-3	6,63E-3	0,155
	weighted	7,10E-5	9,77E-3	0,0376	1,60E-3	0,0859	6,54E-4	8,35E-7	0,0106	0,0406	0,031	0,218
Pelagic fish	unweighted	2,37E-5	9,8E-3	3,55E-3	8,81E-5	3,25E-4	2,43E-5	6,74E-7	1,85E-3	2,72E-4	5,70E-4	0,0165
	weighted	7,10E-5	9,8E-3	3,55E-3	8,81E-5	3,25E-4	2,43E-5	8,18E-7	1,85E-3	5,41E-3	3,00E-3	0,0241
Seabird	unweighted	2,37E-5	9,81E-3	0,0512	0,0297	0,0868	1,35	2,06E-4	0,0346	0,677	5,19	7,42
	weighted	7,10E-5	9,81E-3	0,0512	0,0297	0,0868	1,35	2,49E-4	0,0347	13,5	103	118

Table 106. BNFL Sellafield, Radiation Doses to the Public

	Consumption rates (kg a^{-1})		
	Critical group	Whitehaven Fishery	Public
Fish			
Cod	19,3	23,4	8,2
Plaice	16,9	23,4	8,2
Crustaceans			

Crab	13,3	-	-
lobster	5,7	-	-
Nephrops	2,9	14,2	-
Molluscs			
winkles	6,9	-	-
whelks	-	13,4	-
other	7,8	-	-
Beach occupancy	1000 hours	-	-

Crossover from deposition of materials discharged to atmosphere is also included.

Table 107. BNFL Sellafield, Critical Group Dose

Critical group dose (μSv a^{-1})					
1998	1999	2000	2001	2002	2003
113	103	122	119	169	188

Dose associated with marine discharges received by the critical group (consumers of seafoods (St Bees – Selker).

Table 108. BNFL Drigg, Site Characteristics

Type of Facility	Low level waste disposal facility
Location	Cumbria, England, UK
Date commissioned	1959
Receiving waters and catchment area	Irish Sea (OSPAR Region III)
Volume of effluent discharged into the receiving waters	Information not supplied by site operator

Table 109. BNFL Drigg, Liquid Discharges

	Authorised annual discharge limits (TBq) for liquid effluents (Sea Pipeline)					
	1998	1999	2000	2001	2002	2003
Total Alpha	0,1	0,1	0,1	0,1	0,1	0,1
Total Beta	0,3	0,3	0,3	0,3	0,3	0,3
^{3}H	120	120	120	120	120	120
	Actual annual liquid discharges (TBq) (Sea Pipeline)					
Total Alpha	0,0001	6,85E-05	1,05E-04	<0,00007	0,0000742	6,04E-05
Total Beta	0,002	0,00148	0,00165	0,001	0,00119	8,67E-04
^{3}H	0,53	0,392	0,495	0,36	0,339	0,20

*Provisional figures.
Low level waste and PCM operations at Drigg do not give rise to any significant aerial discharges of radioactivity. This was confirmed by sampling of discharges on stacks associated with the Drigg Grouting Facility and Magazine 3 Retrieval Facility (BNFL 2002).

Table 110. UKAEA Dounreay, Site Characteristics

Type of Facility	Fast Reactor R & D now under decommissioning
Location	Caithness, north coast of Scotland
Date commissioned	1955
Date ceased generation or commenced decommissioning	1994
Installed generating capacity	Not applicable post 1994, Uranium processing is planned for the future as part of the site decommissioning programme,
Receiving waters and catchment area	North Atlantic Ocean (OSPAR Region II)
Volume of effluent discharged into the receiving waters	Approx 50 000 m^3 per year

Table 111. UKAEA Dounreay, Liquid and aerial discharge

	Authorised annual discharge limits (TBq) for liquid effluent					
	1998	1999	2000	2001	2002	2003
^{3}H	130	30,8	30,8	30,8	30,8	30,8
Total Beta (excl ^{3}H)	110	49	49	49	49	49
Total alpha (excl, ^{242}Cm)	0,75	0,27	0,27	0,27	0,27	0,27
^{60}Co	1	0,46	0,46	0,46	0,46	0,46
^{90}Sr	12	7,7	7,7	7,7	7,7	7,7
^{95}Zr + ^{95}Nb	6	0,4	0,4	0,4	0,4	0,4
^{106}Ru	12	4,1	4,1	4,1	4,1	4,1
^{110m}Ag	0,4	0,13	0,13	0,13	0,13	0,13
^{137}Cs	50	23	23	23	23	23
^{144}Ce	12	0,42	0,42	0,42	0,42	0,42

^{241}Pu	15	2,3	2,3	2,3	2,3	2,3
^{242}Cm	1	0,04	0,04	0,04	0,04	0,04
	Actual annual liquid discharges (TBq)					
^{3}H	4,54E-01	1,37E-01	8,80E-02	9,72E-02	8,94E-02	9,480E-02
Total beta	5,84E-01	2,97E-01	3,04E-01	3,09E-01	3,07E-01	3,67E-01
Total alpha	1,21E-02	1,73E-03	1,56E-03	1,40E-03	1,96E-03	2,75E-03
^{60}Co	1,01E-02	3,61E-03	7,00E-04	7,38E-04	4,45E-04	2,49E-04
^{90}Sr	1,71E-01	1,63E-01	1,56E-01	1,61E-01	1,55E-01	1,29E-01
^{95}Zr + ^{95}Nb	1,20E-02	9,44E-04	7,27E-04	6,38E-04	3,93E-04	2,37E-04
^{106}Ru	7,37E-02	2,29E-03	1,75E-03	1,45E-03	8,46E-04	5,48E-04
^{110m}Ag	6,00E-03	3,56E-04	2,72E-04	2,36E-04	1,37E-04	9,61E-05
^{137}Cs	1,82E-01	1,57E-02	1,40E-02	1,49E-02	1,44E-02	1,26E-02
^{144}Ce	6,30E-03	1,71E-03	1,13E-03	1,02E-03	5,58E-04	4,46E-04
^{241}Pu	9,55E-02	8,67E-03	3,03E-03	7,37E-04	1,97E-04	2,05E-04
^{242}Cm	4,80E-04	1,60E-05	2,58E-06	5,13E-07	5,61E-07	4,04E-07
	Actual site annual emissions to air (TBq) (Fuel Cycle Area)					
	1998	1999	2000	2001	2002	2003
^{3}H	0,025	0,19	0,35	0,339	0,233	0,27
^{129}I	2,80E-05	5,60E-05	5,40E-05	6,72E-05	7,21E-05	7,16E-05
Alpha	5,70E-05	3,70E-05	3,90E-05	3,36E-05	3,28E-05	6,24E-05
Beta	3,20E-04	1,80E-04	1,90E-04	2,04E-04	2,21E-04	3,36E-04

Note: Total beta is measured by solid source counting techniques; Total alpha is measured by liquid scintillation techniques.

Table 112. UKAEA Dounreay, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in *Fucus serratus**					
	1998	1999	2000	2001	2002	2003
^{60}Co (mean)	3,95	1,79	0,44	0,18	0,178	0,135
^{60}Co (max)	54	12	1,5	0,46	0,48	0,29
^{137}Cs (mean)	0,54	0,29	0,26	0,29	0,232	0,27
^{137}Cs (max)	4,6	1	0,41	0,4	0,43	0,41
	Activity concentration (Bq kg^{-1} wet wt) in winkles**					
^{90}Sr	0,49	0,19	0,94	0,23	0,19	0,43
^{137}Cs	0,39	0,27	0,29	0,32	0,22	0,23
^{239}Pu + ^{240}Pu	0,22	0,13	0,1	0,11	9,70E-02	9,30E-02
^{241}Am	0,16	0,14	0,12	0,11	9,80E-02	8,40E-02
	Activity concentration (Bq kg^{-1} wet wt) in crab***					
^{90}Sr	0,56	0,93	0,194	0,28	0,193	0,21
^{137}Cs	0,71	1,45E-01	1,89E-01	1,73E-01	1,87E-01	0,14
	Activity concentration (Bq kg^{-1} wet wt) in crab***					
^{239}Pu + ^{240}Pu	5,50E-02	7,10E-02	1,40E-02	3,20E-02	2,20E-02	2,10E-02
^{241}Am	6,20E-02	4,80E-02	4,50E-02	3,80E-02	2,20E-02	2,10E-02
	Activity concentration (Bq kg^{-1} wet wt) in lobster***					
^{90}Sr	-	-	0,094	0,087	0,12	0,14
^{137}Cs	1,18	0,66	0,53	0,36	0,49	0,44
^{239}Pu + ^{240}Pu	5,90E-03	9,90E-03	2,00E-02	1,60E-02	1,20E-02	6,00E-03
^{241}Am	3,90E-02	3,30E-02	4,20E-02	8,70E-02	2,60E-02	1,40E-02

* Within 3,2 km of sea outfall. ** Within 4 km of site (two locations one east and one west). *** Caught near pipeline outlet Results refer to edible sections only and not the whole animal. Results in italics are less than values.

Table 113. UKAEA Dounreay, Doses to marine organisms

	Dose (µGy hr^{-1})*					
Reference organism	1998	1999	2000	2001	2002	2003
Phytoplankton	-	-	-	-	2,4	-
Zooplankton	-	-	-	-	3,7	-
Benthic Mollusc	-	-	-	-	1	-

* Seabed off Dounreay near pipeline outlet.
All other reference creatures are less than 1 mGy h^{-1}. Method used is that defined in R & D Publication 128 "Impact Assessment of Ionising Radiation in Wildlife" by Environment Agency/English Nature.

Table 114. UKAEA Dounreay, Radiation dose to the public

	Dose (µSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003

Winkle consumers who collect them from near site	1,48	0,24	0,12	0,11	0,12	0,13

Doses are from modelling studies and refer to the year of the discharge only; they do not include historic discharges. Model and critical group definition as defined in 1999 Dounreay RSA authorisation.

Table 115. UKAEA Harwell, Site Characteristics

Type of Facility	Nuclear Power Research and Development Site
Location	Oxfordshire
Date commissioned	1947 onwards
Date ceased generation or commenced decommissioning	1990 onwards
Installed generating capacity	n/a
Receiving waters and catchment area	River Thames to Thames Estuary (OSPAR Region II)
Volume of effluent into the receiving waters	169 000 cubic metres per year (2003 figure)

Table 116. UKAEA Harwell, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents (Pipeline)					
	1998	1999	2000	2001	2002	2003
^{3}H	4	4	4	4	4	0,3
Total beta	2,20E-02	2,20E-02	2,20E-02	2,20E-02	2,20E-02	3,30E-03
Total alpha	1,00E-03	1,00E-03	1,00E-03	1,00E-03	1,00E-03	5,00E-05
^{60}Co	7,00E-03	7,00E-03	7,00E-03	7,00E-03	7,00E-03	1,20E-04
^{137}Cs	7,00E-03	7,00E-03	7,00E-03	7,00E-03	7,00E-03	5,40E-04
	Actual site annual liquid discharges (TBq) (Pipeline)					
^{3}H	8,79E-02	4,83E-02	6,51E-02	1,55E-02	1,54E-01	5,30E-03
Total beta	2,98E-03	2,27E-03	1,49E-03	6,06E-04	5,80E-04	3,50E-04
Total alpha	5,12E-05	2,68E-05	1,27E-05	1,22E-05	1,85E-05	1,20E-05
^{60}Co	4,60E-05	7,53E-05	7,86E-05	9,35E-06	1,39E-05	4,60E-06
^{137}Cs	4,90E-04	4,32E-04	1,87E-04	6,26E-05	7,53E-05	5,60E-05
	Actual site annual emissions to air (TBq)					
^{3}H	2,6	2,55	3,63	1,56	1,12	1,1
Total Alpha	1,8E-07	1,15E-07	1,29E-07	1,03E-07	1E-07	6,3E-08
Total Beta	4,00E-06	2,0E-06	2,15E-06	2,32E-06	3,83E-06	3,5E-06
^{222}Rn	-	-	-	-	-	0,36
^{85}Kr	-	-	-	-	-	0,11

1. UKAEA Harwell takes representative samples of the discharges to the Thames during discharge (the effluent is also analysed prior to discharge). Representative samples of surface water flows to the Lydebank Brook are taken using a continuous volume proportional sampler and analysed weekly.
2. The measurement of gross alpha and gross beta activity is carried out using standard techniques after evaporation on to a sample tray. Samples are counted using a gas flow proportional counter calibrated against a certified standard.

Table 117. UKAEA Harwell, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Pike*					
	1998	1999	2000	2001	2002	2003
^{3}H	270	200	130	110	110	48
^{60}Co	<0,04	<0,05	<0,09	<0,05	<0,05	<0,04
^{134}Cs	0,28	<0,06	-	-	-	-
^{137}Cs	26	7,4	3,0	1,7	0,53	0,53
^{155}Eu	<0,14	<0,16	<0,2	-	-	-
^{241}Am	<0,13	<0,25	<0,21	<0,06	<0,14	<0,05
	Activity concentration (Bq kg^{-1} wet wt) in *Nuphar lutea**					
^{3}H	<120	<25	<25	-	-	-
^{60}Co	<0,06	<0,05	<0,05	-	-	-
^{134}Cs	<0,06	<0,04	-	-	-	-
^{137}Cs	1,4	0,23	0,81	-	-	-
^{155}Eu	<0,14	<0,07	<0,11	-	-	-
^{241}Am	<0,19	<0,03	<0,10	-	-	-

* Outfall (Sutton Courtenay).
Note: these samples are freshwater, not marine samples.

Table 118. UKAEA Harwell, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Estuary fish eaters	0,067	0,052	0,029	0,012	0,012	0,016

UKAEA has identified a hypothetical group for modelling and assessing the impact of discharges to the Thames estuary. Modelling includes consideration of consumption of fish, crustacean, molluscs, seaweed plus exposures due to inhalation and sediment exposure via beach occupancy. Historical discharges are also taken in to account.

Table 119. UKAEA Windscale, Site Characteristics

Type of Facility	Research and Development (Decommissioning Pile 1 and WAGR, some waste remediation work and post-irradiation examination (PIE) of nuclear fuel)
Location	Cumbria
Date commissioned	Construction of Pile 1 and Pile 2 began in 1947 Pile 1 went critical in 1950 and Pile 2 went critical in 1951 Windscale's Advanced Gas-cooled Reactor (WAGR) became operational in 1962
Date ceased generation or commenced decommissioning	Piles 1 and 2 shut down in 1957, Pile 1 decommissioning began in the 1993, Pile 2 had fuel removed in 1957 and is now under a regime of care and maintenance WAGR shut down and decommissioning began in 1981
Installed generating capacity	n/a
The receiving waters and catchment area	All liquid wastes are transferred by pipeline or tanker to the adjacent BNFL Sellafield site for treatment and discharge, These discharges are accounted for within BNFL's authorised disposals to OSPAR Region III,
The volume of effluent into the receiving waters	N/A – see above

Table 120. UKAEA Windscale, Aerial Discharges

	Authorised annual discharge limits (TBq) for aerial effluents					
	1998	1999	2000	2001	2002	2003
^{3}H	2,3	2,3	2,3	2,3	2,3	2,3
Total beta	5,00E-03	5,00E-04	5,00E-04	5,00E-04	5,00E-04	5,00E-04
Total alpha	1,20E-05	1,20E-05	1,20E-05	1,20E-05	1,20E-05	1,20E-05
^{131}I	1,20E-03	1,20E-03	1,20E-03	1,20E-03	1,20E-03	1,20E-03
^{85}Kr	14	14	14	14	14	14
	Actual site annual emissions to air (TBq)					
Total alpha	3,09E-07	2,84E-07	2,32E-07	2,54E-07	1,63E-07	1,44E-07
Total beta	4,97E-06	7,22E-06	3,11E-06	5,15E-06	3,18E-06	2,59E-06
^{3}H	4,30E-03	4,19E-03	4,42E-04	7,70E-04	7,90E-03	8,50E-03
^{131}I	2,5E-06	Nil	1,42E-06	3,50E-06	2,74E-06	2,16E-06
^{85}Kr	1,70E-01	5,20E-03	2,6E-03	4,10E-02	2,60E-01	1,00E-01

Actual site annual liquid discharges (TBq), environmental impact and radiation doses to the public for 1998-2003 are included in Sellafield data.

Table 121. UKAEA Winfrith, Site Characteristics

Type of Facility	Former nuclear research centre; reactors all now closed
Location	Dorset
Date commissioned	Site opened in 1957, SGHWR commissioned in 1967
Date ceased generation or commenced decommissioning	SGHWR Closed in 1990
Installed generating capacity	SGHWR was 100 MW electrical, 300 MW Thermal,
Receiving waters and catchment area	The English Channel (OSPAR Region II)
Volume of effluent into the receiving waters	Approximately 83 000 cubic metres per year

Table 122. UKAEA Winfrith, Discharge Data

	Authorised annual discharge limits (TBq) for liquid effluents (inner pipeline)					
	1998	1999	2000	2001	2002	2003
Alpha	0,3	0,3	0,3	0,3	0,3	0,3
^{3}H	650	650	650	650	650	650
^{65}Zn	6	6	6	6	6	6
^{60}Co	10	10	10	10	10	10
Others	80	80	80	80	80	80
	Actual site annual liquid discharges (TBq)(inner pipeline)					
Alpha	1,33E-03	1,14E-03	1,03E-04	1,14E-04	3,40E-04	1,51E-03
^{3}H	3,42	2,65	4,2	2,38	5,9	12,7
^{65}Zn	3,2E-04	3,88E-04	3,24E-04	2,39E-04	2,50E-04	2,17E-04
^{60}Co	3,1E-04	1,46E-02	1,13E-02	1,30E-03	1,30E-03	1,15E-03

Others	8,1E-02	1,48E-03	7,39E-02	1,27E-02	1,80E-02	7,73E-02
	Actual site annual emissions to air (TBq)					
^{3}H	0,35	0,145	0,157	0,127	0,09	0,135
^{14}C	6,6E-04	0,001	8,7E-04	6,5E-04	4E-04	6,16E-04
^{85}Kr	Nil	0,003	Nil	8,00E-04	Nil	Nil
Alpha	2,1E-09	1E-11	3,91E-09	Nil	2E-09	6,0E-10
Beta	3,0E-9	3,8E-09	8,21E-08	Nil	6,6E-08	1,08E-09

Table 123. UKAEA Winfrith, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Crab*					
	1998	1999	2000	2001	2002	2003
Alpha	5,23	5,27E+0	9,77E+0	5,85E+0	5,63E+0	3,53E+0
^{241}Am	3,45E-03	4,49E-03	3,86E-03	2,44E-03	2,84E-03	7,26E-03
^{60}Co	6,83E-01	6,76E-01	3,92E-01	4,19E-01	2,51E-01	2,36E-01
^{65}Zn	1,38E-01	1,81E-01	2,15E-01	1,67E-01	2,01E-01	1,85E-01
^{238}Pu	7,84E-04	8,64E-04	7,14E-04	4,33E-04	4,53E-04	8,90E-04
$^{239}Pu + ^{240}Pu$	5,30E-03	4,83E-03	1,98E-03	1,14E-03	5,52E-03	4,84E-03
	Activity concentration (Bq kg^{-1} wet wt) in Fish**					
Alpha	4,16E-01	3,53E-01	8,95E-01	3,01E-01	2,29E-01	2,54E-01
^{241}Am	1,03E-03	4,73E-03	4,37E-03	5,50E-04	4,20E-04	8,30E-04
^{60}Co	5,78E-02	9,34E-02	6,93E-02	1,52E-01	9,74E-02	1,08E-01
^{65}Zn	1,27E-01	1,99E-01	1,33E-01	3,61E-01	1,88E-01	2,68E-01
^{238}Pu	3,30E-04	8,29E-04	2,50E-04	2,07E-04	1,35E-04	2,23E-04
$^{239}Pu + ^{240}Pu$	2,50E-04	3,59E-03	1,12E-03	4,17E-04	3,52E-04	3,92E-03
	Activity concentration (Bq kg^{-1} wet wt) in Whelks***					
Alpha	7,67E-01	2,76E+0	3,63E+0	3,39E+0	1,33E+0	1,42E+0
^{241}Am	2,61E-03	6,75E-03	3,22E-03	3,75E-03	2,10E-03	1,27E-02
^{60}Co	4,11E-01	3,15E-01	2,88E-01	3,58E-01	2,32E-01	1,91E-01
^{65}Zn	1,69E-01	1,55E-01	1,30E-01	1,13E-01	1,35E-01	1,58E-01
^{238}Pu	7,65E-04	9,96E-04	6,27E-04	6,27E-04	4,67E-04	1,69E-03
$^{239}Pu + ^{240}Pu$	3,30E-03	4,71E-03	2,64E-03	3,56E-03	2,47E-03	1,017E-02

Samples taken from: * Portand, Lulworth, Chapman's Pool, Swanage, Poole; ** Weymouth Bay; ***Lulworth and Poole.

Table 124. UKAEA Winfrith, Radiation Doses to the Public

Reference Group	**Dose (μSv a^{-1})**					
Consumers of seafood caught in Weymouth Bay	1998	1999	2000	2001	2002	2003
	0,3	0,47	0,36	0,37	0,35	0,58

Table 125. GE Healthcare Cardiff, Site Characteristics

Type of Facility	Radioisotope Manufacture
Location	Cardiff
Date commissioned	1980
Date ceased generation or commenced decommissioning	n/a
Receiving waters and catchment area	Ystradyfodwg and Pontypridd public sewer to the Cardiff East Waste Water Treatment Works and into the Severn Estuary at Orchard Ledges (OSPAR Region III)
Volume of effluent into the receiving waters	50-80 cubic metres per day

Table 126. GE Healthcare Cardiff, Discharge Data

	Authorised annual discharge limits for liquid effluents (TBq)					
	1998	1999	2000	2001	2002	2003
^{3}H	900	900	900	900	900	900
^{14}C	2	2	2	2	2	6
$^{32}P + ^{33}P$	10	0,01	0,01	0,01	0,01	2,0E-04
^{125}I	50	0,05	0,05	0,05	0,05	5,0E-04
Other radionuclides	0,5	5E-04	5E-04	5E-04	5E-04	0,04
	Actual annual liquid discharges (TBq)					
^{3}H	277	105	87,2	67,2	59,5	30,2
^{14}C	1,15	1,15	0,6	0,222	0,212	1,70
$^{32}P + ^{33}P$	4,44E-06	7,59E-06	7,4E-06	2,59E-06	6,29E-07	1,15E-04
^{125}I	8,0E-03	0,00996	0,0107	0,00712	7,2E-04	4,75E-06
Other radionuclides	1,2E-05	7,9E-08	Nil	4,81E-07	Nil	Nil
	Actual Discharges to air (TBq)					

Soluble ^{3}H	153	117	104	112	74,1	114
Insoluble ^{3}H	407	383	399	442	327	475
^{14}C	2630	2,05	1,59	1,37	1,87	1,70

The activities of ^{14}C, ^{3}H and ^{32}P are determined using a Wallac 1409 liquid scintillation counter optimised for low level counting.
The activity of ^{125}I is determined using a Sodium Iodide detector (3in x 3in) on a Canberra Packard Accuspec MCA.
For radionuclides where direct measurement is not possible because of the low levels of activity involved (e.g. ^{35}S) an estimate is made based on disposal records in individual laboratories.

Table 127. GE Healthcare Cardiff, Environmental Impact

	Activity concentration (Bq kg^{-1} wet wt) in Flounder					
East of new pipeline	1998	1999	2000	2001	2002	2003
^{3}H Bq/kg (wet)	31000	23000	54000	46000	30000	15000
Organic ^{3}H Bq/kg (wet)	/	16000	51000	/	27000	14000
^{14}C Bq/kg (wet)	640	450	730	420	310	180

Radioactive substances in samples & marine samples: H3, C14 and total beta. Samples are taken of fish, molluscs, seaweed, mud and sand. Concentrations of other radionuclides are due mainly to Sellafield discharges.

Table 128. GE Healthcare Cardiff, Radiation Doses to the Public

	Dose (μSv a^{-1})					
Reference Group	1998	1999	2000	2001	2002	2003
Local fishing community due to fish and shellfish consumption and external radiation	57	53	64	36	31	

These figures are based on ICRP60 methodology and represent the dose critical group shown below arising from radioactivity found in the environment and food pathways. It is not possible to separate the components due to current and historical discharges.

Table 129. GE Healthcare Amersham, Site Characteristics

Type of Facility	Radio-pharmaceuticals
Location	Amersham, Buckinghamshire, HP7 9LL
Date commissioned	1940
Date ceased generation or commenced decommissioning	n/a
Receiving waters and catchment area	Disposed of to public sewer which enters the Maple Lodge Sewage Treatment Works, the output from which discharges to the Grand Union Canal and then into the River Colne, a tributary of the Thames (OSPAR Region II)
Volume of effluent into the receiving waters	2003 volume was 4036 cubic metres

Table 130. GE Healthcare Amersham, Discharge Data

	Authorised annual discharge limits for liquid effluents (TBq)					
	1998	1999	2000	2001	2002	2003
^{137}Cs	0,005	0,005	0,005	0,005	0,005	0,005
^{125}I	0,2	0,2	0,2	0,2	0,2	0,2
^{3}H	0,2	0,2	0,2	0,2	0,2	0,2
β -emitters >0,4 MeV	0,1	0,1	0,1	0,1	0,1	0,1
α-emitters	3,0E-04	3E-04	3E-04	3E-04	3E-04	3,0E-04
Other radionuclides	0,3	0,3	0,3	0,3	0,3	0,3
	Actual site annual liquid discharges (TBq)					
^{137}Cs	3,56E-05	1,88E-05	3,97E-05	3,5E-05	1,68E-05	3,9E-07
^{125}I	0,0022	6,03E-04	4,66E-04	4,51E-04	3,78E-04	1,81E-04
^{3}H	0,0023	0,00140	0,001	0,00211	0,00215	0,0011
β-emitters>0,4 MeV	7,7E-03	0,00865	0,004	0,00422	0,00236	7,35E-04
α-emitters	4,2E-05	3,96E-05	2,57E-05	3,1E-05	2,92E-05	1,58E-05
Other radionuclides	0,056	0,0444	0,032	0,0233	0,0186	0,0139
	Actual site annual emissions to air (TBq)					
Alpha	1,7E-07	1,40E-07	1,40E-07	1,00E-07	1,00E-07	7,50E-08
^{241}Am	2,40E-07	1,00E-07	2,00E-07	1,00E-07	1,00E-07	-
Other (Penetrating)	1,30E-04	7,80E-05	7,30E-05	7,80E-05	7,40E-05	9,8E-05
^{90}Sr	1,30E-04	7,80E-05	7,30E-05	7,80E-05	7,40E-05	-
Other (non-penetrating)	1,30E-02	1,80E-02	1,00E-02	8,40E-03	6,90E-03	6E-03
^{35}S	1,30E-02	1,80E-02	1,00E-02	8,40E-03	6,90E-03	-
^{75}Se	2,80E-04	2,80E-04	2,70E-04	3,00E-04	2,80E-04	2,80E-04

^{125}I	1,40E-02	6,90E-03	5,00E-03	2,80E-03	2,30E-03	2E-03
^{131}I	5,50E-04	5,40E-04	5,10E-04	5,20E-04	5,10E-04	5,0E-04
^{222}Ra	1,60	1,60	2,20	2,80	2,40	1,40