OSPAR COMMISSION

UK Report on application of Best Available Techniques (BAT) in civil nuclear facilities (2008-2011)

Implementation of PARCOM Recommendation 91/4 on radioactive discharges

Radioactive Substances Series

2013

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are: Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties Contractantes sont : l'Allemagne, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède, la Suisse et l'Union européenne.

Acknowledgement

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Contents

1. Summary

This report has been prepared for the Radioactive Substances Committee of the OSPAR Commission as the UK statement on the implementation of PARCOM Recommendation 91/4 on Radioactive Substances, related to the application of Best Available Technology[1] (BAT) to minimise and, where appropriate, eliminate radioactive discharges from the nuclear industry into the marine environment.

Operations at UK nuclear installations are governed by various acts, most notably the Radioactive Substances Act 1993 (as amended) (RSA93), and the Environmental Permitting (England and Wales) Regulations 2010 (EPR10) through which control of discharges to the environment from nuclear licensed sites is exercised. The latter regulations are applied in England and Wales and require that Best Available Techniques (BAT) are applied. In previous reports, the UK requirements were described in terms of the application of Best Practicable Means (BPM) and the Best Practicable Environmental Option (BPEO) techniques. These terms continue to be applied in Scotland and Northern Ireland and their use is effectively equivalent to the application of BAT. The use of BAT, BPM and BPEO in the UK 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 BAT (including BPEO and BPM) 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. The practices and impacts arising from operational and decommissioning nuclear power stations are presented separately at a site level. Other civil nuclear sites involved in the treatment and management of solid low level radioactive waste (such as landfill sites that accept solid low levels wastes) are beyond the scope of this report. 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. the Sellafield site 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 and Devolved Administrations are of the opinion that the procedures and techniques applied in the UK nuclear industry are consistent with the implementation of BAT. Furthermore, the authorisation review process requires that technological developments continue to be reviewed and implemented where appropriate.

A number of processes and waste management activities currently being pursued merit particular mention:

- Development of a Robust Fuel Design for the AGR fleet to reduce carbon deposition on internal reactor surfaces in order to prevent the risk of fuel failure and release of fission products.
- Elimination of secondary neutron sources (used to obtain control information during reactor start-ups following shutdown) at the Sizewell PWR to reduce the levels of tritium (^{3}H) discharged.

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[1] In PARCOM Recommendation 91/4, the term BAT is related to ‘technology’. However, in the UK the term ‘techniques’ is more commonly used in this context, to include both equipment and management practices. This broader interpretation of BAT is applied throughout this report.

- The deployment of hydrocyclone technology at decommissioning sites (Hinkley Point A & Bradwell) for removal of particulates from liquid effluent streams.
- Development and implementation of an Overall Effluent Strategy and discharge forecasting tool at Sellafield, to model the impacts of different discharge strategies to air and water. This model deals with a complex and varying set of interacting source terms, and is of increasing importance in predicting discharges and identifying associated BAT discharge control arrangements as more of the site activities move to Post Operational Clean-Out (POCO), decommissioning and clean-up.
- Commencement of the retrieval of fuels and wastes from a number of Sellafield legacy facilities, representing significant progress in the decommissioning and clean-up of these legacy facilities:
    - Pile Fuel Storage Pond (PFSP): the first fuel moved out of the facility since the 1960s;
    - The transfer of 3,800TBq of radioactive liquors from the Magnox Swarf Storage Silos (MSSS) to the Site Ion eXchange Effluent Plant (SIXEP) for processing to date;
    - Retrieval of 1000m^3 of radioactive sludge from the 3rd floc storage tank.
- For the Sellafield PFSP, a new Local Effluent Treatment Plant is being used to abate pond water activity and associated discharges, and to support the future retrievals and clean-up programme.
- Optimisation of fuel storage and pond-water conditions in the Sellafield Fuel Handling Plant (FHP), and implementation of tighter feed controls for discharges to SIXEP, leading to improved discharge management and control capability.
- Completion of the destruction of sodium-potassium coolant at the Dounreay Fast Reactor and successful sealing of the Dounreay Shaft with a grout curtain, with corresponding decrease in the groundwater ingress into the Shaft.
- Installation of a clarifier with lamella inclined plates at Winfrith's Active Liquid Effluent System for the removal of entrained solids from radioactive effluent arising from site activities.

The UK concludes that these examples demonstrate a continuing commitment to the application of BAT in UK nuclear facilities. Furthermore, the regulatory requirements to demonstrate that BAT is applied, or that BPM have been employed to minimise discharges and the periodic review of permits and authorisations, which entails, *inter alia*, a review of the BPEO, effectively ensures that the application of BAT in UK nuclear facilities is incorporated in UK regulatory practice.

During this reporting period, there have been changes in legislation related to the nuclear industry. The most notable of these has been referred to above regarding the implementation of the EPR10 and the adoption of the term BAT in relation to the regulation of radioactive substances in England and Wales. The review of Exemption Orders, specified under the RSA93, is also significant in changing the definition of 'radioactive material' and 'radioactive waste' and thereby clarifying what is within scope and what is 'out of scope' of radioactive substances regulation. These Exemption Orders have been incorporated within UK legislation under The Environmental Permitting (England and Wales) (Amendment) Regulations 2011 and The Radioactive Substances Exemption (Scotland) Order 2011. One of the principal objectives of the revised legislation was greater harmonisation and alignment with EC legislation and guidance (e.g. RP122).

The UK laid out its initial strategy to implement the agreements reached at the 1998 OSPAR Ministerial Meeting, and subsequent OSPAR Commission meetings on radioactive substances, in its UK Strategy for Radioactive Discharges 2001-2020, which was issued in 2002. This strategy was updated and expanded to cover aerial discharges, decommissioning activities and non-nuclear sectors, for the period 2006-2030 and was published in 2009.

The permitting and authorisation processes applied in the UK, particularly the conditions relating to periodic review, ensure that BAT will continue to be implemented in accordance with the discharge strategy and associated statutory guidance.

Récapitulatif

Le présent rapport a été préparé par le Comité substances radioactives de la Commission OSPAR, à titre de déclaration du Royaume-Uni sur la mise en œuvre de la Recommandation PARCOM 91/4 sur les substances radioactives, portant sur l'utilisation des meilleures technologies disponibles (BAT) 2 afin de minimiser et, le cas échéant, de supprimer la pollution provoquée par les rejets radioactifs de l'ensemble des industries nucléaires dans le milieu marin.

L'exploitation des centrales nucléaires du Royaume-Uni est régie par diverses lois et plus particulièrement par la loi de 1993 sur les substances radioactives (telle qu'amendée) (RSA93), et la réglementation 2010 des autorisations environnementales (Angleterre et Pays de Galles) (EPR10) permettant le contrôle des rejets dans le milieu naturel provenant de sites nucléaires autorisés. Cette dernière réglementation s'applique en Angleterre et au Pays de Galles et exige l'application des meilleures techniques disponibles (BAT). Les impératifs du Royaume-Uni étaient décrits, dans les rapports précédents, du point de vue de l'application des meilleurs moyens pratiques (BPM) et de la meilleure option environnementale applicable (BPEO). Ces termes continuent à s'appliquer en Ecosse et en Irlande du Nord et leur utilisation est équivalente à l'application des BAT. L'utilisation des BAT, BPM et BPEO au Royaume-Uni permet un niveau de contrôle des rejets qui est à tout le moins en cohérence avec celui de la BAT, telle que définie par OSPAR.

Le présent rapport examine les pratiques actuelles de chaque site et installation pertinents et l'application détaillée des BAT (notamment BPEO et BPM) dans le secteur nucléaire au Royaume-Uni. Ces considérations sont regroupées suivant le secteur nucléaire concerné : production de combustible, production d'énergie, retraitement de combustible, recherche et développement. Les pratiques et impacts des centrales nucléaires en fonctionnement et en cours de déclassement sont présentés séparément au niveau d'un site. D'autres sites nucléaires civils impliqués dans le traitement et la gestion de déchets solides faiblement radioactifs (tels que les décharges acceptant les déchets solides faiblement radioactifs) ne sont pas couverts par le présent rapport. Les sites complexes, dans lesquels des centrales individuelles peuvent être en fonctionnement alors que d'autres sont en cours de déclassement sont considérés selon le secteur et le statut de leur processus principal (par exemple le site de Sellafield est abordé en tant que site de retraitement en fonction, bien qu'un certain nombre d'installations individuelles soient actuellement en cours de déclassement).

En plus de l'examen de l'application des BAT, se fondant sur les pratiques actuelles, des technologies en cours de développement au Royaume-Uni et ailleurs ont été identifiées et des comparaisons des performances d'usines similaires au niveau mondial ont été réalisées, le cas échéant.

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[2] Dans la Recommandation PARCOM 91/4, le terme BAT porte sur les « technologies ». Cependant le terme « techniques » est utilisé plus couramment par le Royaume-Uni dans ce contexte, couvrant aussi bien le matériel que les pratiques de gestion. Cette interprétation plus large de la BAT s'applique à l'ensemble du rapport.

Le gouvernement du Royaume-Uni et les administrations responsables pensent que les procédures et les techniques appliquées dans le secteur nucléaire du Royaume-Uni sont en cohérence avec la mise en œuvre des BAT. De plus, le processus d'examen des autorisations exige que les développements techniques continuent à être passés en revue et mis en œuvre, le cas échéant.

Il convient de mentionner en particulier un certain nombre de processus et d'activités de gestion des déchets réalisés actuellement :

- Développement d'un « Robust Fuel Design » pour le parc AGR pour réduire les retombées de carbone sur les surfaces intérieures du réacteur afin d'éviter le risque de défaillance du combustible et le dégagement de produits de fission.
- Elimination de sources de neutrons secondaires (utilisées pour obtenir des informations de contrôle durant le démarrage et l'arrêt du réacteur) au REP de Sizewell pour réduire les niveaux de tritium (3H) rejetés.
- Mise en place de la technologie de l'hydrocyclone dans des sites de déclassement (Hinkley Point A & Bradwell) pour le retrait de particules des flux d'effluents liquides.
- Développement et mise en œuvre d'une stratégie globale pour les effluents et d'un outil de prévision des rejets à Sellafield, afin de modéliser les impacts des diverses stratégies de rejet dans l'air et dans l'eau. Ce modèle traite d'une série complexe et variable de termes sources en interaction et gagne en importance s'agissant de prédire les rejets et de déterminer les dispositions de contrôle des rejets correspondants dans le cadre des BAT car un nombre croissant de ces activités optent pour le nettoyage post-exploitation (POCO), le démantèlement et le nettoyage.
- Début de la récupération de combustibles et de déchets d'un certain nombre d'anciennes installations de Sellafield, ce qui représente des progrès significatifs dans le déclassement et le nettoyage de ces anciennes installations:
    - « Pile Fuel Storage Pond » (PFSP): le premier combustible retiré de l'installation depuis les années 1960;
    - Transfert de 3 800TBq de liquide radioactif des silos de stockage de la limaille de Magnox (MSSS) vers le site de l'usine (SIXEP) qui traite les effluents par échange ionique;
    - Récupération de 1000m3 de boues radioactives de la cuve de stockage de la troisième floculation.
- Pour le PFSP de Sellafield, une nouvelle usine locale de traitement des effluents est utilisée pour réduire l'activité de l'eau du réservoir et les rejets correspondants et pour permettre la récupération et le programme de nettoyage futurs.
- Optimisation du stockage du combustible et des conditions en piscines à l'usine de manipulation du combustible de Sellafield (FHP), et mise en œuvre d'un contrôle plus précis du transfert des rejets vers l'usine SIXEP, conduisant à une meilleure gestion des rejets et de la capacité de contrôle.
- Achèvement de l'élimination du réfrigérant au sodium-potassium du réacteur de Dounreay (Fast Reactor) et isolation de la canalisation avec un coffrage en ciment et une diminution subséquente de l'infiltration des eaux souterraines.
- Ajout d'un procédé de clarification à lamelles inclinées au système de traitement des effluents actifs liquides de Winfrith afin d'éliminer les particules solides des effluents provenant du fonctionnement du site.

Le Royaume-Uni conclut que ces exemples montrent son engagement constant à appliquer les BAT dans les installations nucléaires du Royaume-Uni. De plus, les exigences réglementaires ayant pour but de montrer que les BAT sont appliquées, ou que les BPM ont été utilisés afin de minimiser les rejets et la revue périodique des permis et autorisations, qui implique, entre autre, une revue de la BPEO, assurent de manière efficace que l'application des BAT dans les installations nucléaires du Royaume-Uni est intégrée dans les pratiques réglementaires du Royaume-Uni.

Au cours de cette période de notification, la législation relative au secteur nucléaire a subi des modifications. La plus notable qui est citée ci-avant, porte sur la mise en œuvre de l'EPR10 et l'adoption du terme BAT dans le cadre de la réglementation sur les substances radioactives en Angleterre et au Pays-de Galles. La revue des ordonnances d'exemption, déterminée dans le cadre de la RSA93, joue également un rôle significatif dans la modification de la définition d'une « matière radioactive » et des « déchets radioactifs » et précise ainsi ce qui se trouve dans le champs d'application et ce qui est en dehors du champ d'application de la règlementation sur les substances radioactives. Ces ordonnances d'exemption ont été intégrées dans la législation du Royaume-Uni dans le cadre de la réglementation de 2010 des autorisations environnementales (Angleterre et Pays de Galles) (Amendement) et l'ordonnance de 2011 d'exemption des substances radioactives (Ecosse). L'un des principaux objectifs de la législation révisée est de parvenir à une meilleure harmonisation et un meilleur alignement avec la législation et les orientations de la CE (par exemple RP122).

Le Royaume-Uni a élaboré sa stratégie préliminaire afin de mettre en œuvre les accords convenus par la réunion ministérielle d'OSPAR de 1998, et les réunions ultérieures de la Commission OSPAR sur les substances radioactives, dans sa stratégie sur les rejets radioactifs du Royaume-Uni de 2001 à 2020, qui a été publiée en 2002. Cette stratégie a été actualisée et élargie afin de couvrir les rejets atmosphériques, les activités de déclassement et les secteurs non nucléaires, pour la période allant de 2006 à 2030 a été publiée en 2009.

Les processus d'octroi de permis et d'autorisation appliqués au Royaume-Uni, en particulier les conditions de la revue périodique, permettent de s'assurer que les BAT continueront à être mises en œuvre conformément à la stratégie sur les rejets et aux orientations réglementaires correspondantes.

2. 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 the revised "Guidelines for the submission of information on the assessment of the application of BAT in nuclear facilities" (RSC 04/6/1-E), referred to hereafter as 'the Guidelines'. This report has been prepared in accordance with these Guidelines. The previous reports, submitted to the RSC meeting in 2005 and 2009, were also prepared on the basis of these Guidelines and covered the period 1998-2003 and 2004-2007, respectively. The present report provides an update on the implementation of BAT over the period 2008-2011, together with discharge, environmental concentration and dose data for the six-year period 2006-2011 (in accordance with the Guidelines).

This report, which is the sixth in the series of submissions from the UK to the OSPAR Radioactive Substances Committee, contains information relating to UK civil nuclear licensed sites, illustrated in **Figure 2.1**. Information is provided for the following nuclear industry sectors: fuel manufacture, power generation, fuel reprocessing and research and development. Radioisotope manufacture is considered to be a non-nuclear sector and is included in the annual non-nuclear reports submitted to OSPAR. Sites involved in the treatment and management of low level radioactive wastes (such as landfill sites that accept solid low levels wastes) are considered to be outside the scope of this report and have not been included.

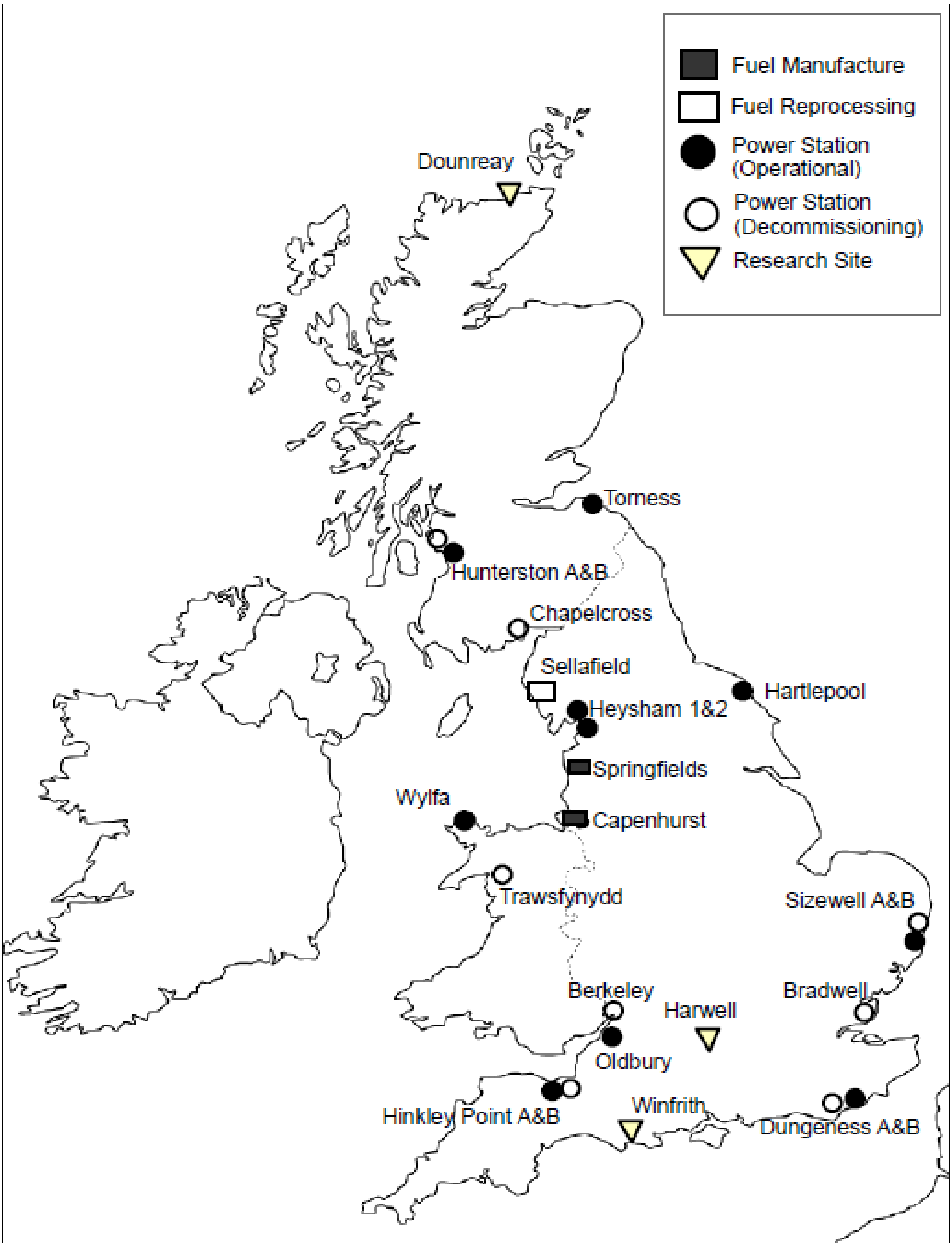
In this report, the implementation of BAT within national legislation and regulations is outlined and the current practices for each relevant site or type of facility (for power generation sites) are reviewed and the detailed application of BAT (or the equivalent Best Practicable Means (BPM) and Best Practicable Environmental Option (BPEO), applied in Scotland) in the UK nuclear industry is discussed. It is noted that the term BAT relates to 'technology' in PARCOM Recommendation 91/4. However, in the UK, the term 'techniques' is more commonly associated with BAT. This is a more inclusive term that explicitly embraces both equipment and management practices. This broader interpretation of BAT is applied throughout the remainder of this report.

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 interaction between liquid and atmospheric discharges, and of the need to maintain a holistic view to provide the Best Practicable Environmental Option (BPEO), including consideration of:

- the balance of radioactive and non-radioactive discharges;
- the relative environmental impacts of discharges to the aquatic and terrestrial environments;
- the issues arising from a policy of containment and land-based disposal of solid wastes.

Figure 2.1 Map Showing Location of Nuclear Sites in the UK



2.1 Structure of the Report

This report is presented in 7 sections. Sections 1 and 2 above provide a summary and the background to the report. Section 3 provides the general information identified in the Guidelines. Sections 4 to 7 provide general and site specific information regarding the following sectors:

- fuel manufacture
- power generation
- fuel reprocessing
- research and development.

Within the power generation sector, information on the practices and impacts arising from operational and decommissioning nuclear power stations are presented separately. Within the context of this report, sites that have permanently ceased operating (including those that are at the stage of defuelling) are considered under the 'decommissioning' heading. 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. the Sellafield site is addressed as an operational reprocessing site, although a number of individual facilities are currently undergoing decommissioning). The Sellafield site also contains facilities (Calder Hall and Windscale) that were previously associated with power generation and research, respectively. Sellafield, Calder Hall and Windscale are managed by Sellafield Ltd and share a single permit under the EPR10. The activities of all three entities are therefore included within the fuel reprocessing section of the report.

The sites within the research and development sector are now concerned primarily with decommissioning and clean-up but are presented under the heading for their original purpose for the sake of consistency with previous reports.

Information regarding discharges from nuclear sites, concentration of radionuclides in food and the environment and doses to the public is provided in the annual Radioactivity in Food and the Environment (RIFE) Reports published by the Environment Agency, Scottish Environment Protection Agency (SEPA), Northern Ireland Environment Agency (NIEA) and Food Standards Agency (FSA). These reports are publicly available and can be accessed via the Environment Agency and SEPA websites.

Section 8 provides a summary of key advances in the application of BAT and some concluding remarks related to the application of BAT in nuclear facilities in the UK.

The appendices contain:

i. Summary of acronyms and key definitions.
ii. Information on general site characteristics.

3. General information

This section of the report provides a summary of the general information, identified in the Guidelines, related to:

- implementation of BAT;
- application of dose limits and constraints;
- rationale for setting discharge limits, general features of environmental monitoring programmes;
- environmental norms and standards;
- authorities responsible for supervision of discharges and the nature of relevant inspection and surveillance programmes.

This information is provided in the following order:

- Competent authorities involved with the development and application of Government policy on radioactive waste (including discharges to the environment).
- National legislation and the basis for regulation.
- Application of BAT in regulatory processes.
- Dose limits, constraints and the rationale for setting discharge limits.
- Regulatory supervision and surveillance.
- Environmental monitoring programmes.
- Dose assessment methods.
- Environmental norms and standards.
- Quality assurance.

3.1 Authorities and responsibilities

The responsibility for radioactive waste policy is devolved and the relevant Government Departments were, during the reporting period: Department of Energy and Climate (DECC) in England[3], the Scottish Government, Welsh Assembly Government and the Department of the Environment in Northern Ireland. The devolved administrations are responsible for the detailed implementation and compliance with international conventions of which the UK, as a single unitary state, is ultimately responsible.

The relevant regulatory authorities ensure that Government policy is implemented. The authorities with responsibility for discharges to the environment are: the Environment Agency in England and Wales, the SEPA in Scotland, and the NIEA in Northern Ireland[4]. A new regulatory authority, The National Resource Body for Wales (NRBW), was created in 2012 to oversee the management of natural resources and the environment in Wales. The NRBW will take over the responsibilities currently conferred to the Environment Agency (including the regulation of discharges from Welsh civil nuclear sites) in 2013.

[3] DECC was established in October 2008 and took over the responsibility for the regulatory framework on radioactive substances from the Department of Environment, Food and Rural Affairs (Defra).
[4] Formerly Environment and Heritage Service of the Department of the Environment in Northern Ireland (EHSNI)

A new independent sector-specific regulatory body, the Office for Nuclear Regulation (ONR) was created in 2011. The ONR, created as an agency of the Health and Safety Executive (HSE) pending its incorporation as a statutory body, took over the safety and security function of the HSE Nuclear Directorate, and the regulation of the transport of radioactive material (by road, rail and inland waterways), previously conferred to the Department for Transport. The ONR is thus responsible for the licensing of nuclear sites, regulation of the management of radioactive material and radioactive waste stored on nuclear sites, and the transport of radioactive material by road, railway and inland waterways.

There are also agencies and advisory bodies that provide relevant advice and guidance. The Radiation Protection Division of the Health Protection Agency (HPA)[5], formerly the National Radiological Protection Board (NRPB), has responsibility for providing information and advice on protection from radiation risks and for undertaking research to advance knowledge about protection from these risks. Other advisory bodies include the Committee on Medical Aspects of Radiation in the Environment (COMARE) and the Radioactive Waste Policy Group (RWPG). More information on these bodies may be found in the UK Strategy for Radioactive Discharges, 2009 (DECC, 2009a).

3.2 National legislation and basis for regulation

The formal basis for the control of radioactive discharges, and other aspects of the control of radioactive materials in the UK, are the Environmental Permitting (England and Wales) Regulations 2010 (EPR10), which came into force in April 2010 and replaces the Radioactive Substances Act 1993 (RSA93) in England and Wales, and the RSA93 (as amended) which remains in force in Scotland and Northern Ireland. Other relevant legislation includes the Ionising Radiation Regulations 1999, Environment Act 1995, 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 1999, the Control of Major Accident Hazards Regulations 1999 and the Water Industry Act 1991. 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 environment. Dose limits, intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable under 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 the previous reporting period (2004-2007) are described in the corresponding UK submission. In accordance with the Guidelines, 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 April 2010, the Environmental Permitting (England and Wales) Regulations 2010 (EPR10) came into force. EPR10 replaces the Radioactive Substances Act 1993 (RSA93) in England and Wales and is implemented by the Environment Agency. RSA93 remains in force in Scotland and Northern Ireland and is implemented by SEPA and the NIEA respectively. Following an extensive review and consultation process, the Exemption Orders, specified under RSA93 were revised and implemented in relevant legislation. The three Agencies work together to ensure that a consistent approach is maintained across the UK.

[5] From April 2013 the HPA will become part of Public Health England.

The EPR10 has not changed the nature or scope of radioactive substances regulation in England and Wales. Authorisations and registrations granted under RSA93 automatically became "environmental permits". There were some procedural changes relating to, for example, application forms, inter-site transfers of radioactive waste, and transfer and surrender of environmental permits. EPR10 also confers power to the Environment Agency to implement staged regulation of geological disposal facilities, a function not provided for in RSA93.

In July 2009, the UK Government and Devolved Administrations published the revised UK Strategy for Radioactive Discharges (DECC, 2009a). The revised UK Strategy builds on and widens the scope of the 2002 Strategy bringing all information on radioactive discharges into one place. The strategy covers the period to 2030 and includes aerial as well as liquid discharges from operational and decommissioning activities, and covers both the nuclear and non-nuclear sectors. It sets out the progress made towards reducing discharges and emissions to the environment; describes, at the sector level, the outcomes which are expected to be achieved and by when; and sets a strategic framework for addressing radioactive discharges over the next 20 years. The strategy demonstrates how the UK is implementing its obligations in respect of the UK's commitments regarding radioactive discharges as a Contracting Party to the OSPAR Convention (1992) and forms the UK's national plan on how the overall and intermediate objectives of the OSPAR Radioactive Substances Strategy will be achieved. The intended effects of the UK Strategy are:

- progressive and substantial reductions in radioactive discharges taking into account any uncertainties;
- progressive reductions in concentrations of radionuclides in the marine environment from radioactive discharges such that by 2020 they add close to zero to historic levels[6];
- progressive reductions in human exposures to ionising radiation resulting from radioactive discharges, as a result of planned reductions in discharges; and delivery of the UK's commitments to OSPAR without compromising the UK energy policy.

In parallel to the strategy, the UK Government published Statutory Guidance (DECC, 2009b) to the Environment Agency concerning the regulation of radioactive discharges into the environment and which introduced the application of BAT in England and Wales. The move to BAT will deliver the equivalent level of environmental protection as BPM and BPEO, and is consistent with the terminology of the environmental protection regimes of the other Contracting Parties and other regimes in England and Wales. Scotland and Northern Ireland will continue to apply BPM and BPEO. Separate guidance on the control of radioactive discharges to the environment has been issued by the Scottish Ministers to SEPA (Scottish Government, 2008).

3.3 The application of BAT in UK legislation

Prior to 2009, regulation of radioactive discharges in the UK was based on the principle of optimisation through application of BPM and BPEO. Following publication of the UK Government's Statutory Guidance to the Environment Agency (DECC, 2009b), the application of BAT replaced BPEO and BPM as the basis for the regulation of radioactive discharges in England and Wales. The Statutory Guidance requires the Environment Agency to ensure that operators use BAT in order to:

- prevent the unnecessary creation of wastes or discharges;
- minimise waste generation;
- minimise the radiological impact of discharges on people and the environment.

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[6] Using the mean of measured values for the period 1995 to 2001 as baseline data

The adoption of BAT in England and Wales is aimed at improving consistency with environment protection regimes in other countries and with the terminology used for environmental regulation of major non-nuclear industries. Scotland and Northern Ireland continue to use BPM and BPEO, which is considered to be broadly equivalent to BAT.

In 2010, the Environment Agency published a guidance document providing an overview of, and setting out, the principles and framework for undertaking studies on optimisation and the identification of BAT (Environment Agency, 2010). These principles are in addition to the established basis for radiation protection (justification, optimisation and the application of limits and conditions) and have been outlined below:

- sustainable development, meeting the needs of the present without compromising the ability of future generations to meet their own needs and achieving the optimum balance in environmental, social and economic outcomes;
- the use of Best Available Techniques (BAT) in England and Wales to prevent and, where that is not practicable, minimise waste generation and discharges to the environment;
- the precautionary principle, that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation";
- the polluter pays principle, by virtue of which the costs of pollution prevention, control and reduction measures are to be borne by the polluter;
- the preferred use of ‘concentrate and contain’ of radioactive waste over ‘dilute and disperse’ in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT is being applied and worker dose is taken into account.

The document recognises that the concept of BAT is progressive and that developments in BAT will be adopted by operators where appropriate, taking into account economic considerations. The document also pointed out that the use of BAT will apply to all phases in the lifecycle of a facility, from the design stage to decommissioning and site restoration, and to the various activities which comprise its management, operation and maintenance.

SEPA recently issued similar guidance on BPM and its role in ensuring that ionising radiation exposures to members of the public are as low as reasonable achievable (ALARA) (SEPA, 2012).

A nuclear sector inter-industry group, the Environment Agencies Requirements Working Group (EARWG), maintains a live database of national and international waste minimisation techniques. This best practice reference is expected to be of assistance to operators in determining suitable options for BAT or BPM and BPEO studies[7].

3.3.1 Application of BAT to new nuclear power plants

In 2008, the UK Government published a Nuclear White Paper (BERR, 2008) stating its position that new nuclear power stations should have a role to play in the country’s future energy mix, alongside other low-carbon sources[8].

In its Statutory Guidance to the Environment Agency, DECC placed specific requirements related to the application of BAT to new nuclear plants, as follows:

“*In relation to any designs for new nuclear power stations, the Environment Agency should ensure that BAT is applied so that the design is capable of meeting high environmental standards. This requirement should be applied at an early stage so that the most modern or best available technology can be incorporated into*

[7] The database is available at www.rwbestpractice.co.uk.

[8] This policy applies to England and Wales only.

the design of the stations, where this would ensure improved standards. The application of BAT should ensure that radioactive wastes and discharges from any new nuclear power stations in England and Wales are minimised and do not exceed those of comparable stations across the world" (DECC, 2009b).

In order to ensure that new nuclear power stations meet acceptable standards of safety, security and environmental protection, the Regulators (the ONR and Environment Agency) established a tiered Generic Design Assessment (GDA) process to consider the acceptability of new nuclear power reactors prior to commencement of the licensing process. The GDA process includes an assessment of the application of BAT and the potential impact of liquid and gaseous discharges of radioactive wastes, carried out in accordance with a process defined in the Process and Information Document (P&ID) (Environment Agency, 2007).

As part of this process, the Environment Agency requires that new nuclear power plants are designed to use BAT to prevent the unnecessary creation of radioactive wastes and, where this is not achievable, that BAT is used to minimise the generation of those wastes. As a consequence, the P&ID specifies that information should be provided that:

i. shows BAT will be used to minimise the production of waste;

ii. describes sources of radioactivity and matters which affect wastes arising.

The GDA process, originally scheduled to be completed in June 2011, was extended to allow the recommendations of an assessment of the potential implications of the Fukushima accident in Japan (ONR, 2011) for the UK nuclear industry to be taken into account. In December 2011, the Regulators granted interim Design Acceptance Confirmations (iDACs) and interim Statements of Design Acceptability (iSoDAs) for two nuclear reactor designs (the Areva UK EPR and the Westinghouse AP1000).

Future licensing of nuclear installations for new nuclear power reactors in England and Wales will follow the standard legal and regulatory processes described in the document Licensing Nuclear Installations (ONR, 2012). The document addresses the law, the regulatory regime, and the nuclear licensing and de-licensing processes and includes considerations of BAT, as indicated above.

3.4 Dose limit, constraints and discharge limit setting rationale

As indicated earlier, the dose limit of 1mSv y^{-1} is set in accordance with both the recommendations of the ICRP and the BSS Directive. This limit is intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable under 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 single site does not exceed 0.5 mSv y^{-1};
- the dose received from any new source does not exceed 0.3 mSv y^{-1}.

In Scotland, SEPA is subject to an equivalent but separate Direction (The Radioactive Substances (Basic Safety Standards) (Scotland) Direction, 2000).

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 for optimisation of 20 µSv 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.

The Statutory Guidance to the Environment Agency on the Regulation of Radioactive Discharges specifies that, where doses are less than 10 µSv y^{-1}, the Environment Agency should not seek to reduce discharge limits further, provided the holder of the authorisation applies and continues to apply BAT. This value is not included in the relevant Statutory Guidance to the SEPA, which is already in place in Scotland (Scottish Government, 2008).

In its guidance on the application of the 2007 ICRP Recommendations to the UK (HPA, 2009), the HPA has recommended that '*the UK Government to select a value for members of the public for new nuclear power stations and waste disposal facilities that is less than 0.15 mSv per year',* in recognition of the fact that '*at the design stage of new plant it is more straightforward to take measures to reduce exposures to the public than it is when measures have to be introduced to existing plant. Therefore, it is recommended that for new nuclear power stations and new facilities for the disposal of radioactive waste, regulators consider applying a more challenging constraint, taking into account the levels of protection that can be achieved internationally* (HPA, 2009).

3.5 Regulation, surveillance and monitoring

The environment agencies review each permit/ authorisation periodically to ensure that it is still suitable and does not require revision. A major review is 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 permit/ authorisation revision. The review process takes account of all relevant activities conducted or foreseen including any modifications, processing (including legacy wastes) and decommissioning. A number of permits/ authorisations have been reviewed and revised during or shortly after the reporting period.

The regulatory authorities identified above work in close concert with the ONR which regulates the safety of nuclear plants (including that for waste storage) and workers. Permits/ authorisations are issued only after consultation with the HSE and the 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. These actions are undertaken to ensure that operators comply with the conditions, including the discharge and emission limits, set out in their EPR10 permits or RSA93 authorisations, as appropriate, and are enforceable in UK law with heavy fines (and custodial sentences if necessary).

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 the 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 agencies' authorisations include quarterly notification levels which are not limits, but triggers for investigation as to whether BAT or BPM has been applied in the control of the relevant discharge; failure to adopt BAT or BPM is a breach of the permit or authorisation.

Operators are also required to take duplicate samples of discharges and to provide these to the regulators as required. These are analysed by regulators' independent analysts as a check in order to be assured that operators' measurements of discharges are accurate.

3.6 Environmental monitoring programmes

All operators of nuclear facilities undertake environmental monitoring, both to comply with conditions in permits/authorisations and to provide the general public with information regarding the impact of the facility on the local environment. Monitoring programmes include sampling of 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.

The Environment Agency and SEPA undertake programmes of monitoring to provide checks on site operators' data and an independent assessment of the exposure to non-food pathways. These checks encompass monitoring of liquid effluents, quality checking of solid waste disposals, measurement of radiation and radioactivity in the environment, air, rainwater and drinking water sources.

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. In Scotland this monitoring is undertaken by SEPA, on behalf of FSA. The results are used to estimate the doses to the representative person[9] (identified through habit surveys). The programmes include 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.

The environmental monitoring programmes of all the relevant UK authorities (SEPA, FSA, NIEA and the Environment Agency) are published in the annual 'Radioactivity in Food and the Environment' (RIFE) reports, which are also available online on the websites of the sponsoring organisations.

The Environment Agency has developed a Performance Standard for organisations undertaking radioanalytical testing of environmental and waste water samples as part of its Monitoring Certification Scheme (MCERTS), established to deliver quality environmental measurements[10]. The MCERTS is based on international standards and covers product certification of instruments, the competency certification of personnel and the accreditation of laboratories. Once published, implementation of the Standard will be mandatory for new nuclear facilities. Adoption of the Standard will be voluntary for existing facilities, although operators will be encouraged to implement it.

3.7 Radiation dose assessment methods

Radiation dose assessments for members of the public arising from radioactive discharges are routinely undertaken independently by site operators, the regulatory authorities and the FSA, as part of the permit/ 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 representative person) are generally assessed for the purposes of comparison with dose limits and constraints.

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[9] The term 'representative person' was adopted in the UK following the publication of ICRP 103 [ref ICRP 103 and HPA advice on its application http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1246519364845 [Accessed 25 October 2012].

It is considered to be equivalent to, and now replaces, the term 'critical group' referred to in the 2008 UK BAT Report

[10] www.mcerts.net

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. Periodic surveys of the habits of representative persons at reference locations across the UK are undertaken, on behalf of the regulatory bodies, to provide robust data that would facilitate realistic assessments of radiological doses to the public that could arise from discharges from nuclear facilities in the UK. The results of the most recent habits survey was published by the Centre for Environment, Fisheries & Aquaculture Science (Cefas) in 201111.

In instances where measurements are not possible, mathematical models are 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 the local representative person. Estimated marine doses to the representative person are summarised in the relevant sections for the individual sites in this report (the full details are provided in the annual RIFE Reports accessible via the Environment Agency and SEPA websites). 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.

The National Dose Assessment Working Group (NDAWG) has continued to work, throughout the reporting period. 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 methods12. Key issues addressed during this period included:

- assessment of short-term releases to atmosphere and rivers;
- recommendations on the acquisition and use of habits data for prospective assessments.

3.8 Environmental norms and standards

Other initiatives have had an increasing effect on the way in which assessments in support of discharge permits/ 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. The ICRP addressed this issue in its revised recommendations (ICRP, 2007), with reference to the framework for the assessment of radiation effects in non-human species proposed in its Publication No. 91 (ICRP, 2003). The ICRP has subsequently expanded the scope of its recommendations in this respect by providing guidance on the concept and use of Reference Animals and Plants, in Publication No. 108 (ICRP, 2008) and on relevant environmental transfer parameters, in Publication No. 114 (ICRP, 2009).

In the UK context, the environment agencies have undertaken programmes of work to fulfil their obligations, for example under the relevant conservation of natural habitats regulations, to review all existing permits/ authorisations that may have an adverse effect on identified European sites. Various levels of assessment of the impacts on designated species have been completed for relevant sites throughout the UK.

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[11] http://www.cefas.defra.gov.uk/publications-and-data/scientific-series/environment-reports.aspx (Accessed 26 October 2012)

[12] http://www.ndawg.org/ (Accessed 26 October 2012)

In 2010, the Environment Agency published Regulatory Guidance Series, No. RSR1, on the environmental principles underlying radioactive substances regulation (Environment Agency, 2010), which update those described in the previous report. This document provides technical guidance that helps underpin the decisions reached by the Agency and addresses all aspects of the regulatory process including permitting and compliance. This document was updated in 2010 take account of the provisions of new EPR10 regime in England and Wales, the Government's 2008 Nuclear White Paper and the Statutory Guidance to the Environment Agency discussed earlier.

The protection of non-human species is included as a principle. A number of considerations were specified, including:

- The objective generally should be to protect populations of species of flora and fauna, rather than to protect every individual organism except where specified by legislation.
- The approach used to assess the adequacy of protection of non-human species should be that described in R&D Publication 128 and R&D Technical Report P3- 101/SP1a (Environment Agency, 2001 and 2003). Key species that need protection in appropriate habitats and habitat features should be identified. Dose rates to these species should be estimated using information in the reports and compared to a guideline value of dose rate below which there appears to be no harm to the species at the population level. Our current guideline value is 40 μGy h^{-1} (Environment Agency, 2005).

3.9 Quality assurance

Quality Assurance (QA) and International Standards Organisation (ISO) Accreditation are common to UK operators to demonstrate 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 minimise the harmful effects on the environment caused by human activities, and to achieve continual improvement of environmental performance[13]. These 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 on the work of operators and a national system of independent regulators (e.g. the Environment Agency and SEPA), advisers (e.g. HPA) and government bodies, each relying on accreditation to an appropriate 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 EPR10 permit or RSA93 authorisation).

Laboratories undertaking analyses for the Environment Agency, 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

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[13] www.iso.org

Kingdom Accreditation Service (UKAS) 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.

3.10 References

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23) 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.

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4. Fuel manufacture

Two sites are primarily concerned with the manufacture of reactor fuel, namely the uranium enrichment plants at Capenhurst, and the uranium purification and fuel manufacture plant at Springfields. Both sites are certificated to the Environmental Management standard ISO 14001. The Springfields site and sections of the Capenhurst site also hold ISO9001 and MCERTS certifications.

4.1 Capenhurst

The Capenhurst site is concerned with uranium enrichment and the decommissioning of a gaseous diffusion plant. The site is under the management of two companies: URENCO UK Ltd (UUK)[14], which owns and operates the centrifuge plants on the site and Sellafield Ltd (SL), which operates the NDA owned portion of the site and is primarily involved in the decommissioning of the redundant gaseous diffusion plant and the storage of uranic materials. The UUK and SL have separate Environmental Permits to discharge and transfer radioactive wastes to a number of disposal sites. In addition, aqueous radioactive liquid arising from UUK operations are transferred to the SL site for discharge.

In December 2011, the NDA and UUK signed an agreement to transfer the NDA-owned portion of the Capenhurst site to UUK. In due course, the latter will take over the decommissioning and uranic storage operations on the site and the whole Capenhurst site will be licensed to UUK.

4.1.1 Sources of liquid effluent

The main activities undertaken on this site giving rise to effluent discharges during the reporting period were:

- decommissioning operations;
- operation of the centrifuge plants;
- UUK laboratories, the laundry facilities and liquid discharges arising from the operation of wet scrubbers on the older centrifuge plants.

Liquids arising from UUK and SL activities are discharged under permit into Rivacre Brook which flows into the tidal section of the River Mersey.

Only small amounts of liquid wastes are discharged from the combined site. The primary source of liquid effluents is the UUK centrifuge operations; SL operations have not resulted in any liquid discharges since March 2009.

4.1.2 Liquid effluent treatment and abatement

Waste streams from the decontamination plant, which supports the operation of the enrichment plant, contain uranium radionuclides and very small amounts of ^{99}Tc and ^{237}Np (associated with historic enrichment activities). These streams are segregated and held in delay tanks for sampling and subsequent discharge to Rivacre Brook. Decommissioning activities at the SL portion of the site do not generally lead to the generation of significant amounts of liquors and any such arisings are kept in storage for settling, sampling and eventual permitted discharge.

The BAT for the management of liquid waste streams on the UUK site were identified in the documents submitted in support of the improvement conditions specified in the UUK Environmental Permit (Punt, A. & George, R., 2011) and are summarised below:

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[14]Previously Urenco (Capenhurst) Ltd (UCL); became Urenco UK Limited in 2008.

- Treatment of bulk aqueous waste by conventional wastewater processes on the Capenhurst site, as far as the treatment works will allow.
- Decontamination, removal of degradation products and other contaminants and reuse where possible of fluorinated and other hydrocarbons. This involves physical cleaning, scraping and removal of breakdown residues, citric acid wash, hot water rinse and, if required, blasting with CO_2 pellets.
- Removal and recovery of uranium from uranium-contaminated aqueous liquors by a third party off-site, followed by further conventional wastewater treatment.
- A number of measures are in place to minimise the arisings and transfer of liquid radioactive waste, including;
    - counter-flow system in the UUK Decontamination Facility which allows decontamination rinse water to be re-circulated into the process;
    - the use of dry ice gun for removal of surface contamination which reduces the requirement for liquid decontaminants;
    - electrical heating of Product and Feed Cylinders in E23 Centrifuge Plant to eliminate the potential for radioactive liquid effluent associated with steam heating;
    - recovery of residues from decontamination processes (e.g. citric acid and degreaser water) by a third party off-site;
    - use of disposable paper overalls, where there is a significant potential for contamination to reduce the amount of material requiring to be laundered and the amount of liquid effluent arising from laundry operations.

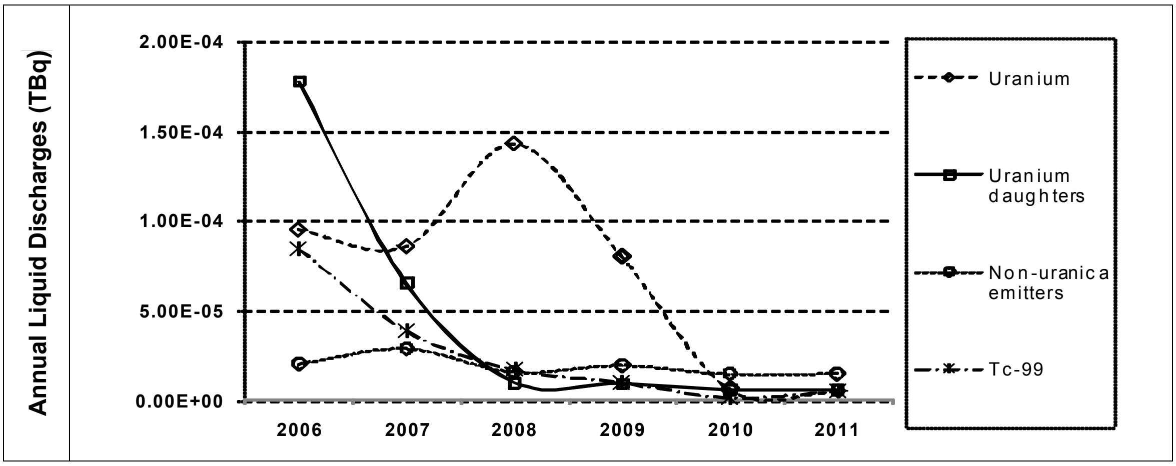
No abatement measures are fitted to laundry or laboratory effluents due to the small quantities and low activity concentrations involved.

Notwithstanding the fact that these management processes are considered to be BAT, UUK installed dry Gaseous Effluent Ventilation Systems (GEVS) into the E22 enrichment plant in 2008. This system replaces a wet venturi scrubber system. As a consequence, contamination will be captured on HEPA filters and liquid effluents will be reduced.

4.1.3 Trends in discharges over the 2006-2011 period

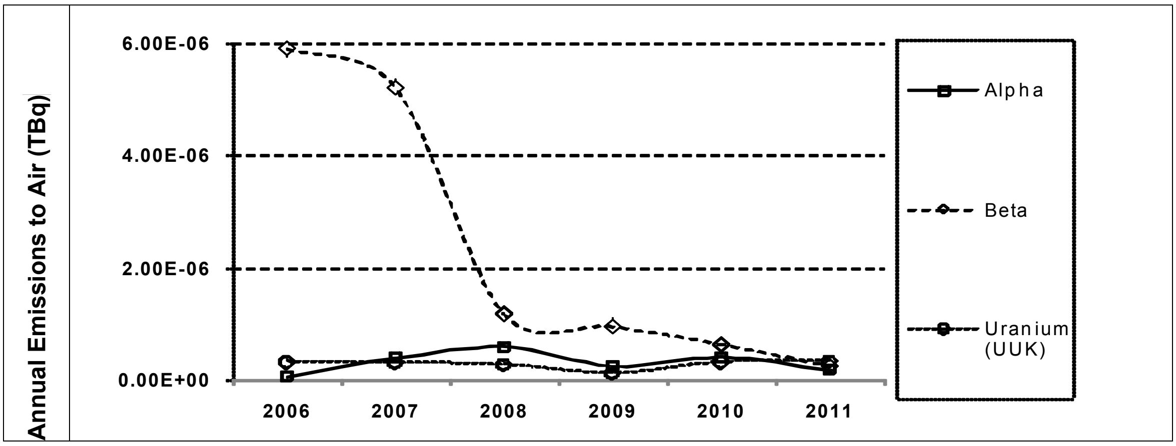
Liquid discharges of ^{99}Tc, uranium alpha activity and uranium daughters from the Capenhurst site have decreased considerably since 2006, with the exception of the spike in uranium discharges in 2008, as illustrated in **Figure 4.1**. Discharge of non-uranium alpha activity, primarily ^{237}Np, has remained relatively stable since 2006.

Figure 4.1 Liquid Discharges from the Capenhurst Site



Emissions to air from the SL operations on the site principally arise from incinerator gases and ventilation air from decommissioning operations. However, the waste incinerator on the SL site has not operated since 2007 and the ventilation systems have been out of use as the bulk of the associated solid waste processing (sorting and segregation) and packaging activities on the site have ceased. Consequently, the emissions of beta radionuclides (particularly ^{3}H) from site decreased significantly over the reporting period, while emissions of uranium by both SL and UUK remained relatively uniform during the same period as demonstrated by **Figure 4.2** below.

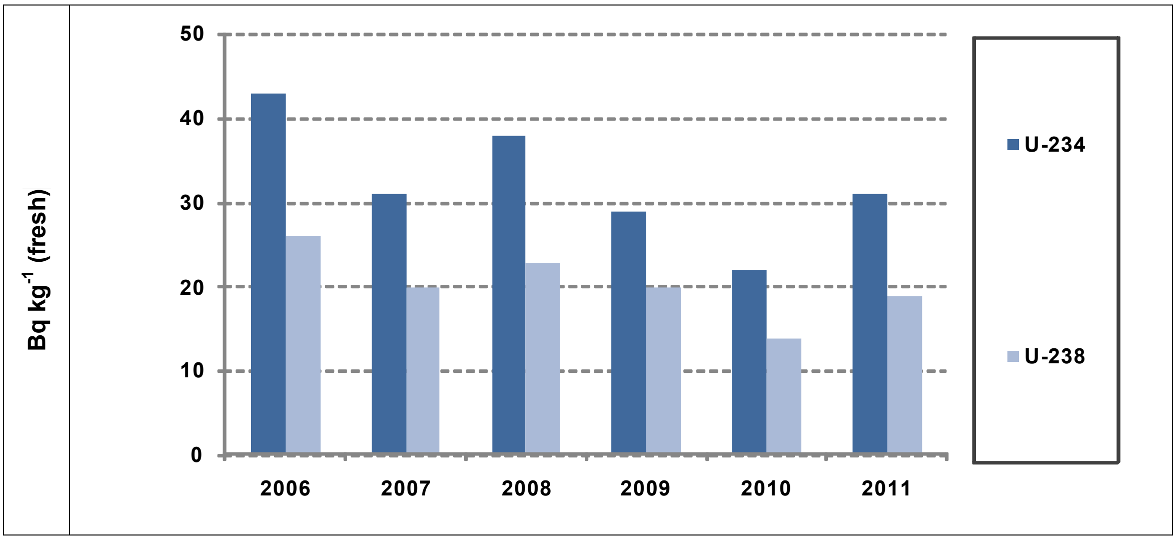
Figure 4.2 Annual Emissions to Air from the Capenhurst Site



4.1.4 Radiological impact of liquid discharges

The environmental monitoring programme around the Capenhurst site includes the collection of samples of freshwater and sediments for analysis of ^{3}H, ^{99}Tc, gamma emitting radionuclides, uranium, ^{237}Np, and gross alpha and beta. Fish and shellfish from the local marine environment are also sampled and measured for a range of radionuclides. The activity concentrations of radionuclides in the environment have generally followed a decreasing trend over the reporting period, as demonstrated by the reported levels of ^{234}U and ^{238}U in sediment in **Figure 4.3** below. The activity concentrations of ^{3}H and ^{237}Np in sediment and freshwater were generally below detection limits. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides as a result of historic discharges from Sellafield.

Figure 4.3 Concentrations of Uranium in Sediment near Capenhurst, 2006-2011



The only identified pathways for doses to the representative person from liquid discharges are gamma irradiation and the inadvertent ingestion of water or silt by children playing in or near Rivacre Brook. The dose arising from combined site discharges has remained around 10 μSv y^{-1} throughout the reporting period. Gaseous discharges from the Capenhurst site give rise to doses off-site of the order of nanoSieverts (nSv).

As part of the authorisation review for the Capenhurst site, the Environment Agency undertook an assessment of the potential impact of discharges from the site on plant and animal life. The Agency's Habitats Stage 3 assessment approach was used (Environment Agency, 2003). This is based on Research and Development Report No. 128 published on behalf of the Agency and English Nature, as discussed previously in Section 3.8. The potential doses to the most exposed species from discharges into the Liverpool and Morecambe Bay estuarial compartment were predicted to be around 1 μGy h^{-1} at the permitted discharge level. This is compared with the Environment Agency's trigger value of 40 μGy h^{-1}; from which it is concluded that discharges at the proposed authorised level would be unlikely to have a significant impact on plant and animal life around the Capenhurst site.

4.1.5 The application of BAT

The Capenhurst site does not discharge directly to the marine environment but into Rivacre Brook, a surface water tributary of the River Mersey. The discharges and the environmental impact of this site continue to be very low. While there are no specific treatment systems in place for radionuclides of uranium, ^{99}Tc or ^{237}Np, the site sewage treatment plant removes material through filtration and sludge settlement processes in advance of discharge. Sample analyses and compliance checks are also undertaken in advance of discharge.

UUK operations are anticipated to continue and will include new processes. A new UUK subsidiary will begin operating a tails deconversion plant and associated facilities comprising cylinder washing, residue recovery, decontamination and maintenance plant for the deconversion of uranium hexafluoride to the more stable uranium oxide.

In addition to new modules being constructed on the latest enrichment plant, UUK are also considering carrying out the following activities in the future:

- Enrichment of recycled uranium, subject market demand and regulatory approval.
- Enrichment of uranium to a higher assay for future generations of nuclear power stations.
- Construction of a centralised waste management facility.
- Possible decommissioning of old centrifuge enrichment plants.

4.1.6 Comparison with performance of similar plants world-wide

The operators of the Capenhurst site maintain a periodic review of national and international developments in best practice for minimising waste disposals and a strategy for reducing discharges, and carry out research and development programme to review BAT.

UUK has a well-established, standardised approach for the design of centrifuge plants, which is used in the UK, the Netherlands and Germany. A new centrifuge plant is being constructed in the USA, which will also follow this template. This design produces no radioactive liquid discharges and all gaseous discharges are abated using a combination of absorbers and HEPA filtration in series. The newest centrifuge plant at Capenhurst, which has been operating since 1997, is also based on this design.

4.2 Springfields

The Springfields site has provided fuel fabrication services since the mid-1940s. Since 2005, the site has been operated and run by Springfields Fuels Limited (SFL), under the management of Westinghouse Electric Company UK Ltd[15], on behalf of the NDA.

In April 2010, Westinghouse entered into an agreement with the NDA for a long-term lease of the Springfields site, which transferred responsibility for the commercial fuel manufacturing business and Springfields Fuels Limited to Westinghouse.

The main activities at Springfields are:

- fabrication of oxide fuels for Advanced Gas-cooled and Light Water Reactors, as well as intermediate fuel products, such as powders, granules and pellets;
- processing of current and historical natural and enriched residues for recovery of uranium and return to the fuel cycle, under contract to the NDA and other customers;
- management of cylinders containing uranium hexafluoride (Hex) for EDF;
- decommissioning and demolition of redundant plants and buildings.

The Springfields site is accredited to the international Quality Management standard ISO 9001, the international Environmental Management standard ISO 14001 and the international Occupational Health and Safety Management System OHSAS 18001. Its laboratories have received UKAS accreditation for analytical laboratories and flow measurement instrumentation has been assessed and certified against the requirements of the Environment Agency's Monitoring Certification Scheme (MCERTS).

4.2.1 Sources of liquid effluent

The sources of liquid effluent include: commercial operations, residue processing (including recovery of uranium) and treatment of legacy material. Examples of liquid waste are:

- liquors from off-gas scrubbers used to minimise aerial discharges;
- spent production process liquors;
- liquors arising as secondary waste from decontamination processes;
- effluent from the site laundry;
- rainwater run-off from potentially contaminated areas.

Storm water and trade effluent are routed via a site-wide drain network to the site effluent complex. Twenty four hour flow proportional samples are taken from both the trade and the storm water drain. The trade effluent and storm water are then combined before being discharged via one of two pipelines to the Ribble Estuary. The flow proportional samples are analysed for a variety of species.

4.2.2 Liquid effluent treatment and abatement

Uranium is recovered from liquors through chemical and physical processing and fed back into the fuel fabrication process. Liquors are recycled and reused, where possible, thus effectively minimising the level of uranium in the liquid waste stream. The Natural and Enriched Uranium Residues Processing Plants are used to recover uranium from solution, thus reducing the activity in liquid effluents. The following technologies are applied:

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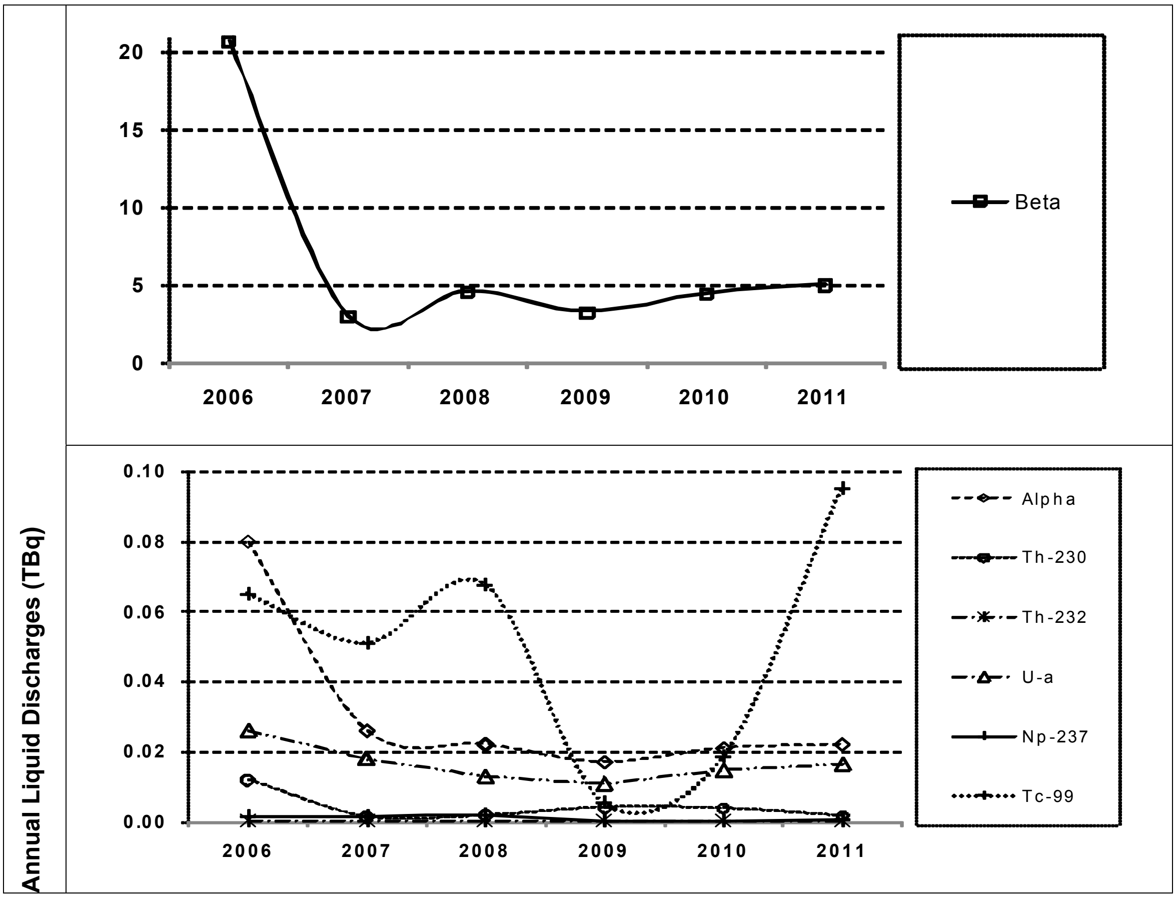
[15] In October 2006, Westinghouse Electric Company UK was included in the sale of Westinghouse Electric Company by BNFL to Toshiba.

- Precipitation and flocculation technologies: selective reagents are used to remove uranium species from solution. For example, the addition of sodium hydroxide forms a precipitate of sodium diuranate, which can be readily separated using physical separation techniques.
- Physical separation technologies: centrifugation of flocculation treated process liquid effluents to remove particulates; decontamination liquors are passed through a hydrocyclone to remove entrained solids, while evaporation is used to allow recycling of distillate in the UO_3 plant as backwash.
- Filtration techniques: process effluents and slurry from precipitation of process effluents are filtered using frame and press filters; a basket filter is used for laundry effluents and oil separators are used to separate oil from aqueous liquids. These simple processes are suitable for the efficient removal of uranium particulates, encountered at Springfields.

4.2.3 Trends in discharges over the 2006-2011 period

As stated in the previous report, considerable decreases in discharges of total alpha, total beta and ^{230}Th were achieved as a consequence of the cessation of Uranium Ore Concentrate (UOC) purification in 2006. The discharge of these and other radionuclides from the Springfields site have remained relatively constant at these reduced levels since 2007 as demonstrated in **Figure 4.4** below.

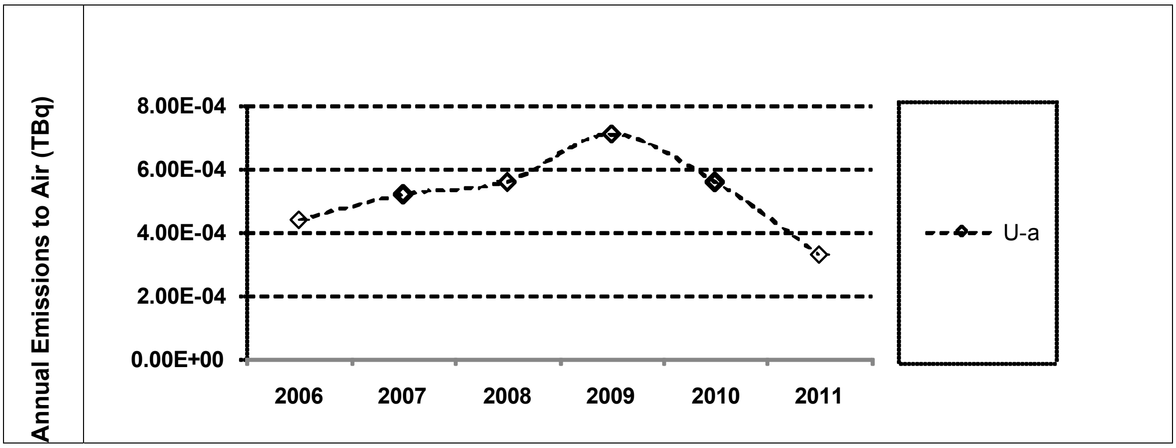
Figure 4.4 Annual Liquid Discharges from Springfields



The amount of ^{99}Tc and ^{237}Np discharged is dependent on the nature of residues processed - only certain residues contain these species. The variation in the discharges of ^{99}Tc is related to the amount of ^{99}Tc residues that have been processed during the reporting period. The elevated discharges of ^{99}Tc recorded in 2011 represent around 16 per cent of the annual limit. The discharge of other radionuclides depends on the production throughput in the fuel production plants and by the type and amount of residues processed.

Aerial emissions have shown small variations since 2006 but remained well below the annual limits.

Figure 4.5 Annual Emissions to Air from the Springfields Site

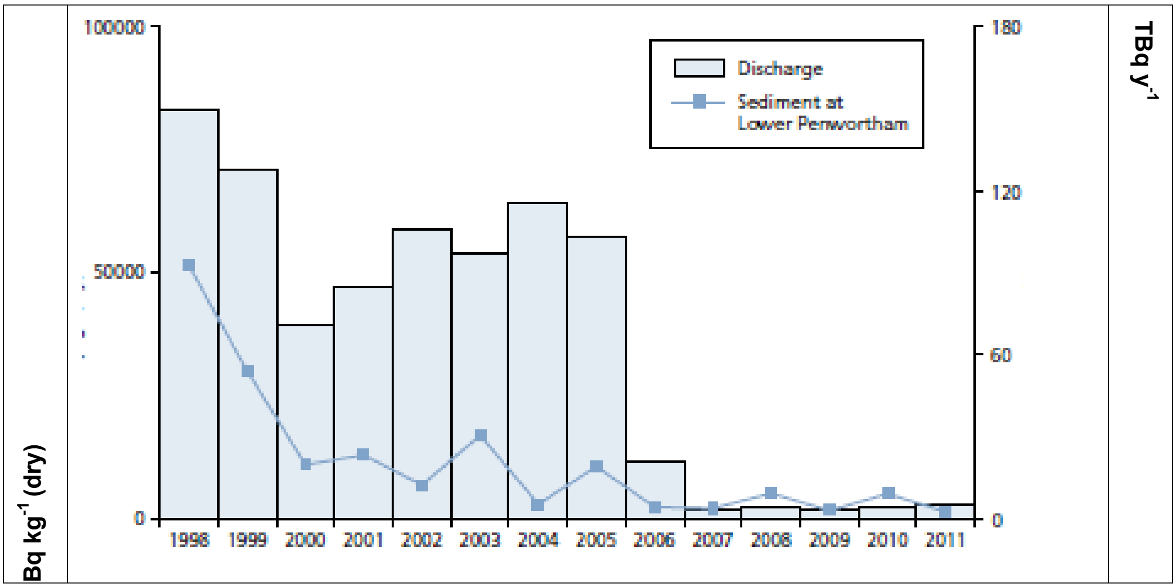


4.2.4 Radiological impact of liquid discharges

Springfields Fuels Ltd 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. A detailed description and illustration of the materials sampled and the associated monitoring locations is provided in the annual RIFE Reports.

Analysis for the following radionuclides is routinely undertaken: ^{40}K, ^{137}Cs, ^{234m}Pa, ^{228}Th, ^{230}Th, ^{232}Th, ^{241}Am, ^{237}Np, total U. Caesium-137, ^{241}Am and isotopes of plutonium were found in biota and sediments along the Ribble Estuary. The presence of these radionuclides is due to past liquid discharges from Sellafield, carried from west Cumbria into the Ribble Estuary by sea currents and adsorbed on fine-grained muds. The concentrations observed were similar to those in recent years. The activity concentrations of radionuclides in environmental samples have declined due to reductions in discharges as shown in **Figure 4.6** below.

Figure4.6 Total Beta Discharges from Springfields and Concentrations in Sediment 1998-2011

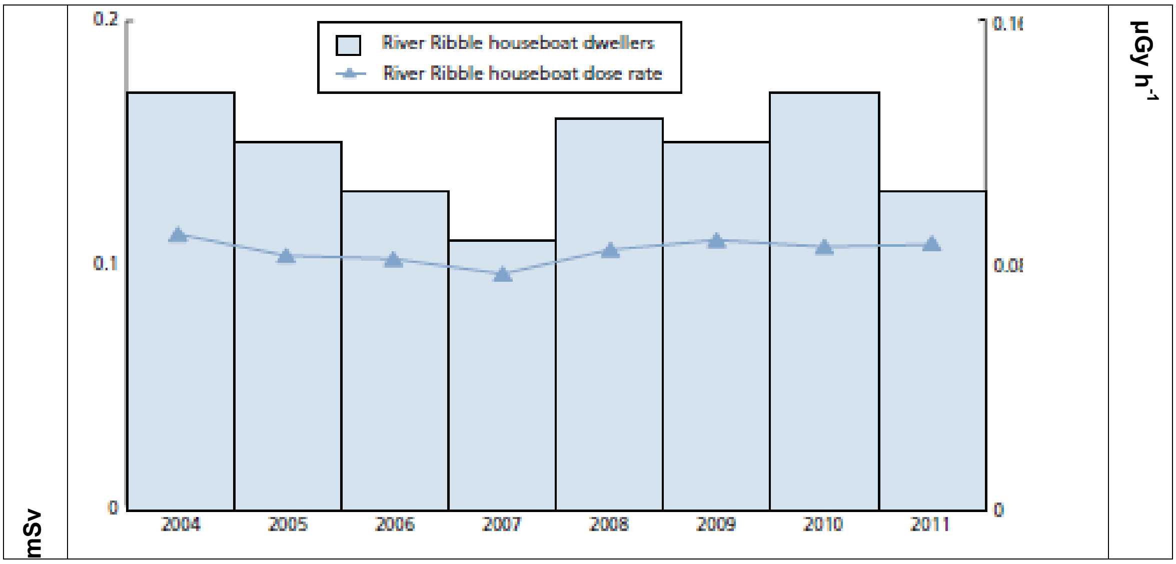


Doses to members of the public are estimated using a combination of measurements and modelling. The potentially exposed groups to liquid discharges from Springfields include:

fishermen, seafood consumers, children playing in inter-tidal areas, houseboat dwellers, anglers and wildfowlers. The annual variations in discharges may result in any one or other of these groups being the representative person for the site in a particular year.

The annual effective dose from fish and shellfish consumption remained at around 20 μSv throughout the period, the majority of which is attributable to ^{241}Am and ^{137}Cs from historic discharges from Sellafield. The highest effective doses were estimated for houseboat dwellers in the Ribble Estuary. These doses have been variable over the reporting period, largely as a result of variations in external exposure, as demonstrated in **Figure 4.7** below. The annual effective dose to wildfowlers and fishermen varied from 27 μSv to around 69 μSv, depending on the habits of the group concerned.

Figure 4.7 Total Dose from all Sources and Dose Rates near Springfields, 2004-2011



In 2009, the Environment Agency commissioned a study to assess the exposures of houseboat owners and wildfowlers in the Ribble Estuary area, taking account of variables such as tidal inundation of channels and shielding from boat hulls and other materials (Punt et al., 2011). The study demonstrated that the current external gamma dose rates, the major contributor to the total dose, are dominated by ^{137}Cs arising from historical discharges from the Sellafield site and that the contribution from Springfields is minimal.

The Springfields site has a variety of semi-natural and manmade habitats which provide a valuable home for a range of wildlife. The site introduced a Biodiversity Action Plan in 2002 to ensure that these habitats are protected and, where possible, enhanced. Springfields was awarded the Biodiversity Benchmark from the Wildlife Trust in 2008 and every year since then for its environmental policy and performance. A comprehensive environmental monitoring programme is in place which demonstrates that there is no significant impact from Springfields operations on local flora and fauna.

In 2007/2008 the Environment Agency and SFL undertook a Stage 3 Habitats Assessment of the radiological impacts of discharges from the Springfields site on freshwater and marine organisms using the ERICA Tool[16]. With the exception of 'vascular plants' in the freshwater ecosystem and 'phytoplankton' in the marine ecosystem, the predicted dose rates to all organisms were found to be below the screening value of 40 μGyh^{-1}, and in most cases below 10 μGyh^{-1}. The predicted dose rates to vascular plants and phytoplankton were based on rather pessimistic assumptions

[16] http://www.erica-tool.com/

and the effects information available indicated that it was highly unlikely that discharges from Springfields would have a detrimental effect on the populations of these organisms.

4.2.5 The application of BAT

Springfield Fuels Ltd commissioned a comprehensive review of national and international developments in best practice for minimising all radioactive waste disposals from the Springfields site, which was completed in 2010. This included comparison of SFL's waste minimisation practices against the Best Practice in Waste Minimisation Database. This demonstrated that SFL's waste minimisation practices are consistent with the waste minimisation practices used within the national and international nuclear industry, and that these practices are suitable for the activity and type of waste generated (i.e. uranium contaminated waste). The site also has a rolling BAT programme to ensure that all plants review their techniques and processes and keep abreast of new developments.

There have been a number of initiatives aimed at reducing radioactive waste arisings and the amount of material requiring treatment at the decontamination centres and residue recovery plants, and therefore the amount of radioactive effluent discharged from the site. These include the implementation of a system that reduces the frequency of absolute HEPA filter changes at SFL's Enriched Uranium Residues Recovery Plant (EURRP), thereby reducing the amount of treatment required through Nitric Acid Wash facility and hence discharges to the Ribble Estuary. Extensive trials have also been carried out in conjunction with the National Nuclear Laboratory (Springfields) on new treatment methods for removing radioactive contamination from oil, which can then sent to specialist contractors for recycling.

During the reporting period, SFL installed a humidrier system to replace the centrifuge employed to treat contaminated water from floor washing and decontamination activities within the Oxides Fuel Complex. The humidrier system uses warm air to evaporate water, leaving behind a slurry which is treated at Residue Reprocessing Plant. The resultant water from the humidrier has no detectable uranium content. Secondary wastes, such as filters, are cleaned within the decontamination facility and disposed of in line with set procedures. A new wet deduster has also been installed in the in Hex Plant[17] to improve the efficiency of the removal of particulates from gaseous effluents.

4.2.6 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 worldwide. However, a number of improvement programmes, including the one outlined above, require SFL to review their activities against national and international developments to keep abreast of, and continue to review, development of new techniques. Springfield Fuels Ltd continue to take an active part in the EARWG and other industry forums, exchanging technical information and promoting best practice in radioactive waste management and other topics related to the regulatory control of radioactive substances. Springfield Fuels Ltd is in the process of establishing links to share best practice with other sites in the Westinghouse group, notably Västerås, the UF_6 to UO_2 conversion plant in Sweden and the Columbia (UO_2) Fuel Manufacturing plant in the United States.

[17] The Hex Plant is where chemically produced uranium tetrafluoride (UF_4) is converted into uranium hexafluoride (UF_6), an essential intermediate product in the manufacture of uranium dioxide fuels.

4.3 References

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2) Environment Agency (2006), Explanatory Document on British Nuclear Group Sellafield Ltd Nuclear Site at Capenhurst near Chester, Environment Agency, Bristol.

3) Environment Agency, SEPA, NIEA, and FSA, Radioactivity in Food and the Environment (RIFE), 2006 - 2011, CEFAS (2007 - 2012).

4) Environment Agency (2003) Habitats regulations for Stage 3 assessments: radioactive substances authorisations. R&D Technical Report P3-101/SP1a. EA, Bristol

5) Punt, A & George, R (2011). BAT Case: Radioactive Process Materials and Wastes, December 2011. Eden Report ref ENE/0034/AP

6) RMC (2006), A Review of National and International Developments in Best Practice for Minimising all Waste Disposals, together with a Strategy for achieving reductions in Discharges, Springfields Fuels Ltd., RMC R06-209 (A).

7) Springfields Fuels Ltd (2011), Annual Environment, Health and Safety Report of 2010/11.

8) Sellafield Ltd (2009, 2010). Monitoring our Environment: Discharges and Monitoring in the United Kingdom. Annual Report 2009, 2010.

9) Urenco (2006), Information in Response to the Environment Agency's Review of the Urenco (Capenhurst) Limited Radioactive Disposal Authorisations, Document No. HSE/2006/0017.

5. Power generation

In the UK, nuclear power generation is currently from three types of power station[18]:

- Magnox design Gas Cooled Reactors.
- Advanced Gas Cooled Reactors (AGR).
- 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[19]. These reactors are currently managed by Magnox Ltd, with the exception of Calder Hall, which is under the management of Sellafield Ltd. These sites were placed under the ownership of the Nuclear Decommissioning Authority (NDA) on 1 April 2005. All the remaining nuclear power stations are operated by EDF Energy, Nuclear Generation Ltd (NGL)[20].

The UK is also the only country to have AGR stations in operation. During the period 2008-2011 no new AGR stations were commissioned, and none of the existing stations began defuelling or decommissioning.

There is only one PWR station in the UK, Sizewell B. This station was commissioned in 1995 and remains in operation.

This section has been divided according to the operational status of the power stations during the reporting period (2008-2011). Information is provided under the appropriate headings for two categories of site:

- Operational sites – those that were operational throughout the reporting period.
- Decommissioning sites – those that permanently ceased operation and began defuelling or decommissioning before 2008.

The sites included under each category are set out in the following table.

Table 5.1. Operational status of power stations in the UK

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

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

[18] 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.

[19] The last Magnox station at Wylfa, Anglesey, was commissioned in 1971.

[20] Formerly known as British Energy

5.1 Operational power stations

For the operational category, the information is reported in two subgroups: a) AGR and PWR and b) Magnox. The practical reason for this distinction is related to the management arrangements; the current fleet of AGRs and the PWR are owned and operated by NGL and the Magnox stations are owned by the NDA and operated by Magnox Ltd. In each case, a generic approach to the management of the sites is adopted, such that it is appropriate to consider them under these subheadings.

There were seven AGRs, one PWR and two Magnox power stations in operation during the reporting period[21].

5.1.1 Sources of liquid effluent for AGRs and PWR

The main sources of radioactive liquid effluent from AGR stations are:

- Reactor gas dryers, which remove water from the gas coolant to prevent the build-up of moisture. The water is then drained from the dryers to the tritiated water storage tanks.
- Pond water treatment plants, which may contain radionuclides as a consequence of corrosion of cladding material, leaching from graphite sleeves surrounding the fuel during storage in the pond, contamination on the fuel cladding surfaces or fuel pin cladding failure and contamination brought in the pond with the fuel transport flask.
- Drainage from radiation controlled areas, which comprises waste water from plant areas, flask decontamination and drainage from change rooms, circulator maintenance areas, waste void sumps, radiochemistry laboratory, active workshops, fuel route maintenance and sumps.
- Activity from storage tanks that contain soluble steel activation and fission products from solid waste such as sludge or resin from the treatment plant.

Radioactive liquid effluent from the only PWR station arises from:

- Reactor coolant system/boron recycling system, which contains activity as a result of fission and activation processes, and which may be transferred to the Liquid Radioactive Waste System. During each fuel cycle borated water is processed by the Chemical and Volume Control System into the Boron Recycle System (BRS).
- Reactor coolant drainage tank, which contains radioactivity from the borated reactor grade water. Its contribution to the overall radioactivity is relatively small.
- Fuel storage pond cooling and clean-up system. Activity in this system originates from the ponds and is mainly due to fuel-cladding corrosion and fuel contamination.
- Resin transfer, storage and encapsulation plant contains the soluble radionuclides from the supernatant liquid from spent resin storage tanks.
- Active drains from radiation controlled areas as a consequence of plant decontamination washings, drainage from the reactor building/support buildings and plant areas, and from change rooms, radiochemistry laboratory, active workshops and sumps.
- Leaks from “secondary-side” plant that may sometimes contain traces of some radionuclides.

The first five sources contain most of the radioactivity and their effluent is usually discharged via the Liquid Radioactive Waste System (LRWS).

Other sources of liquid effluent include the turbine steam and feed water systems. The volume of wastewater is ten times greater than the volume discharged from the LRWS, but this effluent normally contains no more than traces of radioactivity. It is discharged via a dedicated system, which can be redirected to the LRWS if it is found to contain significant amounts of radioactivity.

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[21] The Magnox power station at Oldbury ceased operating in February 2012. It was however operational during the reporting period and is therefore considered as an operational site for the purpose of this report.

Secondary neutron sources used to provide essential control information when a PWR reactor is returned to power (following a period of shut down) are also known to produce tritium as a by-product.

5.1.2 Source of liquid effluents for Magnox

At operational Magnox stations, radioactive liquid effluents arise mainly from reactor and fuel handling operations.

The major source of liquid alpha and beta discharges from Oldbury was the corrosion and subsequent leakage of spent fuel elements stored in cooling ponds prior to being sent to Sellafield for interim storage and reprocessing. Considerable efforts were made to minimise the release of activity from the spent fuel into the pond water by controlling the pond storage conditions.

The only other operating Magnox station, Wylfa, has a dry spent fuel store which effectively eliminates this source.

At both Oldbury and Wylfa, the main source of liquid tritium discharges is tritium build-up in desiccant used to capture water vapour (produced from processes to minimise oxidation of the graphite moderator). The desiccant is recycled by driving off absorbed water, along with the tritium and other radionuclides associated with it.

Additionally, liquid effluents arise from laundry operations.

5.1.3 Management of liquid effluents for AGRs and PWR

All AGR and PWR sites are certified to the international Environmental Management Standard ISO 14001 and are therefore subject to external audit. There is also an internal quality management system for all sites.

AGR Systems and Processes

Fuel pond water is usually the most radioactive contributor to the effluents transferred to the Active Effluent Treatment Plants (AETPs).

On the rare occasion that a defective or leaking fuel element is detected within the reactor, it 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, are thereby minimised. Priority is given to minimising the release of radioactivity to fuel storage ponds.

Other measures taken to minimise liquid discharges from the pond are 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, funda 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.
- Pond water is monitored for ^{137}Cs and its levels are controlled using specialist ion exchange media, as required, before the water is discharged into the AETP.

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 toxic even at moderately elevated concentrations.

All AGRs have an Active Effluent Treatment Plant (AETP), or equivalent system. The function of the AETP is to deal with potentially active effluent by various treatment processes leading to separation of oils, particulate and treated liquids. It comprises filter vessels, pumps, pipes, valves and indicators. The output of these active treatment plants is fed into the final monitoring and delay tanks. The plant is almost totally duplicated, either through secondary stand-by plant or plant currently undergoing maintenance.

Radioactive liquid waste arises as a result of reactor and fuel route operations (including cooling pond water), equipment maintenance, liquid waste treatment plant routine operations and other sources collected in the active drainage system.

The AETPs process the liquid waste by separation to remove oil and filtration to remove particulates. Treatment includes using non-regenerable ion exchange units, to reduce the dissolved activity as far as reasonable practicable.

PWR Systems

The PWR at Sizewell is designed to minimise the production of radioactive wastes and liquid effluents. There are a number of design features and operating practices which assist in minimising either the generation of radioactive liquid wastes or the quantities of radionuclides present in them. For example:

- Use of the hard-facing material Stellite was limited as far as possible in metalwork within the reactor cooling system, because of its high cobalt content.
- The Chemical and Volume Control System and the Boron Recycle System act to decontaminate the reactor coolant (keeping radionuclide concentrations low) and to control the rate of the nuclear reaction inside the reactor core, respectively. Both comprise demineraliser and filters, so the wastewater has already been treated before it reaches the LRWS. The Boron Recycle System holds the let-down reactor coolant in one of two large (300 m^3) tanks before it is fed forward to the LRWS, so that short-lived radionuclides decay before transfer.
- The Fuel Storage Pond Cooling and Clean-up System is designed to control contamination of Fuel Storage Pond and to ensure that the heat from the fuel is removed. The water is almost entirely recycled, thereby reducing the level of radioactivity discharged to the environment, since only a relatively small amount is routed to the LRWS. The ponds are also managed to ensure minimisation of waste. For example, the fuel storage pond water chemistry is controlled to minimise corrosion of the fuel-cladding.
- Reactor Coolant System. The radioactivity in this system is the result of fission and activation processes. Some of this activity is transferred to the LRWS and collected on resins in the LRWS. Where possible, resin beds are changed with sufficient frequency to ensure that they can be disposed of as Low Level Waste.
- Solid Radioactive Waste System contains two low level waste spent resin storage tanks and three intermediate level waste spent resin storage tanks. Supernatant liquid from these tanks is decanted to the Resin transfer System Storage Tank. Excess water in this system is filtered by cartridge filters or demineralisers within the LRWS prior to discharge.

5.1.4 Management of liquid effluents for Magnox

At the Oldbury site, corrosion of the Magnox fuel cladding is minimised through careful pond management, the main features being:

- Maintaining pond water 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 the Magnox fuel cladding surface, could accelerate corrosion).
- Maintaining pond temperature (i.e. removal of decay heat from spent fuel, by use of pond water cooling plant) thus minimising the temperature-dependent rate of Magnox corrosion.
- Carrying out an intensive monitoring and cleaning programme on Fuel Flasks before they are placed into the pond and filled with spent fuel to prevent any cross-contamination
- Use of fuel storage skips that do not show significant paint damage (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 products leakage from mechanically damaged fuel in the ponds.

Spent fuel at Wylfa is stored under dry conditions. The levels of active liquid effluents are therefore less than for sites with pond storage.

5.1.5 Liquid effluent treatment and discharge from AGRs and PWR

At AGR and PWR stations a number of particulate filters are employed. For instance, liquid effluents are generally passed through a sand pressure filter and a back-up filter that is provided to trap any loose sand particles.

Ion exchange resins are used to remove soluble radioactivity from the cooling ponds. This process is optimised by pre-filtration of insoluble particulate materials to maximise the lifetime of the resins.

The active effluent treatment system collects all radioactive or potentially radioactive liquid effluent arisings in a series of tanks, in preparation for being treated and filtered for final disposal. During the collection and treatment stages, sludge is left as a residue in the tanks. This sludge is generally directed to long term storage for subsequent specialist disposal. Additional effluent management systems have been put in place to eliminate (so far as is practicable) discharges of organic material containing organic bound tritium.

5.1.6 Liquid effluent treatment and discharge from Magnox

At the Oldbury site, in-pond treatment plants equipped with a submersible caesium removal unit (SCRU) remove radiocaesium at source[22]. Pond purge water is then passed through the Pond Water Filtration Plant (PWFP) to remove any particulate material, held in one of four Final Delay Tanks and discharged only if chemical and radioanalytical conditions are within annual limits. Other aqueous effluents arising on site are passed through 5 µm sand pressure filters in the AETP to remove residual particulate matter. Effluents are then accumulated in delay tanks, sampled and, if their activity content is acceptably low, are discharged with the station's cooling water ensuring considerable dilution and the avoidance of high local concentrations near the discharge outfall. Filter catchpots[23] have been introduced to the site drainage system prior to the active effluent treatment plant to segregate lower activity liquid sludge before it becomes cross contaminated with higher active liquors.

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[22] The SCRU is equipped with filters and cartridges containing an inorganic zeolite resin material which chemically removes caesium from the pond water.

[23] A catchpot is a vessel inserted in a pipeline to remove solid particles which may be entrained in an effluent stream

At Wylfa, where spent fuel is dry stored, the Active Effluent treatment is rather simpler, reflecting the lower levels of aqueous effluents. Particulate material is removed through the use of radial media filters for liquid effluents and particulate removal system. Effluents are then accumulated in delay tanks and discharged following a similar procedure to that described above for Oldbury. Reactor gas drier liquor is collected and stored for 6 months prior to disposal to allow the decay of ^{35}S.

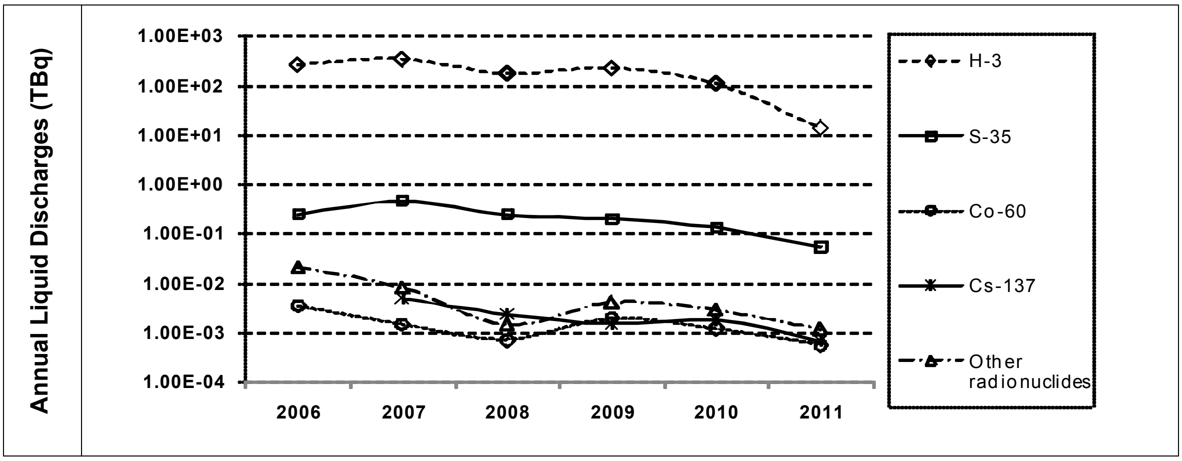
5.1.7 Trends in discharges over the 2006-2011 period

The discharges from operational sites have remained fairly stable throughout the reporting period and most of the apparent variations can be associated with changes in power output (including shutdowns for maintenance operations). **Figures 5.1-5.20** below illustrates the variations in discharges during the 6 year reporting period[24].

Dungeness B: as illustrated in **Figure 5.1**, the liquid discharges of ^{3}H and ^{35}S increased from 2006 to 2007, followed by a decreasing trend, with discharges falling to around a third of the 2007 values by 2010. Discharges of ^{60}Co, ^{137}Cs and 'other radionuclides' exhibited a downward trend during the reporting period with the exception of the small increases in the levels of ^{60}Co and 'other radionuclides' registered in 2009. Further reductions in liquid discharges were noted in 2011 a result of low power generation from the reactors at the station.

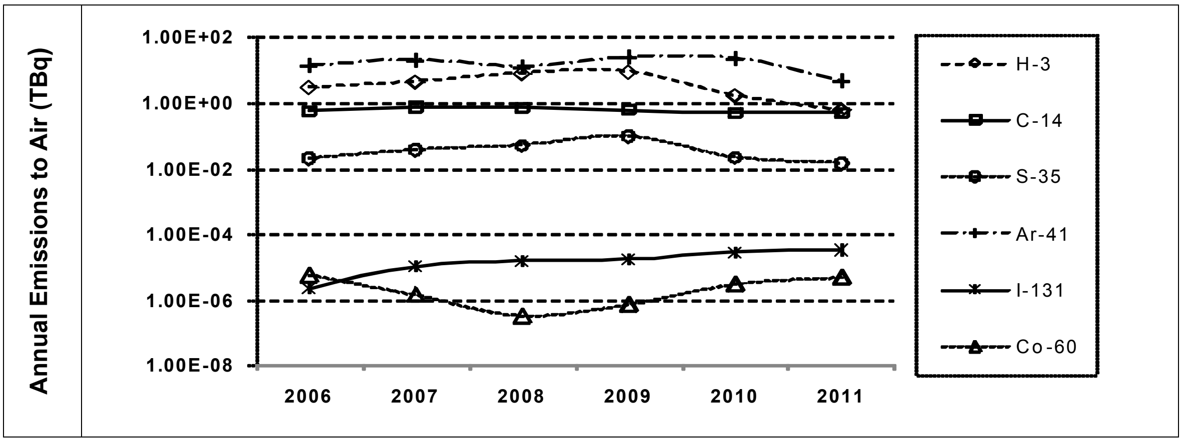
Annual emissions to air from Dungeness B (**Figure 5.2**) were relatively constant throughout the reporting period, although emissions of ^{3}H and ^{35}S increased slightly from 2006-2009. Emissions of ^{131}I have increased since 2010 as a result of low-grade leakage from fuel in the reactors (although it should be noted that the elevated discharges are still below 2% of annual limits). The apparent reduction in discharges of ^{3}H and ^{35}S from 2010 onwards is the effect of improved discharge sampling.

Figure 5.1 Annual Liquid Discharges from Dungeness B



[24] It should be noted that some of the graphical data are presented on a log scale.

Figure 5.2 Annual Emissions to Air from Dungeness B



Hartlepool: liquid discharges of all radionuclides from Hartlepool have remained at a similar level from 2006 to 2011 (as demonstrated in **Figure 5.3**), except for 2008, where very low values were recorded as a result of an extended period of maintenance work.

Emissions to air showed a similar pattern to liquid discharges, with the exception of discharges of ^{131}I and ^{60}Co which followed an increasing trend from 2007 onwards (the maximum discharges of these radionuclides are still below 15% of annual limits).

Figure 5.3 Annual Liquid Discharges from Hartlepool

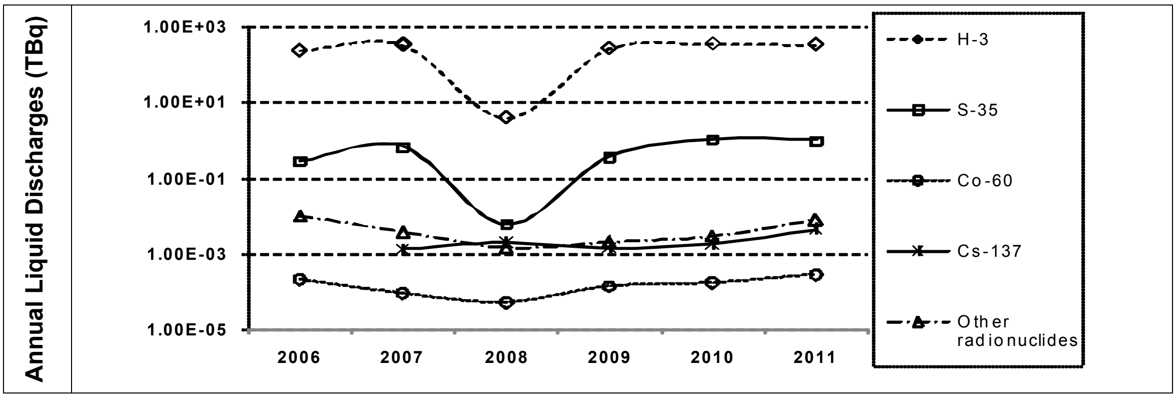
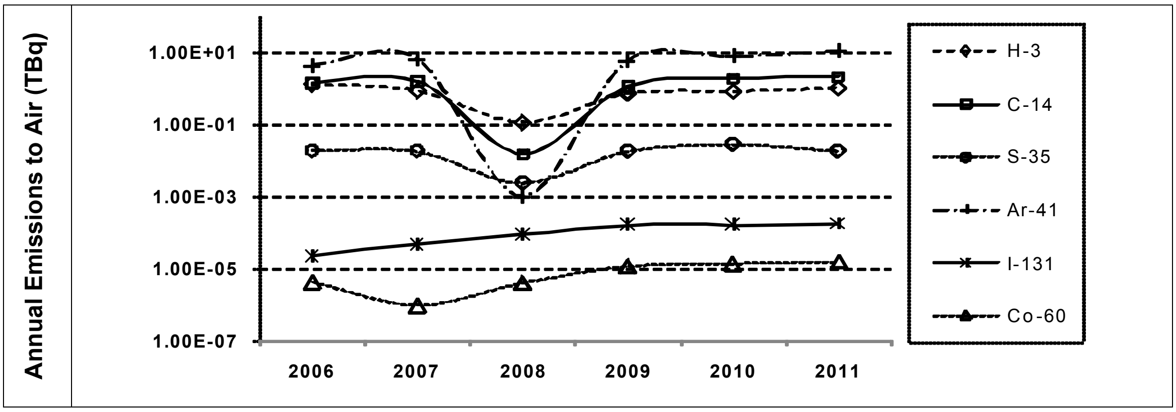


Figure 5.4 Annual Emissions to Air from Hartlepool



Heysham 1: liquid discharges of radionuclides have remained relatively steady during the reporting period, except for 2008, where very low levels of ^{3}H, ^{35}S and ^{137}Cs were discharged as a

result of extended maintenance work undertaken at the station. The increase in ^{60}Co discharges during 2007 is due to an unplanned transfer of ion exchange resin into a sump in the effluent treatment plant. The small increase in the discharge of ^{60}Co during 2011 is a consequence of routine maintenance of the fuel cooling pond.

The emissions to air followed a similar pattern to the liquid discharges, although a drop in the discharge of ^{60}Co was recorded in 2007 and a considerable decrease in the emission of ^{41}Ar during 2009. Emissions of ^{131}I remained constant throughout the reporting period.

Figure 5.5 Annual Liquid Discharges from Heysham 1

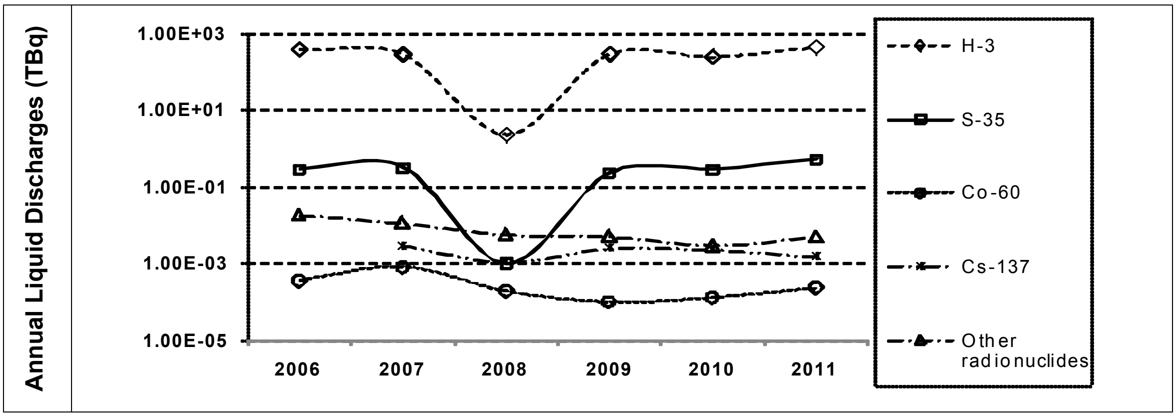
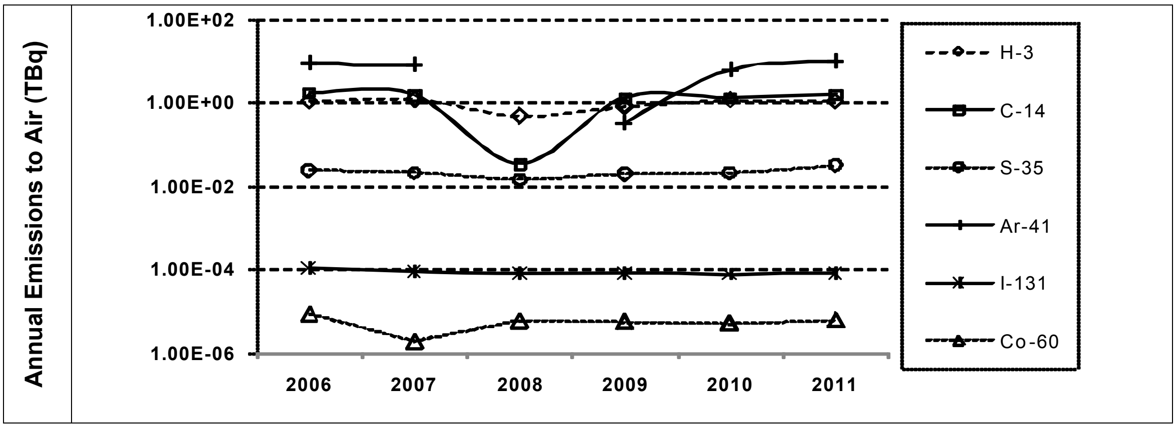


Figure 5.6 Annual Emissions to Air from Heysham 1



Heysham 2: both liquid discharges and emissions to air from this site remained relatively steady throughout the reporting period as demonstrated in **Figures 5.7** and **5.8** below.

Figure 5.7 Annual Liquid Discharges from Heysham 2

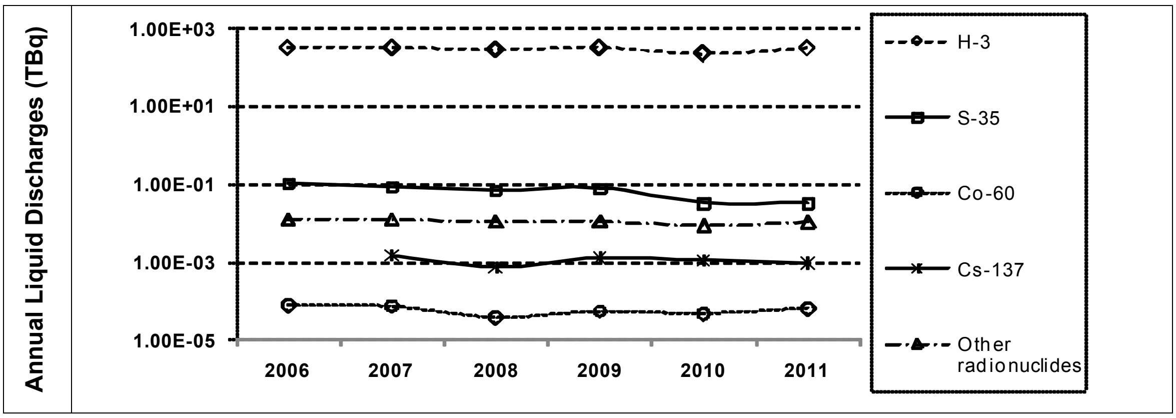
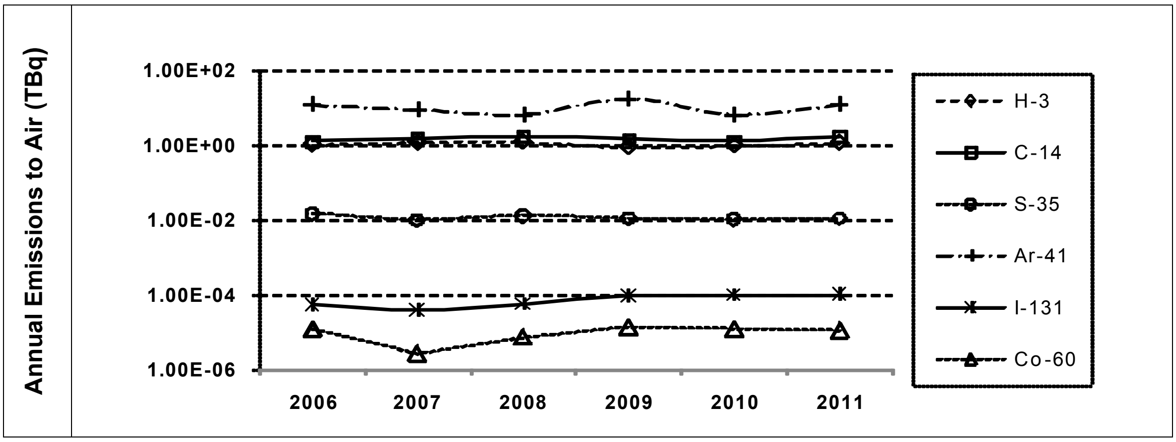


Figure 5.8 Annual Emissions to Air from Heysham 2



Hinkley Point B: liquid discharges remained relatively steady except for the period from 2007 to 2008 during which there were significant reductions in discharges due to an extended outage for maintenance (**Figure 5.9**).

Emissions to air were relatively steady, with similar maintenance related reductions in 2007 and 2008 as illustrated in **Figure 5.10** below.

Figure 5.9 Annual Liquid Discharges from Hinkley Point B

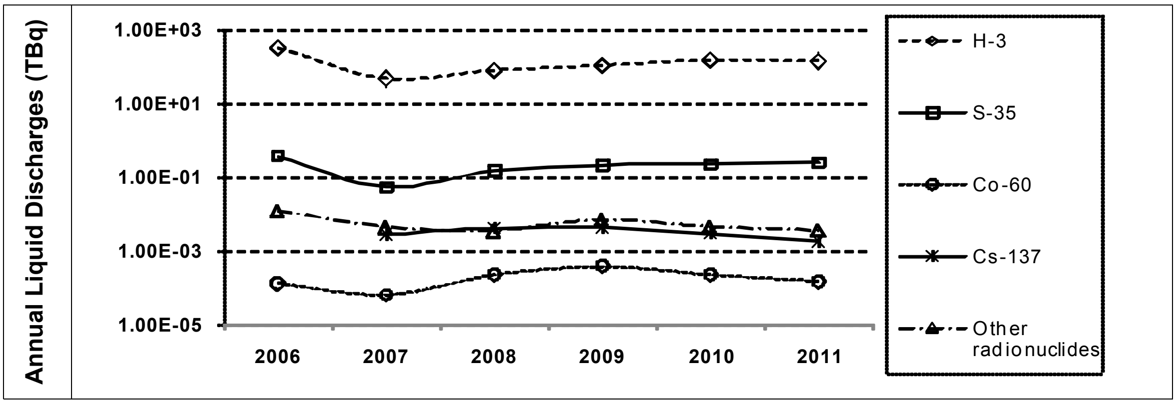
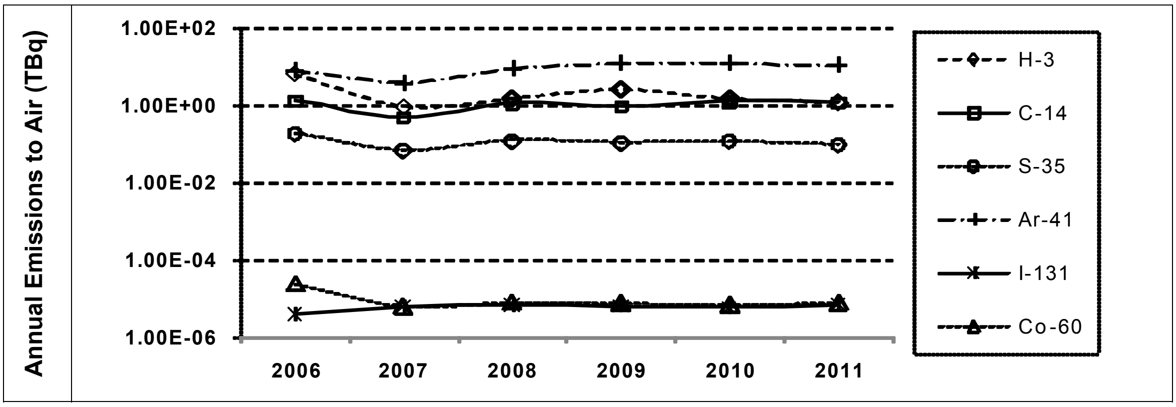


Figure 5.10 Annual Emissions to Air from Hinkley Point B



Hunterston B: liquid discharges have shown no significant variations in activity discharged, with the exception of decreases in ^{3}H levels during 2007 associated with decreased power output, and ^{35}S levels in 2008 as a result of maintenance outages.

The annual emissions to air remained relatively steady during the reporting period, except for the small increases in the levels of ^{35}S and the sharp decrease in the emission of ^{131}I in 2011.

Figure 5.11 Annual Liquid Discharges from Hunterston B

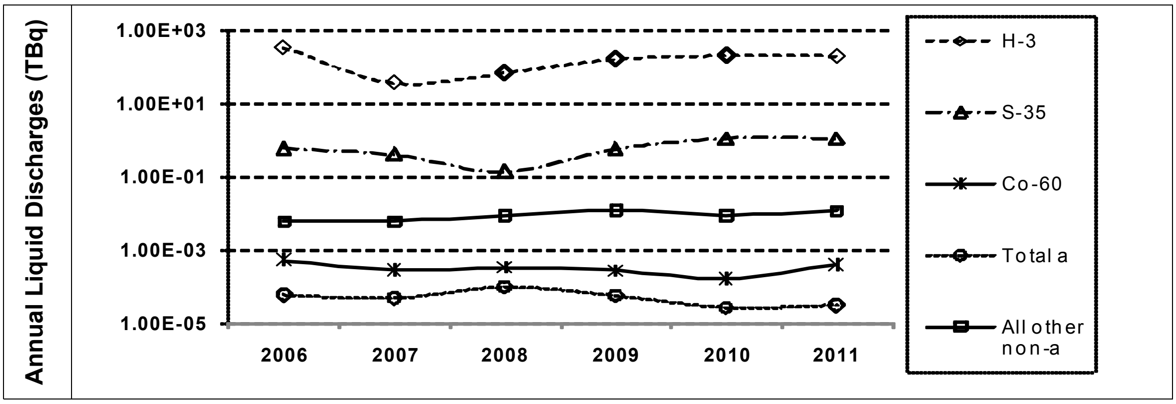
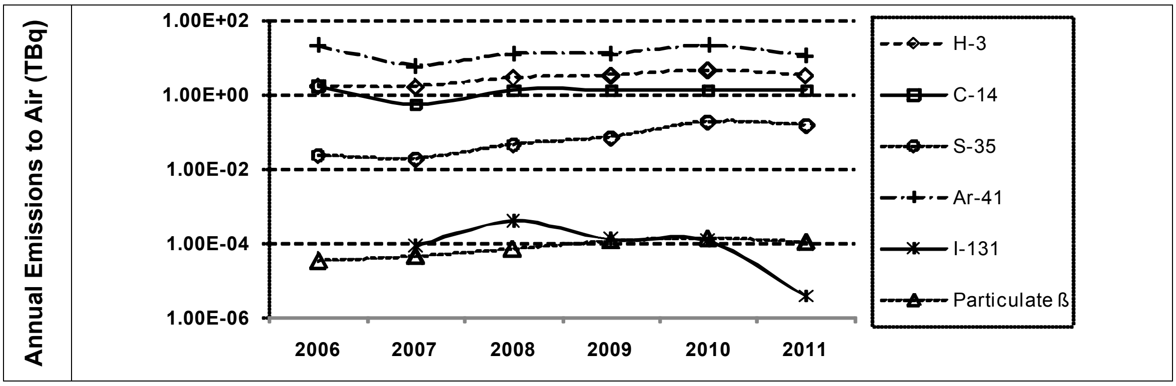


Figure 5.12 Annual Emissions to Air from Hunterston B



Torness: liquid and atmospheric discharges remained stable throughout the reporting period (**Figures 5.13 & 5.14**).

Figure5.13 Annual Liquid Discharges from Torness

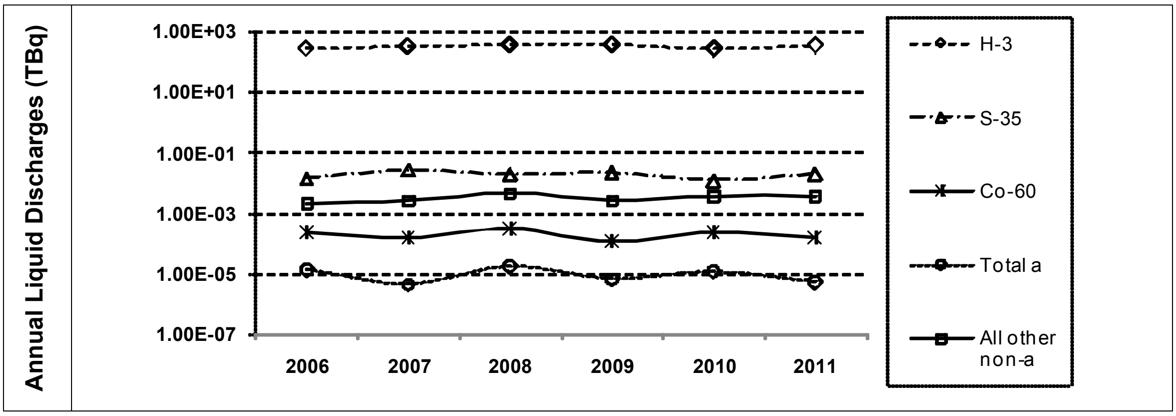
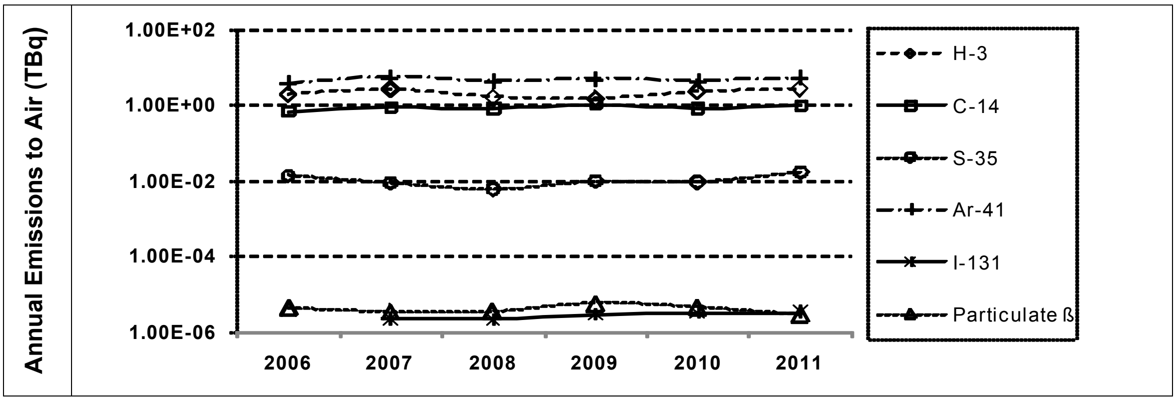


Figure 5.14 Annual Emissions to Air from Torness

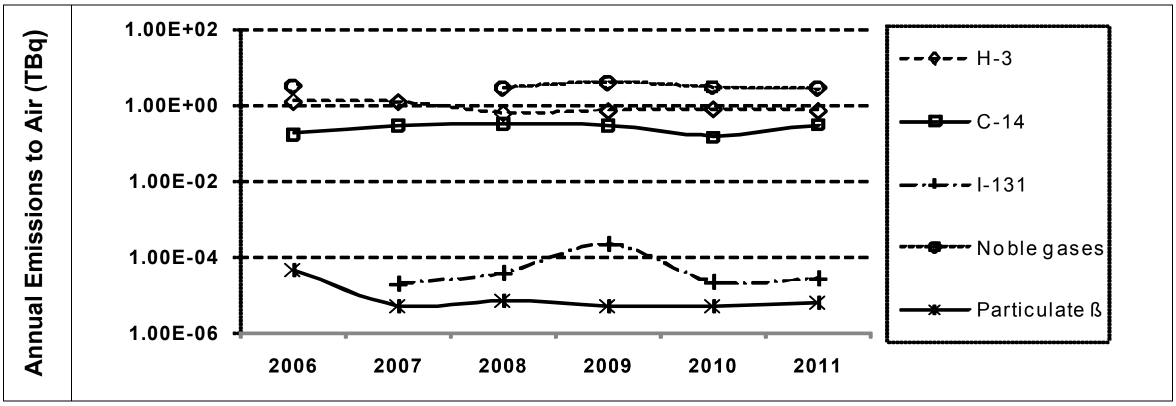


Sizewell B: liquid discharges of radionuclides remained relatively uniform during the reporting period, except for minor fluctuations associated with variations in power output. The small increase in discharge of ^{3}H in 2011 was a consequence of the reactor coming off-load for refuelling.

Emissions to atmosphere were relatively stable throughout the reporting period, although discharges of particulate beta decreased from 2006 to 2007 and an increase in discharges of ^{131}I was registered in 2009 as a result of fuel defects.

Figure 5.15 Annual Liquid Discharges from Sizewell B

Figure 5.16 Annual Emissions to Air from Sizewell B



Oldbury: liquid discharges of ^{137}Cs decreased considerably during the reporting period as a result of the installation of a SCRU in 2006 and improved surveillance and cleaning of fuel flasks placed into the fuel storage pond. Discharges of ^{3}H and radioactivity reported as 'other radionuclides' have fluctuated during the same period, according to output.

The emissions to air from Oldbury decreased during 2007, but show small increases from 2008.

Figure 5.17 Annual Liquid Discharges from Oldbury

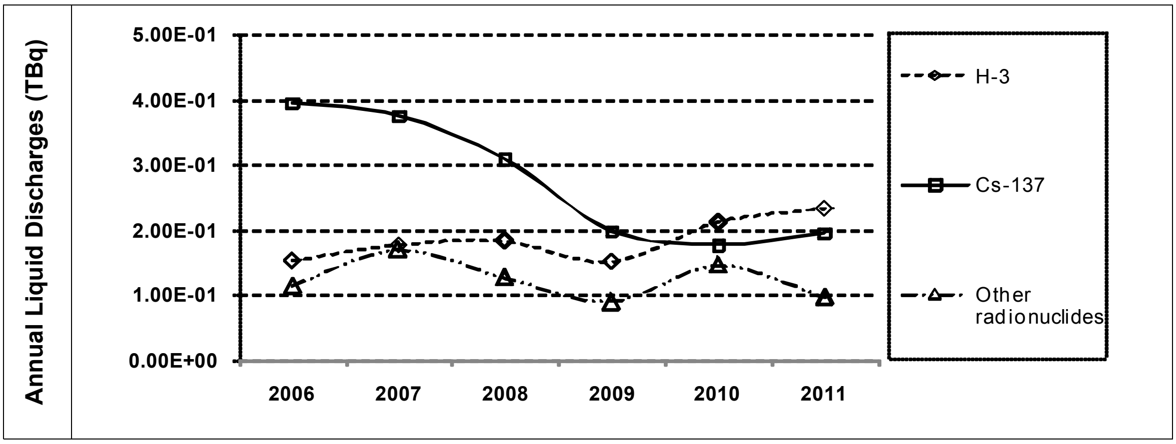
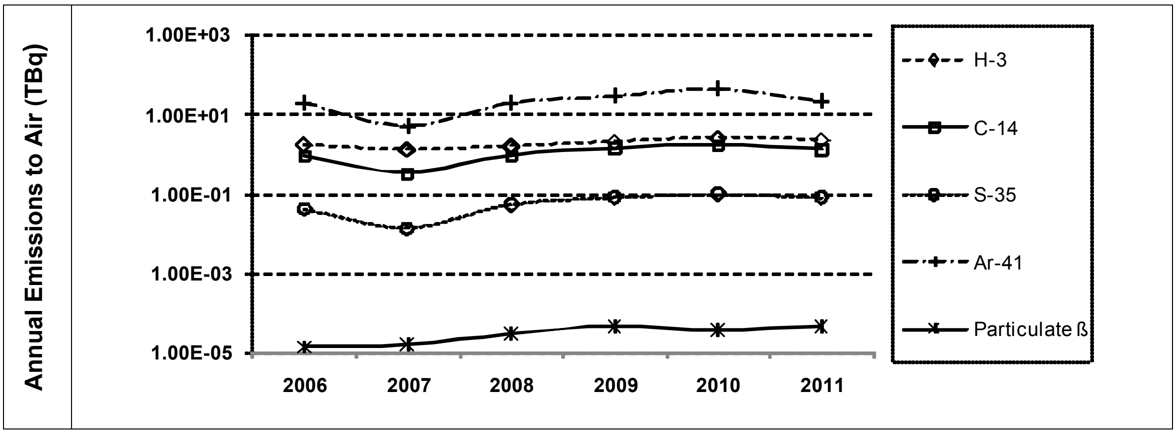


Figure 5.18 Annual Emissions to Air from Oldbury



***Wylfa**:* the discharge of ^{3}H has varied from year to year depending on the number of disposals of gas drier liquors. The discharges of radioactivity reported as 'other radionuclides' have remained steady from 2007 to 2011.

The annual emissions to air have remained relatively stable throughout the reporting period.

Figure 5.19 Annual Liquid Discharges from Wylfa

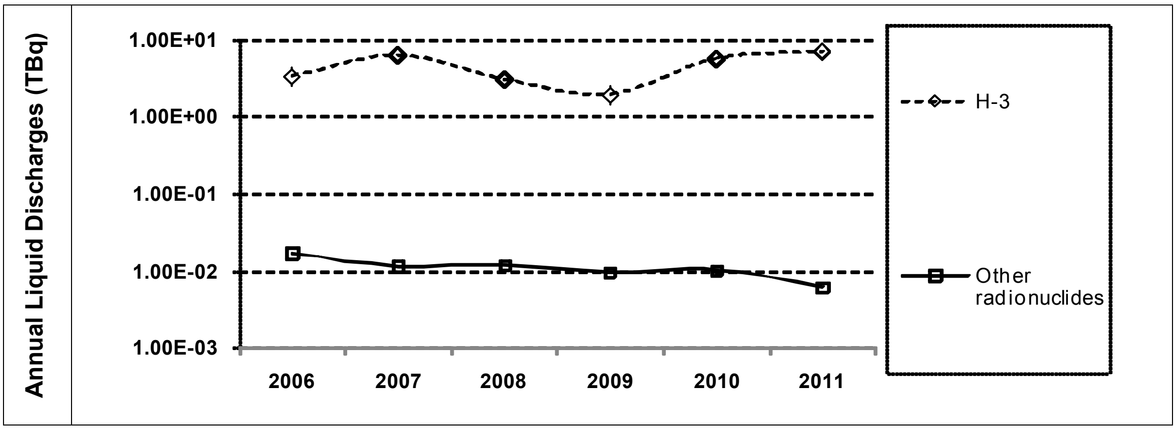
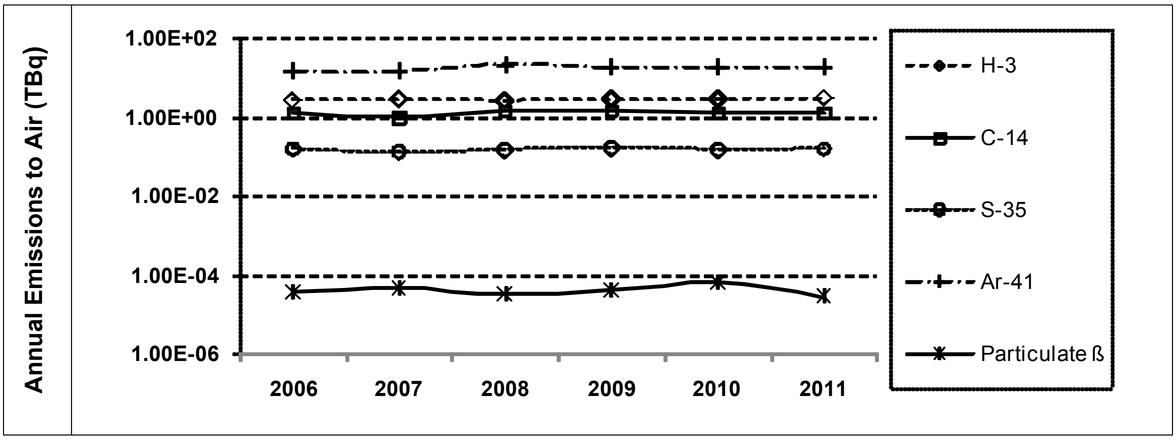


Figure 5.20 Annual Emissions to Air from Wylfa



5.1.8 Radiological impact of liquid discharges for AGRs and PWR

The environmental monitoring programme undertaken by NGL addresses the principal radionuclides, and pathways, of potential significance. Detailed environmental monitoring data related to liquid discharges and emissions to air for each of the NGL sites are published in the annual RIFE Reports.

The environmental monitoring programmes for power stations in England are defined within the Compilation of Environment Agency Requirements (CEARs), which support the revised authorisations for British Energy (now NGL) sites that came into force in 2007.

The CEARs requires Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B and Sizewell B power stations to take routine samples of intertidal sediment, fish, crustaceans, molluscs and seaweed (as available) from several sites ranging from close to the discharge point up to a distance of several kilometres. Samples are analysed by gamma spectroscopy; results are provided for ^{60}Co and ^{137}Cs, together with any other radionuclide positively identified. For sediment samples, ^{40}K is also reported as an indicator of grain size. Gamma dose-rates are measured on beaches, routine measurements of contact dose rate are made on fishing nets/equipment, and the beach strandline is monitored.

The marine monitoring programmes at Hunterston B and Torness power stations are similar to those for the English stations, although the CEARs are not applicable to sites in Scotland. These programmes were revised in 2007, in line with revised site authorisations. Both stations take routine samples of intertidal sediment, fish, crustaceans, molluscs and seaweed (as available) from several sites ranging from close to the discharge point up to a distance of several kilometres. Samples are analysed by gamma spectroscopy; results are provided for ^{60}Co and ^{137}Cs, together with any other radionuclide positively identified. Gross beta is also reported. For sediment samples at Torness, ^{40}K is reported. Gamma dose-rates are measured on beaches.

Several stations (Dungeness B, Hinkley Point B, Hunterston B and Sizewell B,) are adjacent to Magnox stations, and consequently discharge into the same immediate environment as their neighbours, and where monitoring has been undertaken for many years. The impact of these stations cannot be distinguished from the impact of the adjacent Magnox stations from environmental monitoring results alone. The marine environment around stations on the Irish Sea (*e.g.* Heysham) is also influenced by past and present discharges from Sellafield.

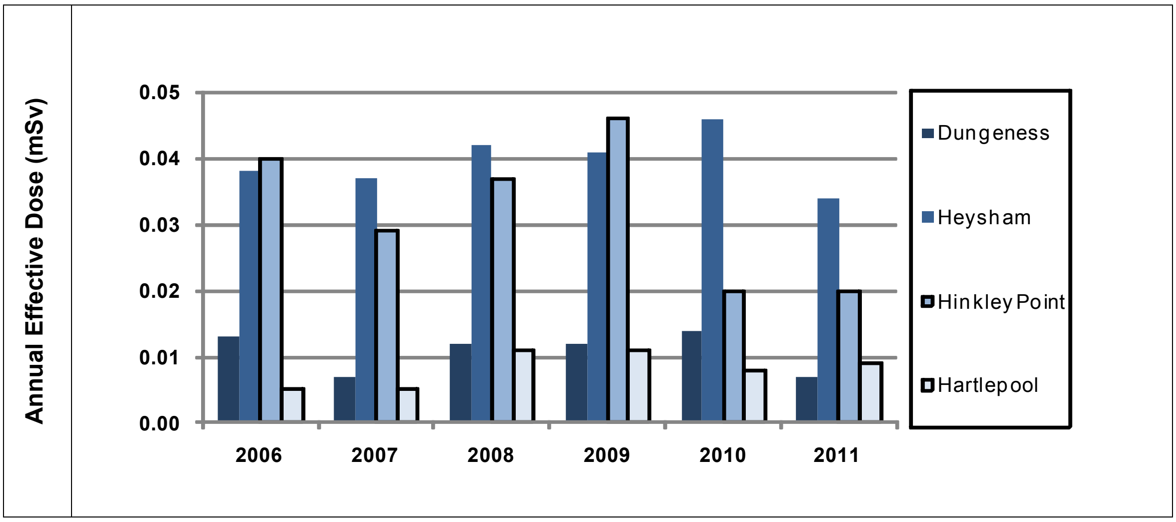
The radiological impact of nuclear sites on members of the public is generally described in terms of the dose to the most exposed members of the public (the representative person) via a single discharge route (*e.g.* liquid discharges). The representative person for liquid discharges from

AGRs and the PWR is generally associated with external exposure over beach sediments and the consumption of local fish and shellfish. The characteristics of relevant groups are determined by habit surveys. The doses estimated on the basis of these survey data and environmental monitoring information are presented for each site in the annual RIFE Reports.

The reported effective doses to the representative person arising from liquid discharges from the PWR at Sizewell and AGRs that are not co-located with Magnox stations (e.g. Torness) are generally in the region of 5 μSv y^{-1} or less.

Figure 5.21 illustrates the doses to the representative person in the vicinity of AGR power stations. The increase in dose around Hartlepool from <5 μSv y^{-1} to around 10 μSv y^{-1} during the reporting period is attributed to variability in measured gamma dose rates along the shoreline. The maximum value of 46 μSv was reported around Heysham in 2010. This is less than the maximum value of 75 μSv stated in the previous report, and includes a component arising from Sellafield discharges.

Figure 5.21 Trends in Doses to the Representative Person in the Vicinity of Selected AGR Sites



The estimated dose around Hinkley Point peaked at 46 μSv in 2009, but sharply declined to 20 μSv in 2010. This includes a component arising from discharges of ^{3}H and ^{14}C from GE Healthcare at Cardiff. The year on year variation in dose is mostly related to changes in the external gamma dose rates over sediment at Stolford and, to a lesser extent, from the reduced occupancy rate used in 2010 and 2011 (using new habits data). The estimated effective dose around Dungeness has remained around 12 μSv y^{-1}. Doses around all AGR and PWR sites remain significantly lower than the dose constraint of 300 μSv y^{-1}.

No site-specific targets exist for determining impacts on non-human biota. However, in their submission for a radioactive substances activity permit for the proposed twin EPR at Hinkley Point, EDF Energy, New Nuclear Build Generation Company (NNB GenCo) undertook an assessment of dose rates to non-human biota. In this assessment, it was estimated that the maximum organism dose was 3 μGy h^{-1}, from discharges from all three operators at the Hinkley site. This value is below generally used screening levels.

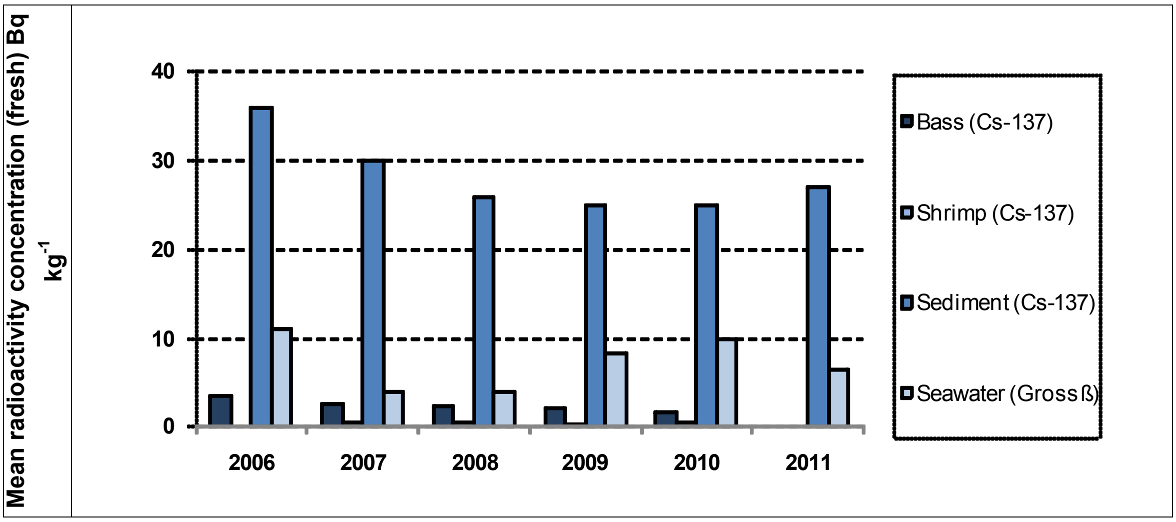
5.1.9 Radiological impact of liquid discharges for Magnox

As with the AGRs and PWR, environmental monitoring around Magnox stations is designed to address the principal radionuclides, and pathways, of potential significance. It includes sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates. Several of the decommissioning Magnox stations adjoin an AGR or PWR site and, in these instances, the stations share a common monitoring programme. Neither of the two operational Magnox stations

(Wylfa and Oldbury) is co-located with an AGR or PWR site. However, the effective doses to members of the public around Oldbury site include a component from the decommissioning Berkeley station. The detailed environmental monitoring data related to liquid discharges and emissions to air for each of the operational Magnox sites are published in the annual RIFE Reports.

Most of the artificial radioactivity detected near Berkeley and Oldbury during the reporting period can be attributed to ^{3}H and ^{137}Cs radioisotopes. The mean concentration of ^{137}Cs in sediment has followed a downward trend since 2006, decreasing from 36 Bq Kg^{-1} (fresh weight) in 2006 to 25 Bq Kg^{-1} by 2010 as illustrated in **Figure 5.22** below. The level of ^{137}Cs around Berkeley and Oldbury represents the combined effect of discharges from the two sites and from other nuclear establishments discharging into the Bristol Channel and weapons testing. The majority of ^{3}H detected in seafood near the sites originates from discharges from the GE Healthcare in Cardiff.

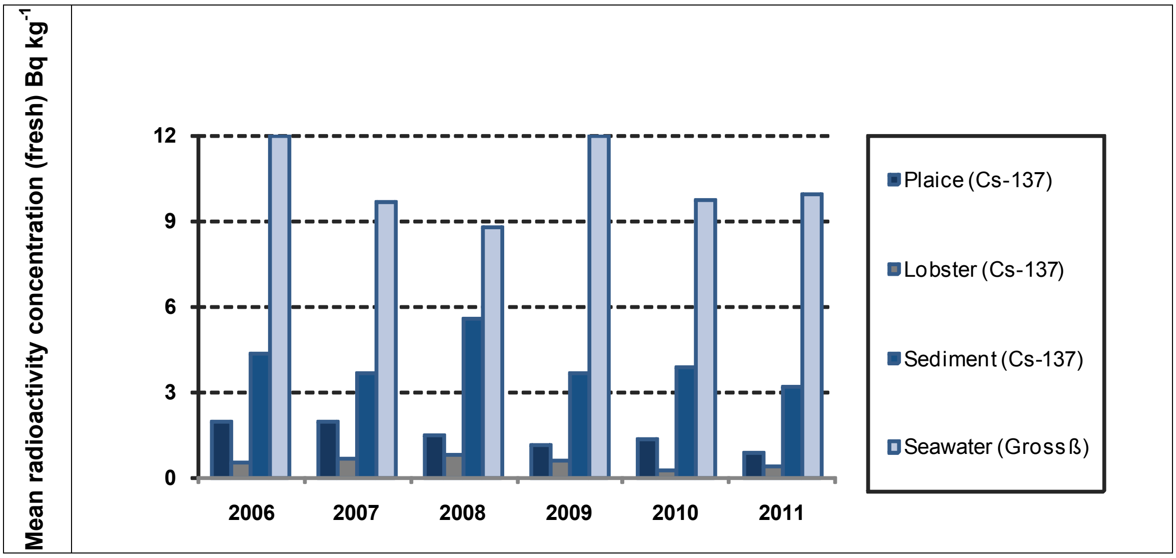
Figure 5.22 Concentrations of ^{137}Cs and Gross Beta in Seafood and the Environment near Berkeley and Oldbury, 2006-2011[25]



The concentrations of radionuclides in seafood and the environment around Wylfa have remained largely the same, as demonstrated in **Figure 5.23**. ^{99}Tc originating from Sellafield continues to be detected in the seafood around the site, albeit at lower concentrations than in previous years.

25 Bass and Shrimp not sampled in 2011.

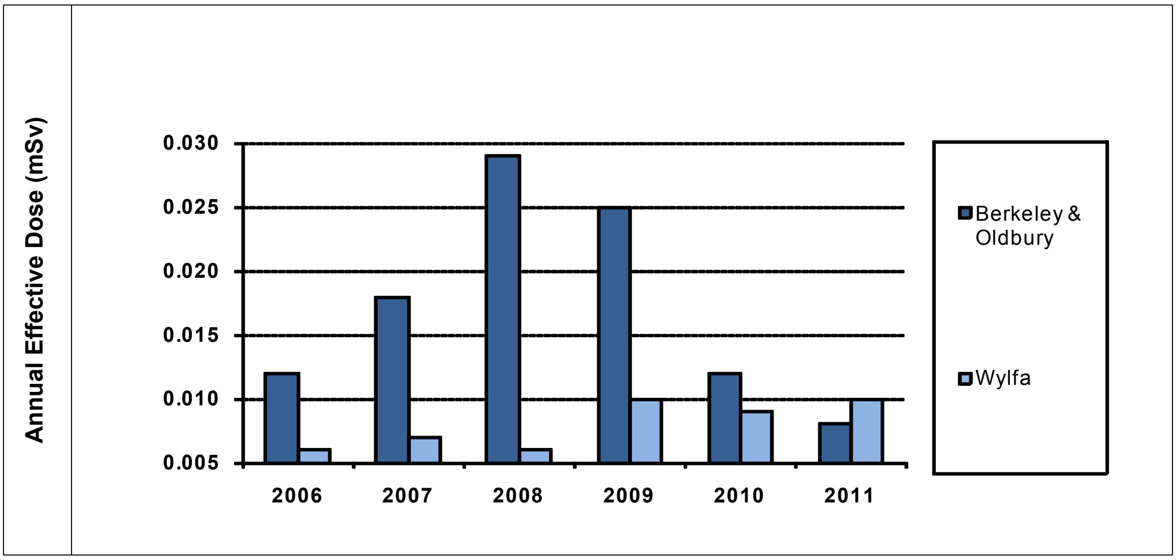
Figure 5.23 Concentrations of ^{137}Cs and Gross Beta in Seafood and the Environment near Wylfa, 2006-2011



The estimated effective dose to high rate consumers of fish and shellfish (who also spend time on intertidal sediments) around Oldbury peaked at 29 μSv in 2008, but decreased to under 10 μSv by 2011, below the levels recorded in 2006, as illustrated in **Figure 5.24** below. The doses attributed to Oldbury includes a component due to the ^{3}H originating from GE Healthcare at Cardiff, and a component of the dose arises from an increase in ^{3}H dose coefficient.

Over the same period, the effective dose to high rate consumers of fish and shellfish at Wylfa remained at or below 10 μSv. Doses from both operational Magnox sites remain significantly lower than the dose constraint of 300 μSv y^{-1}.

Figure 5.24 Trends in Doses to the Representative Person in the Vicinity of Operational Magnox Sites



5.1.10 The application of BAT for AGRs and PWR

NGL's environmental operational rules (referred to as Environmental Specifications or ESpecs) identify: a) which plant should be in service at any time to protect the environment: b) what action should be taken if that plant is not available: and c) appropriate investigation and action levels for radioactivity in effluent. Maintenance of environmentally sensitive plant is controlled via an Environmental Maintenance, Inspection and Testing Schedule (EMITS).

Nuclear fuel is a source of fission products and a management objective is applied to ensuring that fuel delivered to the power station is of high quality and that fission products are contained. The abatement techniques commonly employed at operational AGR and PWR stations are summarised in **Table 5.2**.

Table 5.2 Operational AGR and PWR Power Station Abatement Techniques

Station	**Liquid Abatement**	**Aerial Abatement**
AGRs and PWR	Fuel Integrity Delay Tanks Ion exchange Filtration Coolant chemistry	HEPA Chemical Adsorption Sintered metal filters (and charcoal filters for emergency situations)

AGR Approach

Once an aqueous effluent has reached the AETP, there is further capability to remove particulate and soluble radioactivity in the supernatant water, if required. Particulate filtration is normally used but the AETPs also contain ion exchange units, which are used as appropriate. Since the normal wastes from the AETP contain relatively low levels of radioactivity, the routine use of these units is not considered to constitute BAT as it would lead to the production of associated solid waste. Furthermore, the high ionic strength of the liquids in the AETP reduces the effectiveness of these units in reducing radioactivity levels. However, these ion exchange units are available to use if there were a significant increase in the level of radionuclides in the liquid effluent.

There are a number of ways in which the radioactivity present in the fuel pond is reduced:

- Dry-bottle storage for fuel that has been found to be defective in-reactor, thus guarding against the release of significant quantities of fission products into the fuel pond water.
- Buffer storage of irradiated fuel stringers, which reduces the time that fuel is held in the cooling ponds, and so reduces the time over which radioactivity is released into the pond water. This is especially relevant for failed fuel, where the BAT assessment suggests retention of the fuel in the buffer store for several months or years to allow for decay.
- Controlling the pond water chemistry to minimise corrosion of fuel cladding.
- Carrying out an intensive monitoring and cleaning programme on fuel flasks before they are placed into the pond and filled with spent fuel to prevent any cross-contamination.

All these measures minimise the release of loose particulate radioactivity into the pond water. There are additional measures to reduce the levels of radioactivity released in liquid effluents, including the retention of liquids in the Tritiated Water Storage Tanks to retain organic compounds floating on the water surface. At some stations, additional filtration has been installed on the discharge line from the Tritiated Water Storage Tanks to retain particulate organic material that has been found in some of those tanks. This reduces the discharge of organically bound tritium.

The discharge control management system applied at AGR sites has evolved over the years and is appropriate for the discharges and the plants. Its aim is to ensure that the technology is reliable, currently available and meets regulatory requirements. Current discharges are believed to be as low as reasonably practicable, although measures to further reduce discharges are continuously reviewed and remain under consideration.

Several AGR reactors exhibit carbon deposition on internal reactor surfaces, including the fuel. This inhibits efficient heat transfer and can result in the fuel over-heating and leaking fission products into the coolant, which can then be discharged. Two approaches have been adopted to minimise this risk. A revised fuel design (robust fuel) has been implemented to minimise the risk of fuel failure through over-heating. Robust fuel is being introduced into reactors through their normal refuelling programme; it may take up to 14 years for reactor inventories to be completely replaced. Although the introduction of robust fuel may result in a small increase in discharges, it is unlikely that such increase will be detectable over the usual variability.

In addition to this, it is intended to inject carbonyl sulphide (COS) into the primary coolant to inhibit the deposition of carbon. This will result in increased discharges of ^{35}S, both in gaseous and aqueous form.

Both approaches have undergone assessments to demonstrate that the consequent discharges are consistent with BAT. At present, the full timescale for COS introduction is unknown, although it is likely to start with a pilot project in one of the two reactors at Hartlepool.

PWR Approach

At Sizewell B, relevant and reliable systems are also in place to manage discharges. Discharges are filtered, and ion exchange is used when the activity of effluent is such that significant reductions can be achieved. The quality of resins has recently been improved to reduce the amount of ILW generated.

Sizewell B was constructed with two evaporators: one for recycling boric acid from the reactor coolant system, and one for abatement of liquid radioactive waste. However, evaporation of liquid for either purpose is not currently considered BAT, primarily because the consequent reduction of public dose is much less than the increased operator doses associated with the use of these systems. In addition, the small reduction in public dose is not considered sufficient to justify the cost of processing (evaporator and encapsulation) and the production of sufficient high quality steam to run the evaporators.

The chemical conditions within the Reactor Coolant System (RCS) are designed to reduce steel corrosion. The optimisation of coolant chemistry has been pursued at PWRs throughout the world. Organisations such as the Electric Power Research Institute (EPRI), to which Sizewell subscribes, have made significant contributions on this topic. Therefore the optimum coolant chemistry for each fuel cycle is reviewed and improvements are made accordingly.

Following refuelling, the RCS is filled with boric acid made from demineralised water. The presence of dissolved gases (oxygen and nitrogen) in the demineralised water is strictly controlled in order to reduce production of ^{14}C and ^{16}N within the system.

As described earlier, secondary neutron sources used to provide essential control information when the reactor is returned to power following a period of shut down are known to produce ^{3}H. After a review of their continued use, comparing the nuclear safety risks versus the reduction in activity, it has been decided to remove them completely to eliminate that source of ^{3}H from discharges.

5.1.11 The application of BAT for Magnox

The abatement technologies used at Magnox power stations are presented in **Table 3**. 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; and, particulate filtration, these are described further below.

- CRU (Caesium Removal Unit): the Caesium removal units use a non-regenerable resin to remove caesium. The CRUs are 60-98% efficient depending on the time for which they are used.
- Ion Exchange Plants consist 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 ^{137}Cs.
- Particulate filters: There are a number of particulate filter systems used at the Magnox stations, which include:
    - Fine Filters of 5 to 10 µm filters, often used in conjunction with coarse filters (15 micron), to remove particulate from the waste stream.
    - The radial media filter used at Wylfa, with a 10 µm filter is 97.7 % efficient. This filter is also 90% efficient at removing particles of 5 µm.
    - Sand Pressure Filters (SPFs).

At Wylfa, the liquid effluent from the gas dryer system is continuously collected. When the container is full it is stored for six months prior to discharge to allow the radioactive decay of ^{35}S. Wylfa have also established a ‘Black Label’ plant availability scheme to ensure that any defects or unavailability of plant are addressed without delay. Focusing on water usage has also led to improvements in leak management, which has reduced volumes entering the active aqueous effluent streams.

At Oldbury, filter catchpots have been introduced to the site drainage system prior to the active effluent treatment plant to segregate lower activity liquid sludge before it becomes cross contaminated with higher active liquors.

Table 5.3 Operational Magnox Station Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
Oldbury	Delay tanks Sand filters Facet filters Ion exchange resin caesium removal units.	Charcoal iodine absorbers (emergency only) and sintered metal candle filters on blowdown stack and HEPA filters on contaminated ventilation systems.
Wylfa	Delay tanks Radial media filter (particulate removal system) 6 months delay of liquid effluent from gas dryer system to allow decay of ^{35}S	Charcoal iodine absorbers (emergency only) and sintered metal filters on blowdown stack and HEPA filters on contaminated ventilation systems. Improved control of post-outage reactor gas pressure cycling and changes to condensate polishing plant resin and system to reduce boiler leaks.

Magnox Ltd is committed to maintaining BAT in order to minimise discharges and emissions from its sites. Recent projects include the re-lining of liquid effluent monitoring tanks at Oldbury and current engineering studies are looking at optimising the performance of sand pressure filters and liquid effluent monitoring equipment.

5.1.12 Comparison with performance of similar plants world-wide

There are no directly comparable AGR installations outside the UK, but the dose impact is comparable to that from other types of power stations.

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 the BPEO.

The normalised liquid discharges from Sizewell B for the period 2006-2011 are presented in **Table 5.4** below.

Table 5.4 Normalised Liquid Discharges from Sizewell B

	Normalised liquid discharge (TBq/GWh)					
	2006	**2007**	**2008**	**2009**	**2010**	**2011**
^{3}H	6.19E-03	2.84E-03	5.55E-03	5.79E-03	5.27E-03	4.97E-03
Total activity excluding ^{3}H	2.44E-06	1.27E-06	1.61E-06	2.42E-06	4.23E-06	1.85E-06

These discharges are generally higher than those presented in the UNSCEAR report (see **Table 5.5** below).

Table 5.5 Normalised Liquid Discharges from Nuclear Reactors

	UNSCEAR Reports(TBq/GWh)[a]		
	1990-1994	**1995-1997**	**1998-2002**
^{3}H	2.51E-03	2.17E-03	2.28E-03
Other radionuclides	2.17E-06	9.13E-07	1.26E-06

[a]UNSCEAR (2008), normalized to 'per hour' using 8766 hours per year.

A comparison can also be made between Sizewell B (1200 MW) and the 1300 MW tranche of reactors in France. Gaseous discharges are broadly comparable; Sizewell B discharges more noble gases and slightly more ^{14}C, but less ^{3}H since removal of the neutron sources. Discharges of ^{131}I and other activity are very similar. Aqueous discharges of ^{3}H from Sizewell B are slightly higher, while other activity is similar. However, the composition of other activities discharged differs; at Sizewell B it is dominated by a mix of fission and activation products, whereas the French 1300 MW reactors discharge a mixture of activation products and ^{14}C (to the extent that ^{14}C may be the critical radionuclide in aqueous discharges).

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. However, Oldbury implements Magnox Company Standards for the operation of fuel storage ponds and both Oldbury and Wylfa implement Magnox Company Standards for reactor gas chemistry, sampling and analysis of effluents, environmental monitoring procedures, etc. The standards are reviewed and updated on regular basis to reflect current best practice amongst the Magnox fleet, as well as incorporating proven practice from other organisations.

5.2 Decommissioning power stations[26]

By the end of 2011, the majority of Magnox power stations in the UK had ceased operation and had started defuelling and decommissioning. Berkeley, Bradwell, Hunterston A, Hinkley Point A and Trawsfynydd power stations all began decommissioning before 2002. These reactors were defuelled before 2005 and decommissioning is progressing at the sites. Chapelcross, Dungeness A and Sizewell A stations ceased power generation during 2004-2006 and are currently at the defuelling stage.

Defuelling and decommissioning strategies for Magnox stations and other UK civil nuclear facilities are the responsibility of the NDA. The Magnox defuelling programme, relevant for the reporting period, is described in the March 2008 issue of the Magnox Operating Programme (MOP8)[27].

Current reactor decommissioning plans are based on the following phases:

- Defuelling: Provided that reprocessing capacity is available at Sellafield, sites will be defuelled as soon as practicable after cessation of electricity generation. Where reprocessing capacity is constrained then fuel will remain in reactors until reprocessing capacity is available. This will minimise the time that fuel is stored wet, in order to reduce consequent discharges from the fuel cooling ponds.
- Care and Maintenance (C & M) preparations: All buildings except the reactor buildings will be decontaminated and demolished and the reactor buildings will be put into "Safestore[28]", making them weather and intruder resistant for the extended C & M period. All operational Intermediate Level Waste (ILW), except for Miscellaneous Activated Components (MAC) and desiccants, will be retrieved, packaged for safe interim storage until a decision is reached on their suitability for final disposal Desiccants will be decay stored until final site clearance. MAC will be safely contained within storage locations inside concrete vaults[29] (except at Trawsfynydd, see Section 5.3) and retrieved for disposal during reactor dismantling.
- C & M: During this period, reactor sites will remain in a state of passive safety for about 70 from cessation of generation. Sites will continue to be monitored and maintained to ensure they remain in a passively safe and secure state.

It is recognised that short-term increases in discharges may arise during the defuelling and decommissioning processes.

The current status of the defuelling and decommissioning power stations discussed in this section is summarised in the following table.

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26 This category of sites comprises all power stations that have permanently ceased to operate and includes those in all stages of defuelling and decommissioning.

27 This document is available on the NDA website at http://www.nda.gov.uk/documents/upload/MOP8-Update.pdf MOP 8 was updated in 2012 (MOP 9). The key change introduced by MOP 9 is the use of a performance range approach rather than a single delivery schedule to take account of uncertainties associated with Magnox reprocessing.

28 'Safestore' is a component of the preferred strategy for the decommissioning of UK Magnox and AGR. It refers to the period following defuelling of reactors and C&M preparation, during which intruder-proof and weather-proof structures are constructed around the remaining site buildings housing the active reactors. The structure is left in a passive-safe state with minimum maintenance (other than routine surveillance) for around 100 years to allow for radioactive decay, after which the remaining structures on site are dismantled and the site restored and delicensed.

29 There is no MAC at Chapelcross.

Table 5.6 Status of Decommissioning Sites

Site	Defuelling Status	Defuelling/ Decommissioning Status
Berkeley	Defuelled	Berkeley reactors 1 and 2 have now achieved safestore status. 5 Berkeley boilers (312te each) have been sent to Sweden for recycling (2 now complete). Other buildings remain on site awaiting remediation / demolition
Bradwell	Defuelled	Fuel cooling pond partially decontaminated and drained between 2008 and 2011 reducing the source term for liquid discharges.
Chapelcross	Defuelling in progress	Fuel pond 1 was drained during the reporting period, resulting in the removal of a significant mobile waste hazard from the Site. 2 reactors have been defuelled and work is on-going to defuel the other two reactors by mid-2013
Dungeness A	Defuelling in progress	Site decommissioning commenced in 2007. Activities have focused on the deplanting, demolition of structures and the retrieval, processing and disposal of wastes. Defuelling operations have been undertaken at the site. The active effluent line was extended into the English Channel to improve the mixing and dispersion of the effluent in the marine environment in 2007.
Hinkley Point A	Defuelled	The site was defueled prior to 2005 and is now undergoing decommissioning. Decommissioning activities have focused on the retrieval and disposal of wastes from the fuel cooling ponds to prepare for draining. Preparation works are on-going for the retrieval, processing and storage of intermediate level wastes.
Hunterston A	Defuelled	Hunterston A is undergoing decommissioning, having been defueled prior to 2005. The major work on site at present is the construction of wet and solid ILW retrieval facilities. A new Active Effluent Treatment Facility has been commissioned during the reporting period. This has been used to reduce the radioactivity in the Cartridge Cooling Pond (CCP) prior to discharge to sea. The CCP is currently being dewatered.
Sizewell A	Defuelling in progress	Following the cessation of power generation at the end of 2006, Sizewell A began defuelling and had despatched 28% of its fuel by the end of 2011. Defuelling is expected to be completed in 2014
Trawsfynydd	Defuelled	An Intermediate Level Waste (ILW) Store was constructed in 2008 and both Miscellaneous Activated Components (MAC) Vaults were emptied by 2009. All Orphan Low Level Waste (LLW) has been removed from the Active Waste Vaults and 13 fuel element debris boxes have been retrieved. The Reactor 2 vessel was purged in 2011 to reduce moisture levels. Capping roofing has been installed in both reactor buildings.

5.2.1 Sources of liquid effluent

Radioactive liquid effluents arise from reactor and fuel handling operations, and from practices such as removal of fuel cooling pond liquor and the retrieval and processing of wastes. The principal sources for defuelling and decommissioning sites are:

- Spent fuel ponds management (where irradiated fuel is stored under water before being despatched for reprocessing).
- Reactor defuelling and decommissioning operations.
- Laundry operations.

During defuelling, the most radiologically significant source of liquid effluents is the spent fuel storage pond water. Subsequently, the retrieval and processing of wastes and activities such as draining pond water become the major contributors to aqueous effluents from decommissioning sites. At decommissioning stations, site dryer liquors and spent fuel are no longer a source of activity.

Effluents produced as a result of reactor defuelling and decommissioning activities are considered as part of a BAT (or BPEO) study and optimised accordingly.

5.2.2 Liquid effluent treatment and discharge

Discharges associated with large decommissioning projects are assessed in advance in order to define appropriate procedures to minimise discharges.

All aqueous effluents are strained/filtered prior to discharge to remove residual particulate matter, for example by the use of sand pressure filters. The removed particulates are stored in suitable containers for future disposal. Effluents are accumulated in delay tanks, sampled, and if their activity content is acceptably low, are discharged via sites' existing pipelines at a time and in a manner so as to avoid high local concentrations near the discharge outfall.

At some defuelling sites, pond temperature and pH are controlled to optimum conditions to prevent corrosion of the fuel and leaking fuel is dispatched as soon as practicable to reduce ^{137}Cs leakage into the ponds. Other sites use ion exchange systems to remove caesium activity from pond water prior to transfer to the settling tanks.

As part of any plant modification or decommissioning process, all changes in the plant configuration or introduction of projects are subject to an assessment to evaluate the impact on the radioactivity discharges. If it is identified as having a potential impact then the BAT (or BPM/BPEO) considerations are included in process planning.

5.2.3 Trends in discharges over the 2006-2011 period

All of the sites described in this category are undergoing defuelling or decommissioning. The variation in discharges is therefore primarily associated with the phasing of such operations. The liquid discharges and emissions to air reported during the period 2006-2011 are presented for each site, below.

Berkeley: liquid discharges of ^{137}Cs and other radionuclides have remained relatively stable throughout the reporting period, except during 2008-2009 when increases were noted. The increase in discharges of ^{3}H from 2008 is as a result of the drainage of a small pond from a research area on the site.

Annual emissions to air have remained effectively constant throughout the period.

Figure 5.25 Annual Liquid Discharges from Berkeley

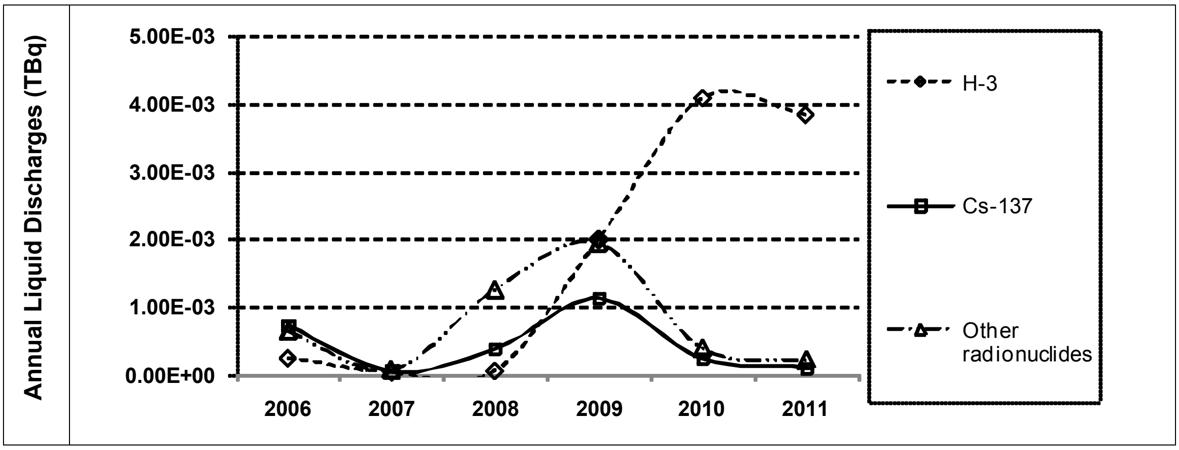
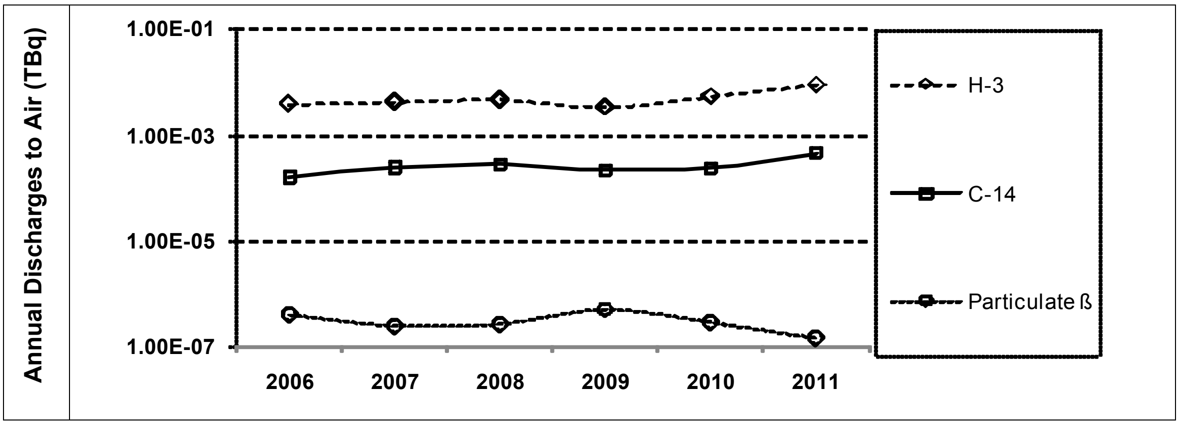


Figure 5.26 Annual Discharges to Air from Berkeley

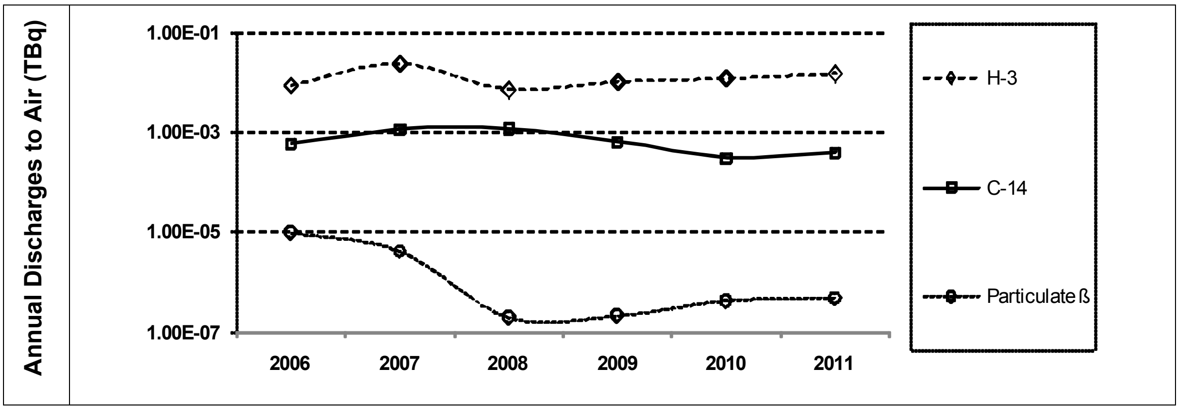


Bradwell: defuelling was completed in 2005, resulting in considerable decreases in the discharges of all radionuclides in liquid effluents particularly during 2006-2007 (**Figure 5.27**). The drainage and cleanup of fuel ponds at the site resulted in increases in the discharge of ^{137}Cs and other radionuclides from 2007-2009. All pond water was removed and the pond walls were partially decontaminated using ultra high pressure water jetting. Since 2009, discharges have decreased due to a reduction in source term during and following pond drainage.

Annual emissions to air from Bradwell have decreased since 2002 as the reactor was defuelled and management of the reactor atmosphere was relaxed. Emissions have remained steady during the reporting period (**Figure 5.28**). Further reductions in ^{14}C and beta particulate activity are due to refinements in monitoring techniques. The lower reduction in ^{3}H emissions is due to the continuing clean-up work and other decommissioning activities.

Figure 5.27 Annual Liquid Discharges from Bradwell

Figure 5.28 Annual Discharges to Air from Bradwell



Chapelcross: discharges of ^{3}H and total beta in liquid effluent have been variable during the course of the reporting period. Discharges of both radionuclides initially decreased during 2006-2008, followed by increases in ^{3}H and total beta discharges in 2009 and 2010, respectively. These increases are as a result of activities associated with commencing the decommissioning of the ^{3}H processing plant, which was shut down in 2005, leading to a general reduction in the level of ^{3}H discharged. The increased ^{3}H discharge in 2009 was comparable to the levels that arose during plant operation. Liquid discharges of total alpha remained steady during the reporting period.

The emissions to air of ^{3}H have shown a decreasing trend over the reporting period (**Figure 5.30**).

Figure 5.29 Annual Liquid Discharges from Chapelcross

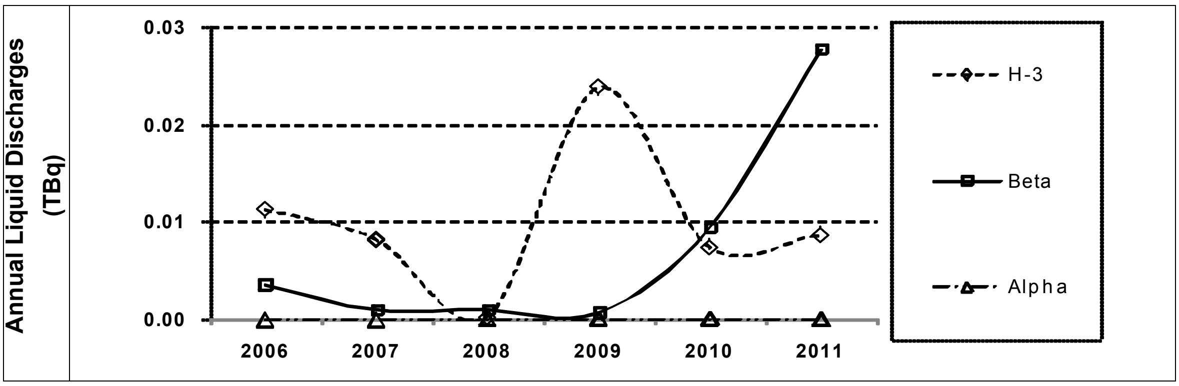
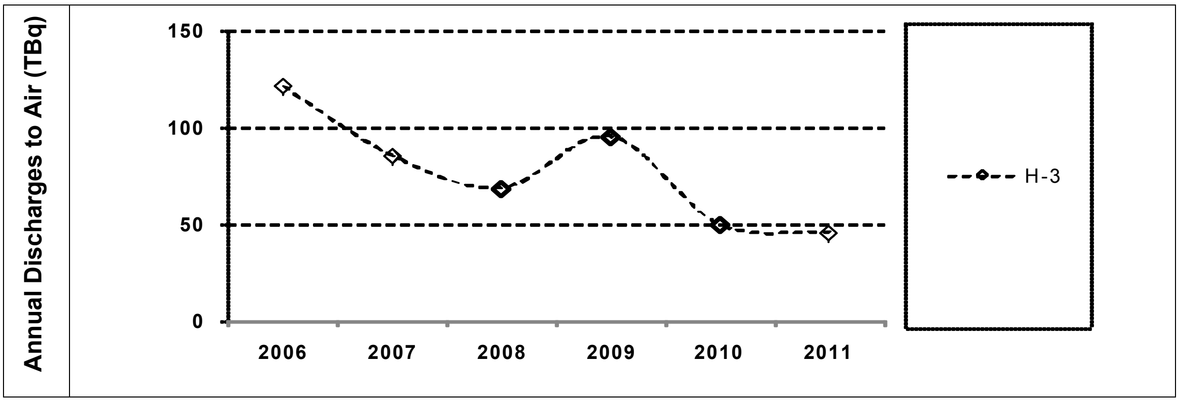


Figure 5.30 Annual Discharges to Air from Chapelcross



Dungeness A: liquid discharges of radionuclides have steadily decreased following cessation of power generation in 2006 with the exception of a small increase in discharges of ^{3}H in 2007 arising from reactor shutdown and the disposal of a backlog of gas processing liquors (as discussed in the previous report).

The annual emissions of ^{3}H, ^{14}C and other radionuclides to air also show a decreasing trend as a result of the dry air compressor no longer being in continuous use, following a BAT study.

Figure 5.31 Annual Liquid Discharges from Dungeness A

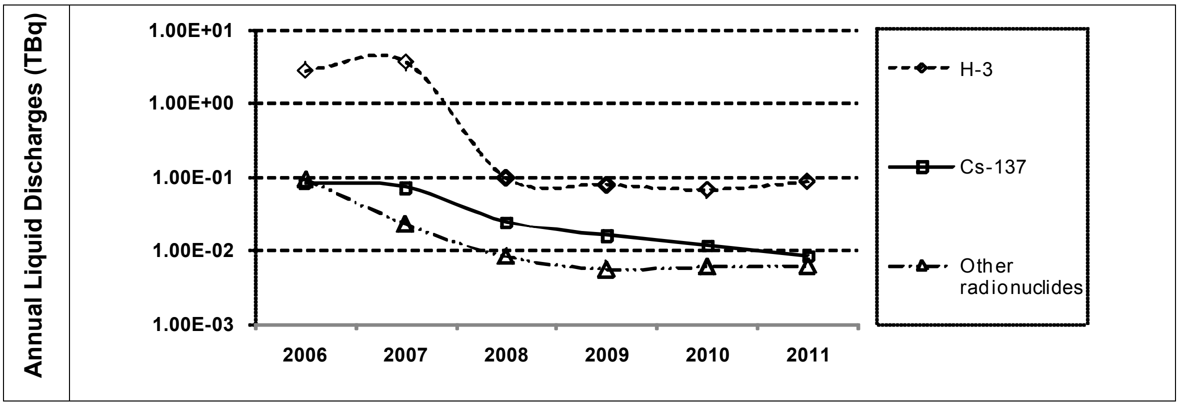
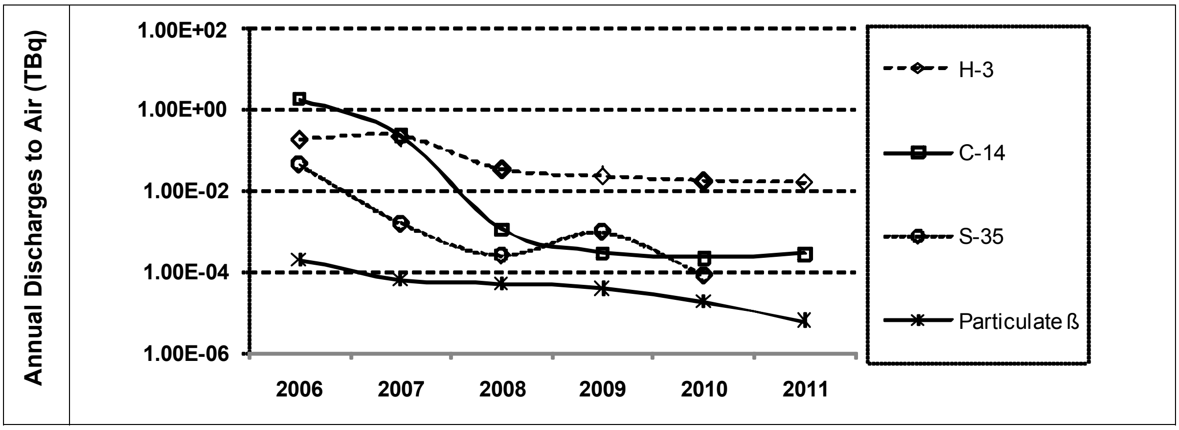


Figure 5.32 Annual Discharges to Air from Dungeness A



Hinkley Point A: discharges of aqueous ^{3}H and ^{137}Cs have continued to decrease during the reporting period as a consequence of the completion of removal of fuel fragments and waste items from the fuel cooling ponds. The discharge of other radionuclides has fluctuated over the period depending on activities related to decommissioning of the former fuel cooling ponds.

Annual gaseous emissions of ^{3}H, ^{14}C and beta particulate activity have remained relatively stable and are significantly lower than the annual limits.

Figure 5.33 Annual Liquid Discharges from Hinkley Point A

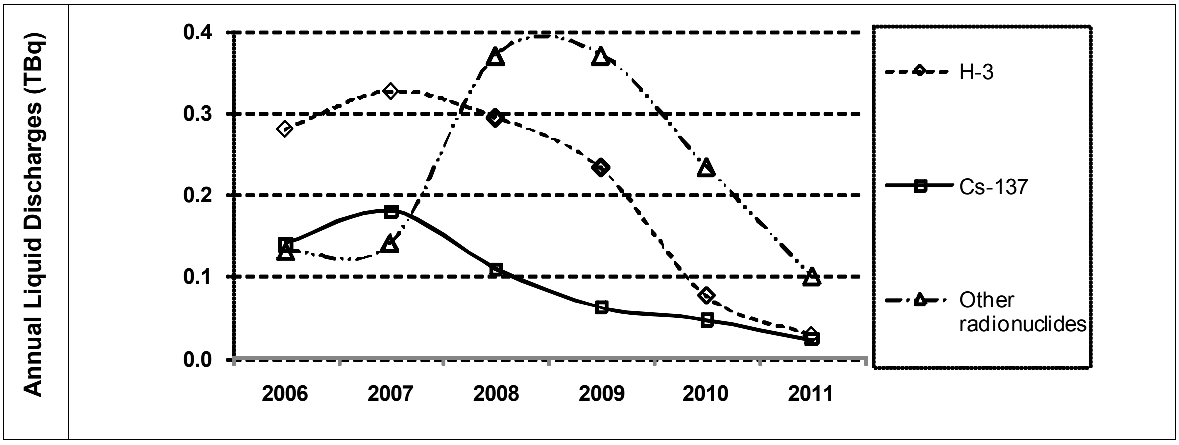
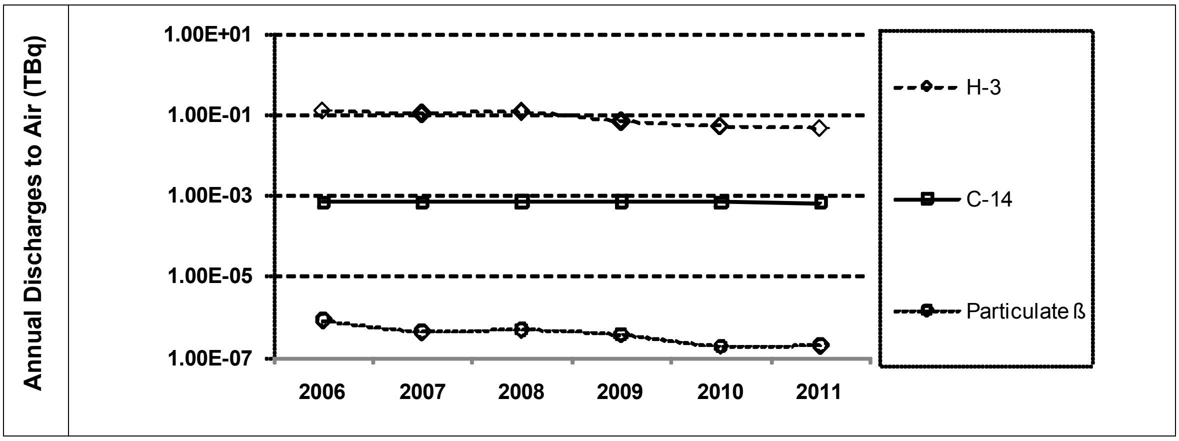


Figure 5.34 Annual Discharges to Air from Hinkley Point A



Hunterston A: liquid discharges of alpha activity and ^{241}Pu increased from 2007-2010 as a result of the discharge of water from the cartridge cooling pond (CCP) and other miscellaneous effluent, as agreed with the regulator (SEPA). Total beta activity in liquid discharges has decreased since 2008 due to use of the Modular Active Effluent Treatment Plant (MAETP) to reduce activity in the CCP water.

There has been a decrease in gaseous emissions of ^{3}H and ^{14}C due to a reduction of activity in the reactor core graphite. A slight increase in beta particulate in gaseous discharges is noted due to an increase in the work carried out in contaminated plant areas on site.

Figure 5.35 Annual Liquid Discharges from Hunterston A

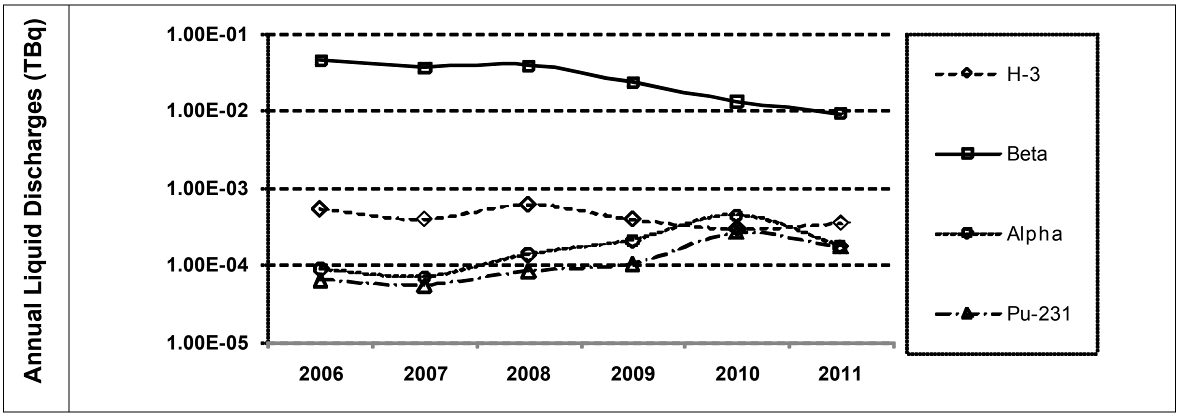
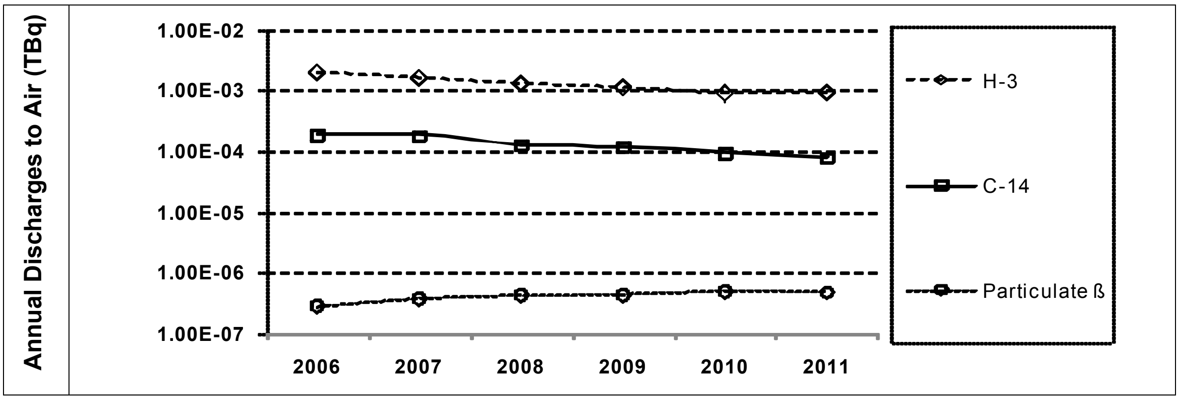


Figure 5.36 Annual Discharges to Air from Hunterston A



***Sizewell A**:* Sizewell A ceased operation in December 2006 and liquid discharges of all radionuclides have shown a general decreasing trend except for a peak in discharges of ^{3}H in 2007 associated with reactor shutdown.

The annual emissions to air have also followed a decreasing trend throughout the reporting period. Further reduction in discharges of ^{3}H and ^{14}C were achieved following modifications of the existing purge air system in 2010 to improve the conditioning of the air prior to entering the reactors and thus reducing the liberation of the gases from the core.

Figure 5.37 Annual Liquid Discharges from Sizewell A

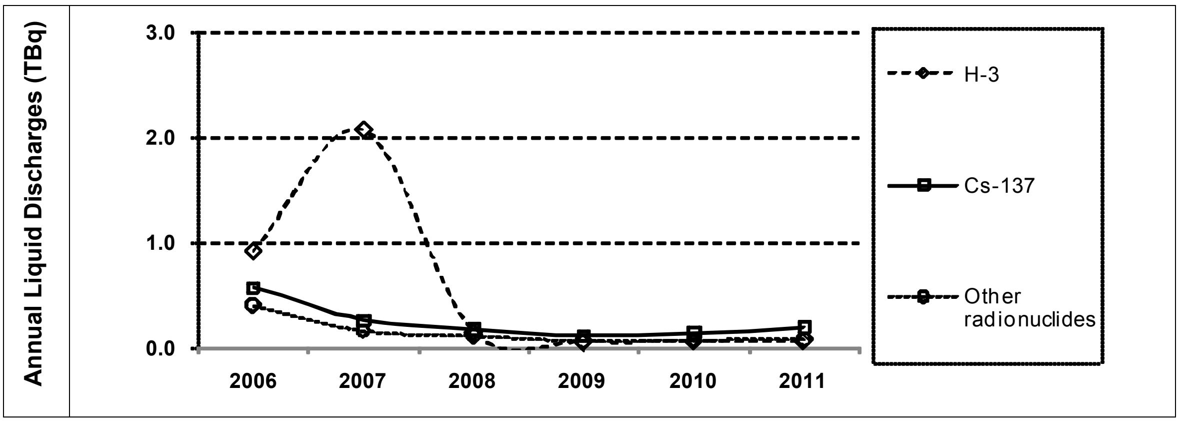
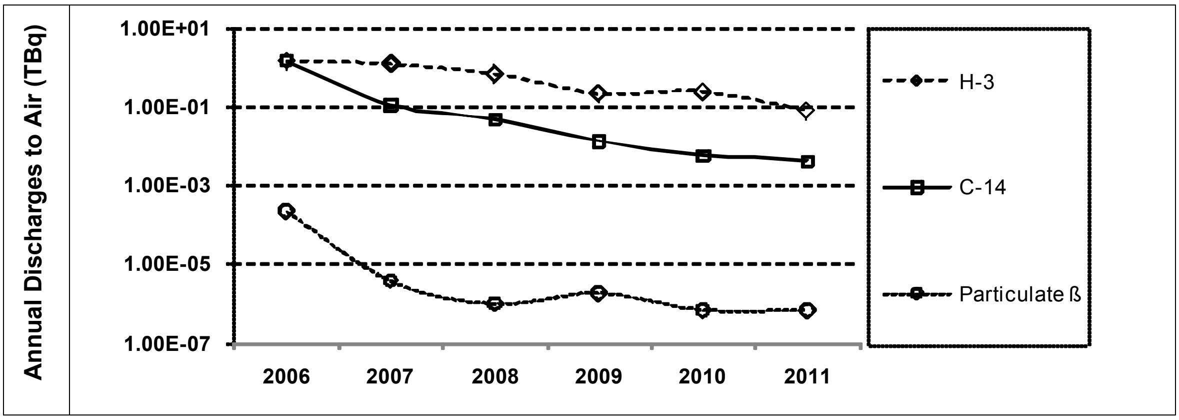


Figure 5.38 Annual Discharges to Air from Sizewell A



Trawsfynydd: the liquid discharges are made to a freshwater lake and do not impact on OSPAR waters. However, the discharge data are presented here for completeness. There has been a general decreasing trend in liquid effluent discharges during the reporting period. On-going decommissioning works on the site have focussed on solid waste stream, which have a minimal impact on liquid effluent discharges.

Annual emissions to air have remained relatively constant, except for emissions of ^{3}H, which have increased from 2010 as a result of purging of one of the reactor vessels to reduce moisture.

Figure 5.39 Annual Liquid Discharges from Trawsfynydd

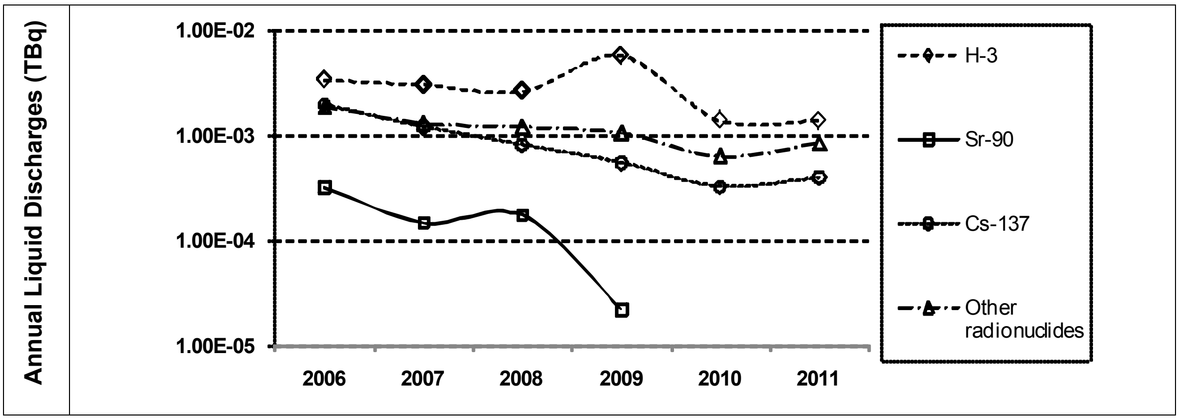
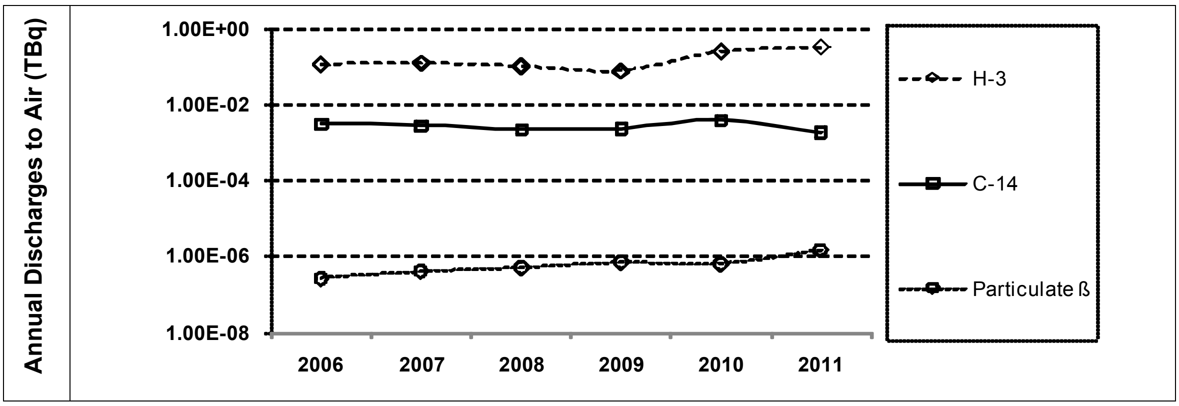


Figure 5.40 Annual Discharges to Air from Trawsfynydd



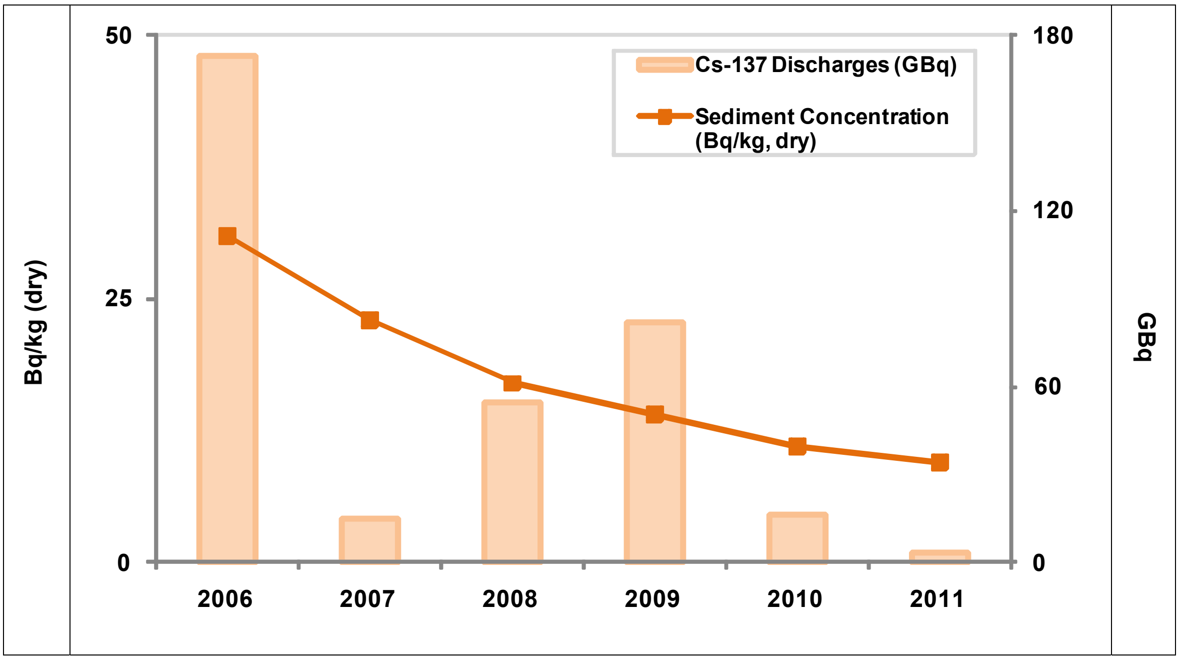
5.2.4 Radiological impact of liquid discharges

Environmental monitoring programmes are in place around each of the sites or, in the case of Berkeley, Dungeness A, Hinkley Point A and Hunterston A, joint programmes are in place with adjacent operational stations. Representative environmental monitoring data are published in the annual RIFE Reports.

The concentration of radionuclides in the seafood and the environment near Bradwell remained very low, often below detection limits, throughout the reporting period. The concentration of ^{137}Cs in sediment at the Blackwater Estuary has steadily declined in line with decreasing radioactive discharges from the Bradwell Nuclear Power Station as shown in **Figure 5.41** below. Low levels of ^{99}Tc were detected in seaweed are likely to have been due to the long distance transfer of Sellafield derived activity. Similarly, concentrations of artificial radionuclides in the marine environment near Chapelcross are largely due to the effects of historical Sellafield discharges; concentrations of most radionuclides remained at similar levels during the period.

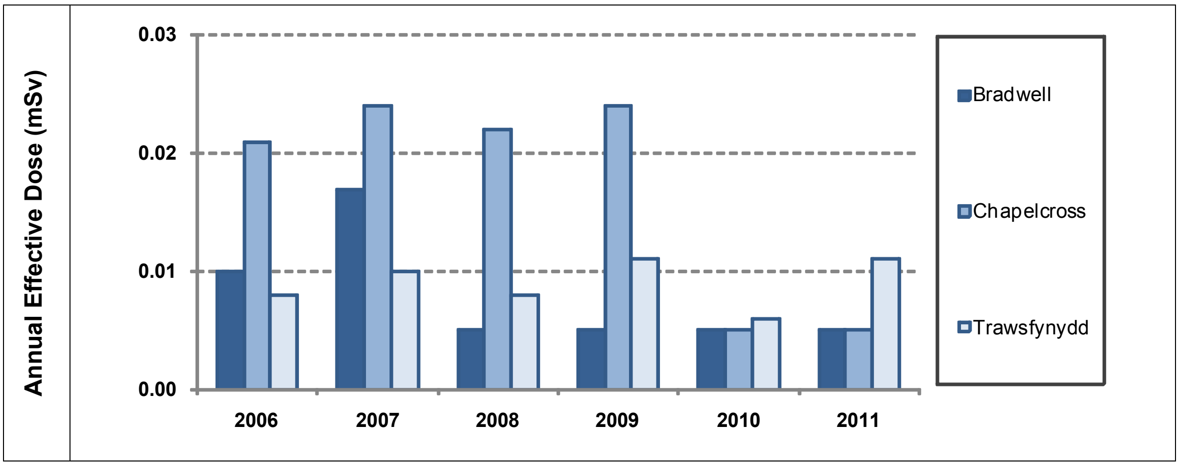
Trawsfynydd discharges into an inland lake environment and does not impact OSPAR waters. The important radionuclides are ^{137}Cs and, to a lesser extent, ^{90}Sr, although discharges of ^{90}Sr reduced to nil in 2010. The concentration of ^{137}Cs in sediment has shown a substantial decline since the mid-1990s in line with reducing discharges.

Figure 5.41 Discharges of ^{137}Cs from Bradwell and Concentration in Sediment at Blackwater Estuary 2006-2011



The trends in estimated doses to the representative person around Bradwell, Chapelcross and Trawsfynydd sites are illustrated in **Figure 5.42**. The estimated doses at all other sites include a contribution from an operational station, and were discussed in Section 5.1.

Figure 5.42 Trends in Doses to the Representative Person near Decommissioning Sites



The annual effective doses to the representative person around Bradwell (from the consumption of fish and shellfish and intertidal occupancy) have decreased to less than 5 µSv since 2008 due to a reduction in the gamma dose rate on the beach. The annual effective dose to the representative person around Trawsfynydd (arising from consumption of freshwater fish and external dose to anglers) has remained around to 10 µSv. These doses represent around 1 percent or less of the dose limit to members of the public.

The sharp decrease in the effective dose to the representative person around Chapelcross from 2010 is the effect of an amendment in the habits assumed in the assessment. As a result of recent habit surveys, high-rate crustacean consumers and wildfowlers who also consume salmonids are considered. Prior to 2010, the greater proportion of the dose around Chapelcross can be attributed to the discharges from Sellafield.

5.2.5 The application of BAT

The abatement techniques commonly applied at decommissioning Magnox stations are summarised in Table 5.7.

Table 5.7 Defuelling and Decommissioning Magnox Stations: Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
Chapelcross	Delay tanks Settling tanks Ion exchange units	HEPA filters on contaminated ventilation systems.
Dungeness A	Delay tanks Fine filters Ion exchange Settling tanks Submersible Caesium Removal Unit Sand pressure filter Pond temperature and water chemistry	HEPA filtration
Sizewell A	Delay tanks Ion exchange Sand pressure filters Settling tank Ponds chemistry Submersible Caesium Removal	HEPA filtration Conditioning of purge air

Station	Liquid Abatement	Aerial Abatement
	Unit (where appropriate)	
Berkeley	Sand pressure filters (10 micron) Centrifugal disc filters	HEPA filters
Bradwell	Non regenerable ion exchange resin in pond water treatment plant Sand filters on effluent plant	HEPA filters
Hinkley Point A	Delay tanks Chemical precipitation Sand pressure filters Cross-flow filtration using fine filter units Hydrocyclone Ion exchange resin to reduce caesium and strontium radionuclides	HEPA filters on contaminated ventilation systems
Hunterston A	Delay Tank Ultrafiltration Sand pressure filters Ion-exchange removed; awaiting new ion-exchange units	HEPA filtration. No shield cooling or iodine filters
Trawsfynydd	Delay tanks Sand pressure filters Ion exchange units	HEPA filters on contaminated ventilation systems

The main function of the final delay tanks is to allow activity to be monitored prior to discharge into the sea.

Pond temperature and pH are controlled to optimum conditions to prevent corrosion of the fuel and leaking fuel is dispatched as soon as practicable to reduce ^{137}Cs leakage into the ponds. The ion exchange resins are used to control pond chemistry, notably the levels of ions such as Na^+ and Mg^{2+}present in the liquid and to remove radionuclides such as ^{137}Cs and ^{90}Sr.

The sand pressure filters reduce the amount of radioactive particulates discharged; their efficiency varies between individual radionuclides and depends upon particle size distribution in waste stream. Dungeness A has also installed fine filters of 5 µm size.

At *Sizewell A*, some plant modifications have been carried out to modify or update operational systems, such as the replacement of the two settling tanks on site with the Wash Collection Tank. Back-washing of the Effluent Treatment Sand Pressure Filters was previously performed on a weekly routine basis. Its initiation is now based on the differential pressure of the filters, vastly reducing the frequency of the back-washing and therefore decreasing the volume of effluent to be discharged.

At *Chapelcross* pond chemistry control, the use of zeolite skip and settling or filtration are in place to reduce activity discharged in liquid effluent. Dry decontamination techniques are used to minimise liquid waste arisings. A site-wide review of liquid effluent abatement is in progress. The results of this review will be implemented as part of a Multi Media Authorisation (MMA) under the RSA93. The MMA is currently under consultation.

A BAT study was undertaken at *Dungeness A* to determine the appropriate use of the dry air compressor, now that fuel is no longer in place. This has resulted in the intermittent rather than continual use of this equipment, leading to a reduction in the discharges of ^{3}H and ^{14}C from the site.

Pond temperature and pH are controlled to optimum conditions to prevent corrosion of the fuel and leaking fuel is dispatched as soon as practicable to reduce ^{137}Cs leakage into the ponds. The processes of natural settlement and filtration are the main means applied to achieve abatement of discharges to the environment. Treated effluent is routed into Final Delay Tanks (FDTs) and Collection Monitoring Tanks (CMTs), to allow sampling and analysis. Active effluent is filtered through sand pressure filters with a filtration capability of 10-20 µm and through fine filters with a filtration capacity of a nominal 5 µm and 10 µm absolute rating. The results are inspected by an appointed “suitably qualified and experienced person” (ASQEP) who will recommend whether further treatment is appropriate before discharge to sea.

The active effluent discharge line was recently extended into the English Channel to improve the mixing and dispersion of effluent in the marine environment.

At *Berkeley*, the current techniques being used for the control of liquid discharges have followed a detailed BAT process. Prior to a project commencing decommissioning work, formal assessment is undertaken to ensure that the BAT are used to minimise the production of secondary waste, including liquid effluent, at source. Effluent is treated with sand pressure filters as well as centrifugal disc filters.

At *Bradwell* the pond water treatment plant management and operation changed in 2006 as all fuel was removed from the ponds; the result was observed in the reduction of liquid discharges. During the cleaning and draining of the cooling ponds, several abatement systems were trialled including: electro-coagulation, hydrocyclone filtration and polymer precipitation. However, none of these systems were fully implemented at the site due to the low success in abatement and the cost of full implementation on a decommissioning system. Currently, 5µm effluent sand filters are used to abate all radioactive liquid discharges. Non-regenerable ion exchange resins are available for use if determined as BAT to do so.

A new aqueous Discharge Abatement Plant (ADAP), designed to abate specific waste-streams from the Bradwell site – particularly the Fuel Element Debris (FED) dissolution plant and to replace the pond water treatment plant which is being decommissioned, is due to be commissioned by December 2012. It is expected that the plant will abate 99% of the discharges and targets ^{137}Cs, ^{60}Co and ^{63}Ni. The abatement will produce solid wastes in the form of chemically precipitated solids and spent ion exchange resins. This waste is to be dried and disposed of as ILW.

Hinkley Point A uses the process of natural settlement and filtration to achieve abatement of discharges to the environment. Treated effluent is routed in final monitoring delay tanks to allow sampling and analysis before being discharged. Changes to abatement plant in the period have involved re-assessing the effluent fine filter requirements and limited usage of a hydrocyclone, and the use of chemical flocculants to protect existing abatement plant and minimise secondary waste generation.

At *Hunterston A*, radioactive liquid effluent is discharged to sea via the Active Effluent Treatment Facility. The effluent is retained in receiving tanks before undergoing treatment through ion exchange and filtration in the MAETP. The effluent is then held in delay tanks for re-circulation and sampling to ensure the effluent meets the requirements of the discharge authorisation. A new Active Effluent Treatment Facility was commissioned in 2009 which uses submersible caesium removal units and filtration to reduce caesium activity in the CCP water. The decision to use the MAETP was the result of an extensive BPEO process. New radioactive gaseous discharge stack samplers were installed in 2010 to increase the reliability of samplers.

At Trawsfynydd, sand pressure filters, delay tanks and ion exchange units for aqueous discharges and HEPA filtration for atmospheric discharges are used. Trials of the Arvia™ system for destruction of high alpha oils were successfully undertaken on site during 2010/ 2011.

5.2.6 Comparison with performance of similar plants world-wide

Magnox Ltd management procedures are periodically reviewed and updated to reflect current best practice within the Magnox Fleet and practices from other organisations. There are numerous forums in which the company reviews performance. Internally, the company applies optioneering (e.g. BAT assessments), strategy development, research and development programmes through environment and waste peer groups. Externally, Magnox Ltd supports and participates in EARWG (an industry forum which reviews BAT as it is applied to waste management). This includes reviewing practices worldwide. The company also participates in the Nuclear Industry Sector Working Group. This is a joint EA, SEPA and industry forum which is used to benchmark performance on key performance indicators.

5.3 References

1) UNSCEAR 2008. Sources and Effects of Ionizing Radiation. Report to the General Assembly. United Nations Scientific Committee on the Effects of Atomic Radiation. Volume 1, Annex B. 2010. New York

2) Environment Agency and SEPA websites (http://www.environment-agency.gov.uk/ and http://www.sepa.org.uk/)

3) Environment Agency, SEPA, NIEA, and FSA, Radioactivity in Food and the Environment (RIFE), 2006 - 2011, CEFAS (2007 - 2012).

4) Environment Agency Nuclear Regulation Report to Sizewell Stakeholder Group on Sizewell B Power Station: February-June 2011

6. Fuel reprocessing

The Sellafield site is the largest nuclear complex in the UK and, amongst other activities, undertakes the reprocessing of spent Magnox and oxide fuels[30] connected with the UK nuclear electricity generation programme and spent oxide fuel from other countries.

The Sellafield site is owned by the NDA and operated by Sellafield Ltd (the Site Licence Company) under the management of Nuclear Management Partners Ltd (NMP)[31], under contract to the NDA. The National Nuclear Laboratory (NNL) also conducts operations in facilities located on the Sellafield site.

The Sellafield site encompasses the Calder Hall nuclear power station, which is currently undergoing defuelling and decommissioning. This is under the management of Sellafield Ltd. The Windscale Nuclear Licensed Site is also enclosed entirely within the Sellafield site. Calder Hall, Windscale and Sellafield are managed by Sellafield Ltd and share a single permit under the Environmental Permitting Regulations 2010. The activities of all three entities are therefore included within this section of the report.

The Sellafield site is certificated under both the international Environmental Management Standard ISO14001 and the international Quality Management Standard ISO9001. In addition, the Analytical Services, based on the Sellafield site, are accredited under the UK Accreditation Service.

6.1 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.
- Storage of uranium and recovered plutonium.
- Processing and storage of HLW and ILW.
- Processing of LLW for disposal to the Low Level Waste Repository (LLWR).
- Clean up and decommissioning of redundant facilities, including those on the Windscale Nuclear Licensed Site and treatment/ conditioning of inventories of liquid and solid wastes.
- Research and development (including activities carried out by the NNL); and,
- Disposal of VLLW.

The reprocessing of spent fuel is still a major activity at Sellafield, although there has been an increased focus in recent years on the clean-up of legacy waste and decommissioning of redundant facilities, with the overall objective of reducing the hazards associated with the site.

The Thermal Oxide Reprocessing Plant (THORP) and the Magnox Reprocessing Plant (MRP) have continued to operate throughout the reporting period. The NDA recently announced the outcome of a strategic review regarding the future of the THORP plant, in which it affirmed that completing the reprocessing contracts at THORP remains a viable and cost-effective strategy[32].

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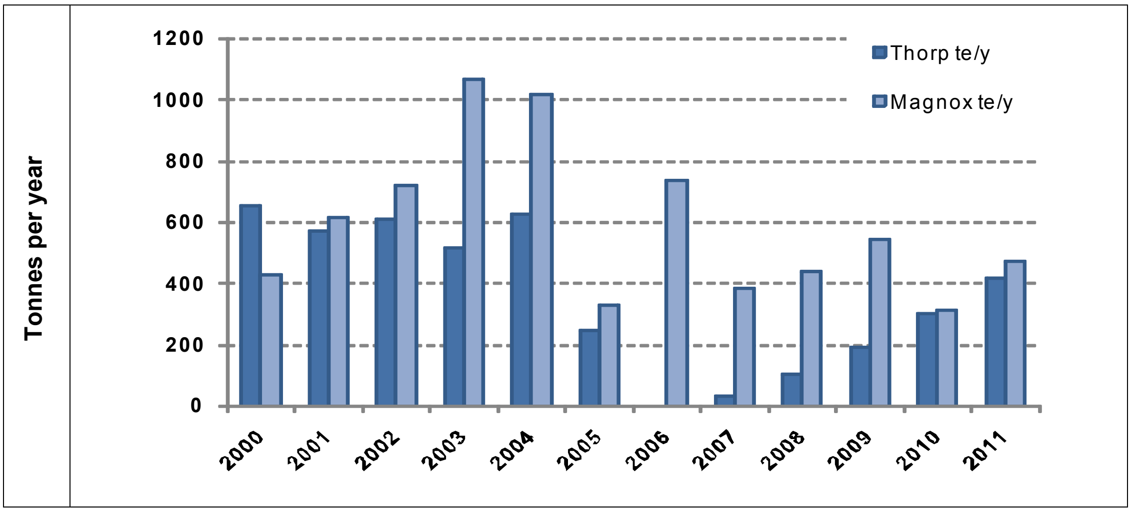
[30] Sellafield Ltd holds contracts for the reprocessing of all spent Magnox fuel arising from the UK nuclear electricity generating programme. It does not currently hold contracts to reprocess all AGR or PWR fuel.

[31] Transfer of the PBO to Nuclear Management Partners Ltd was completed 24th Nov. 2008.

[32] http://www.nda.gov.uk/documents/upload/Oxide-Fuels-Preferred-Options-June-2012.pdf

Any remaining AGR fuel, including any future arisings, will be placed into interim storage pending a decision to dispose of it in a geological disposal facility. This will result in the reprocessing contracts being completed by 2018, at which time THORP would cease reprocessing activities and enter a post-closure and clean out phase prior to decommissioning.

Figure 6.1 Sellafield Reprocessing Rates



Details of the timescales for the completion of Magnox reprocessing activities are set out in the ninth version of the Magnox Operating Programme (MOP9), available on the NDA website. The programme identifies that the reprocessing of spent Magnox fuel will complete by March 2017 if a throughput rate of 740tpy is maintained, and by December 2020 if a rate of 450tpy is achieved.

A mixed oxide fuel fabrication facility, the Sellafield MOX Plant (SMP), operated until 2011. This was a dry process, generating negligible liquid effluent such that it made an insignificant contribution to liquid discharges.

Progress has been made since 2008 on the clean-up of legacy facilities and decommissioning activities. This includes:

- The commissioning of a local effluent treatment plant to treat Pile Fuel Storage Pond (PFSP) pond water prior to discharge via the site low activity effluent treatment and discharge system, significantly reducing discharges to sea from this facility, and providing abatement for discharges associated with the legacy fuels and materials removals programme.
- The commencement of legacy fuel removals from the PFSP, with a first skip of metal fuel having been transferred to the Fuel Handling Plant for interim storage pending a final disposal option being confirmed.
- Installation of a new plant and equipment to support sludge retrieval from the PFSP. The current intention is that radioactive sludge in PFSP will be pumped to this new Local Sludge Treatment Plant for processing in the future.
- Commencement of other solid waste removals from the PFSP, with over 20 tonnes of steel decontaminated and removed for disposal as Low Level Waste (LLW) in 2011/12.
- Progress in dealing with radioactive sludge in the First Generation Magnox Storage Pond (FGMSP), including the refurbishment of FGMSP infra-structure and the on-going construction of a new Sludge Packaging Plant to support pond de-sludging.

- Commencement of routine transfers of radioactive liquor from the Magnox Swarf Storage Silo (MSSS) to the Site Ion eXchange Effluent Plant (SIXEP) effluent treatment facility, with over 3800 TBq of activity having been retrieved by October 2012, thus reducing overall environmental risk of the facility.
- Completion of the decommissioning of the reactor core and pressure vessel of the Windscale Advanced Gas-cooled Reactor.
- Commencement of removal of fuel from the Calder Hall power station.
- Ongoing management of historic floc[33], which was stored in sludge storage tanks. This is being transferred from the original tanks to a higher integrity buffer tank for onward treatment via the Enhanced Actinide Removal Plant (EARP).

6.1.1 Sources of liquid effluent

Radioactive liquid effluents arise from fuel reprocessing and storage operations, decommissioning operations, processing of legacy wastes and research and development activities. 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 (WVP); they are not therefore discharged to the environment.

The largest contributors to radioactive waste arisings are currently 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. It is anticipated that reprocessing will continue to represent the major contributor to liquid waste arisings for the immediate future. However, this will shift as the balance between clean-up, decommissioning and operational activities changes. Once reprocessing ceases, legacy clean-up will dominate the effluent discharges.

Whilst new effluent streams will be generated as a result of legacy clean-up activities on site, some historic effluent streams are being managed such that they are no longer discharged from the site. For instance, some of the effluents from Magnox reprocessing operations were concentrated and collected in storage tanks on site and commonly referred to as Medium Active Concentrate (MAC). Since 2003, fresh MAC arisings have been diverted into the Highly Active Liquor route for vitrification, and no longer contribute to liquid discharges.

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. Some surface water is also discharged via the Factory Sewer which runs through the site and contains very low levels of radioactivity. There are a number of other surface water drainage systems which discharge to the local rivers and the Irish Sea, though these are not currently used as radioactive discharge points.

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

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

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[33]The sludge comes from early reprocessing operations, in which actinide-containing nitric acid streams, using the iron and aluminium present, were neutralised with ammonia to produce ammonium nitrate and precipitate an insoluble alumino-ferric flocculant (floc). This was allowed to settle out of suspension in primary sludge tanks before the supernate was discharged to sea. The retrievals and treatment of this 'floc' from the tanks is currently being undertaken.

- 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 ^{90}Sr released as a consequence of fuel reprocessing is removed in the highly active liquid waste stream. Other sources include the Segregated Effluent Treatment Plant (SETP) and arisings from legacy facilities.
- 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: Discharges to sea arise from the treatment, by caustic scrubbing, of the ventilation air stream associated with reprocessing. THORP is generally the main source of ^{129}I discharges to sea, although this varies dependent on throughput rates through the two reprocessing plants.
- Caesium-137: The majority of ^{137}Cs arisings are the result of Magnox reprocessing and miscellaneous historical arisings. The vast majority of the ^{137}Cs released 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 SIXEP. Clean-up of legacy facilities will result in different effluent feed challenges over coming years, including, but not limited to ^{137}Cs. Effluents associated with the retrievals of wastes from legacy facilities may contain varied quantities of active and non-radioactive species, which could behave in a different way during treatment.
- Plutonium and Americium: 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. Small residual liquid arisings of plutonium isotopes and ^{241}Am are discharged via SETP.

6.1.2 Liquid effluent treatment and abatement

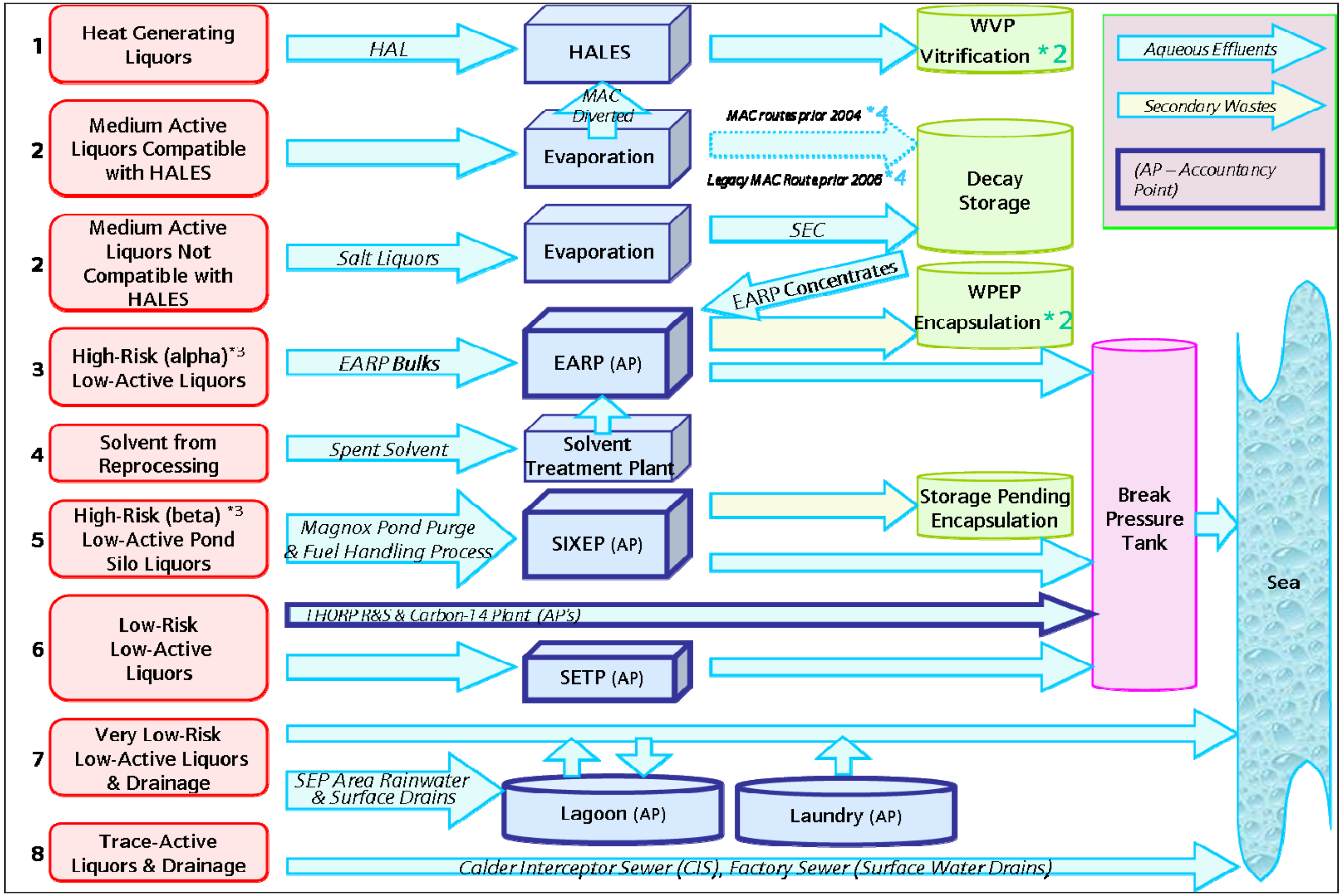
Main (site-wide) treatment plants

The major liquid effluent treatment facilities operating on the site are summarised below.

- The Highly Active Liquor Evaporation and Storage (HALES) plant evaporates highly active liquors prior to vitrification in WVP.
- The Salt Evaporator is designed to condition and concentrate waste streams for interim decay storage prior to treatment in the EARP.
- SIXEP is designed to reduce discharges of effluents containing beta-emitting radionuclides.
- EARP has the primary purpose of reducing the levels of plutonium and other actinides in liquid discharges. TPP (tetraphenylphosphonium bromide) precipitation of ^{99}Tc has also been used at the EARP to process a backlog of MAC.
- 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 high specific gravity particulates using a hydrocyclone.

These plants are well established and have been described in detail in the previous report. **Figure 6.2** below provides a schematic representation of the Sellafield liquid effluent treatment system showing the routings of the different liquid waste arisings.

Figure 6.2 Liquid Effluent Management System



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 washing 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, and the solid waste arisings are 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.

Examples of other treatment plants at Sellafield

A number of other parallel plants and projects have been introduced to reduce liquid effluents over the long term. These include:

- *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 and is now fully operational.
- *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 are now being retrieved and treated in the EARP concentrates plant prior to encapsulation, the first batch being treated in April 2005.

A number of other treatment options have been subject to review and research, with many of these being specific to legacy wastes. For example, the Local Effluent Treatment Plant (LETP) reduces beta discharges from the PFSP. The operation of the LETP is continually being optimised, achieving successes such as fewer ion exchange cartridges being generated than originally anticipated and less raw water being used for back-washing. An example of optimisation has been in defining the best periods to run the LETP in recycle mode in order to maintain suitable differential pressure across LETP.

Future waste treatment facilities

Major new facilities currently being developed include:

- Silos Direct Encapsulation Plant: to encapsulate the waste from the MSSS. The programme and timescales for building and commissioning this facility are, at the time of writing, being developed.
- Sludge Packaging Plant: to provide storage for sludge from pond retrieval and treatment operations prior to generation of a disposable product. Sludge buffering[34] operations are projected to commence in 2014, with conditioning expected to begin around 2024.

It should be noted that as aqueous discharges are forecasted to decrease significantly over the next decade following cessation of reprocessing, Sellafield Ltd is considering whether discharges currently routed to SETP could be more effectively treated by routing to EARP.

34 To allow early risk reduction of a high hazard facility by moving legacy waste into modern containment prior to treatment.

Exclusion of entrained solids

From November 2006, enhanced beach contamination monitoring identified numerous contaminated items (i.e. pebbles and stones) and particles on the beaches near to Sellafield. This has resulted in Sellafield undertaking a range of measures to improve the removal of entrained solids from radioactive aqueous waste before it is discharged to the sea. Work has built on existing arrangements for the exclusion of solids at the site, and range from implementing simple filtration techniques at source plants to extensive trials to underpin, optimise and potentially improve final filtration systems on effluent discharges.

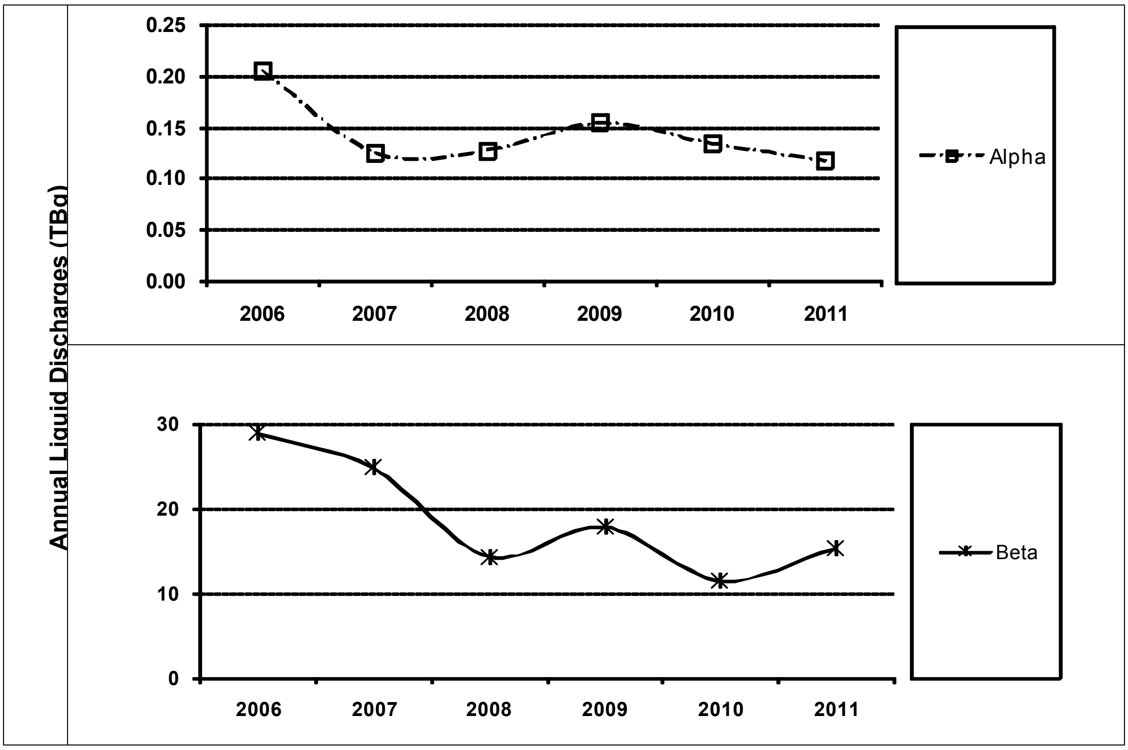
6.1.3 Trends in liquid discharges 2006-2011

In recent years, there has been a general downward trend in all discharges from the main site pipeline. The discharge of most radionuclides from the Sellafield site have either decreased or remained relatively consistent throughout the reporting period as demonstrated by the overall trends in alpha and beta discharges (**Figure 6.3)**.

Discharges of total beta activity, which is an overall control measure, continued to decrease, falling by around 50% from 29 TBq in 2006 to 15 TBq by 2011. However, it should be noted that some increases in discharges over the next few years cannot be ruled out depending on reprocessing throughput rates and clean-up of legacy facilities.

The trends in liquid discharges of key radionuclides from 2004-2011 are also presented in **Figure 6.5** below.

Figure 6.3 Liquid Discharges of total alpha and total beta from the Sellafield Site



Liquid discharges from the site are also authorised via the Factory Sewer. This is a minor outlet and discharges of total alpha, total beta and ^{3}H are several orders of magnitude lower than the reported discharges, and have remained relatively constant over the reporting period.

Discharges of liquid radioactive effluents from the Sellafield site are heavily dependent on the amount of fuel reprocessed, though there are also discharges associated with the clean-up of legacy wastes and decommissioning. There have been changes to the contributions to the recent annual discharges due to the improved management of legacy fuel pond stocks and associated pond water activities and discharges. This includes washing highly contaminated corroded fuel to remove the bulk of the activity source prior to returning to pond storage. This has led to a significant reduction of the average pond water activity.

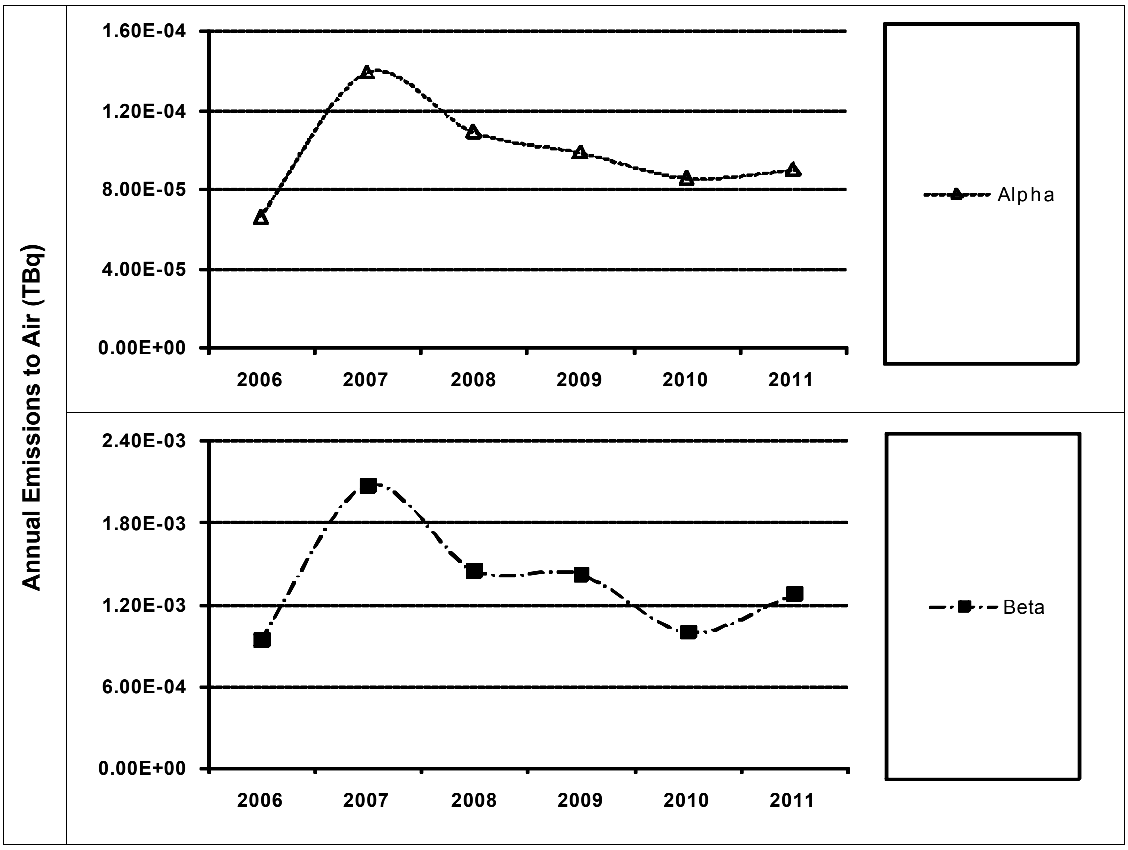
6.1.4 Aerial discharges relevant to the maritime environment

Radioactive aerial effluent discharges arise from ventilation air from process plants during operations associated with the receipt, storage, reprocessing and management of spent nuclear fuels, together with ventilation air from decommissioning projects.

Discharges to atmosphere are minimised through the use of HEPA filters (to reduce particulate activity), wet scrubbers (on streams where significant volatile activity is present) and other equipment such as electrostatic precipitators, packed beds, chemical clean-up systems, condensers and pre-heaters (to prevent condensation in the filters). Over the reporting period Sellafield Ltd has undertaken a programme of review and replacement of its HEPA filters across the site, to ensure that all operational HEPA filters comply with relevant standards on longevity.

In the period since 2006, emissions of most radionuclides to air have either decreased or remained relatively stable, as demonstrated by the trend in alpha and beta emissions in **Figure 6.4** below.

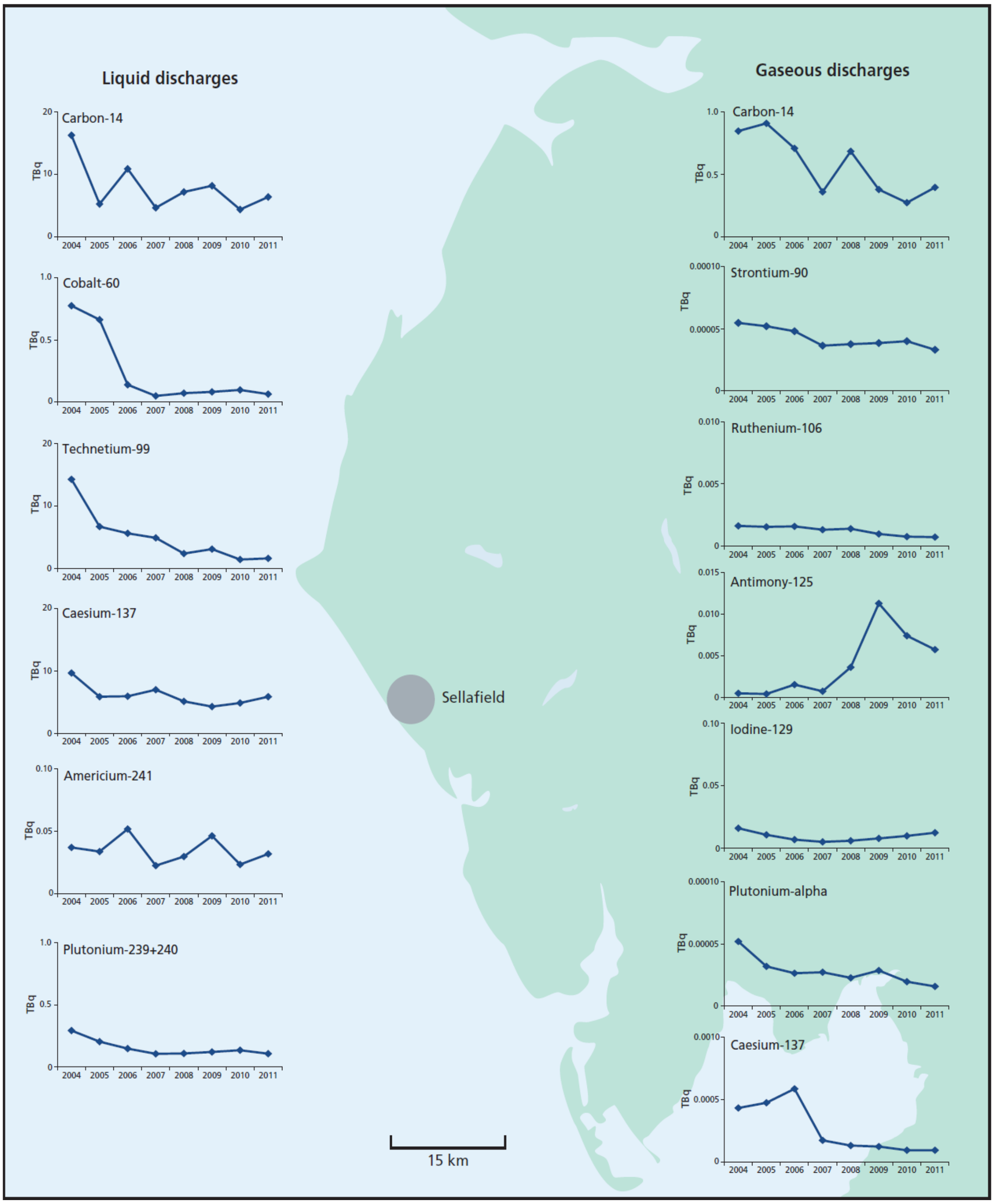
Figure 6.4 Annual Emissions of total alpha and total beta to Air from the Sellafield Site



Variations in the emission of some radionuclides, such as ^{3}H, are largely influenced by reprocessing rates on the site.

Figure 6.5 below illustrates the annual variations in discharges of key radionuclides in liquid discharges and gaseous emissions from 2004 – 2011.

Figure 6.5 Authorised discharges of gaseous and liquid wastes, Sellafield (2004-2011)



Overall, the discharges exhibit a declining trend over the reporting period, with the exception of the gaseous discharge of ^{125}Sb, which was released in greater quantities as a consequence of an increase in the reprocessing of higher burn-up Magnox fuel from the remaining operational Magnox reactors. The Environment Agency considers that continued reprocessing, rather than delaying or suspending reprocessing of this fuel, is the BPEO and in 2010 increased the site limit for gaseous discharges of ^{125}Sb accordingly.

6.1.5 Radiological impact of liquid discharges

The marine environmental monitoring programme around Sellafield covers the collection of data for a variety of species in a number of locations. There is an extensive environmental monitoring programme carried out around Sellafield. The primary objective of this programme is to produce an annual retrospective radiological dose assessment.

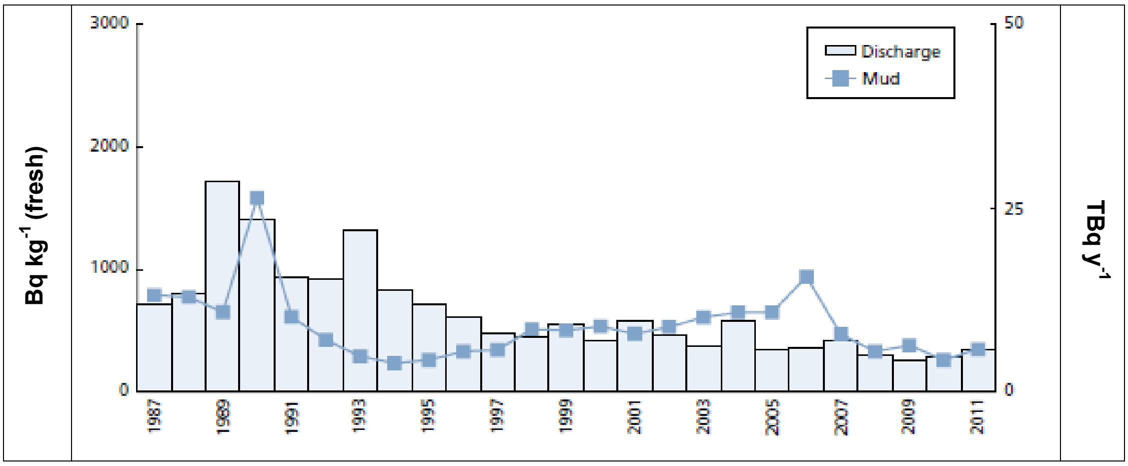
The Sellafield monitoring programme is reviewed frequently to ensure that it represents best practice in compliance with statutory requirements on the use of BAT in designing and implementing monitoring programmes. Improvements to sampling and analytical methods are also assessed and implemented when they represent best practice. Results from the monitoring programme and subsequent assessments are discussed briefly below, though much more information is provided in the annual RIFE Reports.

Radionuclide concentration in seafood and the environment

Concentrations of radioactivity in samples of seawater from the Sellafield area were generally similar to those of recent years, with most values being below detectable limits, with the exception of ^{3}H and total beta activity, which ranged from 220-710 Bql^{-1} and 10-14 Bql^{-1} (respectively) from 2006-2011. Concentrations of radioactivity in sediments have historically fluctuated with considerable decreases have been noted in the concentrations of both artificial and enhanced natural radionuclides over the last 2 decades, as demonstrated by the data for ^{137}Cs in **Figure 6.6** below.

Overall, concentrations of most radionuclides have decreased over the previous decades, largely in response to decreases in discharges. Concentrations generally continue to reflect changes in discharges, and over time periods, characteristic of radionuclide mobility and organism uptake.

Figure 6.6 Liquid Discharge of ^{137}Cs from Sellafield and Concentration in Mud at Ravenglass, 1987-2011



For many radionuclides, activity concentrations in seafoods have followed a decreasing trend from historical levels as demonstrated in **Figures 6.7 & 6.8** below, which illustrates the variations in the concentrations of ^{137}Cs and ^{99}Tc in plaice, lobsters and winkles for the period from 2001 to 2010. Full details of environmental concentration of other radionuclides around Sellafield are published in the annual RIFE Reports. Concentrations of ^{137}Cs, $^{239+240}$Pu and ^{241}Am in plaice, lobsters and winkles remained more or less constant over the period, except for anomalous spikes in the concentration of $^{239+240}$Pu and ^{241}Am in lobster registered in 2007 and 2008 respectively. The average concentrations of ^{14}C and ^{60}Co in all three organisms decreased during the reporting period - falling by around 30% and 70% (respectively) in lobster.

Figure 6.7 Liquid Discharges of ^{137}Cs and Concentrations in Plaice, Lobsters and Winkles near Sellafield, 2002-2011

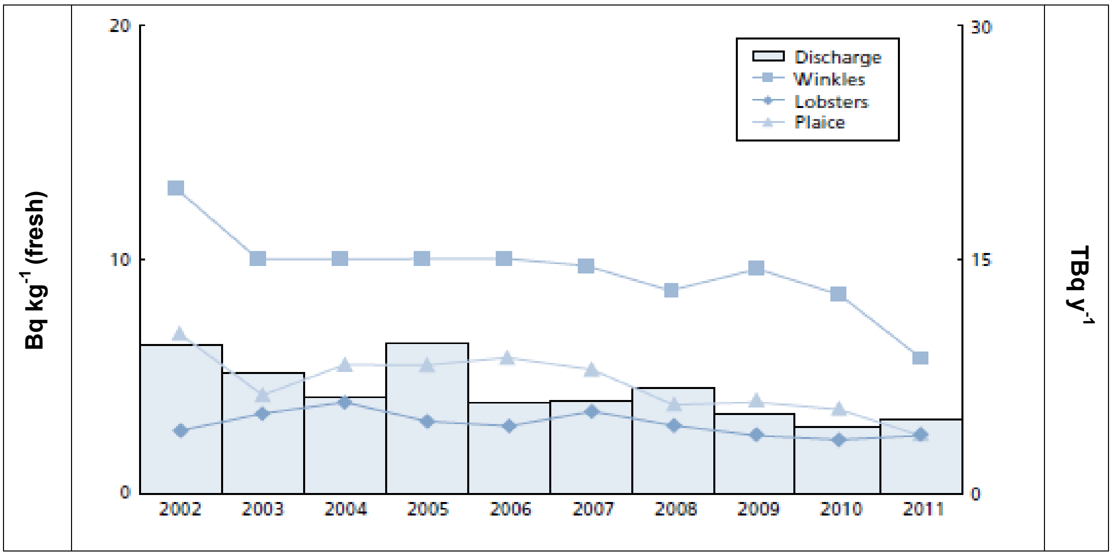
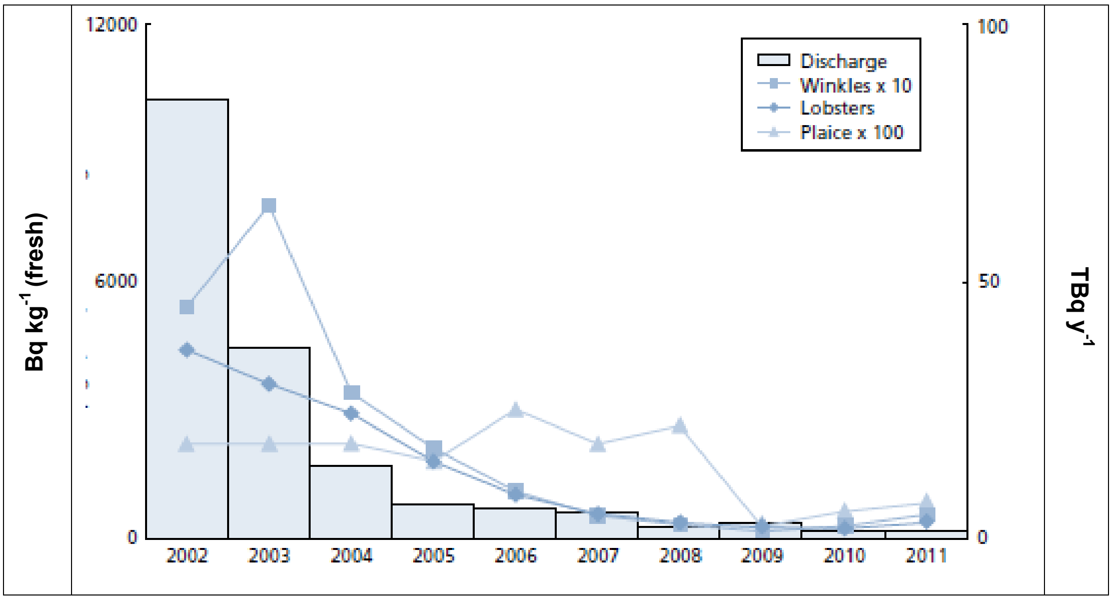


Figure 6.8 Liquid Discharges of ^{99}Tc and Concentrations in Plaice, Lobsters and Winkles near Sellafield, 2002-2011

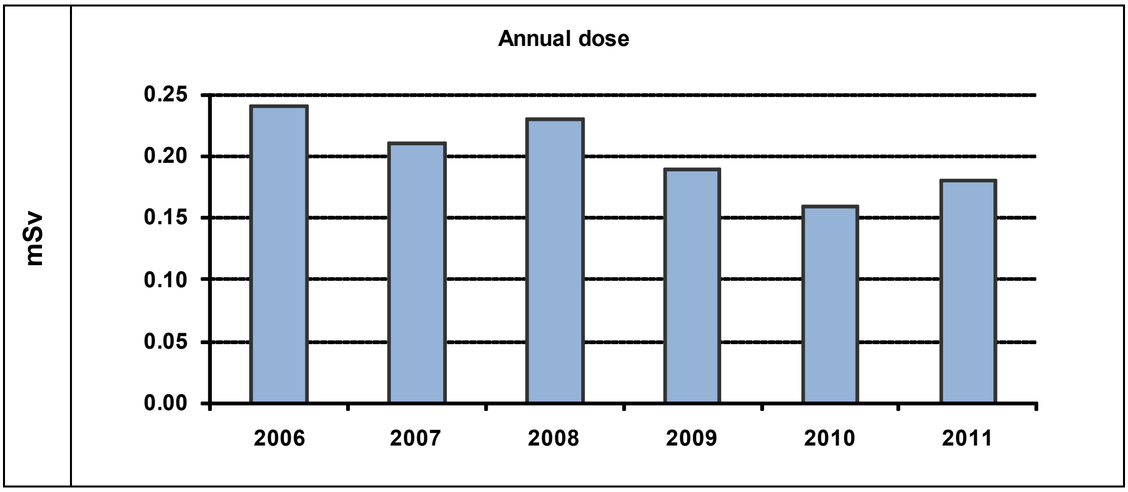


Doses to the public

The reductions in radioactive liquid and gaseous discharges from Sellafield over the last few decades have been substantial, such that doses to even the most exposed groups are now a small fraction of that associated with exposure to natural background radiation.

Doses to the representative person for marine pathways (identified as high rate consumers of fish and shellfish from the local waters of the Irish Sea, who also spend time on local beaches) are affected by the discharge profile, although they are also affected by variations in consumption habits and the resuspension of previously released radioactivity. The estimated annual dose to the representative person has shown a decreasing trend from 2006-2011 as shown in **Figure 6.9**.

Figure 6.9 Annual Total Dose to Local Seafood Consumers around Sellafield, 2006-2011[35]



A significant fraction of the consumption dose to the representative person from marine pathways derives from historic discharges (notably of the actinides). Whilst this cannot be quantified accurately, except by the use of complex modelling techniques, the contribution from historic discharges may amount to more than two-thirds of the total dose received.

Other reference groups of relevance to liquid discharges from Sellafield include houseboat dwellers on the Ribble River in Lancashire and stakenet fishermen in southwest Scotland. Estimated doses to these groups are published in the annual RIFE Reports. The effective doses to houseboat dwellers on the Ribble ranged from 130-160 μSv during 2008-2010. The recorded doses prior to 2008 were generally below 76 μSv and the increases from 2008 were largely due to increases in external dose from radionuclides (particularly ^{137}Cs) originating from Sellafield, deposited in intertidal sediments along the Ribble Estuary.

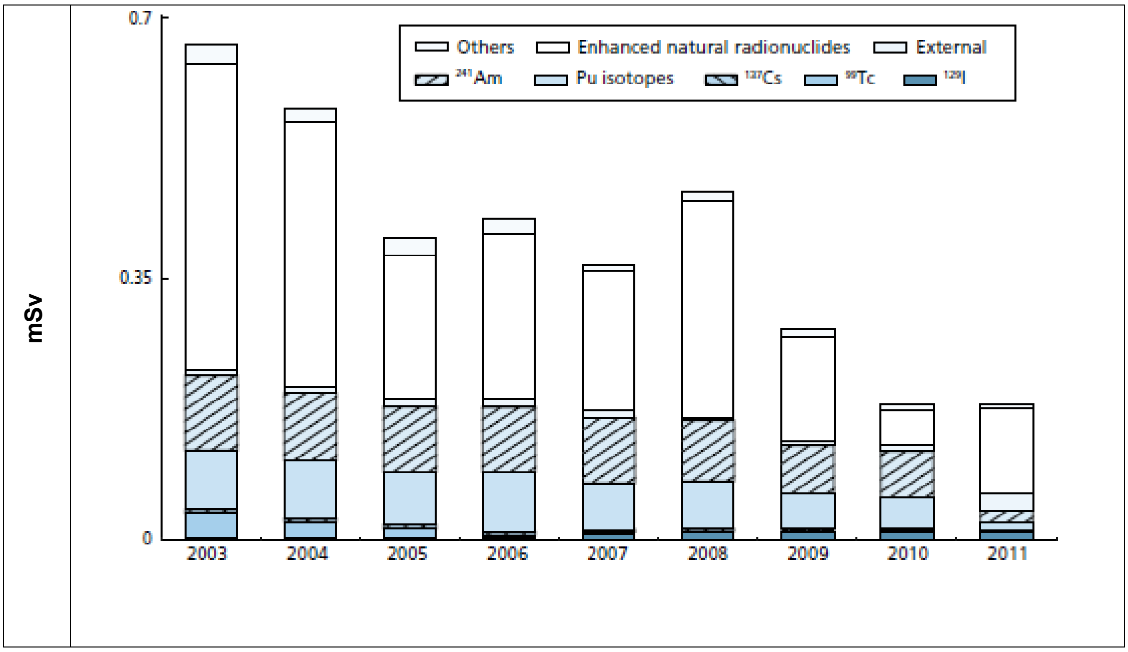
Doses to representative persons exposed mainly via terrestrial pathways generally remain at lower level, being well below 30 μSv for the whole of the period of 2008-2011.

Some crossover in pathways is recognised and consumers of local agricultural produce (particularly milk) may derive a fraction of their dose from radionuclides released to the marine environment and subsequently returned to land. It is not possible to determine this quantitatively, except by modelling.

The main pathways that contribute to doses to the local population from liquid discharges are: internal exposure from the consumption of seafoods (particularly fish and shellfish); 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. The total doses to the local population from all sources are well below the annual dose limit of 1000 μSv as demonstrated in **Figure 6.10** below.

35 Includes a dose component arising from external exposure

Figure6.10 Contributions to Total Dose from all Sources around Sellafield, 2003-2011



A component of the dose around Sellafield originates from historical discharges from a phosphate processing works at Whitehaven (decommissioned in 2002). Discharges from the phosphate works have resulted in an increase in the concentrations of naturally-occurring radioactive material in the environment around Whitehaven. The concentration of these ‘technologically enhanced naturally-occurring radioactive material’ (TENORM) have reduced in recent years. However, ^{210}Po has been found in seafood at levels above natural background and was estimated to contribute up to 60% of the dose received by high rate consumers of seafood in 2011.

Dose rates to non-human biota

A review has been recently carried out, of the Sellafield dose impacts on non-human biota since the last Natura 2000 review performed in 2004. All the dose rates examined (except for phytoplankton) were below the Environment Agency regulatory action threshold level of 40 Gyh^{-1}.

6.1.6 The application of BAT

Overarching management arrangements at Sellafield support the application of BAT in facilities and activities that are undertaken at the site. There arrangements operate in a tiered approach, to ensure that environmental issues are considered at all levels of decision making. This includes the following components:

- Development and implementation of Environment Cases for all operating plants and new project developments. Environment Cases require consideration of BAT by a process of options identification and assessment, to ensure that any associated discharges are minimised. Environment Cases are maintained by periodic review. Modifications to existing plant are also subject to full assessment of environmental issues such as how to minimise discharges as far as is reasonably practicable.
- Formally established committees are in place to identify and share environmental best practice (e.g. the Environmental Performance Committee and The Aqueous and Gaseous Waste Strategy Steering Group). SL also tracks developments in the application of BAT on other sites and in other industries, e.g. the Environment Agency Requirements Working Group (EARWG) to share and understand Learning From Experience (LFE).

- Sellafield has recently updated its effluent management strategy, taking into account current and future operations, with the aim of ensuring Government policy is implemented in the form of a deliverable plan. This is supported by an Overall Effluent Strategy and discharge forecasting tool, developed to model the impacts of different strategies on discharges to air and water. It will be of increasing importance in predicting discharges and identifying associated BAT discharge control arrangements as more of the site activities move to Post Operational Clean-Out (POCO), decommissioning and clean-up.
- Sellafield Ltd also supports a range of research and development work, to facilitate improved management of effluents. For instance, academic work has been supported to explore approaches to the modelling of colloidal filtration. The work is intended to support optimal operation of filters when challenged with colloid bearing streams. Another example is an investigation of the abatement of alpha and alpha bearing colloids from legacy waste streams. This looked at improving the understanding of abatement through existing plant (SIXEP) and included evaluation of advanced ion exchange media for alpha abatement.

Examples of the technological application of BAT in Sellafield’s management of liquid discharges are given in section 6.1.2 above in terms of major treatment facilities (e.g. SIXEP and the LETP). Notable improvements over the reporting period also include:

- Commencement of operation of a Local Effluent Treatment Plant (LETP) in the Pile Fuel Storage Pond (PFSP). The plant comprises sand-bed filtration and ion exchange abatement, and provides both significant reduction in pond water activity and final discharges from this pond, and also important abatement capability to support future fuels and retrievals work.
- Implementation of projects for best practice to exclude solids from aqueous discharge streams. These projects have built on existing solids exclusion arrangements at site, and range from implementing simple filtration techniques at source plants to extensive trials to underpin, optimise and potentially improve final filtration systems on effluent discharges.
- Recycling of filtrates from the processing of Salt Evaporator Concentrate through the EARP ‘bulks’ route to reduce overall discharges of ^{241}Am and ^{106}Ru. This move has been facilitated by the use of new consolidated discharge limits for EARP in the Environmental Permit (formerly separate limits were in place for EARP ‘bulks’ and ‘concentrates’). The limits are lower than the total of the previous individual limits for most nuclides, but the consolidated approach provides significantly increased operational flexibility to meet site hazard reduction obligations and the long term effluent strategy, along with enhancing the ability to implement BAT.
- De-canning and re-containerisation of a significant quantity of the corroded fuel inventory in the Fuel Handling Plant pond. This has minimised loss of activity into the pond water which in turn contributes to lower activity in discharges from this source. Similarly, improvements to pond water cooling and pH control in the Fuel Handling Plant have led to further reductions in pond water activity.
- Tighter Conditions for Acceptance have been imposed on pH and competing ion values for feeds from donor plants to SIXEP, to optimise SIXEP plant abatement performance. Additionally, R&D studies have been carried out to improve SIXEP performance and ensure that it will be able to deal with future feed challenges from decommissioning and clean-up activities. These studies include:
    - active column trials to assess the abatement performance of potential alternative ion exchange materials;
    - assessment of the potential for deployment of a third ion exchange bed;
    - plant trials of a pre-treated clinoptilolite ion exchange material.

6.1.7 Comparison with performance of similar plants world-wide

Due to the complex nature of operations and decommissioning activities on the Sellafield site, and recognising that many of the process plants are specially commissioned, 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. Due to the different processes involved, it is not possible make direct comparisons between liquid discharges from THORP and La Hague.

Nonetheless, in terms of process, the Environment Agency review of the Sellafield authorisation (now permit) 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.

During the reporting period, as discussed in the above section, Sellafield Ltd has continued to perform periodic reviews of developments in effluent technology, to support subsequent BAT assessments. Although not a direct comparison of performance against other plants in the world, this does involve reviewing best international practice. In addition R&D is on-going to support the development of effluent technologies for decommissioning operations. This is supplemented with a portfolio of sponsored academic research, all of which is coordinated by the SL centre of expertise for effluent technology.

6.2 Calder Hall

Radioactive liquid effluent discharges from the Calder Hall Magnox nuclear power station are controlled within the terms and conditions of the Sellafield site permit. The impact of discharges from Calder Hall is indistinguishable from other discharge streams. Calder Hall ceased operating in March 2003 and defuelling of reactor 4 began recently.

The majority of spent fuel previously discharged from Calder Hall has been reprocessed at Sellafield. Once removed from the reactor, the spent fuel is stored in the main Sellafield receipt and storage ponds for reprocessing. Discharges and abatement technologies described in Sections 6.1.1 and 6.1.2 are therefore inclusive of contributions from Calder Hall.

6.3 Windscale

Initially, in the period 1950-1957, the Windscale pile reactors were concerned with the production of plutonium for the UK atomic weapons programme. The reactors ceased operation after the Windscale fire in 1957. Later (1963-1981), the site undertook research into the development of the advanced-gas cooled reactor design including the operation of the prototype Windscale Advanced Gas Reactor (WAGR) and operation of a shielded facility for ‘post-irradiation examination’ of spent fuel and for various waste management activities. The WAGR ceased operation in 1981 and decommissioning activities commenced in 1982 – defueling of the reactor core was completed in 1983. The decommissioning of the reactor within WAGR was safely completed in May 2011.

The site licence for Windscale was transferred to Sellafield Ltd in 2008, integrating the Windscale and Sellafield sites. Liquid effluents from the Windscale site are transferred to the Sellafield site for treatment and subsequent discharge and are therefore included in the discharge data presented above.

6.4 References

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13) Sellafield Integrated Waste Strategy – Update to Version 2, June 2008.

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18) NDA (2012) The Magnox Operating Programme (MOP 9) http://www.nda.gov.uk/documents/upload/The-Magnox-Operating-Programme-MOP9.pdf

19) Environment Agency, SEPA, NIEA, and FSA, Radioactivity in Food and the Environment (RIFE), 2006 - 2011, CEFAS (2007 - 2012).

7. Research and development

The UK has four licensed nuclear research sites at Dounreay, Windscale, Harwell and Winfrith. The reactors located on these sites have been closed down and are at various stages of decommissioning. Harwell is owned by UKAEA (a Non Departmental Public Body) and leased to the NDA, whilst the remaining three sites are owned by the NDA. Harwell and Winfrith are operated by Research Sites Restoration Ltd (RSRL) under the management of Babcock International Group. The Dounreay site was operated by UKAEA until April 2008, and is now operated and managed by Dounreay Site Restoration Ltd (DSRL), a wholly-owned subsidiary of the Babcock Dounreay Partnership Ltd[36]. Windscale is located immediately adjacent to the Sellafield site and continues to be managed by Sellafield Ltd; this site is therefore discussed in Section 6. These sites are operated by the respective companies on behalf of the NDA.

A number of companies are tenants on some of these sites and hold separate authorisations/ permits to discharge radioactivity. The discharge arrangements for these companies are outlined in the relevant sections below.

Over the next 20 years, the main activities leading to discharges of radioactivity into the environment from these sites will be associated primarily with the decommissioning of redundant nuclear facilities. Future discharges will, therefore, depend on the decommissioning programme for each site, which is itself dependent on NDA funding for these sites.

During the reporting period, radioactive discharges from the research sector generally decreased as the decommissioning of research and prototype reactors reach advanced stages, and abatement is applied to the remaining discharges.

BAT (or BPM) is applied at all research sites by taking steps to ensure that the effluent management systems and controls are implemented effectively. These include:

- *Acceptance criteria*: The operator 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*: Mandatory procedures are enforced through audits 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 the 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

[36] A consortium of Babcock International Group, CH2MHILL and URS

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.

The operators each have an integrated management system in place, which satisfies the requirements of national and international standards. Each of the research sites has environmental management systems certified to ISO 14001 and work within quality assurance procedures that are ISO 9001 certified, and are regularly audited both internally and externally. All work, including record keeping and management of processes, are carried out in accordance with these procedures. Internal and external analytical laboratories are used for the analyses performed in support of discharge measurements and environmental sample analysis.

Significant milestones achieved during the reporting period at the research sites are summarised in the following table.

Table 7.1 Summary of Progress in the Decommissioning of Research Sites

Site	Decommissioning status
Dounreay	Shaft isolation was completed in September 2008. A grout curtain was installed around the shaft, attenuating groundwater ingress to the shaft which is subsequently pumped to LLLETP[37] Destruction of NaK coolant at the Dounreay Fast Reactor was completed in March 2012.
Harwell	The second Retrieval Machine (RM2) was commissioned and put in operation in 2009 and has been used to significantly speed up the rate at which waste cans from storage holes can be recovered. Building 462 waste recovery has resulted in processing 2,500 cans of ILW for transferral to interim storage in the Vault Store. A major programme to decommission and repackage redundant glove boxes from the site radiochemistry facility has been completed. Radium contaminated waste conditioning has continued with wastes packaged ready for long-term storage. The radiochemistry facility entered care and maintenance in March 2012. Remediation of part of the eastern end of the Harwell site has been completed, opening up land for de-licensing and de-designation. Post operational clean out of the Active Handling Plant at Harwell has been completed, enabling the facility to move over to care and maintenance.
Winfrith	Processing of ex SGHWR[38] sludges by Winfrith Encapsulation Treatment Plant (WETP) decommissioned and demolished. Completion of the A59 decommissioning and demolition project

7.1 Dounreay

This site was previously concerned with research and development of fast reactor technology, including reprocessing of fast reactor fuel. There are now no reactors operating. The Prototype Fast Reactor (PFR), the last of the three reactors, ceased operation in March 1994. The older Dounreay Fast Reactor (DFR) ceased operations in March 1977. The reprocessing facilities ceased operation in 1996, with reprocessing formally being terminated in 2001. The focus for the site is now on decommissioning and waste handling (including irradiated fuel), operation and further construction of waste treatment and storage facilities and, finally, site restoration. There have been reductions in the amount of radioactivity discharged to the environment. DSRL has

[37] Low level liquid effluent treatment plant

[38] Steam generating heavy water reactor

applied for a new multi-media authorisation to reflect the fact that it is no longer an operational site: the requested limits are generally lower than those in the existing authorisation.

7.1.1 Sources of liquid effluent

The principal radionuclides discharged are: ^{3}H, total alpha, total beta (excluding ^{242}Cm), ^{90}Sr, and ^{137}Cs. Liquid alpha and beta discharges are mainly associated with the decommissioning of the reprocessing facilities and fuel cycle areas. Liquid ^{3}H discharges are mainly from the dissolution and destruction of alkali metals (sodium and potassium (NaK)) formerly used as fast reactor coolant.

Since 2010, destruction of the bulk liquid sodium coolant from the DFR was progressed (and completed in March 2012). This process involved treatment of NaK metal with water under a blanket of nitrogen to create a sodium hydroxide solution that is subsequently neutralised with nitric acid. The resultant solution of sodium salt is contaminated with various fission and activation products, the principal examples of which were: ^{3}H, ^{22}Na and ^{137}Cs.

7.1.2 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. The high activity liquid wastes from past reprocessing will be immobilised in cement for disposal as solid ILW.

Before completion of DFR bulk sodium destruction operations, the aqueous solution associated with these operations was treated by filtration and passage through ion exchange material 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 of a 600 metre long liquid waste discharge pipeline in the 1950s. The Government agreed with UKAEA that the waste should be retrieved, and conditioned for long-term storage and final disposal. Adventitious groundwater leaking into the Shaft is pumped to the site’s liquid discharge system. Occasionally, higher levels of radioactivity have been found in the pumped effluent from the Shaft. An ion exchange plant was installed in 2000, which is brought into operation in the event of high levels of activity being detected. In 2007/2008 the rock structure around the Shaft was successfully sealed with grout with a corresponding decrease in groundwater ingress in to the Shaft. The attenuated groundwater is subsequently pumped to the Low Level Liquid Effluent Treatment Plant (LLLETP).

The design and operation of LLLETP allows for the settlement of any entrained particulate, with the effluent being pumped through a 50 µm filter before discharge to sea; the use of ion exchange columns at the DFR has achieved a ^{137}Cs decontamination factor in excess of 1 million. The clean out of the settlement tanks associated with the Dounreay Material Test Reactor has involved using pond clean-up units to filter out any sludge before the effluent is passed through ion exchange columns and a 1 µm filter prior to sentencing to LLLETP via the Low Active Drain.

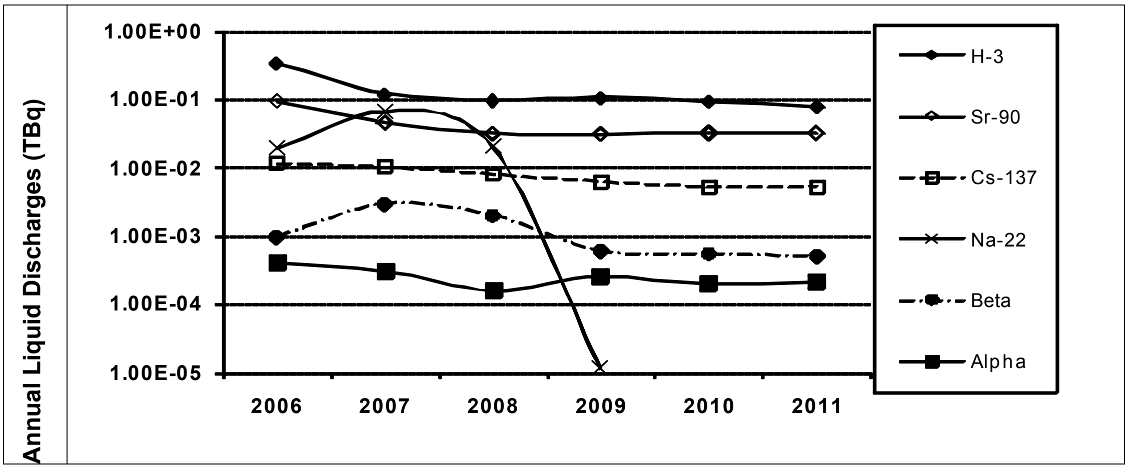
Prior to discharge of effluents to the site active drain system and subsequently to the LLLETP, procedures are in place to sample, analyse and approve liquor movements where this is practicable. This analysis allows trend monitoring of cumulative discharges and comparison with internal limits and is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

HEPA filters are used to minimise discharges to atmosphere with pre-filters being installed on building ventilation extract grills to reduce the amount of inactive dust entering active ventilation systems.

7.1.3 Trends in discharges over the 2006-2011 period

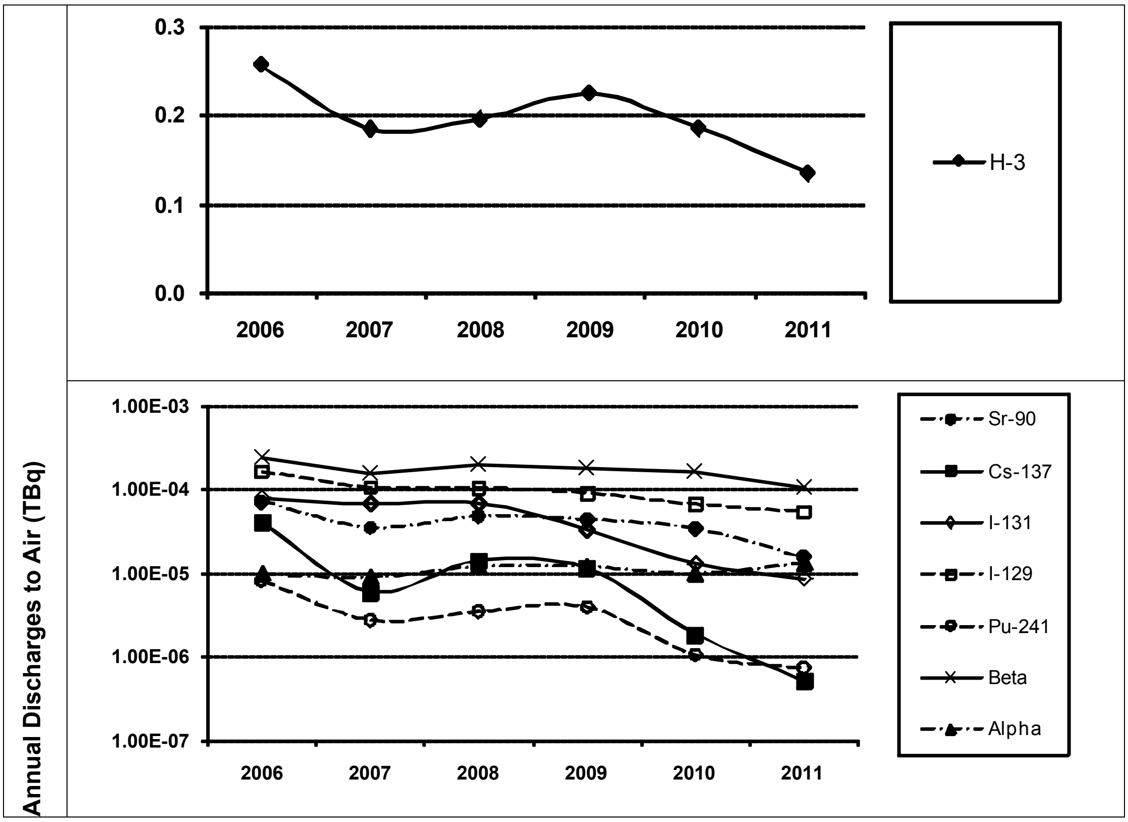
Discharges of radioactive liquids followed a general downward trend during the reporting period with the exception of total beta which increased in 2007 as illustrated in **Figure 7.1** (below). In all cases, the liquid discharges are a small fraction of the authorised limits. Sodium is no longer discharged following the completion of its destruction at the PFR.

Figure 7.1 Annual Liquid Discharges from Dounreay



The annual emissions to air from the site's Fuel Cycle Area are illustrated in **Figure 7.2**. These have remained fairly constant throughout the reporting period, with noticeable decreases in emissions of ^{137}Cs, ^{241}Pu and isotopes of Iodine from 2010. A new ventilation extract facility was installed at the Fuel Cycle Area which may have contributed to the observed decreases in emissions during 2010-2011.

Figure 7.2 Annual Discharges to Air from Dounreay



7.1.4 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. Representative environmental monitoring data are presented in the annual RIFE Reports.

Samples are collected from a range of marine environmental media as part of the site's Environmental Monitoring Programme. Where a sample exceeds a pre-agreed activity level the regulator (SEPA) is notified. The notification levels are both sample and radionuclide specific. These levels represent 1 per cent or less of site-defined Derived Limits[39] . Notification levels are also set for terrestrial samples.

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 600 m offshore. Crustaceans are collected from the seabed near to the outfall point as are samples of seabed sediment and seawater. The results for the marine samples generally show low concentrations of radioactivity in recent years, often below detection limits.

The main exposure pathway to members of the public arising from liquid discharges from the Dounreay site is from the collection and consumption of winkles from the vicinity of the site. Doses are calculated from discharge information and the results are cross-checked against the results of environmental sample analyses. The sample analysis results include contributions from historic discharges and from discharges from other sites, weapons tests and Chernobyl fallout. The effective dose to the representative person for liquid discharges (based on adult consumers of fish and shellfish) increased from <5 µSv in 2006 to 11 µSv in 2009, and then dropped to 6 µSv in 2010; in 2011, the corresponding dose was 10 µSv These variations in dose are attributed to fluctuations in gamma dose rates over the sediment of local beaches. Other exposure groups 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 representative person, identified above.

Between 2007 and 2011 the total dose to the representative person[40] from all pathways and sources of radiation decreased from 59 µSv to 47 µSv largely due to lower levels of ^{137}Cs in venison in 2011 (the most consumed game meat in the area). A large proportion of this dose can be attributed to ^{137}Cs which is present in the environment from a number of sources, such as Chernobyl and weapons testing fallout, and historic discharges together with authorised releases from the site.

7.1.5 Particles on the Dounreay foreshore

Previous UK submissions 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 1985, 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

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[39] Relating activity concentrations in media to the dose limit using dose conversion factors from the IAEA Safety Series No. 115 and local Habits Survey Results.

[40] Adult consumers of game meat. The dose for 2011 was inferred from the 2010 data.

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;
- the behaviour of particles in the marine environment and their distribution, together with modelling of potential particle transport.

Following publication of the Fourth DPAG report, SEPA, DSRL and the Scottish Government decided that a new group was required to consider the particle recovery operation at Dounreay. The Particles Retrieval Advisory Group (Dounreay) was established in May 2009 to provide expert scrutiny of information generated during the implementation of a BPEO study by the targeted retrieval of off-shore particles. This group reports to SEPA and DSRL on an annual basis[41].

7.1.6 The application of BAT

As new decommissioning and waste treatment projects are planned, abatement of potential discharges at source is used where practicable, to reduce the requirement to abate in the discharge route.

Further ^{3}H recovery was not considered to be BPM in NaK destruction as the high salt content in the effluent and the presence of gamma emitting radionuclides made these liquid effluents unsuitable for treatment with currently available techniques.

A BPEO study was undertaken and published in 2003, to underpin the Dounreay Site Restoration Plan, in which it was concluded that evaporation of effluent and solidification of the residue would be neither practical nor cost effective (estimated to cost £400 million for very little benefit over the rest of the Dounreay Lifetime Plan). An updated BPEO was submitted to SEPA in June 2009. The updated BPEO concluded that the current waste management strategies for the gaseous and all RHILW[42] waste streams did not require further consideration along with most of the CHILW[43] waste streams. It was also concluded that the majority of the LLW, HVLA, Clean[44] and Exempt waste streams did not require review. The following waste streams were identified as requiring further assessment:

- Solid CHILW Graphite – THTR[45] Graphite and Activated Graphite.
- LLW Sludge - LSA[46] Scale, Granular, and Putrescible.
- Clean and Exempt Hazardous Sludge – Putrescible.

Two bespoke Medium Volume Combination Tankers were purchased in 2010 and 2011 for the purpose of cleaning gullies in the Fuel Cycle Area (FCA) and General Site Areas (GSA), to reduce the ingress of standing water into the Low Active Drain ducts in these areas. The tankers also

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[41] http://www.sepa.org.uk/radioactive_substances/decommissioning/dounreay/particles_advisory_group.aspx (Accessed 26/10/2012)

[42] Remote handled intermediate level waste

[43] Contact handled intermediate level waste

[44] Clean waste streams refer to non-radioactive wastes.

[45] Thorium high temperature reactor

[46] Low specific activity

carried out cleaning operations in the northern part of the site adjacent to the coast. Trace radiological cleanings were discharged to LLLETP. There is now a regular cleaning schedule for FCA and GSAs to maintain the non-active status of these drains.

Further improvements were made in the diversion of off-site water that had previously run onto the Dounreay Site. This had the effect of reducing the loading on the Non-Active Effluent (NAE) and ingress to the Low Level Waste Pits, which in turn discharge to LLLETP.

Radiologically contaminated drains in the NAE Drainage System in the FCA change room were isolated, sealed, and bypassed in 2011.

7.1.7 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 worldwide, DSRL 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 contained more ^{137}Cs (due to fuel and coolant contact as a result of fuel pin cladding failure) than similar plants elsewhere such as the US Department of Energy's EBR2 operated by Argonne National Laboratory; and the French fast breeder reactors Phenix and SuperPhenix.

Due to the often highly specialized requirements, new systems are determined by various means of optioneering (e.g. in the form of HAZOP 1 and 2 methodologies).

7.2 Harwell

Historically, the Harwell site included several research reactors, the most significant of which were the Harwell materials testing reactors. The last of these ceased operation in 1990. Current activities include: decommissioning of research reactors; a radiochemical facility and auxiliary facilities; and the management of low and intermediate level wastes arising from these decommissioning activities.

All low level liquid discharges are mainly made via a pipeline to the River Thames, and subsequently the Thames estuary, following treatment and monitoring.

7.2.1 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 Science and Innovation Campus.

7.2.2 Liquid effluent treatment and discharges

Liquid effluents are produced from several buildings on the nuclear licensed site, many of which were previously used for different radiological research purposes and are now being decommissioned. A few buildings still house active operations associated with waste treatment. In addition, a number of buildings are leased from RSRL by tenants who undertake commercial activities resulting in the production of radioactive effluent which is discharged to the RSRL 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.

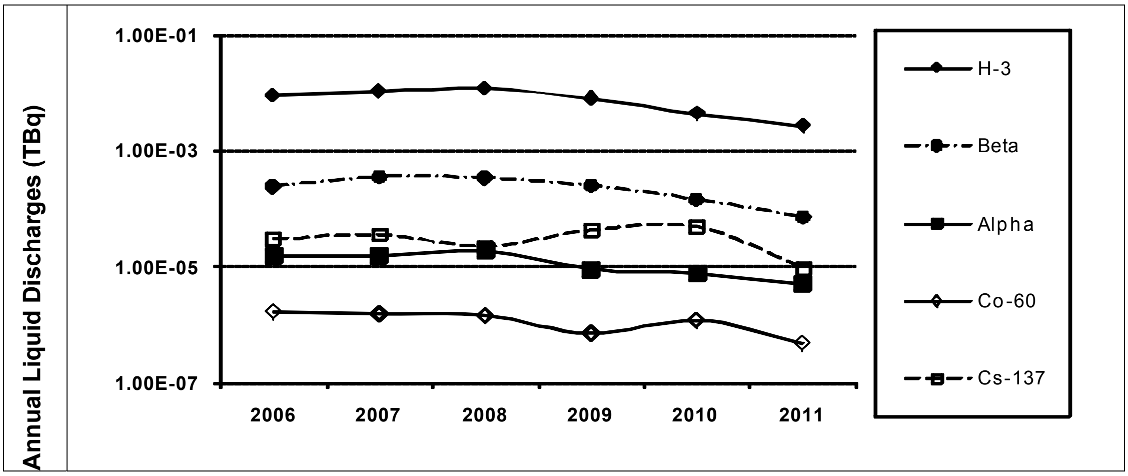
For liquid effluents, current treatment processes include chemical flocculation treatment for precipitation of alpha and beta activity followed by filtration using compact filter cartridge systems for removal of precipitate. The filtrate is pumped into a post-treatment holding tank, sampled to confirm 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 discharged activity is calculated). The slurry is pumped into a settling tank, allowing further thickening of solids prior to sampling and cementation.

The volume and activity of materials discharged have reduced during the reporting period as a result of progress in the site's decommissioning programme. For instance, volumes of liquid discharged declined from 16,000 m^3 to 4000 m^3 in the period 2008-2011. Consequently, the LETP has become inappropriately large for the quantity of effluents now generated on the site and will be decommissioned in the near future.

7.2.3 Trends in discharges over the 2006-2011 period

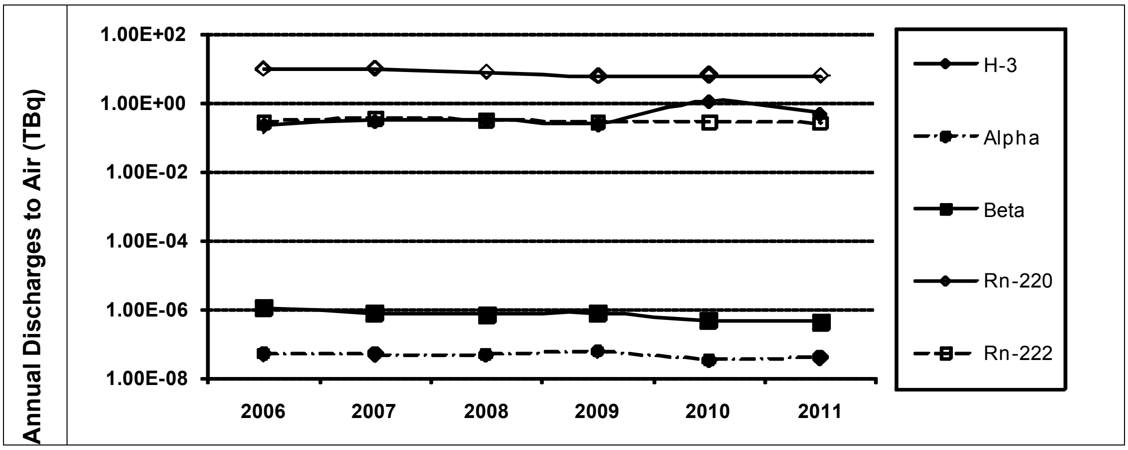
The volume of effluents discharged from Harwell has decreased considerably during the reporting period. Similarly, discharge of all radionuclides have shown a general decreasing trend, with the exception of discharges of ^{137}Cs, which has been variable and has shown marginal increases from 2008 as illustrated in **Figure 7.3** (below).

Figure7.3 Annual Liquid Discharges from Harwell



Emissions to air have remained relatively steady over the reporting period, as indicated in **Figure 7.4**. There was a slight increase in discharges of ^{3}H during 2010 due to a short-term increase from reactor decommissioning activities at the beginning of the year, coupled with an increase of the levels assessed for unventilated areas in the solid waste treatment facility. This retuned to levels registered in previous years during 2011.

Figure 7.4 Annual Discharges to Air from Harwell



7.2.4 Radiological impact of liquid discharges

RSRL makes discharges to the middle reaches of the River Thames which then flows into the Thames Estuary. No marine monitoring is undertaken. Samples taken from the Thames region cover radionuclides in fish, lilies, water and silt. Activity concentrations of radionuclides in environmental media are typically between 0.01% and 1% of the Generalised Derived Limits (GDLs) published by the Health Protection Agency (HPA, 2008). In the case of silts, levels are around 5-10% of the GDLs for the case of ^{137}Cs in silt close to the liquid discharge outfall but remain closer to 1% for all other locations. Activity concentrations of all other radionuclides are below 1% of GDLs at all locations.

RSRL has identified anglers as the representative person for modelling and assessing the impact of liquid discharges to the Thames Estuary. Modelling includes consideration of consumption of fish and exposures via occupancy. Pathways are added together where applicable, e.g. consumers of fish are also assumed to spend time along the river bank. Modelling includes effects from past discharges. The resulting estimated effective doses to anglers from this site have remained below 10 µSv throughout the reporting period. The total dose to the most exposed group from all sources ranged between18-26 µSv during the period from 2007-2011, most of which is attributed to direct radiation from the site.

7.2.5 The application of BAT

Current radionuclide removal rates vary due to the effluent composition differing from batch to batch. However, 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).

Current arrangements are for a targeted chemical treatment of effluents, based on laboratory tests undertaken on a representative sample of effluent from the delay tank. This allows the most effective chemical treatment to be subsequently applied to the tank contents. Any chemical treatment is followed by settling in a final discharge tank.

RSRL is now planning to install a small and compact treatment plant that will incorporate an evaporation stage and cementation of residuals, if feasible. This plant is currently expected to become operational in 2013. Key target nuclides would be ^{137}Cs and ^{90}Sr, but the process would be equally efficient for all radionuclides. According to manufacturers' specifications, decontamination factors could be as high as 99.999%, although the RSRL is currently assuming a value of around 99.9%. As a by-product of this process, tritium in the liquid stream would be transferred in the evaporation process to a condensate stream, which would then be discharged to local sewer course.

Residues from the treatment of liquid effluent would be subject to cementation, such that the removal fraction should approach 100% for the low level 'treatable' effluent stream. Under these circumstances, there would continue to be large volume/low-activity effluent streams for which no treatment is viable, because the activity component is too small. However, these will also reduce in magnitude and are planned to be discharged (under permit) to the Didcot Sewage Treatment Works (DSTW) along with the evaporator condensate, rather than to the River Thames. This will facilitate the closure of discharge pipeline and decommissioning of the LETP.

7.2.6 Comparison with performance of similar plants world-wide

There are difficulties in comparing the performance of the treatment plant with other plants since decontamination factors achieved are highly dependent on input concentrations. However, the general techniques applied are consistent with those used at other facilities.

Comparisons on expected performance of the proposed evaporator at Harwell with equivalent evaporators in nuclear applications elsewhere are not readily available. However, the choice of evaporator was made after reviewing those in use elsewhere in the nuclear industry (e.g. the AWE evaporator) and some industrial evaporators from the non-nuclear sector.

7.3 Winfrith

Historically, this site was concerned with research to support reactor development, fuel manufacture and waste treatment and storage, including operation of the Steam Generating Heavy Water Reactor (SGHWR). All test reactors were shutdown prior to 1995. A part of the site was sold to English Partnerships (now ZOG) in 2004. The current focus of work on the site is the decommissioning of remaining reactors and supporting waste management operations. All liquid discharges are made via pipelines to the English Channel.

7.3.1 Sources of liquid effluent

Current operations at Winfrith are concerned primarily with decommissioning activities. Discharges from this site therefore depend on the decommissioning programme. Tenants on the RSRL Winfrith Site transfer liquid waste to the RSRL active liquid effluent system. The principal radionuclide discharged is tritium; a significant component of which arises from the waste processing work of a tenant (Inutec, formerly WMT Ltd).

7.3.2 Liquid effluent treatment and discharges

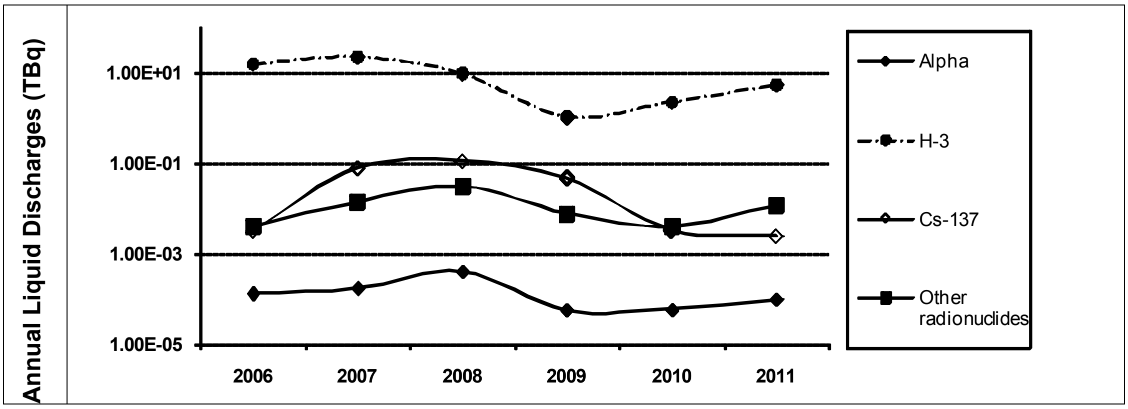
In accordance with RSRL procedures, the volume and radioactive content of waste arisings are minimised at source and by the application of BAT. Liquid wastes at Winfrith are not treated, with the exception of pH adjustment, prior to discharge.

Active process effluent is isolated in a tank and sampled for pre-discharge analysis. The pH level is modified to fall within the permitted range. Repeat sampling and analysis is carried out until the pH criterion is met. Additional analysis is carried out to measure: gross alpha, gross beta, and tritium activities, free chlorine content, suspended solids content and chemical oxygen demand. If the results are acceptable, the effluent is mixed and, prior to discharge, additional samples are taken for post discharge analysis.

7.3.3 Trends in discharge over the 2006-2011 period

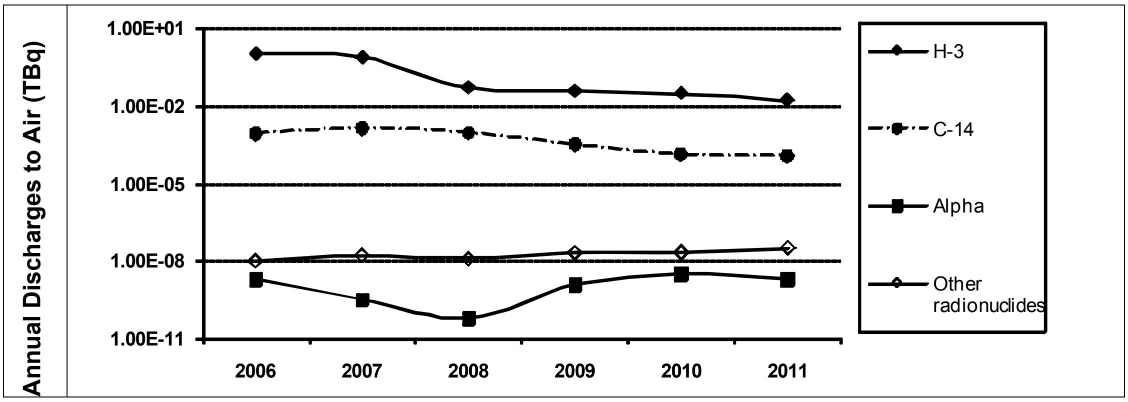
Liquid discharges and atmospheric emissions from Winfrith during the reporting period are illustrated in **Figures 7.5** & **7.6** below. Discharges of radionuclides from Winfrith remain low and, with the exception of ^{3}H, have decreased steadily since 2008. It should be noted that these discharges contains a significant active component received from a tenant (Inutec Ltd) who discharge to the RSRL Active Liquid Effluent System (under transfer permit granted by EA). All discharges are well within permitted limits.

Figure 7.5 Annual Liquid Discharges from Winfrith



Emissions of ^{3}H and ^{14}C to air have steadily decreased during the reporting period as demonstrated in the **Figure 7.6** below, whereas emissions of other radionuclides have remained relatively stable during the same period. Discharges of alpha activity to air declined from 2006-2008, but has shown an increasing trend since then. This apparent increase is largely attributable to the use of more sensitive equipment to count filter papers from 2009.

Figure 7.6 Annual Discharges to Air from Winfrith



7.2.4 Radiological impact of liquid discharges

RSRL undertakes environmental monitoring in the vicinity of the Winfrith site and representative environmental concentration data collected over the reporting period can be found in the annual RIFE Reports. Concentrations of radionuclides in the marine environment have largely remained at the low levels found in recent years. Gamma dose rates were difficult to distinguish from natural background.

The total dose to the representative person from all pathways and sources of radiation remained at <5 μSv throughout the reporting period.

7.2.5 The application of BAT

All activities that have the potential to generate radioactive wastes are subject to BAT assessments. These assessments identify the methods by which production of radioactive waste is minimised, in accordance with the requirements of the site permit. Techniques that are not adopted are also identified and the reasons for their non-selection are recorded.

Discharges to sea are very small and have remained so throughout the reporting period; nonetheless RSRL continue to apply BAT.

During the reporting period a clarifier was installed at the Active Liquid Effluent System. The clarifier contains lamella inclined plates which allow the removal of entrained solids from the aqueous phase by sedimentation. The system also has a multi-layer pressure filter installed in series to further remove finer solids before the effluent is discharged. This system became operational in July 2011.

The principal radionuclide discharged is tritium. As noted earlier, the discharges recorded and reported by RSRL Winfrith (particularly tritium) contains a significant active component received from a tenant (Inutec Ltd) who discharge to the RSRL Active Liquid Effluent System (under transfer permit granted by EA). 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 Plant (WETP) was constructed to solidify SGHWR sludge waste by cementation thereby allowing decommissioning of the External Active Sludge Tanks (where the sludges originate) and ensuring environmentally responsible storage pending final disposal. The recovery and encapsulation of the SGHWR sludges was completed in 2010, after which the WETP began decommissioning.

7.2.6 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 worldwide. RSRL does, however, maintain a watching brief on international best practice in this field.

In addition, RSRL is a member of the Environment Agencies Requirements Working Group (EARWG) which is a cross industry group with a joint interest across the industry for the management, disposal and discharge of radioactive waste. The output from this group is a production of a database which contains options for radioactive waste management (some non-radioactive wastes are also considered) detailing how and where these technologies have been used. This resource is used to feed in to the BAT assessment process.

7.4 References

1) HPA (2008), Documents of the NRPB, Generalised Derived Limits for Radioisotopes of Hydrogen, Carbon, Phosphorus, Sulphur, Chromium, Manganese, Cobalt, Zinc, Selenium, Technetium, Antimony, Thorium and Neptunium, HPA, Chilton.

2) Environment Agency, SEPA, NIEA and FSA (2006-2011). Radioactivity in Food and the Environment, 2006-20011. RIFE (11-17), CEFAS.

8. The development and application of BAT

The UK regulatory framework requires Best Available Techniques to be used to minimise activity in radioactive discharges to air and to water from nuclear facilities (BPM/BPEO in Scotland). The UK regulators ensure that these requirements are met via conditions in the permits and authorisations that they issue to operators, and by programmes of inspection and audit of the operator's facilities. The regulatory controls require that BPEO assessments are undertaken to inform the application of BAT or BPM to limit the activity of waste discharged, as described in Section 3. Furthermore, the way in which discharge authorisations/permits are applied and reviewed places a continuing pressure to improve technologies. Thus, BAT, or BPM, as defined in the UK, together with the way in which these concepts are applied, delivers a level of discharge control that is at least consistent with that implied by BAT, as defined by OSPAR.

Since the last report, the UK Strategy for Radioactive Discharges has been expanded and consolidated with the aim of ensuring, among other things, that the objectives of the OSPAR Strategy with regard to Radioactive Substances are adhered to. The authorisations/permits to dispose of radioactive substances continue to be periodically reviewed in a transparent, consultative and integrated approach. The decision and explanatory documents associated with authorisations/permits are generally available on the environment agencies' websites and demonstrate the level of detail underlying the consideration of different abatement technologies and the corresponding discussions between the operator and authorising authority.

An additional condition is generally included (implicitly or explicitly) in these authorisations/permits that require operators to keep abreast of new abatement and treatment technologies (and report within stipulated timescales). This has led to broad discussion on such issues and the establishment of a nuclear sector inter-industry group, the Environment Agencies Requirements Working Group (EARWG), which was established in 2003. The work of the group is included on a web-based data base[47].

The abatement technologies under development and in use in the UK were summarized in our previous report, 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

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[47] The database is available at http\\ www.rwbestpractice.co.uk.

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 uses 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, ion exchange resin 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 also form part of the EARP plant

8.1.2 Caustic scrubbers

Carbon-14 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. Carbon-14 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 the 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 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, clinoptilolite, 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.

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 particle density, 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 use 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.

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 Conclusions

Progress in the application of BAT in the UK's nuclear facilities is clearly demonstrated in this report, specific examples of processes and waste management activities currently being pursued:

8.2.1 Fuel Manufacture

- UUK operations at Capenhurst are anticipated to continue and will include new processes to address which the construction of a centralised waste management facility is under consideration.
- SFL at Springfields have undertaken a number of initiatives aimed at reducing radioactive waste arisings, including the successful implementation of a system to reduce the usage of filters at the Enriched Uranium Residues Recovery Plant (EURRP), thus reducing the amount of treatment required through Nitric Acid Wash facility and consequent discharges to the Ribble Estuary. SFL has also installed a humidrier system to replace the centrifuge employed to treat contaminated water from floor washing and decontamination activities within the Oxides Fuel Complex. The humidrier system uses warm air to evaporate water, leaving behind slurry which is treated at Residue Reprocessing Plant.

8.2.2 Power Generation (operational)

- Discharge control management system applied at AGR sites has evolved over the years and measures to further reduce discharges are continuously reviewed and remain under consideration. These include measures to reduce carbon deposition on internal reactor surfaces, which can result in the fuel over-heating and enhanced levels of fission products into the coolant, which are then discharged. Two approaches have been adopted to minimise this:

  i. A revised fuel design (robust fuel) has been implemented to minimise the risk of fuel failure through over-heating. Robust fuel is being introduced into reactors through their normal refuelling programme; it may take up to 14 years for reactor inventories to be completely replaced.

  ii. Injection of carbonyl sulphide (COS) into the primary coolant to inhibit the deposition of carbon. Although this will result in some increased discharges of ^{35}S, both in gaseous and aqueous form, any resulting impact will be trivial, and more than outweighed by the positive effects of preventing carbon deposition.

- At Sizewell B (the only PWR currently operating in the UK) relevant and reliable systems are also in place to manage discharges. The optimum coolant chemistry for each fuel cycle is reviewed and improvements are made accordingly. The presence of dissolved gases (oxygen and nitrogen) in the demineralised water is strictly controlled in order to reduce production of ^{14}C and ^{16}N within the system. Following review, secondary neutron sources were removed to eliminate that source of ^{3}H from discharges.
- Recent projects at operational Magnox sites include the re-lining of liquid effluent monitoring tanks at Oldbury. Current engineering studies are also looking at optimising the performance of sand pressure filters and liquid effluent monitoring equipment. Filter catchpots have been introduced to the site drainage system prior to the active effluent treatment plant to segregate lower activity liquid sludge before it becomes cross contaminated with higher active liquors. At Wylfa focusing on water usage has also led to improvements in leak management, which has reduced volumes entering the active aqueous effluent streams.

8.2.3 Power Generation (decommissioning)

- At Sizewell A, plant modifications have been carried out to modify or update operational systems, such as the replacement of the two settling tanks on site with the Wash collection Tank. Back-washing of the Effluent Treatment Sand Pressure Filters is now based on the differential pressure of the filters, which reduces the frequency of the back-washing and therefore decreasing the volume of effluent to be discharged.

- A BAT study was undertaken at Dungeness A to determine the appropriate use of the dry air compressor, now that fuel is no longer in place. This has resulted in the intermittent rather than continual use of this equipment, leading to a reduction in the discharges of ^{3}H and ^{14}C from the site. Pond temperature and pH are controlled to optimum conditions to prevent corrosion of the fuel and leaking fuel is dispatched as soon as practicable to reduce ^{137}Cs leakage into the ponds. The active effluent discharge line was also recently extended into the English Channel to improve the mixing and dispersion of effluent in the marine environment.
- At Bradwell the pond water treatment plant management and operation changed in 2006 as all fuel was removed from the ponds; the result was observed in the reduction of liquid discharges. During the cleaning and draining of the cooling ponds, several abatement systems were trialled including: electro-coagulation, hydrocyclone filtration and polymer precipitation. However, none of these systems were fully implemented at the site due to the low success in abatement and the cost of full implementation on a decommissioning system. Currently, 5 μm effluent sand filters are used to abate all radioactive liquid discharges. Non-regenerable ion exchange resins are available for use if determined as BAT to do so. A new aqueous Discharge Abatement Plant (ADAP), designed to abate specific waste-streams from the Bradwell site to replace the pond water treatment plant which is due to be commissioned shortly.
- At Hinkley Point A Changes to abatement plant in the period have involved re-assessing the effluent fine filter requirements and limited usage of a hydrocyclone and the use of chemical flocculants to protect existing abatement plant and minimise secondary waste generation.
- At Hunterston A, A new Active Effluent Treatment Facility was commissioned in 2009 which uses submersible caesium removal units and filtration to reduce caesium activity in the CCP water.

8.2.4 Fuel Reprocessing

- The development and implementation of Environment Cases for all operating plants and new project developments at Sellafield site.
- Development and implementation of an Overall Effluent Strategy and discharge forecasting tool at Sellafield to model the impacts of different strategies on discharges to air and water. This model deals with a complex and varying set of interacting source terms, and is of increasing importance in predicting discharges and identifying associated BAT discharge control arrangements as more of the site activities move to Post Operational Clean-Out (POCO), decommissioning and clean-up.
- Commencement of operation of a Local Effluent Treatment Plant (LETP) in the Sellafield Pile Fuel Storage Pond (PFSP). The plant comprises sand-bed filtration and ion exchange abatement, and provides significant reduction in pond water activity and final discharges from this pond, and also important abatement capability to support future fuels and retrievals work.
- Commencement of the retrieval of legacy fuels and materials from the Sellafield Pile Fuel Storage Pond (PFSP), the retrieval of radioactive liquors from the Magnox Swarf Storage Silos (MSSS), and the retrieval of sludge from the floc tanks: all represent significant milestones in the decommissioning and clean-up of these legacy facilities.
- Implementation of additional arrangements at Sellafield site to exclude solids ranging from implementing simple filtration techniques at source plants to extensive trials to underpin, optimise and potentially improve final filtration systems on effluent discharges.
- Recycling of filtrates from the processing of Salt Evaporator Concentrate through the Sellafield EARP ‘bulks’ route to reduce overall discharges of ^{241}Am and ^{106}Ru.

- De-canning and re-containerisation of a significant quantity of the corroded fuel inventory in the Sellafield Fuel Handling Plant pond, and improvement in pond water cooling and pH control in the Fuel Handling Plant, leading to low and stable pond water activity levels, and correspondingly reduced discharges to the SIXEP plant.
- Imposition of tighter controls on donor plant feeds to SIXEP, and on-going R&D, to optimise SIXEP plant abatement performance.

8.2.5 Research

- At Dounreay, improvements have been made in the diversion of off-site water that had previously run onto the site. This had the effect of reducing the loading on the Non-Active Effluent (NAE) and ingress to the Low Level Waste Pits, which in turn discharge to LLLETP.
- At Harwell, RSRL is planning to install a small and compact treatment plant that will incorporate an evaporation stage (and cementation of residuals, if feasible. Key target nuclides would be ^{137}Cs and ^{90}Sr, but the process would be equally efficient for all radionuclides.
- At Winfrith, a clarifier has been installed at the Active Liquid Effluent System. The clarifier contains lamella inclined plates which allow the removal of entrained solids from the aqueous phase by sedimentation. The system also has a multi-layer pressure filter installed in series to further remove finer solids before the effluent is discharged. This system became operational in July 2011.

The procedures and techniques applied in the UK nuclear industry are consistent with BAT. Measures are in place, as part of the authorisation review process, to ensure that technological developments continue to be reviewed and implemented where appropriate. A requirement that operators keep abreast of new abatement and treatment technologies is implicit within authorisation/permits. This has led to the establishment of a broader discussion on such issues and the establishment of a nuclear sector inter-industry group, the Environment Agencies Requirements Working Group (EARWG), which reviews information and data on national and international minimisation techniques. This information is included on a web-based information data base, as indicated above.

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.

Appendices

A1. ACRONYMS AND KEY DEFINITIONS

A1.1. Key definitions

Best Available Techniques (**BAT**) has been defined as follows:

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.

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.

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.

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

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 SEPA in authorisations issued under the RSA93. 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 minimizing 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.

A1.2. Acronyms

AETP	Active Effluent Treatment Plant
AGR	Advanced Gas-cooled 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 Technology or Techniques (see Section 3 for more information)
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
BSS	Basic Safety Standards
CCP	Cartridge Cooling Pond
CEAR	Compilation of Environment Agency Requirements
Cm2919	Command 2919, Review of Radioactive Waste Management Policy, Final Conclusions (July 1995)
CMT	Collection Monitoring Tanks
COMARE	Committee on Medical Aspects of Radiation in the Environment COS Carbonyl Sulphide
CRU	Caesium Removal Unit
DECC	Department of Energy and Climate Change
DEFRA	Department of the Environment, Food and Rural Affairs
DF	Decontamination Factor
DOENI	Department of the Environment, Northern Ireland
DFR	Dounreay Fast Reactor
DPAG	Dounreay Particles Advisory Group
DRSL	Dounreay Site Restoration Limited
EA	Environment Agency of England and Wales
EARP	Enhanced Actinide Removal Plant
EARWG	Environment Agencies Requirements Working Group
EHS	Environment and Heritage Service Northern Ireland
EPR10	Environmental Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EURRP	Enriched Uranium Residues Recovery Plant
FASSET	Framework for Assessment of Environmental Impact
FDT	Final Delay Tanks
FED	Fuel Element Debris
FGMSP	First Generation Magnox Storage Pond
FHP	Fuel Handling Plant
FSA	Food Standards Agency
GDA	Generic Design Assessment
GEVS	Gaseous Effluent Ventilation Systems
HALES	Highly Active Liquor Evaporation and Storage
HEPA	High Efficiency Particulate Air
HLW	High Level Waste (waste containing >4 GBq α and/or 12 GBq β/γ and with heat generating properties).

HPA	Health Protection Agency
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
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)
LRWS	Liquid Radioactive Waste System
MAC	Medium Active Concentrate
MAETP	Modular Active Effluent Treatment Plant
MCERTS	Monitoring Certification Scheme
MMA	Multi-Media Authorisation
MOP	Magnox Operating Programme
MRP	Magnox Reprocessing Plant
MSSS	Magnox Swarf Storage Silo
MXD	Magnox Dissolution Plant
NAE	Non Active Effluents
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NGL	Nuclear Generation Ltd
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NRBW	National Resource Body for Wales
ONR	Office for Nuclear Regulation
PFR	Prototype Fast Reactor
PFSP	Pile Fuel Storage Pond
POCO	Post Operational Clean-Out
PWFP	Pond Water Filtration Plant
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
RIFE	Radioactivity in Food and the Environment
RSA93	Radioactive Substances Act (1993)
RSRL	Research Site Restoration Limited
RWPG	Radioactive Waste Policy Group

SCRU	Submersible Caesium Removal Unit
SEC	Salt Evaporator Concentrate
SEPA	Scottish Environment Protection Agency
SETP	Segregated Effluent Treatment Plant
SFL	Springfields Fuels Limited
SGHWR	Steam Generating Heavy Water Reactor
SIXEP	Site Ion Exchange Effluent Plant
SMP	Sellafield Mox Plant
STP	Solvent Treatment Plant
TENORM	Technologically Enhanced Naturally-Occurring Radioactive Material
THORP	Thermal Oxide Reprocessing Plant
TPP	Tetraphenylphosphonium bromide
UCL	Urenco Capenhurst Ltd
UUK	Urenco UK
UKAS	United Kingdom Accreditation Service
UKAEA	UK Atomic Energy Authority
UOC	Uranium Ore Concentrate
WAGR	Windscale Advanced Gas-cooled Reactor
WETP	Waste Encapsulation Treatment Plant
WVP	Waste Vitrification Plant

A2. SITE CHARACTERISTICS

A2.1. Fuel manufacture

- **Table A1. Capenhurst Site Characteristics**

Type of Facility	Uranium enrichment by centrifuge					
Location	Cheshire					
Date Commissioned	1976					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Rivacre Brook into Mersey Estuary (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed Capacity (Tonnes)	No information					
Tonnes U product per year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	523	587	Average of 750			

- **Table A2. Springfields Site Characteristics**

Type of Facility	Production of fuel and intermediates (UF6, UO_2 powder & pellets and AGR Fuel)					
Location	Lancashire					
Date Commissioned	1949					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	River Ribble (discharges into OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed Capacity (Tonnes)	6,000 MTU (UF6 production)					
Annual production	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Tonnes U in product	Approx. 5000		4643	4937	5360	5373
Tonnes U in residues processed	n/d		263	169	195	253

A2.2. Power generation

A2.2.1. Operational sites

- **Table A3. Dungeness B Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Kent					
Date Commissioned	1983					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	English Channel (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1110					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	5114	5843	3,490	3,970	3,614	1,347

- **Table A4. Hartlepool Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Cleveland					
Date Commissioned	1984					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	North Sea (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1210					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	4831	6874	-78	6,825	8,104	7,354

- **Table A5. Heysham 1 Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Lancashire					
Date Commissioned	1984					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Morecambe Bay and Irish Sea (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1150					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	7819	5463	-70	6,330	5,184	8,570

- **Table A6. Heysham 2 Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Lancashire					
Date Commissioned	1988					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Morecambe Bay and Irish Sea (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1250					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	9421	8650	8,585	8,762	6,373	8,466

- **Table A7. Hinkley Point B Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Somerset					
Date Commissioned	1976					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Bristol Channel (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1220					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	6474	3591	5,325	4,929	6,386	6,076

- **Table A8. Hunterston B Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	Ayrshire					
Date Commissioned	1976					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Firth of Clyde (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1190					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	5688	2895	4,428	6,036	6,835	6,342

- **Table A9. Torness Site Characteristics**

Type of Facility	AGR Power Station (2 Reactors)					
Location	East Lothian					
Date Commissioned	1988					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	North Sea (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1250					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	7289	8317	9,269	9,115	7,055	9,001

- **Table A10. Sizewell B Site Characteristics**

Type of Facility	PWR Power Station (1 Reactor)					
Location	Suffolk					
Date Commissioned	1995					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	North Sea (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	1188					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	8908	10264	9,301	9,095	4,724	8,627

- **Table A11. Oldbury Site Characteristics**

Type of Facility	Magnox Power Station (2 Reactors)					
Location	Gloucestershire					
Date Commissioned	1967					
Date of cessation of operation	2012 (operational during reporting period)					
Receiving waters and OSPAR catchment area	Severn Estuary (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	434					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	691	1028	1620	2076	3115	1989

- **Table A12. Wylfa Site Characteristics**

Type of Facility	Magnox Power Station (2 Reactors)					
Location	Anglesey					
Date Commissioned	1971					
Date of cessation of operation	n/a					
Receiving waters and OSPAR catchment area	Irish Sea (OSPAR Region III)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	980					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	6683	5826	5984	5574	5053	5028

A2.2.2. Decommissioning Sites

- **Table A13. Berkeley Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Gloucestershire
Date Commissioned	1962
Date of cessation of operation	1989
Receiving waters and OSPAR catchment area	River Severn (OSPAR Region III)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	300
Annual electricity generation, GWh(e)	n/a

- **Table A14. Bradwell Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Essex
Date Commissioned	1962
Date of cessation of operation	2002
Receiving waters and OSPAR catchment area	Blackwater Estuary (OSPAR Region II)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	246
Annual electricity generation, GWh(e)	n/a

- **Table A15. ChapelcrossSite Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Dumfriesshire
Date Commissioned	1959
Date of cessation of operation	2004
Receiving waters and OSPAR catchment area	Solway Firth (OSPAR Region III)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	196
Annual electricity generation, GWh(e)	n/a

- **Table A16. Dungeness A Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Kent
Date Commissioned	1965
Date of cessation of operation	2006
Receiving waters and OSPAR catchment area	English Channel (OSPAR Region II)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	550
Annual electricity generation, GWh(e)	n/a

- **Table A17. Hinkley Point A Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Somerset
Date Commissioned	1964
Date of cessation of operation	2000
Receiving waters and OSPAR catchment area	Bristol Channel (OSPAR Region III)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	470
Annual electricity generation, GWh(e)	n/a

- **Table A18. Hunterston A Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Ayrshire
Date Commissioned	1964
Date of cessation of operation	1990
Receiving waters and OSPAR catchment area	Firth of Clyde (OSPAR Region III)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	n/a
Annual electricity generation, GWh(e)	n/a

- **Table A19. Sizewell A Site Characteristics**

Type of Facility	Decommissioning Magnox Power station
Location	Suffolk
Date Commissioned	1965
Date of cessation of operation	2006
Receiving waters and OSPAR catchment area	North Sea (OSPAR Region II)
Volume of effluent discharged into the receiving waters	No information
Installed electrical generation capacity, MW(e)	580
Annual electricity generation, GWh(e)	n/a

- **Table A20. Trawsfynydd Site Characteristics**

Type of Facility	Decommissioning Magnox Power station					
Location	Gwynedd					
Date Commissioned	1965					
Date of cessation of operation	1993					
Receiving waters and OSPAR catchment area	Lake Trawsfynydd					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	500					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	n/a					

A2.3. Fuel Reprocessing

- **Table A21. Sellafield Site Characteristics**

<table>
<tr><td colspan="2">Type of Facility</td><td colspan="6">▪ Reprocessing Magnox and Oxide fuels
▪ Manufacture of Mixed Oxide fuels
▪ Management of stored wastes & clean-up of historical facilities
▪ Decommissioning Magnox Power Station (Calder Hall)
▪ Decommissioning Research & Development Reactor (Windscale WAGR) and Plutonium Production Plant (Windscale Piles)</td></tr>
<tr><td colspan="2">Location</td><td colspan="6">Cumbria</td></tr>
<tr><td colspan="2">Date Commissioned</td><td colspan="6">▪ THORP - 1991
▪ MOX - 2001
▪ Calder Hall – 1956
▪ Windscale Piles: Pile 1 – 1950; Pile 2 - 1951</td></tr>
<tr><td colspan="2">Date of cessation of operation</td><td colspan="6">▪ B205 Magnox reprocessing – in operation
▪ THORP – in operation
▪ MOX – in operation
▪ Calder Hall – 2003
▪ Windscale WAGR - 1981
▪ Windscale Piles - 1957</td></tr>
<tr><td colspan="2">Receiving waters and OSPAR catchment area</td><td colspan="6">Irish Sea (OSPAR Region II)</td></tr>
<tr><td colspan="2">Volume of effluent discharged into the receiving waters</td><td colspan="6">No information</td></tr>
<tr><td colspan="2">Installed electrical generation capacity, MW(e)</td><td colspan="6">50 (per reactor)</td></tr>
<tr><td rowspan="3">Tonnes of U processed annually</td><td></td><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td></tr>
<tr><td>Magnox</td><td>594</td><td>457</td><td>512</td><td>450</td><td>233</td><td>603</td></tr>
<tr><td>Oxide</td><td>0</td><td>51</td><td>116</td><td>217</td><td>349</td><td>430</td></tr>
</table>

A2.4. Research and Development

- **Table A22. Dounreay Site Characteristics**

Type of Facility	Various Decommissioning Research Reactors					
Location	Caithness					
Date Commissioned	1955					
Date of cessation of operation	1994					
Receiving waters and OSPAR catchment area	North Atlantic Ocean (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	n/a					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	n/a					

- **Table A23. Harwell Site Characteristics**

Type of Facility	Nuclear Power Research and Development Site					
Location	Oxfordshire					
Date Commissioned	1946					
Date of cessation of operation	1990					
Receiving waters and OSPAR catchment area	River Thames to Thames Estuary (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	n/a					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	n/a					

- **Table A24. 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 of cessation of operation	SGHWR Closed in 1990. Last reactor shutdown in 1995					
Receiving waters and OSPAR catchment area	The English Channel (OSPAR Region II)					
Volume of effluent discharged into the receiving waters	No information					
Installed electrical generation capacity, MW(e)	SGHWR was 100 MW electrical, 300 MW Thermal.					
Annual electricity generation, GWh(e)	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
	n/a					

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