OSPAR COMMISSION

Implementation of PARCOM Recommendation 91/4 on liquid discharges

Report from the United Kingdom - Part I

Radioactive Substances Series

2009

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

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. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

Acknowledgement

This report has been prepared by Ms Carol Robinson of Enviros Consulting Limited for the United Kingdom.

Contents

1. EXECUTIVE 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 (including research and reprocessing facilities, but excluding defence and medical facilities) into the marine environment.

Operations at UK nuclear installations are governed by various acts, most notably the Radioactive Substances Act (1993, as amended), through which control of discharges to the environment from nuclear licensed sites is exercised. The UK requires operators to apply Best Practicable Means (BPM) to minimise discharges. This obligation, together with a continuing authorisation review process, places a requirement on operators both to use the best available technologies and to apply best practice in their application. In combination this delivers a level of discharge control that is at least consistent with that implied by BAT, as defined by OSPAR.

In this report, current practices at each relevant site and facility and the detailed application of BPM and, by extension, BAT in the UK nuclear industry are reviewed. These considerations are grouped by the following nuclear industry sectors: fuel manufacture, power generation, fuel reprocessing, research and development. The practices and impacts arising from operational and decommissioning nuclear power stations are presented separately at a site level. Facilities which changed status during the reporting period (*i.e*. were operational in 2003 but had ceased operating or commenced decommissioning by the end of 2007) are also addressed separately. Complex sites, where individual plants may be operational whilst others are undergoing decommissioning are considered according to the sector and status of their main process (*e.g*. the Sellafield site is addressed as an operational reprocessing site, although a number of individual facilities are currently undergoing decommissioning and considerable research and development is also being undertaken on site).

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 those identified in recent reviews of available technologies and 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:

- Internal effluent management arrangements (*e.g*. conditions for acceptance and internal authorisations for materials transfer) prevent, minimise and control effluents at source.

- Abatement of ^{99}Tc discharges from treatment of stored MAC by use of TPP in EARP and the continued use and combination of SETP, SIXEP and EARP plants at Sellafield;

[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.

- Abatement of ^{99}Tc discharges from treatment of current MAC arisings by processing through the HALES plant at Sellafield, prior to vitrification;

- Use of the Salt Evaporator, in combination with other treatment plants at Sellafield, has reduced discharges of plutonium and in various short lived fission products, such as ^{95}Zn, ^{95}Nb and ^{106}Ru;

- The Solvent Treatment Plant at Sellafield, which destroys solvents currently stored on site (producing an aqueous residue which can be processed through EARP) is now fully operational;

- The development and increased application of Submersible Caesium Removal Units (IONSIV IE-911) in Magnox fuel storage ponds;

- Measures to prevent dilution of radioactive effluents in order to achieve higher removal rates as a consequence of treatment methods and the consideration of evaporation technologies at Harwell.

The UK concludes that these examples demonstrate a continuing commitment to the application of BAT in UK nuclear facilities and, furthermore, the combination of the regulatory requirement to demonstrate the use of Best Practicable Means to minimise discharges and the periodic review of authorisations, which entails, *inter alia*, a review of the Best Practicable Environmental Option (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 the legislation related to the nuclear industry. Although these changes are not directly relevant to the application of BAT, they have had an effect on ownership and operation of nuclear sites, and are therefore noted here in the interests of completeness.

The Nuclear Decommissioning Authority (NDA) was established under the Energy Act 2004. It is responsible for the decommissioning and clean-up of the UK's civil public sector nuclear sites and has a mission to deliver safe, sustainable and publicly acceptable solutions to nuclear clean-up and waste management, without compromising on safety or security. The NDA approach, together with the existing authorisation process which continues to be applied to decommissioning sites, ensures that decommissioning is undertaken in a manner that is consistent with BAT objectives.

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. A process to update and expand the scope of this strategy to cover aerial discharges, decommissioning activities and non-nuclear sectors, for the period 2006-2030, has been undertaken during the reporting period. A consultation document was published in June 2008. The final strategy document will be published in 2009.

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

1. RECAPITULATIF

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 oeuvre de la Recommandation PARCOM 91/4 sur les rejets radioactifs, en ce qui concerne l'application de la meilleure technologie disponible[2] (BAT) afin de minimiser et, le cas échéant, de supprimer la pollution provoquée par les rejets radioactifs de l'ensemble des industries nucléaires, (notamment les installations de recherche et de retraitement, mais à l'exclusion des installations de défense et médicales) dans le milieu marin.

L'exploitation des installations nucléaires au Royaume-Uni est régie par diverses lois, la plus notable étant la loi de 1993 sur les substances radioactives (tel qu'amendée), qui contrôlent les rejets dans l'environnement provenant des sites nucléaires autorisés. Le Royaume-Uni exige que les exploitants nucléaires utilisent les meilleurs moyens réalisables (BPM) afin de minimiser les rejets. Cette obligation, ainsi qu'un processus continu de revue des autorisations, imposent aux exploitants aussi bien l'utilisation des BAT que l'application des meilleures pratiques au cours de leur application. Ceci permet de parvenir à un niveau de contrôle des rejets, en cohérence avec celui supposé par la BAT, telle que défini par OSPAR.

Le présent rapport passe en revue les pratiques actuelles de chaque site et installation pertinents et l'application détaillée des BPM et, par extension, de la BAT par l'industrie nucléaire du Royaume-Uni. Ces considérations sont groupées par secteurs de l'industrie nucléaire comme suit: production de combustible, production d'énergie, retraitement de combustible, recherche et développement. Les pratiques et les impacts découlant des centrales nucléaires en exploitation et démantelées sont présentés séparément au niveau d'un site. Les installations qui ont changé de statut au cours de la période de notification (c'est-à-dire qui étaient opérationnelles en 2003 mais ont cessé toute exploitation ou ont commencé à être démantelées à la fin de 2007) sont également traitées séparément. Les sites complexes qui comportent des usines individuelles pouvant être opérationnelles et d'autres en cours de démantèlement sont considérés selon le secteur et le statut de leur processus principal (par exemple le site de Sellafield est traité comme un site de retraitement opérationnel, bien qu'un certain nombre d'installations individuelles soient en cours de démantèlement et que ce site comporte des installations de recherche et de développement considérables).

En plus de la revue de l'application de la BAT, se fondant sur les pratiques actuelles, on a déterminé les technologies en cours de développement au Royaume-Uni et ailleurs et effectué des comparaisons avec la performance d'usines similaires au niveau mondial, le cas échéant.

Le gouvernement et des administrations déconcentrées britanniques pensent que les procédures et techniques appliquées dans l'industrie nucléaire du Royaume-Uni sont en cohérence avec celles déterminées dans les revues récentes des technologies disponibles et avec la mise en oeuvre de la BAT. De plus, le processus de revue des autorisations exige que l'on continue à passer en revue et à mettre en œuvre, le cas échéant, les développements technologiques.

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

- dispositions internes de gestion des effluents (par exemple conditions d'acceptation et autorisations internes pour le transfert des matériaux) empêchant, minimisant et contrôlant les effluents à la source;

[2] Le terme "BAT" fait référence aux "technologies" dans la Recommandation PARCOM 91/4 alors que le Royaume-Uni utilise plus couramment le terme "techniques" dans ce contexte, afin d'inclure le matériel et les practiques de gestion. Cette interprétation plus large de la BAT s'applique à l'intégralité du rapport.

- réduction des rejets de Tc-^{99}provenant du traitement du MAC stocké en utilisant du TPP à l'usine EARP et utilisation et conjugaison continues des usines SETP, SIXEP et EARP à Sellafield;

- réduction des rejets de Tc-^{99}provenant du traitement du MAC apparaissant actuellement grâce à son traitement par l'usine HALES à Sellafield, avant la vitrification;

- utilisation de l'évaporateur à sel, en conjugaison avec d'autres usines de traitement à Sellafield, réduisant les rejets de plutonium et dans divers produits de fission à vie courte, tels que Zn-^{95}, Nb-^{95} et Ru-^{106};

- usine de traitement de solvant à Sellafield, qui détruit les solvants stockés actuellement dans le site (produisant un résidu aqueux qui peut être traité par EARP) complètement opérationnelle maintenant;

- développement et application en hausse des unités submersibles de retrait du caesium (IONSIV IE-911) dans les piscines de stockage de combustible Magnox;

- mesures de prévention de la dilution des effluents radioactifs afin de parvenir à des taux de retrait plus élevés grâce aux méthodes de traitement et considération des technologies d'évaporation à Harwell.

Le Royaume-Uni conclut que ces exemples démontrent qu'il s'engage continuellement à appliquer la BAT dans ses installations nucléaires. Ils démontrent de plus que la conjugaison de l'exigence réglementaire de démontrer l'utilisation des BPM afin de minimiser les rejets et de la revue périodique des autorisations, qui entraîne entre autres une revue de la meilleure option environnementale applicable (BPEO), permet effectivement d'incorporer dans la pratique réglementaire du Royaume-Uni l'application de la BAT dans les installations nucléaires du Royaume-Uni.

La législation relative à l'industrie nucléaire a subi des modifications au cours de cette période de notification. Ces modifications ont affecté la possession et l'exploitation des sites nucléaires, bien qu'elles ne soient pas directement pertinentes à l'application de la BAT, et sont donc mentionnées afin de présenter un tableau complet.

L'Autorité de démantèlement nucléaire (NDA) a été créée dans le cadre de la loi sur l'énergie de 2004. Elle est responsable du démantèlement et du nettoyage des sites nucléaires du secteur privé civil britannique. Elle est chargée de trouver des solutions sûres, durables et acceptables pour le public pour le nettoyage et la gestion des déchets nucléaires qui ne compromettent pas la sûreté et la sécurité. L'approche de la NDA, ainsi que le processus d'autorisation en place, qui continue à être appliqué aux sites de démantèlement, permettent d'entreprendre le démantèlement en cohérence avec les objectifs de la BAT.

Le Royaume-Uni a mis en place sa stratégie initiale afin de mettre en oeuvre les accords convenus par la Réunion ministérielle OSPAR de 1998 et les réunions suivantes de la Commission OSPAR sur les substances radioactives dans la Stratégie du Royaume-Uni en matière de déchets radioactifs pour la période 2001-2020, qui a été publiée en 2002. Un processus d'actualisation et d'expansion de la portée de cette stratégie afin de couvrir les rejets aériens, les activités de démantèlement et les secteurs non nucléaires pour la période 2006-2030, a été entrepris au cours de la période de notification. Un document consultatif a été publié en juin 2008. Le document stratégique définitif sera publié en 2009.

Le processus d'autorisation appliqué au Royaume-Uni, et les conditions d'autorisation liées à la revue périodique, permettent de poursuivre la mise en oeuvre de la BAT conformément à la stratégie en matière de rejets et aux orientations règlementaires 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 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 report, submitted to the RSC meeting in 2005, was also prepared on the basis of these Guidelines and covered the period 1998-2003. The present report provides an update on the implementation of BAT over the period 2004-2007, together with discharge, environmental concentration and dose data for the six-year period 2002-2007 (in accordance with the Guidelines).

This report, which is the fifth 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 1.1.

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 Best Practicable Means and Best Practicable Environmental Option (and by extension BAT) 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.

Information is provided for the following nuclear industry sectors: fuel manufacture, power generation, fuel reprocessing, research and development. In previous submissions, the UK also reported on the application of BAT in the radioisotope manufacture industry. However, this has recently been included in the reporting procedures for the non-nuclear sector. To avoid double-reporting it is no longer included here.

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 an holistic view to provide the Best Practicable Environmental Option, including consideration of:

- the balance of radioactive and non-radioactive discharges;
- the relative environmental impacts of discharges to the aquatic and terrestrial environments; and,

- the issues arising from a policy of containment and land-based disposal as solid wastes.

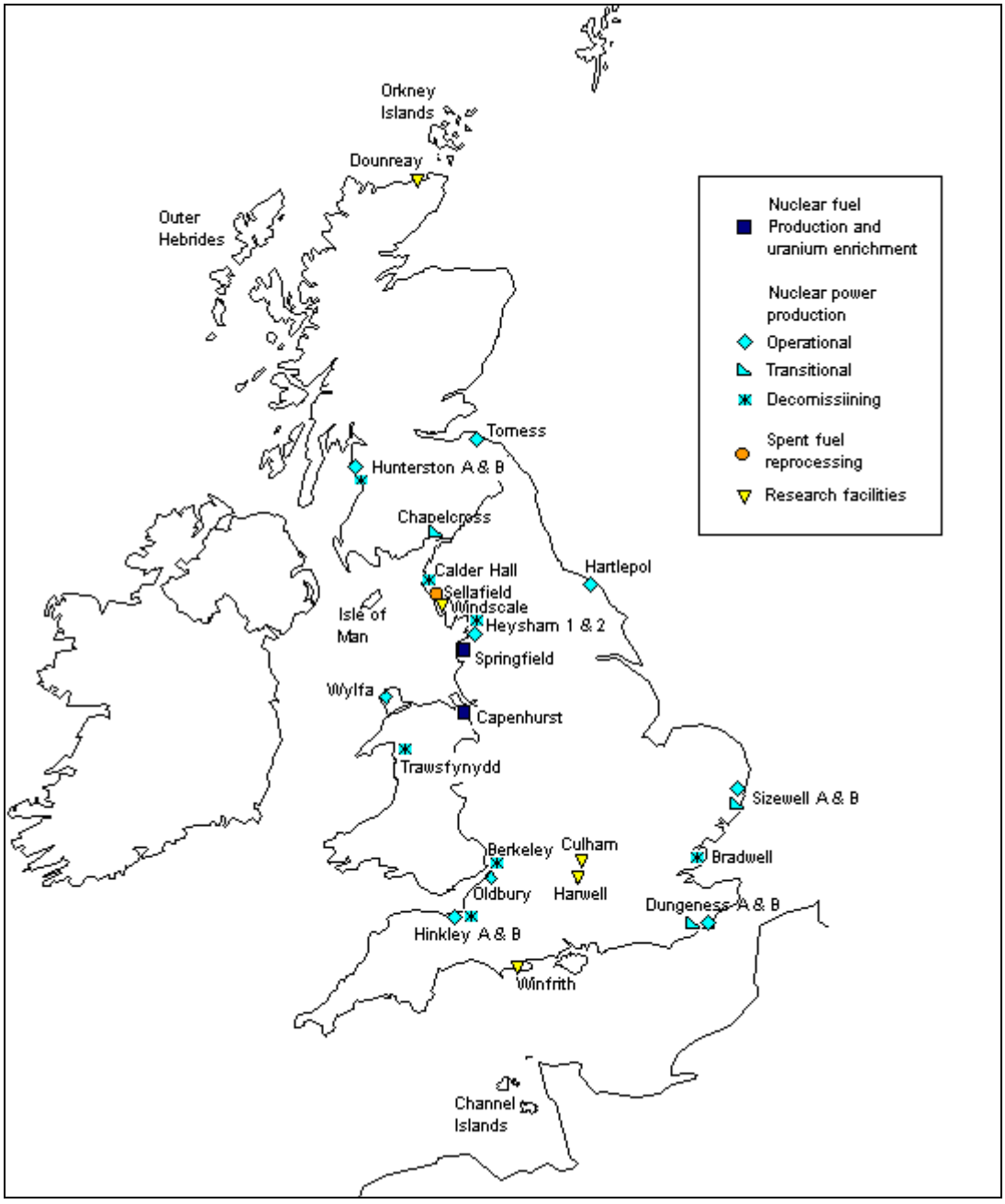

Figure 1.1 Map Showing Location of Nuclear Sites in the UK

2.1 Structure of the Report

This report is presented in two parts. Part 1 provides a description of progress towards the application of PARCOM Recommendation 91/4 with the aid of some illustrative graphics; Part 2 is a compilation of tables containing the discharge, environmental and dose information specified in the Guidelines. Part 2 also includes

a complete compilation of graphs demonstrating trends in discharges[3]. The structure of Part 1 is outlined in more detail below.

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, and
- 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. Facilities which changed status during the reporting period (*e.g.* that were operational in 2003 but had ceased operating or commenced defuelling or decommissioning by the end of 2007) are also addressed separately (and referred to as transitional sites). 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 and a considerable amount of research and development is also undertaken on site).

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.

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.

Section 9 is a summary of acronyms and key definitions.

[3] Figures and Tables included in Part 1 are numbered with the prefix 1 (*e.g.* Table 1.1), while those in Part 2 have a prefix of 2 (*e.g*. Figure 2.1).

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; and,
- 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; and,
- 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: Defra in England[4], 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 regulators ensure that Government policy is implemented. The authorities with responsibilities for discharges to the environment are: the Environment Agency (EA) in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland, and the Environment and Heritage Service of the Department of the Environment in Northern Ireland (EHSNI). In addition, the Nuclear Installations Inspectorate (NII) of the Health and Safety Executive (HSE) regulates the management of radioactive waste on nuclear sites, in respect to its production, treatment and storage.

[4] In 2008, relevant responsibilities in England were transferred to the Department of Energy and Climate Change (DECC).

There are also agencies and advisory bodies that provide relevant advice and guidance. The Radiation Protection Division of the Health Protection Agency (HPA), 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. 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 2008 Discharge Strategy Consultation document, and on the website identified below[5].

3.2 National legislation and basis for regulation

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

The UK has consistently applied the radiological protection principles recommended by the International Commission on Radiological Protection (ICRP) to reduce levels of radioactive discharges and doses of ionising radiation to humans, and in so doing has reduced concentrations in the wider environment. Dose limits, intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances, have long been established, and a dose limit for members of the public of 1 mSv y^{-1} has been adopted in the UK since 1993. The legislation, regulatory provisions and principles in place during previous reporting period (1998-2003) 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 2002, the UK Strategy for Radioactive Discharges 2001-2020 (the UK Strategy) was published (Defra, 2002), which described how the UK intended to implement the agreements reached at the 1998 Ministerial meeting, set out in the OSPAR Strategy with regard to Radioactive Substances. This document also provided more detail on the national and international context for the regulation of radioactive discharges. During the reporting period, this Strategy has been subject to a full review to extend its scope and timescales and a consultation document was released in June 2008. An updated UK Strategy will be published in its final form in 2009.

The targets and profiles included in the revised strategy are based on current assumptions about the future activities in each sector. It is recognised that these assumptions may need to be modified if assumptions change, for example through the implementation of a programme of new-build nuclear power stations in England and Wales. The potential discharges from a new build programme cannot yet be accurately quantified and are therefore not included in current discharge profiles. However, such a programme would replace or exceed current generating capacity, using modern technologies with low associated discharges, such that it would not be expected to prevent the UK from achieving the objective of the OSPAR Radioactive Substances Strategy. The Government intends to review its discharge strategy, objectives and discharge profiles, about every five years. This review process will thus take account of any future changes in Government policy, commercial decisions

[5] http://www.defra.gov.uk/environment/radioactivity/government/discharges/index.htm

within the nuclear industry, technological advances and improvements to our knowledge of the impacts of radionuclides in the marine environment.

During the reporting period, the organisational and legal arrangements under which decommissioning activities are performed in the future have changed. Under the Energy Act 2004, the Nuclear Decommissioning Authority (NDA) was established. The NDA is a non-departmental public body which is responsible for the decommissioning and clean-up of the UK's civil public sector nuclear sites. The Department for Business, Enterprise and Regulatory Reform (BERR) and the Scottish Ministers sponsor the NDA and approve its strategy, plans and budget. The NDA has a mission to deliver safe, sustainable and publicly acceptable solutions for nuclear clean-up and waste management, without compromising on safety or security. Its strategic priorities include encouraging the highest standards in safety, security and environmental management. Furthermore, the authorisation process for the discharge of radioactive substances continues to be applied at decommissioning sites, such that this change is unlikely to affect the delivery of OSPAR objectives.

3.3 The Application of BAT in UK legislation

The regulation of radioactive waste discharges and disposals is currently governed by two optimisation approaches that have been part of UK pollution law for many years and which, taken together with the ongoing pressure for review and improvement underlying their application, are considered to be at least equivalent to BAT, as defined by the OSPAR Commission. These concepts are Best Practicable Means (BPM) and Best Practicable Environmental Option (BPEO) and (definition included in Section 9). As part of their responsibilities under RSA 93, the regulators require operators to use BPM to minimise radioactive waste arisings and BPM to minimise discharges and disposals of radioactive waste, in order to deliver radiation risks to the public and environment that are as low as reasonable achievable (ALARA). BPEO is a related decision-aiding procedure that allows waste management options to be measured and compared in terms of their relative environmental and other impacts.

In its recent consultation document on Statutory Guidance to the Environment Agency, Defra recommended that the concept of BAT replace those of BPM and BPEO, in order to deliver a regime that is more consistent with environmental regimes in other countries and other regimes in England and Wales. BPM will continue to be used in Scotland and Northern Ireland.

In its recent consultation exercise on the 2008 Discharge Strategy, a number of additional principles are acknowledged. For example, the Government recognises that the unnecessary introduction of radioactivity into the environment is undesirable, even at levels where doses to humans and other species are low and, on the basis of current knowledge, are unlikely to cause harm. In addition, activities involving ionising radiation are subject to the following controls:

- Justification[6] of practices by the Government to ensure that the environmental, social and economic benefits they provide to society exceed the potential detriment resulting from them.

- Optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (ALARA).

- Application of limits and conditions to control discharges from justified activities to ensure that individuals (workers and members of the public) and sensitive

[6] Justification is a process whereby a case must be made to Government for any new types of activity involving exposure to radioactive substances http://defraweb/environment/radioactivity/government/legislation/justification.htm

environmental receptors are not exposed to unacceptable radiation risks from these practices.

In addition to the discussion of BAT and the general principles mentioned above, the 2008 discharge strategy is based on the following principles:

- 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 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"[7].
- 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' in the management of radioactive waste over 'dilute and disperse' in cases where there would be a definite benefit in reducing environmental pollution.

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

A nuclear sector inter-industry group, the Environment Agencies Requirements Working Group, has developed 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.[8]

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

The Government's commitment to achieving the goals of the OSPAR Strategy with regard to Radioactive Substances may be illustrated by its extension and update of the UK strategy for radioactive discharges. The consultation stage of this document has been completed and a final version will be released in 2009.

3.4 Dose limit, constraints and discharge limit setting rationale

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

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

[7] Rio Declaration on environment and development: Annex 1 of Report of the United Nations conference on environment & development. UN General Assembly, June 1992.

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

- 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, the Scottish Environment Protection Agency (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 to 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. This value was retained in the UK Discharge Strategy document.

In parallel with its consultation on the revised UK Discharge Strategy, Defra is undertaking a consultation exercise on Statutory Guidance to the Environment Agency on the Regulation of Radioactive Discharges. The principles included in this document are outlined in the section above. In this draft statutory guidance, it was proposed that, where doses are less than 10 μSv y^{-1}, regulators should not seek to reduce discharge limits further[9]. This value is not included in the relevant Statutory Guidance to the Scottish Environment Protection Agency, which is already in place in Scotland[10].

3.5 Regulation, surveillance and monitoring

The environment agencies review each authorisation periodically to ensure it is still suitable and does not require a major revision. A major review and reauthorisation process 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 authorisation revision. The authorisation review process takes account of all relevant activities conducted or foreseen including any modifications, processing (including legacy wastes) and decommissioning. A number of authorisations have been reviewed and revised during or shortly after the reporting period. These changes are outlined in more detail under the relevant sections of this report.

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

Regulation and surveillance take a number of forms, for example: site inspection, scrutiny of waste disposal (including discharge and emission) returns, independent

[9] Defra, 2008, Consultation on Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment, '*where prospective dose to the most exposed group of members of the public is below 10 μSv/y from the overall discharge of an authorised site under the Radioactive Substances Act 1993 the Environment Agency should not seek to reduce further the discharge limits that are in place, provided that the holder of the authorisation applies and continues to apply BAT'*

[10] Scottish Government, 2008, SEPA and the UK Strategy for Radioactive Discharges, Statutory Guidance, February 2008.

sampling, and environmental monitoring. It is undertaken to ensure that the operator is complying with the conditions, including the discharge and emission limits, set out in the RSA 93 authorisation which is enforceable in UK law with heavy fines (and custodial sentences if necessary) for offenders.

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

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

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

3.6 Environmental monitoring programmes

All operators of nuclear facilities undertake environmental monitoring, both to comply with conditions in 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. It encompasses liquid effluents (as described above), quality checking of solid waste disposals, measurement of radiation and radioactivity in the environment, air, rainwater and drinking water sources.

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 members of critical groups (which are 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, EHS, DOENI and EA) 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.

3.7 Radiation dose assessment methods

Radiation dose assessments for members of the public arising from discharges of radioactive wastes are routinely estimated independently by site operators, the regulatory authorities and FSA, as part of the authorisation setting and review process. The doses to those members of the public likely to be most exposed as a

result of their habits and/or location (the critical group) are generally assessed for the purposes of comparison with dose limits and constraints. Total doses are assessed, taking account of both intakes of radionuclides and external irradiation pathways. Data to support these assessments are collected by the relevant operators, regulatory authorities and other bodies, such as the FSA, with relevant responsibilities.

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

The National Dose Assessment Working Group (NDAWG) has continued to work, throughout the reporting period, with the aim of bringing together people and organisations with responsibility for, and/or an interest in, the assessment of radiation doses to the public from the nuclear industry and from minor users of radioactivity. The objectives of this group are *inter alia* to facilitate the exchange of data and views between all parties on assessment methodologies, to advance the understanding between groups likely to have differing views and to facilitate the development of coherent and transparent methods. Key issues addressed during this period included:

- Consideration of uncertainties in radiological assessments;
- Principles for assessment of retrospective doses;
- Methods for assessment of total doses in the radioactivity in food and environment report and,
- The collection and use of habit data for retrospective dose assessments.[11]

3.8 Environmental norms and standards

Other initiatives have had an increasing effect on the way in which assessments in support of discharge authorisations are conducted and assessed, and are relevant to the scope of the OSPAR Strategy with regard to Radioactive Substances. There has been an increasing focus on the potential effects of ionising radiation on non-human species in a number of international fora, as indicated by recent reports to OSPAR RSC from the European Community and the International Atomic Energy Agency. 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 (2003).

The ICRP initiative has been supported by work undertaken in the EC-funded research programmes known as FASSET (Framework for the Assessment of Environmental Impact) and ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management), which continued until 2007, and provided an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionising radiation. A coordinated action project was initiated in 2006 called PROTECT (Protection of the Environment from Ionising Radiation in a Regulatory Context) to evaluate the different approaches to protect the environment from ionising radiation and compare them with the approaches used for non-radioactive contaminants to propose numerical targets or standards for protection of

[11] http://www.ndawg.org/index.htm

the environment from ionising radiation. The Environment Agency, SEPA and other UK bodies, continue to be heavily involved in these projects.

In the UK context, the environment agencies have been working to fulfil their obligations, for example under the relevant conservation of natural habitats regulations, to review all existing 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.

The environment agencies have also characterised the impacts from the environmental pressure of radioactive substances on water bodies, in line with wider Water Framework Directive characterisation work, and screening levels for the activity concentration in water of radionuclides have been proposed.

Screening levels have been derived for three types of water body as a result of environmental radiological monitoring programmes and modelling:

- Freshwater and seawaters in proximity to nuclear sites which received authorised discharges from these sites.
- Water bodies which are likely to receive combined discharges from predominantly non-nuclear sites (*e.g*. hospitals, universities, pharmaceutical industry).
- Background water bodies which are sources of drinking water (*e.g*. reservoirs, rivers and groundwaters).

During the reporting period, the Environment Agency has developed Radioactive Substances Regulation Environmental Principles (REPs) to guide its decisions related to radioactive substances regulation[12]. This document outlines an overall hierarchy of environmental principles, objectives related to radioactive substances regulation and the fundamental and devolved principles for the management of radioactive substances. The fundamental principles include the selection and implementation of management options and the protection of human health and the environment, while the devolved principles include requirements related to the creation of radioactive waste, the application of BPM and BPEO.

3.9 Quality Assurance

Quality Assurance and 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 minimize harmful effects on the environment caused by its activities, and to achieve continual improvement of its environmental performance (www.iso.org). Such standards are globally recognised. Most UK operators demonstrate QA and sound environmental management through ISO 9000 and ISO 14000 accreditation. Organisations that are not accredited use in-house management techniques, often based on ISO standards.

The quality of environmental and discharge sample measurements, and the assessment of the impact of discharges and emissions on members of the general public, is based on the work of operators and a national system of independent regulators (*e.g*. EA, SEPA), advisers (*e.g*. HPA) and government bodies, each relying on accreditation to an appropriate International Standards Organisation (ISO) or other standard. Quality is therefore an in-depth feature of the system and arises from both the standard of individual laboratories and from cross-checking results and intercomparison of assessment techniques.

[12] http://publications.environment-agency.gov.uk/pdf/GEHO0908BOLA-e-e.pdf?lang=_e

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

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

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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. Details are given in Tables 2.1–2.8 in Part 2 of this report. Both sites are certificated to the Environmental Management standard ISO 14001.

There is also a new mixed oxide fuel fabrication facility at the Sellafield site in Cumbria. The Sellafield MOX Plant (SMP) commenced active commissioning in 2001 and is included, with other sites on the Sellafield complex, under the Fuel Reprocessing heading (Section 6).

4.1 Capenhurst

The Capenhurst site is concerned with uranium enrichment. The site was split into two companies in March 1993: Urenco (Capenhurst) Limited (UCL)[13], which owns and operates the centrifuge plants on the site, and BNFL Capenhurst, which is now operated by Sellafield Ltd (SL) under the ownership of the NDA, and is primarily concerned with the decommissioning of the redundant plant and the storage of nuclear materials. UCL has authorisations from the Environment Agency to discharge and transfer radioactive wastes to the part of the site operated by SL. There is a gaseous discharge authorisation and two inter-site authorisations for the transfer of solids and liquid radioactive waste from UCL operations to SL facilities. These authorisations will be replaced by a multi-media authorisation in 2009. These wastes are accounted for in the liquid discharge figures for the SL part of the site.

4.1.1 Sources of liquid effluent

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

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

Liquids are discharged into Rivacre Brook under authorisations for uranic materials and for discharges from the former tritium processing facility.

Only small amounts of liquid wastes are discharged from the combined site. The primary source of liquid effluents from the SL operations at Capenhurst is from the decommissioning operations. During the reporting period, SL at Capenhurst continued to provide a uranic storage service to the nuclear industry.

4.1.2 Liquid effluent treatment and abatement

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

The fitting of a dry scrubber, in place of a wet scrubber, to the waste incinerator on the SL site, has resulted in virtually no liquid discharges from the facility. However,

[13] The name of the company changed to Urenco UK Limited in 2008. However, the name Urenco (Capenhurst) Ltd (UCL) is retained in this report as being appropriate for the reporting period concerned.

decommissioning activities on the SL site continue to generate small quantities of radioactive liquid effluent.

The BPEOs for the management of liquid waste streams on the UCL site were identified as follows in the documents submitted in support of the 2006 authorisation review:

- 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 reuse of fluorinated hydrocarbons;
- Decontamination, removal of other contaminants and reuse where possible of non-fluorinated hydrocarbons;
- Removal and recovery of uranium from uranium-contaminated aqueous liquors, 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 UCL Decontamination Facility which allows decontamination rinse water to be re-circulated into the process;
- Dry ice gun use for removal of surface contamination which reduces the requirement for liquid decontaminants;
- Electrically heated Product and Feed Cylinders in E23 Centrifuge Plant eliminates the potential for radioactive liquid effluent, should a fault occur on the feed chest;
- Recovery of residues from decontamination processes (*e.g.* citric acid and degreaser water) at Springfields;
- Use of disposable paper overalls, where there is a significant potential for contamination, and incineration of contaminated clothing in order to prevent contaminated clothing being washed in the laundry, thus minimising activity in resulting effluent;
- Segregation of residues from laboratory analyses and uranium recovery at Springfields.

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 BPM, UCL installed dry Gaseous Effluent Ventilation Systems (GEVS) into the E22 enrichment plant in 2008. This plant 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 discharge over the 2002-2007 period

The liquid discharges from Capenhurst over the reporting period are presented in Table 2.1. As illustrated in Figure 1.2 below, discharges of ^{99}Tc, uranium alpha activity and uranium daughters have decreased by over an order of magnitude since 2002. The discharge of tritium has also decreased by almost an order of magnitude over same the period. The discharge of non-uranium alpha activity, primarily ^{237}Np, has increased.

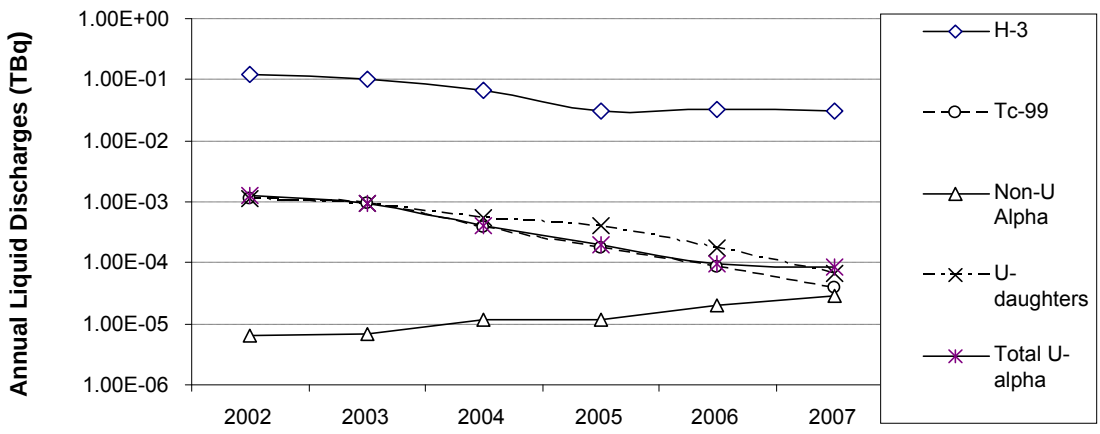

Figure 1.2 Liquid Discharges from the Capenhurst Site

Emissions to air from the SL site principally arise from incinerator gases and ventilation air from decommissioning operations. The emissions of tritium and uranium from the SL site decreased over the reporting period, as demonstrated by Table 2.1 and Figure 1.3 (below). These trends may be explained by the phasing of decommissioning operations and the cessation of a former tritium processing facility in 2003. The emissions of uranium from the UCL site have remained steady throughout the reporting period.

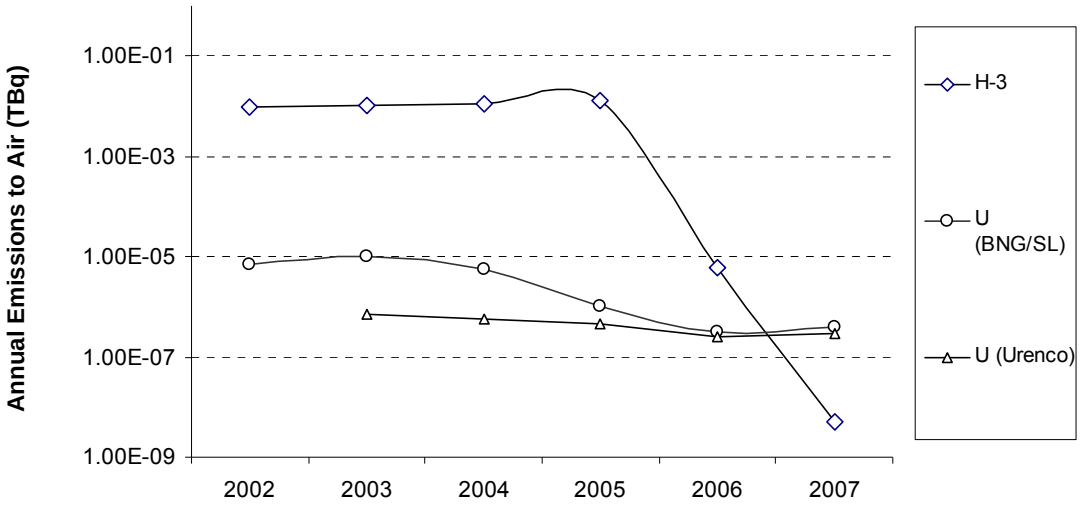

Figure 1.3 Annual Emissions to Air from the Capenhurst Site

4.1.4 Radiological impact of liquid discharges

Sellafield Ltd undertakes an environmental monitoring programme around the Capenhurst site which includes silt sampling at two locations (at the plant outlet and at around 1.5 km downstream) with additional samples of water and water weed (*Cladophora*) at the more distant location. The reported levels of ^{99}Tc in environmental samples, and cockles and shrimps in particular, have decreased substantially over the period (see Table 2.3). The activity concentrations of other radionuclides have remained relatively steady or decreased over this period and are, in many instances, below detection limits.

The only identified critical pathway for liquid discharges is the dose due to the inadvertent ingestion of water or silt by children playing in or near Rivacre Brook. The dose arising from combined site discharges is estimated to have been around 10 μSv/y throughout the reporting period (see Table 2.4). 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. 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 at the authorised discharge level. This is compared with the Agency's trigger value of 40 μGy/h; 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 discharges and the environmental impact of this site are very low, and discharges will decrease further when the planned decommissioning work is completed in 2009/10. Beyond that time, the only operational facilities remaining on the SL site will be a uranic store. Urenco operations are anticipated to continue and may include new processes, including deconversion of uranium hexafluoride to the more stable uranium oxide and the use of different feed material. These considerations were included in the recent authorisation review process, which included a review of the application of BPEO and BPM at the SL site. It was concluded that the approaches adopted were generally reasonable and should be kept under regular review.

Replacing feed and wet scrubber systems with HEPA filter based systems to eliminate liquid discharges from the scrubbers in the oldest plants was undertaken in 2008. The new plant design effectively eliminates radioactive liquid discharges and reduces gaseous discharges by a factor of approximately 10 when comparisons are made with the earlier designs of centrifuges, which are still operating at Capenhurst.

In addition to new modules being constructed on the latest enrichment plant, UCL are also considering carrying out the following activities before 2030:

- Construction and operation of a tails deconversion plant and associated facilities comprising cylinder washing; residue recovery, decontamination and maintenance.
- Enrichment of recycled uranium. Operations are anticipated to commence in 2011 subject to regulatory approval;
- Enrichment of uranium to a higher assay for future generations of nuclear power stations;
- Construction of a centralised waste management facility; and
- Possible decommissioning of old centrifuge enrichment plants.

4.1.6 Comparison with performance of similar plants world-wide

As part of the authorisation conditions under RSA 93, the operators of the Capenhurst site are required to, among other things, provide the Environment Agency with a periodic review of national and international developments in best practice for minimising waste disposals and a strategy for reducing discharges, and to carry out research and development programme to review BPEO/BPM issues.

Urenco has a well established, standardised approach to 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. The site has witnessed many changes over the years. In 2005, responsibility for the assets and liabilities of the site transferred to the Nuclear Decommissioning Authority (NDA). A new company – Springfields Fuels Limited (SFL) – was created to run the site which continues to be managed and operated by Westinghouse Electric Company UK Ltd on the NDA's behalf.

In October 2006, Westinghouse Electric Company UK was included in the sale of Westinghouse Electric Company by BNFL to Toshiba. This included the management and operations contract to run Springfields on the NDA's behalf.

Springfields focuses on three main activities:

- Fabrication of uranium metal fuel for the UK's Magnox reactors, which are now coming to the end of their working lives, until 2007 when Magnox fuel production ceased.
- Fabrication of oxide fuels for Advanced Gas-cooled and Light Water reactors, as well as intermediate fuel products, such as powders, granules and pellets.
- 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 is being assessed against the requirements of the Environment Agency's Monitoring Certification Scheme (MCERTS).

4.2.1 Sources of liquid effluent

The sources of liquid effluent are as follows: 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;
- Rainwater run-off from potentially contaminated areas;
- Effluent from the site laundry.

Discharge is made through a pipeline to the Ribble estuary. The pipeline receives both storm water and trade effluent discharges which are routed via a site-wide drain network through the site effluent complex. The effluents are sampled and analysed prior to discharge.

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 minimizing 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:

- 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 may 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 UO3 plant to be recycled as backwash;

- Filtration techniques: process effluents and slurry from precipitation 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 discharge over the 2002-2007 period

Liquid discharges arising from operations on the Springfields site have fallen substantially over the reporting period as a consequence of the cessation of Uranium Ore Concentrate (UOC) purification in 2006. Table 2.6 and Figure 1.4 (below) demonstrate that the discharges of liquid alpha activity in 2007 were around 12% of the discharge in 2002, while the corresponding values for liquid beta discharges demonstrate a 97% reduction over the same period. Reductions in the discharge of other radionuclides is also evident.

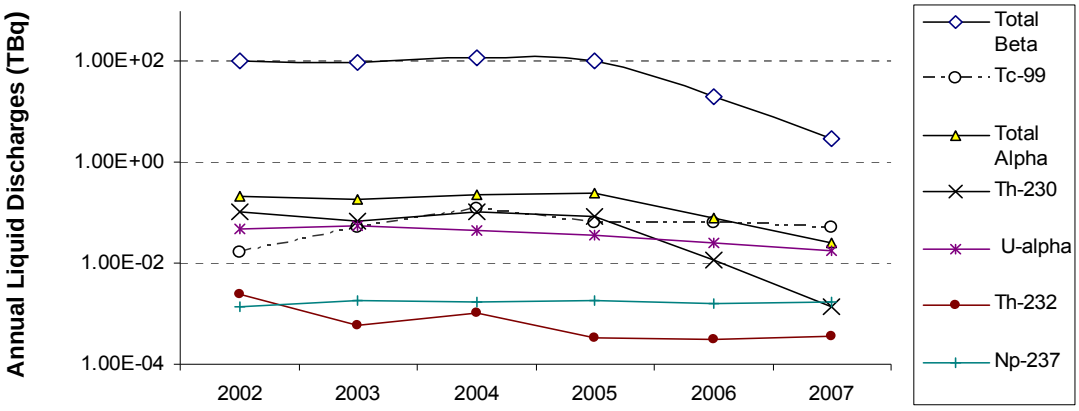

Figure 1.4 Annual Liquid Discharges from Springfields

Table 2.6 and Figure 2.4 (Part 2) present the emissions of uranium alpha activity to the atmosphere. There has been a slight reduction in the discharge of uranium alpha activity over the period. These levels have remained well below the authorised limits. This trend is a consequence of the on-going decommissioning and demolition of older plant on the site.

4.2.4 Radiological impact of liquid discharges

SFL 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 report, see for example RIFE 12. 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. A sample of the results routinely presented in the RIFE reports is given in Table 2.7, from which it can be seen, that activity concentrations in fish are generally below detection limits. The ^{137}Cs values are a result of discharges from the Sellafield site in West Cumbria. The level of ^{99}Tc in shrimps has fallen by over 75% of its 2002 value and the activity concentrations of radionuclides in other environmental samples have also fallen in the time period.

Doses to members of the public are estimated using a combination of measurements and modelling. The calculated doses to the most exposed groups of the population are presented in Table 2.8.

The following potentially exposed groups from 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 critical group 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 gradually decreased over the period, from 120 µSv received in 2002 to around 75 µSv in 2006 and 2007, although an improvement in measurement procedures resulted in a slight increase in apparent doses between 2005 and 2006. The annual effective dose to anglers and wildfowlers varied between 7 and around 30 µSv, depending on the habits of the group concerned.

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 were protected and, where possible, enhanced. Springfields was awarded the Biodiversity Benchmark from the Wildlife Trust in 2008 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.

4.2.5 The application of BAT

In response to the Environment Agency's 'Improvement and Additional Information Requirements', contained within their authorisation under the Radioactive Substances Act 1993, SFL 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 2006. 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).

This review identified a number of recommendations which may assist in further reducing the discharges from the Springfields site. These include consideration of the optimum addition of reagents to precipitate uranium, whilst minimising the amount of precipitate generated. This has been incorporated within the site's rolling programme to ensure BPM.

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 world wide. However, as outlined above, Springfields 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 2006, and continue to take an active part in the EARWG and other industry forums to promote best practice and to keep abreast of and continue to review development of new techniques.

4.3 References

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5. POWER GENERATION

In the UK, nuclear power generation is currently from three types of power station[15]:

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

The UK is the only country to have operational Magnox stations, the majority of which commenced operation in the 1950s and 1960s[16]. These reactors are currently managed by two Site Licence Companies (SLCs); Magnox South and Magnox North, with the exception of Calder Hall, which is under the management of Sellafield Ltd. As indicated earlier, 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 British Energy.

The UK is also the only country to have AGR stations in operation. During the period 2004-2007 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, transitional or decommissioning status of the power stations during the reporting period, 2004-2007. Information is provided under the appropriate headings for the following categories of site:

- Operational sites – those that were operational throughout the reporting period;
- Transitional sites – those that ceased operation during the reporting period;
- Decommissioning sites – those that ceased operation and began defuelling or decommissioning before 2004.

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

Table 1.1 Operational status of power stations in the UK

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

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

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 that the AGRs and PWR are owned and operated by British Energy and the Magnox stations are owned by the Nuclear Decommissioning Authority and operated by Magnox SLCs. In

[15] 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.
[16] The last Magnox station at Wylfa, Anglesey, was commissioned in 1971.

each case, a generic approach to the management of the sites is adopted, such that it is appropriate to consider them under these subheadings.

5.1 Operational Sites

There are seven AGRs, one PWR and two Magnox power stations in operation at the present.

5.1.1 Sources of liquid effluent for AGRs and PWR

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

- 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 the 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 treatment plant.

All AGRs have an Active Effluent Treatment Plant (AETP), or equivalent system. The main function of these systems is to deal with active effluent by various treatment processes leading to separation of oils, particulate and treated liquids. The AETPs comprise filter vessels, pumps, pipes, valves and indicators. The output of this active treatment plants is fed into the final monitoring and delay tanks.

The main sources of radioactive liquid effluent from the only PWR station arise 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 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 but can be redirected to the LRWS if it is found to contain significant amounts of radioactivity.

5.1.2 Source of liquid effluents for Magnox

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

The major source of liquid alpha and beta discharges from Oldbury is 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 are 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.

In the AGRs, 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 plant is almost totally duplicated, either through secondary stand-by plant or plant currently undergoing maintenance.

Radioactive liquid waste arises from operations 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.

AGR Pond Management

Pond Water is usually the most radioactive contributor to the effluents transferred to the AETP.

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 and ion exchange filter beds;
- Chloride ion concentration is controlled in order to minimise the incidence of stress corrosion of the stainless steel cladding of the fuel, so reducing the chance of fuel corrosion in the pond;
- Pond radiochemical factors are monitored through a process of routine sampling and analysis.

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

AGR Active Effluent Treatment Plants

The AETPs process the liquid waste by filtration to remove particulates and 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 creation 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 LWRS, 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 two 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;
- 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 product leakage from mechanically damaged fuel being in the ponds.

Spent fuel at Wylfa is dry stored.

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.

At the PWR, secondary neutron sources are used to provide essential control information when the reactor is returned to power following a period of shut down. The sources are known to produce tritium as a by-product. These sources were replaced in 2003 by a new design. These sources were predicted to produce less tritium. The sources are expected to be replaced again towards the end of 2012.

5.1.6 Liquid effluent treatment and discharge from Magnox

At the Oldbury site[17], in-pond treatment plants equipped with an IONSIV cartridge remove radiocaesium at source. Pond purge water is then passed through the Pond Water Filtration Plant (PWFP) to remove any particulate material, held in one of four

[17] Wylfa has no ponds, so there are no arisings from this source.

Final Delay Tanks and discharged only if chemical and radioanalytical conditions are within authorised limits. Other aqueous effluents arising on site are passed through 5 µm sand pressure filters in the Active Effluent Treatment Plant 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.

At Wylfa, where spent fuel is dry stored, the Active Effluent treatment is rather simpler, reflecting the lower levels of aqueous effluents, and particulate material is removed through gravity settling channels.

5.1.7 Trends in discharge over the 2002-2007 period for all operational sites

A detailed breakdown of discharges over this period are provided for each site in Part 2 Tables 2.11, 2.16, 2.21, 2.26, 2.29, 2.34, 2.39, 2.44, 2.49 and 2.54. The trends in liquid discharges and emissions to air are also illustrated in Figures 2.5–2.24. Some general features of the liquid discharge profiles are identified below.

The discharges from operational sites have remained fairly stable throughout the reporting period, as demonstrated in the tables and figures in Part 2, referred to above. The graphs illustrating discharge trends for the first site mentioned are reproduced below for illustrative purposes.

Dungeness B As illustrated in Figure 1.5 (below), the liquid discharges of ^{3}H and ^{35}S remained relatively constant over the period with the exception of 2003, where there was an increase in the discharge of both radionuclides. The increase of these radionuclides can be attributed to an increase of electricity generation during 2003 and 2004.

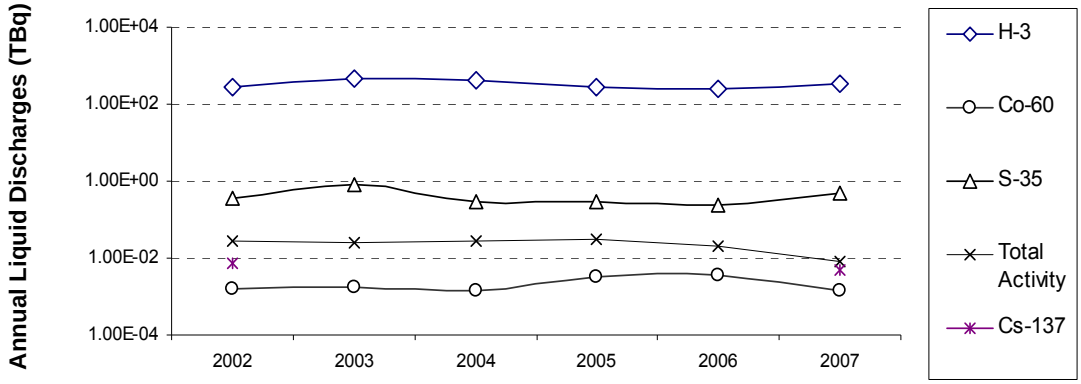

Figure 1.5 Annual Liquid Discharges from Dungeness B

The discharges of ^{60}Co increased by 100% from 2004 to 2005 and continued at this level until 2006 due to engineering operations carried out for monitoring of capacity of resin vaults. Discharges of ^{60}Co returned to 2004 levels in 2007.

Annual emissions to air were relatively constant throughout the period (Figure 1.6 below).

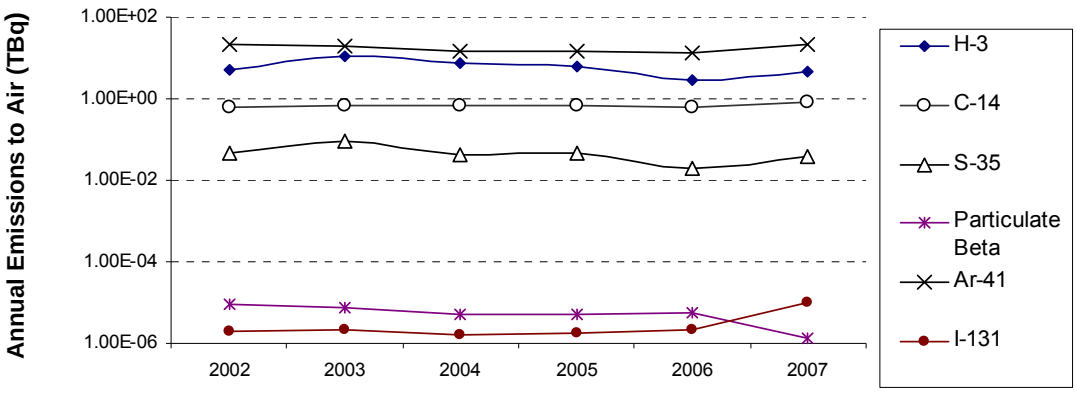

Figure 1.6 Annual Emissions to Air from Dungeness B

Hartlepool liquid discharges of ^{3}H and ^{35}S decreased from 2002 to 2004 and remained at a similar level from 2004 to 2006. In 2007 there was an increase in the these discharges, as a consequence of the increase of electricity generated during this year, but the values in 2007 were 20% and 60% lower than those in 2002, respectively (Figure 2.7).

There has been a significant decrease of ^{60}Co from 2005 – 2007 as a consequence of a change in the analytical methods to new generic method that had been developed over several years. The discharge in 2007 is around 1% of the corresponding figure for 2002.

Discharges of total activity (excluding ^{3}H, ^{35}S, ^{60}Co) were constant over the period 2002 to 2004 but fluctuated somewhat during the period 2005 to 2007.

As illustrated in Figure 2.8, the emission to air of ^{35}S has steadily decreased by around 80% over the reporting period, while the emission of other radionuclides remained steadier. The atmospheric release of particulate beta activity decreased significantly in 2007.

At *Heysham 1*, the discharges of ^{3}H have shown a steady decrease from 2002 until 2004 and then an increase from 2004 to 2006 and in 2007 the discharges were at the same level as in 2004 (Figure 2.9). There was an increase of ^{60}Co in 2007 due to an unplanned transfer of ion exchange resin into a sump in the effluent treatment plant. The decrease of the activity in 2007 in all other radionuclides discharges was due to an extended maintenance outage.

The emissions to air remained relatively steady throughout the period (Figure 2.10), although there is evidence for a reduction in the discharge of particulate beta activity in 2007.

Heysham 2 The liquid discharges from this site remained relatively steady over the period, with the exception of ^{60}Co, which had decreased to a third of its 2002 value by 2007 (Figure 2.11). The emissions to air from this site were also steady throughout the period (Figure 2.12).

At *Hinkley Point B*, liquid discharges remained relatively steady although in 2007 there was a significant reduction in all of the radionuclides discharges due to an extended outage for maintenance (Figure 2.13). Emissions to air were relatively steady, with a similar reduction in 2007 (Figure 2.14).

At *Hunterston B* power station, liquid discharges have shown no significant variation from 2002 to 2005, with the exception of ^{35}S, which decreased by over a factor of 2 in that period (Figure 2.15). There is a general decrease in the activity discharged in

2007, due to an extended outage from November 2006 to June 2007. The annual emissions to air demonstrated a similar trend (Figure 2.16).

Trends in liquid discharges from *Oldbury* are illustrated in Figure 2.17 and show a gradual decrease from 2002 to 2007; for example, the discharge of the 'other radionuclides' category decreased by around 40% over this period. The emissions to air also demonstrate a steady decrease (Figure 2.18). For example, the atmospheric discharge of ^{3}H and ^{14}C has decreased by a factor of around 2 and 10 respectively over the period.

At *Sizewell B*, the liquid discharge of ^{3}H has decreased slightly since 2003 as a consequence of a change in the neutron sources used, (see Figure 2.19). Total activity (excluding ^{3}H) has also shown a steady decrease from 2002 to 2007. Emissions to atmosphere were relatively stable, with the exception of halogens, for which data show a minimum discharge in the year 2005 and an increase in the years following (Figure 2.20). However, the discharge of halogens in 2007 is significantly lower than that in 2002.

Liquid and atmospheric discharges from *Torness* remained stable throughout the reporting period (Figures 2.21 and 2.22).

At *Wylfa* the ^{3}H discharges have been quite variable with differences greater than 30% from year to year from 2002 to 2007. The discharges of radioactivity reported as 'other radionuclides' have shown a steady decrease from 2002 to 2007 (Figure 2.23), with the value in 2007 being around 16% of that in 2002. The annual emissions to air have remained relatively stable throughout the reporting period (Figure 2.24).

5.1.8 Radiological impact of liquid discharges for AGRs and PWR

The environmental monitoring programme undertaken by British Energy addresses the principal radionuclides, and pathways, of potential significance. Representative environmental monitoring data related to liquid discharges are presented for each of the British Energy sites in Part 2 Tables 2.12, 2.17, 2.22, 2.30, 2.35, 2.44 and 2.49.

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

The CEARs now require that 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.

Environmental monitoring programmes at Hunterston B and Torness power stations have also been revised with the new Authorisations that came into force in 2007, although SEPA do not produce the equivalent of a CEAR document. The marine monitoring programme is similar to that for the English stations. 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, so discharge into the same immediate environment as its neighbour, where monitoring has been undertaken for many years. The impact of these stations cannot be distinguished from the impact of the adjacent Magnox station from environmental monitoring results alone.

The radiological impact from nuclear sites on members of the public is generally described in terms of the dose to the most exposed members of the public via a single discharge route (*e.g.* liquids). The most exposed members of the public from all discharges from the site is referred to as the critical group. The most exposed individuals from liquid discharges from AGRs and the PWR are generally associated with external exposure over beach sediments and the consumption of local fish and shellfish. The characteristics of the 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 Part 2 Tables 2.13, 2.18, 2.23, 2.31, 2.36, 2.46 and 2.51.

The reported effective doses to members of the most exposed groups from liquid discharges from AGRs and PWR are generally in the region of <5 µSv/y. The maximum value of 75 µSv was reported by Heysham in 2003 but the dose has decreased steadily to a value of 37 µSv in 2007 (Figure 1.7 below).

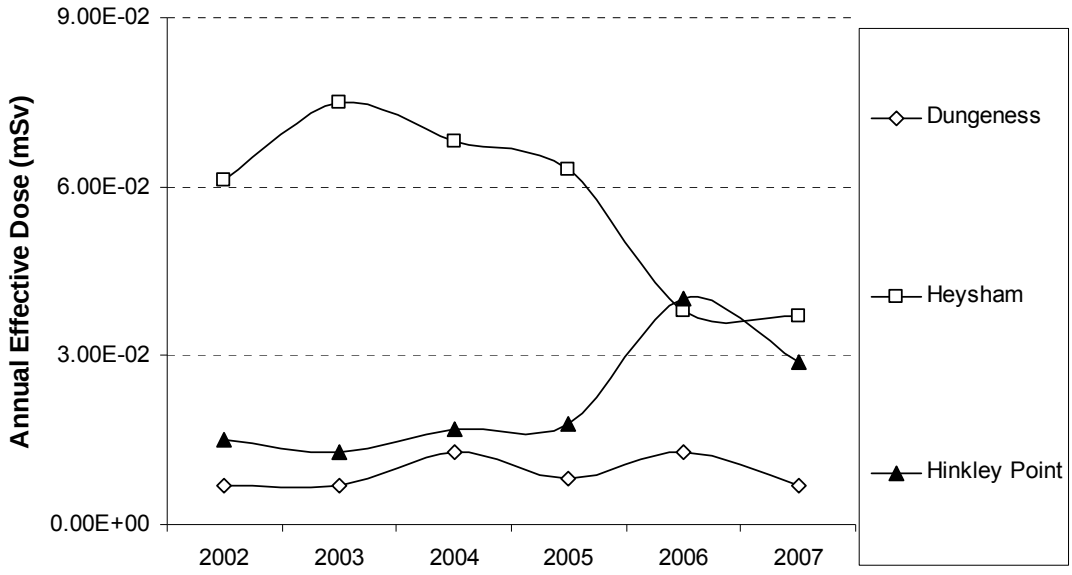

Figure 1.7 Trends in Critical Group Doses from Liquid Discharges from AGR and PWR Sites

The only other sites to consistently report doses greater than 5 µSv/y over the reporting period are Dungeness and Hinkley Point B. The estimated effective doses at Dungeness have remained around 10 µSv, while those for Hinkley Point Bincreased to 40 µSv in 2006. This fell again to 29 µS in. The increase around Hinkley Point B in 2006 is attributed to discharges from the neighbouring Hinkley Point A, which increased discharges as a result of fuel pond clean-up prior to decommissioning the ponds. Doses from all AGR and PWR sites remain significantly lower than the dose constraint of 300 µSv y^{-1}.

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. Several of the decommissioning or transitional Magnox stations adjoin

an AGR or PWR site (see Sections 5.2 and 5.3) and, in these instances, the stations share a common monitoring programme.

Neither of the two operational Magnox stations is co-located with an AGR or PWR site, and representative environmental monitoring data for Oldbury and Wylfa are presented in Tables 2.40 and 2.55. However, the effective doses to members of the public around Oldbury site include a component from the decommissioning Berkeley station.

The estimated effective dose to critical group consumers of fish and shellfish (who also spend time on intertidal sediments) around Oldbury increased steadily over the period from a value of 8 μSv in 2002 to 18 μSv in 2007, as illustrated in Figure 1.8 below. The increase in critical dose calculations in 2007 for Oldbury and Berkeley is due to revised habit data identified during a 2007 survey.

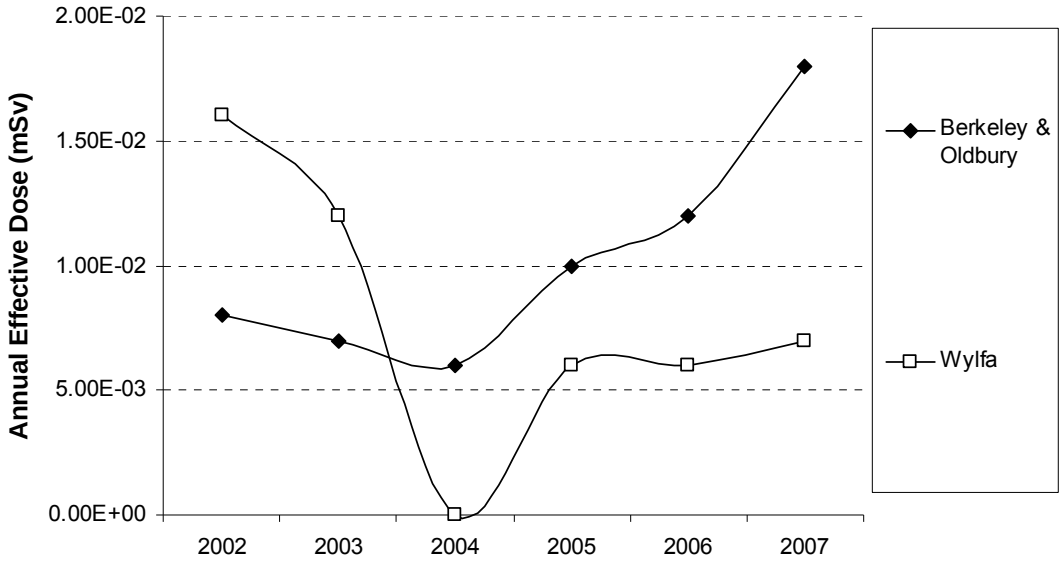

Figure 1.8 Trends in Critical Group Doses from Liquid Discharges from Operational Magnox Sites

Over the same period, the effective dose to critical group consumers at Wylfa decreased from 16 μSv in 2002 to 7 μSv in 2007. A minimum value of <5 μSv was reported in 2004. Doses from both operational Magnox sites remain significantly lower than the dose constraint of 300 μSv y^{-1}.

5.1.10 The application of BAT for AGRs and PWR

British Energy has made new additions to its environmental management system. These are environmental operational rules referred to as Environmental Specifications or ESpecs. The 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. An Environmental Maintenance, Inspection and Testing Schedule (EMITS) has been developed to provide a through approach to environmentally sensitive plant.

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 1.2.

Table 1.2 Operational AGR and PWR Power Station Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
AGRs and PWR	Fuel Integrity Delay Tanks Ion exchange Coolant chemistry	HEPA Chemical Adsorption (PWR)

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 BPM 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 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 BPM 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.

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. 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 discharge and the plant, its reliability, available technology and 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.

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 BPM. The

consequent small 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 deionised water. The presence of dissolved gases (oxygen and nitrogen) in the deionised water is strictly controlled in order to reduce production of ^{14}C and ^{16}N within the system.

5.1.11 The application of BAT for Magnox

The abatement technologies used at Magnox power stations are presented in Table 1.3. 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 caesium.

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

    - Fine Filters of 5 to 10 micron filters, often used in conjunction with coarse filters (15 micron), to remove particulate from the waste stream;

    - The 'FilTore', used at Wylfa, with a 10 micron filter is 97.7 % efficient. This filter is also 90% efficient at removing particles of 5 microns;

    - 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 introduced a Black Level Scheme to ensure that any defects or unavailability of plant are addressed without delay.

Table 1.3 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 FilTore advanced 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.

The current techniques being used for the control of liquid discharges are regarded as BPM and therefore, by extension, BAT. The industry maintains a review of developments in liquid effluent processing and, as demonstrated in the past, is willing to embrace proven technology. For example, the following abatement technologies are currently being considered:

- Improvement of ion exchange systems, including management of pre- and post-filter systems;
- Physical filtration techniques to control particulates, centrifuge systems for sedimentation and filtering designs, and de-watering units for reducing retrieved wet wastes.

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 station.

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 Best Practicable Environmental Option. The normalised liquid discharges from Sizewell B for the period 2002-2007 are presented in Table 1.4 below.

Table 1.4 Normalised Liquid Discharges from Sizewell B

	Normalised liquid discharge (TBq/GWh)					
	2002	2003	2004	2005	2006	2007
^{3}H	7.07E-03	7.75E-03	1.89E-03	3.56E-03	6.19E-03	2.84E-03
Total activity excluding ^{3}H	5.43E-06	4.97E-06	2.18E-06	3.27E-06	2.44E-06	1.27E-06

These discharges are generally higher than those presented in the UNSCEAR and EC reports (see Table 1.5 below).

Table 1.5 Normalised Liquid Discharges from Nuclear Reactors

	UNSCEAR Report [a]		EC Report [b]
	1990-1994	1995-1997	1995-1999
H-3 (TBq/GW h)	2.5E-3	2.2E-3	2.71E-3
All other radionuclides (GBq/GW h)	2.2E-3	9.1E-4	4.19E-4[c]

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

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 Transitional sites

Defuelling and decommissioning strategies for Magnox stations and other UK civil nuclear facilities are the responsibility of the NDA. The Magnox defuelling programme has recently been revised and is described in the March 2008 issue of the Magnox Operating Programme (MOP8).[18] The 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", making them weather and intruder resistant for the extended C & M period. All operational Intermediate Level Waste (ILW), except for Miscellaneous Activated Materials (MAM) and desiccants, will be retrieved, packaged for final disposal and transferred to on-site interim ILW stores. Desiccants will be transferred to containers for storage. MAM will be safely contained within storage locations inside concrete vaults (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 100 years 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.

There are three Magnox sites that are classified as transitional; Chapelcross, Dungeness A and Sizewell A.

[18] This document can be obtained from the NDA at www.nda.gov.uk.

5.2.1 Sources of liquid effluent

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

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

During defuelling, as with operational stations, the most radiologically significant source for liquid effluents is the spent fuel storage pond water and controls are in place to minimise the release of activity from the spent fuel into the pond water.

5.2.2 Management of liquid effluent treatment and discharge

Management procedures at transitional sites remain in place to reduce arisings of radioactive waste and effluent arisings.

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

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 BPEO/BPM considerations are included in process planning.

At *Chapelcross* all fuel previously stored in ponds has been despatched to Sellafield for reprocessing. Fuel remains in the reactor, where it is essentially in dry store, and will be defuelled and despatched direct to Sellafield without interim pond storage. Remaining pond water is retained on site within the ponds and is not currently being discharged.

Best practicable means are used to minimise the production of liquid radioactive waste. Liquid waste that is produced during defuelling and decommissioning activities is discharged via settling and discharge tanks.

At *Dungeness A*, 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 Magnox Dissolution Plant (MXD), located at Dungeness A, is designed to reduce the volume of solid waste arising from the removal of lugs etc from the external surface of Magnox spent fuel elements. The plant dissolves the essentially inactive debris in carbonic acid and leaves a residue of insoluble mildly-radioactive solid. The process effluent passes through a sand bed and a 5 µm cartridge filter (resulting in very low levels of radioactivity) and is discharged with the station's other routine active effluents. The MXD plant has been refurbished since the previous report. As a consequence of the dissolution of a new type of materials, the proportions of activity discharged changed slightly with an increase in the monthly averages of ^{3}H discharged but significant reductions in ^{137}Cs levels.

At *Sizewell A*, the treatment of liquid waste routed into the treatment plant has remained broadly similar to that described in our last report. Minimization of the use of the plant via strategic management was required, following the failure of the

recirculation line in 2007 and the subsequent plant outages for repair/replacement of the system.

The Effluent Treatment Plant systems have been updated and the use of the Submersible Caesium Removal Unit (Ionsiv Resin) has been introduced.

5.2.3 Trends in discharge over the 2002-2007 period

A detailed breakdown of the discharges over this period for the transitional sites (Chapelcross, Dungeness A and Sizewell A) is provided in Part 2Tables 2.59, 2.64 and 2.67.

Chapelcross ceased operation in June 2004 and the liquid discharges of ^{3}H and total beta have been decreasing year by year (see Figure 1.9). The ^{3}H and total beta discharges in 2007 are only 3% and 1%, respectively, of the discharges in 2003. Discharges of total alpha activity also decreased during the period of 2002 to 2007, with a peaked in 2003 due to the fact that one of the ponds was emptied but subsequently decreased during 2004 to 2005. The reported discharge for 2007 is around 16% of that in 2002.

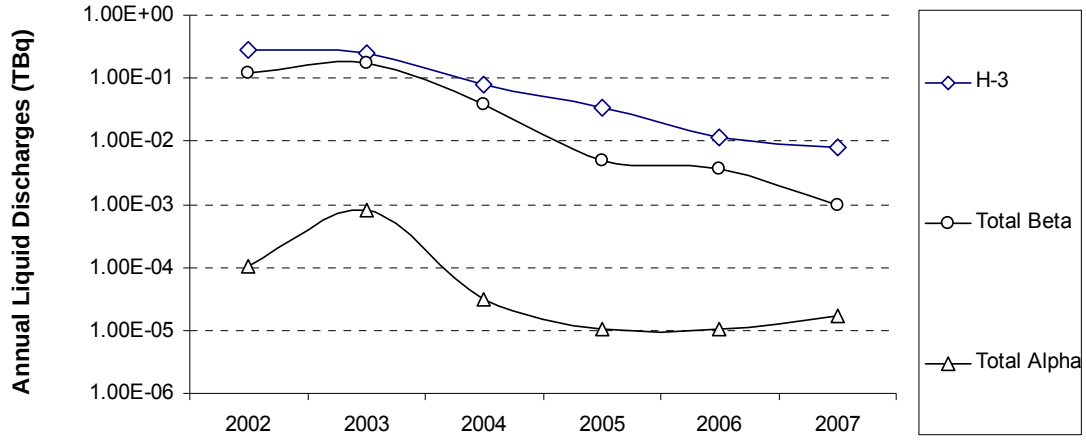

Figure 1.9 Annual Liquid Discharges from Chapelcross

The emissions to air have also reduced steadily over the reporting period (Figure 2.28).

Dungeness A ceased operation in December 2006. The liquid discharges of ^{3}H decreased significant from 2002 to 2004. However, since then, there has been an increase of the ^{3}H discharges (Figure 2.29). This trend is a consequence of a campaign to dispose of a 2 year backlog of gas processing liquors and the quantity produced when the system was fully drained, following the shutdown of the reactors. A BPM exercise was undertaken to justify this process, which was accepted by the Environment Agency. Discharges of ^{137}Cs and "other radionuclides" in liquid effluents have shown a steady decrease from 2002 – 2007. The annual emissions to air remained steady from 2002-2006. A reduction in all discharges is evident in 2007, following the cessation of operation (Figure 2.30).

Sizewell A ceased operation in December 2006. Liquid discharges of ^{3}H have varied. A peak discharge in 2003 was followed by a significant decrease in 2004 and 2005, with a further increase in 2006 and 2007 (Figure 2.31). Discharges of ^{137}Cs and other radionuclides remained at a similar level from 2002 until 2006, followed by a significant 50% decrease in 2007, following cessation of operations. The annual emissions to air decreased in 2007 (see Figure 2.32).

5.2.4 Radiological impact of liquid discharges

The Magnox Site Licence Companies undertake environmental monitoring around the sites. It was noted in Section 5.1 that sites located adjacent to operational AGR or PWR stations (which is the case for Dungeness A and Sizewell A, respectively) share a single environmental monitoring programme. Data for these sites, together with the derived effective doses to members of the public, have been reported in Section 5.1, Part 2 Tables 2.12-2.13 (Dungeness sites) and 2.44-2.45 (Sizewell sites). Annual effective doses for Sizewell (A and B station combined) were reported to be below 5 µSv, and the doses to the corresponding group at Dungeness (A and B station combined) were estimated to receive around 10 µSv, throughout the reporting period.

Environmental data for Chapelcross are presented in Part 2 Table 2.60. The associated dose to the identified critical group in the vicinity of Chapelcross was 39 µSv in 2002, reducing to 24 µSv in 2007 (Table 2.61). It should be noted that these estimated doses include a contribution from Sellafield.

The trends in critical group doses around transitional sites are illustrated in Figure 1.10 below.

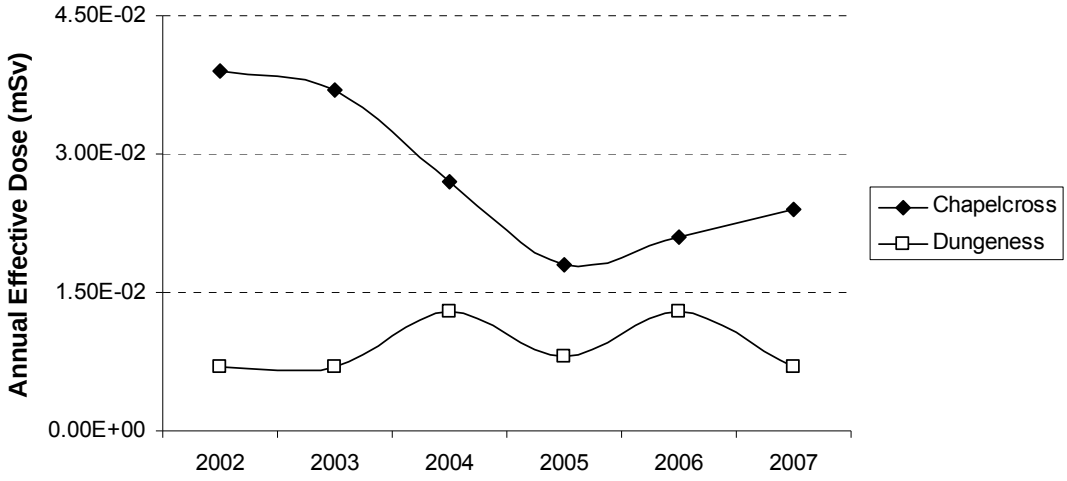

Figure 1.10 Trends in Critical Group Doses from Transitional Sites

*Estimated effective doses for the Sizewell site are reported to be <0.005 mSv per year throughout the reporting period.

Critical group doses derived for all transitional Magnox sites, even including the contribution deriving from operation of other, nearby, sites remain significantly lower than the dose constraint of 300 µSv y^{-1}.

5.2.5 The application of BAT

At Chapelcross, Dungeness A and Sizewell A there are different abatement systems in order to manage and decrease activity present in the liquid discharges.

Table 1.6 Transitional Magnox 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 • Doulton filters • Ion exchange • Settling tanks • Submersible Caesium Removal Unit (Ionsiv Resin) Pond temperature and water chemistry	• HEPA filtration
Sizewell A	• Delay tanks • Ion exchange • Sand pressure filters • Settling tanks • Submersible Caesium Removal Unit (Ionsiv Resin)	• HEPA filtration

The main function of the delay tanks is to allow short half-life radionuclides to decay and also to allow activity to be monitored prior to discharge into the sea.

The ion exchange resins are used to remove mainly ^{137}Cs and ^{90}Sr and their efficiency will depend on the levels of other ions present in the liquid, such as Na^{+} and Mg^{2+}.

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 implemented Doulton filters of 5 µm size.

At Sizewell A, some plant modifications have been carried out to modify or update operational systems, such as the Effluent Treatment Plant. The use of the Submersible Caesium Removal Unit (Ionsiv Resin) was introduced in 2003.

At Chapelcross a site-wide review of liquid and aerial discharge abatement approaches is being undertaken, which will be completed before April 2009. Any recommendations of the review will be considered and, where appropriate, will be implemented.

5.2.6 Comparison with performance of similar plants world-wide

There are no reactors of this type now operating elsewhere in the world so no meaningful comparisons of the application of BAT or of environmental performance are possible. However, in accordance with revised authorisation conditions, the operator is required to review alternative abatement techniques.

5.3 Decommissioning Power Stations

Berkeley, Bradwell, Hunterston A, Hinkley Point A and Trawsfynydd power stations all began decommissioning before 2002. All these reactors were defuelled before 2005.

As noted above, it is recognised that short-term increases in discharges may arise during the defuelling and decommissioning processes.

5.3.1 Sources of liquid effluent

Radioactive liquid effluents arise from reactor and fuel handling operations. The principal sources for decommissioning stations are:

- Laundry operations; and,
- Reactor defuelling (until completion) and decommissioning operations.

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

5.3.2 Liquid effluent treatment and discharge

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

All aqueous effluents are filtered prior to discharge to remove residual particulate matter, for example by the use of sand pressure filters. The removed particulates are stored for future encapsulation. Effluents are accumulated in delay tanks, sampled and, if their activity content is acceptably low, are discharged via the station's existing pipelines, using cooling water, or alternative water supplies, to ensure considerable dilution and the avoidance of high local concentrations near the discharge outfall.

5.3.3 Trends in discharge over the 2002-2007 period

All of the sites described in this category are undergoing defuelling and decommissioning. The discharges are therefore primarily associated with the phasing of such operations. The liquid discharges and emissions to air reported during the period 2002-2007 are presented in Part 2 Tables 2.68, 2.71, 2.75, 2.77 and 2.79.

Berkeley liquid discharges of ^{3}H, ^{137}Cs and other radionuclides remained at the same level from 2002 until 2004 when a peak in the discharges of all radionuclides was recorded in 2005. From 2005 until 2007, there was a decrease in discharges level year to year (Figure 2.34). Annual emissions to air have remained effectively constant throughout the period (Figure 2.35).

At *Bradwell*, the liquid discharges of ^{137}Cs and other radionuclides remained at the same level from 2002 to 2005. From 2005, which marked the end of the defuelling stage, there has been a small decrease to 2006 with a further significant decrease in 2007 (Figure 1.11). The liquid discharges of ^{3}H decreased markedly from 2002– 2003 and then show a small increase from 2003 to 2005 and remain at the same level in 2006, followed by a significant decrease in 2007 (Figure 1.11).

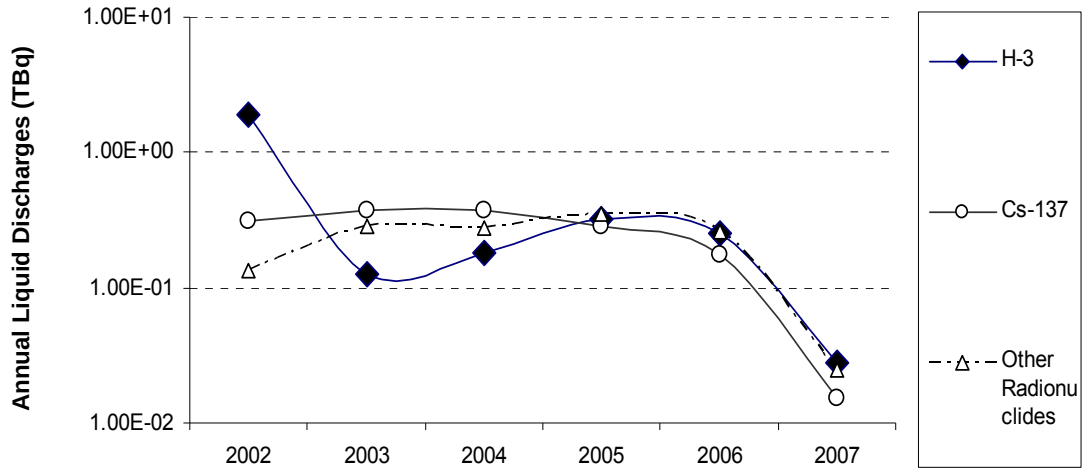

Figure 1.11 Annual Liquid Discharges from Bradwell

This figure demonstrates the type of variation in discharge patterns arising from the phasing of decommissioning operations.

Annual emissions to air decreased markedly between 2002 and 2003 and continued to demonstrate a downward trend for the remainder of the period, although emissions of ^{3}H and ^{14}C increased slightly in 2007 (Figure 2.37).

At *Hinkley Point A* the liquid discharges of ^{3}H and ^{137}Cs have decreased from 2002 to 2006 with a small increase from 2006 to 2007 (Figure 2.38). The liquid discharge reported in 2007 was lower than that reported for 2002. The discharge of other radionuclides has increased over the period due to the activities to decommission the former reactor cooling ponds. Annual emissions of ^{14}C and particulate beta activity have decreased slightly since 2002, while the emission of ^{3}H has increased slightly over the same period (Figure 2.39).

At *Hunterston A* the liquid discharges for all radionuclides do not show significant changes from 2002 to 2007 (Figure 2.40). The emissions to air have also remained relatively constant throughout the period (Figure 2.41).

At *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. The levels of all radionuclides discharged have decreased from 2002 to 2007 (Figure 2.42), although there is a peak in discharges of ^{90}Sr and other radionuclides in 2004. Annual emissions to air have remained relatively constant (Figure 2.43).

5.3.4 Radiological impact of liquid discharges

Environmental monitoring programmes are in place around each of the sites or, in the case of Berkeley, Hinkley Point A and Hunterston A, joint programmes are in place with adjacent operational stations. Representative environmental monitoring data are presented for Bradwell and Trawsfynydd in Tables 2.72 and 2.80.

The trends in critical group doses around these sites are illustrated in Figure 1.12. The estimated doses at all sites except Bradwell and Trawsfynydd include a contribution from an operational station, and were discussed in Section 5.1.

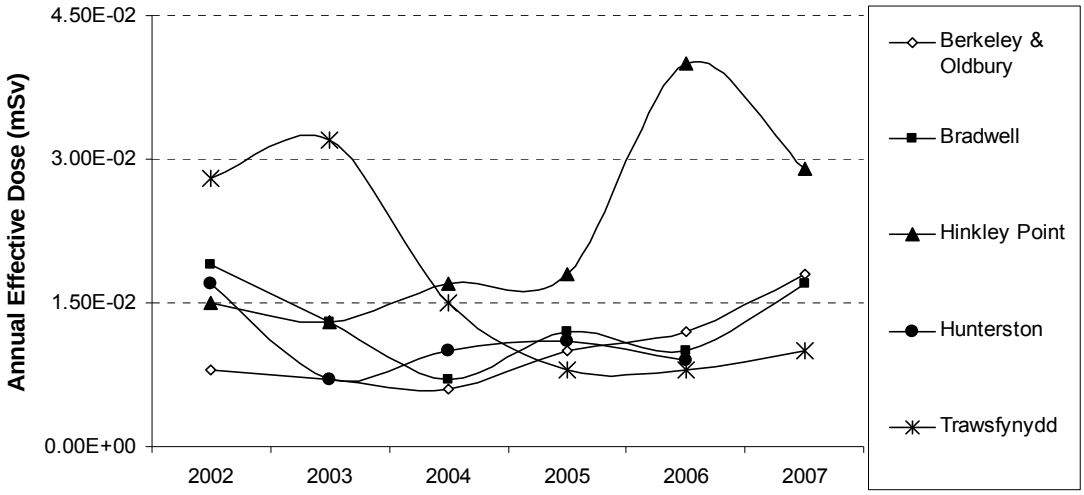

Figure 1.12 Trends in Critical Group Doses from Liquid Discharges from Decommissioning Sites

* Estimated effective doses for Berkeley and Hinkley Point A include contributions from adjacent operational stations.

The annual effective doses to the critical group around Bradwell (from the consumption of fish and shellfish and intertidal occupancy) have fluctuated slightly over the period but, in round terms, have remained between 10 and 20 µSv. The annual effective dose to the critical group around Trawsfynydd (arising from consumption of freshwater fish and external dose to anglers) has decreased by a factor of around 3 over the reporting period, to 10 µSv in 2007. These doses represent less than 1 percent of the dose limit to members of the public.

5.3.5 The application of BAT

The abatement techniques commonly applied at decommissioning Magnox stations are summarised in Table 1.7.

Table 1.7 Decommissioning Magnox Abatement Techniques

Station	Liquid Abatement	Aerial Abatement
Berkeley	Sand pressure filters (10 micron) Funda filters	HEPA filters
Bradwell	Sand filters in pond water treatment plant Non regenerable ion exchange resin in pond water treatment plant Sand filters on effluent plant	HEPA filters
Hinkley Point A	Delay tanks Fine filter units Ion exchange resin to reduce caesium and strontium radionuclides	HEPA filters on contaminated ventilation systems
Hunterston A	Delay Tank SPF, ion-exchange removed; awaiting new IONSIV	HEPA filtration. No shield cooling or iodine filters
Trawsfynydd	Sand pressure filters and ion exchange units	HEPA filters on contaminated ventilation systems

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

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 the sampling and analysis before being discharged.

At *Hunterston A*, liquid discharges are passed through sand pressure filters and then stored in a delay tank prior to discharge to sea. A new effluent treatment system is currently undergoing active commissioning.

Sand pressure filters and ion exchange units are also used at *Trawsfynydd*.

5.3.6 Comparison with performance of similar plants world-wide

The Magnox Site Licence companies have company standards which are periodically updated and reviewed to reflect current best practice within the Magnox fleet and practices from other organisations. In addition, in accordance with EA authorisations, the operators are required to review alternative abatement techniques as part of their authorisation requirements.

5.4 References

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

Environment Agency, Authorisation Decision Documents

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

6. FUEL REPROCESSING

The Sellafield site is the largest nuclear complex in the UK and undertakes the reprocessing of spent magnox and oxide fuels [19] connected with the UK nuclear electricity generation programme and spent oxide fuel from other countries.

Since the previous report to OSPAR, the Nuclear Decommissioning Authority has taken over ownership of the Sellafield site (from 1 April 2005). The site is currently operated on a day to day basis by Sellafield Ltd (the Site Licence Company) under the leadership and management of Nuclear Management Partners Ltd (NMP)[20] who are the Parent Body Organisation under contract to the NDA.

The Sellafield site encompasses the Calder Hall nuclear power station, which is currently undergoing decommissioning. This is also under the management of Sellafield Ltd and is reported on here together with Sellafield operations (see Section 6.2). In addition, within the Sellafield site the Windscale site forms an enclave. Until recently, this was operated independently from Sellafield and continues to be reported on separately within this report (see Section 7.3). However, the Sellafield and Windscale sites are being integrated and, for instance, since the previous report now share a single authorisation under the Radioactive Substances Act (1993) and are both operated by Sellafield Ltd.

The Sellafield site is certificated under both the international Environmental Management standard ISO14001 (2004) and the international Quality Management standard ISO9001 (2000). 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;
- Recovered plutonium and uranium storage;
- Mixed Oxide fuel fabrication;
- Processing and storage of HLW and ILW;
- Processing of LLW for disposal to the Low Level Waste Repository (LLWR);
- Decommissioning of redundant facilities and treatment/conditioning of inventories of liquid and solid wastes;
- Research and development (including activities carried out by the National Nuclear Laboratory); and,
- Disposal of VLLW.

Information relating to site activities is also summarised in Table 6.1.

[19] 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.

[20] On 24th November 2008 the shares in Sellafield Ltd were transferred from BNFL to NMP who became the Parent Body Organisation under contract to the NDA.

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

Since the previous submission, the Thermal Oxide Reprocessing Plant (THORP) and the Magnox Reprocessing Plant (MRP) have continued to operate, although THORP was shutdown during much of 2005-2007 and throughput was very restricted. The plant has now returned to operation.

A mixed oxide fuel fabrication facility, the Sellafield MOX Plant (SMP), has been developed at Sellafield. This commenced active commissioning in 2001 and has been progressing through different phases of commissioning and improving plant performance during the reporting period. This is a dry process and hence does not contribute to liquid discharges.

More recently, with the inception of the Nuclear Decommissioning Authority, the site's primary function is changing to clean up and decommissioning of its nuclear facilities. LifeTime Plans (LTPs) have been developed with an enhanced clean up programme and the NDA has identified Sellafield as a priority site for the allocation of finances to reduce hazards (NDA Business Plan, 2008).

The Magnox reprocessing programme, which was previously anticipated to complete in 2012, is now scheduled to be complete around 2016. The future of oxide reprocessing, which was previously uncertain beyond 2010, will extend to 2015 (through THORP), based on current plans. Operation beyond that date is dependent on the receipt and approval, by Government, of new orders. It should be noted that these recent time extensions to both Magnox and Oxide fuel reprocessing primarily reflect reduced fuel throughput rather than inclusion of additional fuel for reprocessing and will not increase overall discharges. Any proposals for new contracts would be reviewed to take account of, inter alia, their consistency with the UK's environmental objectives and international obligations.

Over the reporting period, there have been no incidents at Sellafield which have resulted in significant impacts as a result of effluent releases. There has been one liquid release rated at INES level 1, 'anomaly'.

6.1.1 Sources of liquid effluent

Radioactive liquid effluents arise from fuel reprocessing and storage operations, decommissioning of the Calder Hall reactors (see Section 6.2), other on-site 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; they are not therefore discharged from the site.

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 some years to come, although this will eventually shift as the balance between decommissioning and operational activities changes.

Effluents from Magnox reprocessing operations were previously 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.

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

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 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.

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: Much of the tritium disposed of at Sellafield is discharged to sea. This comprises almost 90% of the ^{3}H contained in Magnox fuel when it is reprocessed.

- 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.

- 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 the legacy facilities in the Magnox Separation Area.

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

- Iodine-129: Discharges to sea arise from the treatment, by caustic scrubbing, of the ventilation air stream associated with spent fuel dissolution in the two reprocessing plants. THORP is generally the main source of ^{129}I discharges to sea, although this varies dependent on throughput rates through the two reprocessing plants. The very low or zero fuel throughputs for THORP 2005-2007 was reflected in reduced ^{129}I discharges in these years. With the resumption of oxide fuel reprocessing some reversal of this trend may be anticipated in future years.

- Caesium-137: The majority of ^{137}Cs arisings are the result of Magnox reprocessing and miscellaneous historical arisings. Over 99% 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 the Site Ion eXchange Effluent Plant (SIXEP).

- 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. The main source of the small residual liquid discharges of plutonium isotopes and ^{241}Am is from the 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 the Waste Vitrification Plant (WVP).
- The Salt Evaporator is designed to condition and concentrate waste streams for interim decay storage prior to treatment in the Enhanced Actinide Removal Plant (EARP).
- SIXEP is designed to reduce fission product discharges.
- EARP has the primary purpose of reducing the levels of plutonium and other actinides in liquid discharges.

These plants are well established but, in view of the importance of these plants in reducing the level of liquid effluents from Sellafield, they are described briefly below.

The highly active liquid waste that arises from both reprocessing plants is evaporated to reduce its volume, and subsequently stored, in the HALES plant. It then passes through a series of processes to vitrify it into a glass-like solid, suitable for long term storage in robust, stainless steel containers in the vitrified product store.

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

SIXEP consists of an array of regenerable sand bed pressure filters, pH reduction processes using counter flow contact with CO_2, and ion exchange columns containing an alumino-silicate zeolite, clinoptilolite, which is effective in removing caesium and strontium isotopes. This plant has been designed to take purge water from the Magnox fuel storage and decanning facilities, Oxide fuel storage ponds, and from AGR fuel storage and dismantling. SIXEP is highly efficient for the removal of caesium isotopes. Decontamination factors for caesium of around 3000 are typical, although this will vary with the feed liquors. Optimisation of SIXEP performance, and associated minimisation of liquid discharges, has been subject to detailed research on the effect of competing ions in feed liquors (British Nuclear Group, 2007). Research and development to further improve environmental performance continues to be conducted, with current activities seeking to improve SIXEP capability to allow processing of greater amounts of liquors and to investigate the sources of Sr-90 and Sb-125 in aqueous effluents from SIXEP in order to further reduce the activity of discharges from the plant.

EARP is particularly aimed at removal of alpha activity but a number of beta-emitting radionuclides are also removed efficiently. The process increases the pH of effluent liquors so that the iron present is precipitated in the form of ferric floc. The alpha-emitters, plutonium and americium, together with some beta-emitters, co-precipitate with the ferric floc. Additional removal of beta-emitters, particularly caesium, is also achieved by the use of an ion exchanger sodium nickel hexacyanoferrate. The solid precipitate is separated from the very low active liquor by ultrafiltration and these are

encapsulated in cement in the Waste Packaging and Encapsulation Plant (WPEP). The low active liquor from the ultrafilters is collected, sampled and analysed prior to discharge to sea. Decontamination factors are >1000 for alpha-activity and >10 for beta activity. The exception is ^{99}Tc, which is not removed by this process. This radionuclide is contained in MAC and liquid discharges of ^{99}Tc to the Irish Sea increased markedly after 1994 as a consequence of commencing EARP treatment of a backlog of MAC accumulated as a result of Magnox reprocessing since 1981.

Treatments specific to ^{99}Tc

In February 2000, the EA initiated a full re-examination of its regulation of ^{99}Tc discharges to the Irish Sea. Subsequent to that review in September 2001, the EA required two specific approaches to be pursued.

i. To use the existing vitrification process (used to treat highly radioactive liquid waste from reprocessing) to treat future arisings of MAC from Magnox reprocessing.

ii. The continuation of research and development work into the use of TPP (tetraphenylphosphonium bromide) to precipitate ^{99}Tc from older MAC already in store and which is incompatible with vitrification due to its higher salts content.

MAC routing to vitrification has been implemented since July 2003.

Following close co-operation between regulators and operators, the use of TPP was trialled successfully at the end of 2003 and since April 2004 the new technique has been in use at EARP, with over 95% of the ^{99}Tc contained within the stored MAC now transferred into a solid waste form for encapsulation. The backlog of stored MAC has now been treated using this process and this has led to a significant reduction in ^{99}Tc discharges from the site (see Section 6.1.4).

Treatment plants specific to THORP

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

Other treatment plants

A number of other parallel plants and projects have been introduced to reduce liquid effluents. 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.

- *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.

A number of other treatment options have been subject to review and research and have been reported on as part of the Site's Lifetime Plans. Many of these are specific to legacy wastes.

Removal of sludge from the Pile fuel storage pond has now started and is being facilitated by a Local Effluent Treatment Plant (LETP). This is reducing discharges arising during treatment of this waste.

A trial has been completed of the encapsulation of First Generation Magnox Storage Pond sludge at the Waste Encapsulation Plant (WEP). Sludge was retrieved, loaded to a 500 litre drum, transferred to WEP and successfully encapsulated in grout by in-drum mixing. A further trial has been carried out on the encapsulation of Miscellaneous Beta-Gamma Waste (MBGW) from the pond. MBGW was retrieved, transferred to WEP and encapsulated under the existing Letter of Compliance (LoC). In addition to proving the specific route, this also potentially establishes a precedent for the encapsulation of certain MBGW streams from other sources. Further trials are currently ongoing to improve understanding of legacy waste behaviour and inform development of retrievals plans.

Supernate from the Magnox Swarf Storage Silos has been transferred successfully to SIXEP and the trials have demonstrated that SIXEP is able to handle quantities of silo liquor with no observable adverse impact on performance and discharge quality. This provides an effective treatment for the liquid waste stream and will also enable immobilisation of activity within the solid phase.

Future waste treatment facilities

Major new facilities currently being developed include:

- Silos Direct Encapsulation Plant: to encapsulate the waste from the Magnox swarf storage silo, operational post 2010.

- Sludge Packaging Plant: to provide storage for sludge from pond retrieval operations into a directly disposable product, active commissioning expected post 2010.

- Box Encapsulation Plant and Product Store: to encapsulate some of the retrieved waste from the legacy ponds and store both untreated waste from the pile fuel cladding storage silo and treated waste from the remaining legacy ponds and silos; active commissioning expected ca. 2015.

Public consultation on waste treatment strategy

A number of ponds and silos used to store fuel prior to reprocessing and to hold the separated fuel cladding contain 'legacy' wastes that have accumulated over a period of around 50 years. Whilst these wastes are safely managed, they cannot continue to be retained indefinitely in their current facilities. Therefore, Sellafield Ltd is developing new facilities to retrieve and condition the legacy wastes for long-term storage and eventual disposal, ensuring that such facilities and operations represent BAT.

Public consultation on high level strategic options for the management of legacy ponds and silos was undertaken December 2005 to February 2006.

It is anticipated that whatever new facilities are commissioned some liquid and aerial effluents will inevitably require discharge to the environment.

6.1.3 Authorised liquid discharge limits

An authorisation under the Radioactive Substances Act (RSA) covering disposals to all environmental media, was introduced in October 2004, following a detailed review and consultation undertaken by the Environment Agency (EA 2002, 2004) identified in our previous report. This single authorisation replaced the 6 separate authorisations previously in force. Significant decreases in the authorised discharge limits for liquid effluents were introduced for a number of radionuclides. No increased discharge limits were set.

The Environment Agency keeps the RSA authorisation under regular review and has granted several minor variations since 2004 to the authorisation which have included changes (up and down) to individual facility (plant) limits where necessary. In addition, the authorised site discharge limit for ^{99}Tc was further reduced from 20 TBq/y to 10 TBq/y in April 2006 in line with the UK Strategy for Radioactive Discharges which set a target of the end of 2006 to achieve this (note that the actual discharge had reduced to less than 10 TBq in 2005).

In April 2008, the Sellafield and Windscale RSA authorisations were merged and a number of other minor changes were made.

6.1.4 Trends in liquid discharges 2002-2007

There has been a general downward trend in all discharges from the main site pipeline since the last reporting period (see Table 2.83 and Figures 2.45 and 2.46). In some instances, the lower discharges are linked to the low reprocessing throughput rates experienced 2005-2007. Total alpha discharges fell over this period due both to the reprocessing rate and to the improved management of legacy fuel pond stocks and associated pond water activities. The alpha discharge in 2007 is around 35% of the corresponding figure for 2002. It is anticipated that by 2020, discharges of liquid total alpha will consistently be less than 0.2 TB per year.

The recent reductions in liquid discharges of ^{99}Tc, resulting from the modifications in treatment outlined above, are put into context in Figure 1.13 below. Discharges have decreased by more than 90% over the reporting period and are now similar to levels before treatment of stored MAC commenced in 1994. It is anticipated that discharges will reduce further, to below 1 TBq/year, by 2016.

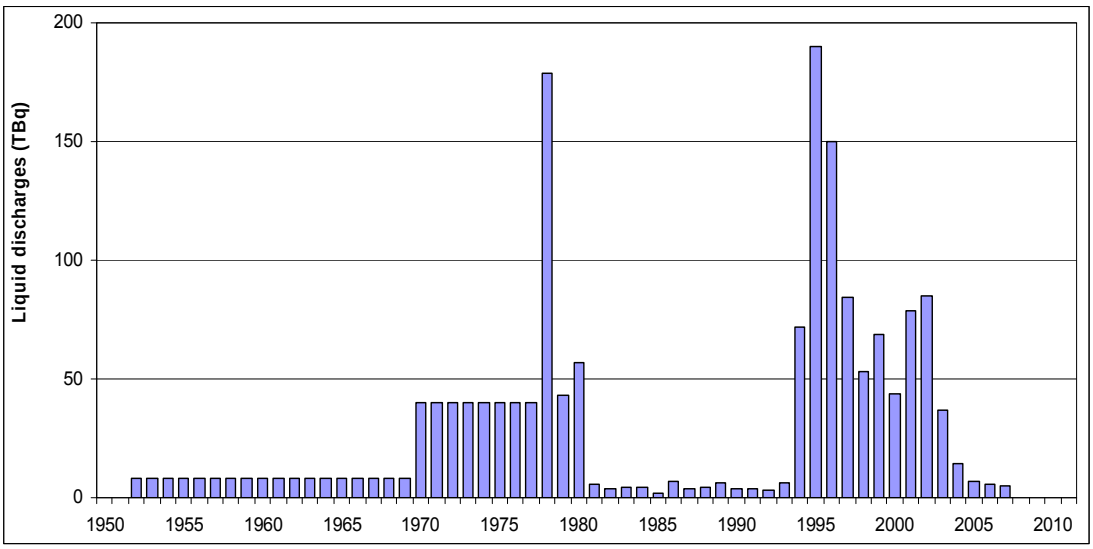

Figure 1.13 Liquid discharges of ^{99}Tc from Sellafield, 1952 to 2007

Discharges of total-beta, which is an overall control measure, fell by over 70% from 112 TBq in 2002 to less than 30 TBq by 2007 (See Table 2.83 and Figure 2.46). Some increases in discharges over the next few years cannot be ruled out as reprocessing returns to more typical throughput rates, although it is anticipated that by 2020 discharges of liquid total beta will be consistently less than 50 TBq per year.

Discharges from the site are also authorised via the Factory Sewer. This is a minor outlet (see Table 2.83) and discharges of total-alpha, total-beta and ^{3}H have remained relatively constant over the reporting period.

6.1.5 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).

In our previous report to OSPAR it was noted that, following an investigation of the levels of volatilised ^{14}C produced by Highly Active Liquor evaporation prior to vitrification, a caustic scrubber was installed, leading to a reduced aerial discharge and a significantly reduced overall dose impact although liquid discharges increased. Over the period since 2003, liquid discharges of ^{14}C fell from 17 TBq to <5 TBq in 2007 (see Table 2.83 and Figure 2.45). Some of this reduction reflects the low reprocessing rates over that period and discharges may increase again over the next few years. Discharges to air have remained below 1 TBq a^{-1} (Table 2.83) over the reporting period, falling to 0.36 TBq in 2007.

Discharges of ^{85}Kr have fallen with the low reprocessing throughput, and discharges of ^{41}Ar have ceased with the closure of the Calder Hall reactors in 2003 (Table 2.83). Neither of these radionuclides impacts significantly on the marine environment.

Discharges of ^{35}S have ceased with the closure of the Calder Hall reactors. Discharges of ^{3}H to atmosphere have varied more or less in line with reprocessing rates and the discharge in 2007 was around 30% of that in 2002 (Table 2.83).

6.1.6 Radiological impact of liquid discharges

The marine environmental monitoring programme around Sellafield covers a variety of species in a number of locations. The Sellafield monitoring programme is reviewed frequently and the new authorisation requires an annual review.

For many radionuclides, activity concentrations in seafoods over the period 2002 to 2007 showed little consistent variation (see Table 2.84). Concentrations of Cs, Pu and Am remained more or less constant over the period. Specific declines in concentration were observed for total-beta in lobster (but not in crab) by about a factor 3. The average concentrations of ^{99}Tc in crustaceans (both crab and lobster) declined to around 10% of the levels observed in 2002 and concentrations in winkles fell to less than 2% of the concentrations reported for 2002.

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 total beta activity which was between 12-16 Bql^{-1} throughout the period (Table 2.84). Concentrations of radioactivity in sediments have fluctuated over the reporting period with little evidence for an overall trend (Table 2.84).

The main pathways that contribute to local elevated doses relevant to 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 (Table 2.85).

The Sellafield 'marine critical group' is identified (in the RIFE report and elsewhere) as high rate consumers of fish and shellfish from the local waters of the Irish Sea, who also spend time on local beaches. The estimated annual dose to members of this group remained between 200-300 μSv per year, with an increase in the period 2003 / 2004 (Table 2.86) arising from estimated increases in the rates of seafood consumption. A significant fraction of the consumption dose to the marine critical group 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.

The dose has since declined to around 210 μSv in 2007 (Table 2.86), primarily due to the reducing concentrations of ^{99}Tc in marine organisms and the continuing slow decline in actinide concentrations. 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. Doses to these groups are reported annually both by the Site operator (*e.g.* Sellafield Ltd 2007) and the regulatory authorities (*e.g.* EA et al. 2007). Representative data are also presented in Table 2.86. The effective doses to houseboat dwellers on the Ribble have decreased from 120 μSv in 2002 to around 70 μSv in 2007.

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.

Doses to biota resulting from liquid effluent discharges of ionising radiation from the Sellafield site have been determined for the reference year 2002 and reviewed annually[21]. Dose calculations, using the method developed for English Nature and the Environment Agency (2001), are based on monitoring data for marine biota sampled

[21] The report has not been updated as the discharges have not increased over the period since 2002 and no changes to the biota have been identified.

along the Cumbrian coastline (see Table 2.87). In all cases 9with the exception of seabirds[22]), the doses are substantially below levels identified in the EC funded FASSET / ERICA programmes where "the threshold for statistically significant effects in most studies is about 10^2 μGy h^{-1}; the responses then increase progressively with increasing dose rate and usually become very clear at dose rates >10^3 μGy h^{-1} [when incurred] over a large fraction of the life-span" (FASSET 2001).

6.1.7 The application of BAT

The review of BPM / BPEO undertaken prior to the introduction of the revised authorisation for the Sellafield site in 2004, and the subsequent international comparison of Best Practice [RMC 2007] underpins the following BAT considerations:

- Tritium: Application of BPEO and plant optimisation in THORP has resulted in recovery of ^{3}H from airborne effluents to the liquid waste stream by dehumidification. The possibility of immobilization in solid waste was considered as a potential route to reduce liquid discharges of tritium, but this would result in large amounts of solid waste that would require storage and disposal. The volume of waste could be reduced by enrichment and four possible enrichment techniques were identified, all of which would require substantial research and development work: distillation of water; cryogenic distillation; electrolysis and hydrogen/water chemical exchange. It has been accepted that the cost of implementing tritium recovery on the liquid waste streams would be grossly disproportionate to the benefit implied, and would not represent BAT.

- Carbon-14: This is removed from the atmospheric waste stream at THORP by caustic scrubbers, followed by treatment and encapsulation in cement. The disbenefits of providing a similar plant for Magnox reprocessing were assessed as outweighing the potential radiological benefits, particularly given the planned closure of Magnox reprocessing in the near future.

- Cobalt-60: A number of abatement options have been considered to reduce discharges including chemical dissolution and precipitation or electrolysis and re-routing THORP feed pond purge water to SIXEP before discharge to sea. Further investigations have confirmed BPM is already being applied.

- Strontium-90: Diversion of MAC arisings to vitrification has been implemented within the ^{99}Tc strategy (see below). The latter has been implemented within the ^{99}Tc strategy (see below), which reduces discharges of Sr-90 to the environment. In addition, B29 has installed an in-pond Local Effluent Treatment Plant (LETP). This is designed to abate the beta activity in discharges (primarily caesium and strontium). The treated discharge is routed via the Low Active Drain to SETP.

- Technetium-99: Stored MAC not suitable for vitrification has been treated through EARP using TPP. All new technetium rich arisings have been diverted since 2003 for vitrification (note: this also has the effect of reducing the levels of ^{90}Sr, ^{106}Ru and ^{137}Cs discharged to sea).

- Ruthenium-106: In THORP, the active waste stream containing this radionuclide is evaporated, combined with the highly active waste stream, and vitrified. Arisings from Magnox reprocessing are evaporated, stored for decay, and then treated in EARP where radionuclides are removed by precipitation with iron salts. The precipitate is encapsulated in cement.

- Iodine-129: Alternative abatement techniques were considered that would transfer iodine from the gaseous to the solid waste stream, including precipitation of iodine (*e.g.* as a silver salt) and absorption on a solid matrix. Plant trials, seeking to reduce aerial discharges, based on adding iodic acid to the fuel dissolution

[22] Study undertaken by Westlakes Scientific Consulting (2006)

process in THORP proved inconclusive and will not be pursued. At present, disposal of ^{129}I to sea remains consistent with BPEO.

- Caesium-137: A number of abatement options to further reduce liquid discharges have been considered, including: additional treatment of Magnox fuel pond purge water and the routing of THORP fuel pond water to SIXEP. The diversion of MAC to vitrification, implemented to reduce discharges of ^{99}Tc (see above) has led to reduced discharges of ^{137}Cs. An ion exchange skip has been introduced to THORP Receipt and Storage to help to abate ^{137}Cs. As part of this work, ion-exchange material is also being studied for combination with the funda filters (^{137}Cs specific) as well as various other options to ensure pond activity arisings continue to be managed in line with the principles of BPM.

- Plutonium isotopes and americium-241: The SETP was designed to deal with high volume/low activity acidic waste streams that are unsuitable for further abatement. The introduction of EARP in 1994 was the culmination of a programme of work to provide a means for removing actinides from various waste streams. It is highly efficient and there is little scope for further improvement.

To summarise, following a detailed review of available technologies, the BPEO for disposing of the principal liquid waste streams at Sellafield is considered to be:

- vitrification of highly active liquid waste;

- diversion of new MAC arisings from Magnox reprocessing to vitrification;

- removal of radionuclides from SEC in EARP and subsequent encapsulation in cement;

- continued operation of EARP, SETP and SIXEP for low active waste streams; and,

- treatment of organic solvent in the Solvent Treatment Plant.

In the case of waste lubricating oil, which presents a very specific non-aqueous liquid effluent not suitable for discharge or treatment through other liquid waste stream facilities, the BPEO is determined to be thermal treatment.

The RSA authorisation effective from 1 October 2004 (as varied) includes requirements on the site to continue to review developments in best practice, report annually on techniques introduced, carry out assessments of BPEO and to consider a number of other improvements (Environment Agency, 2004). The RSA authorisation also continues to require the site Operator to use Best Practicable Means to minimise the activity of aqueous waste discharged to the environment.

Since the introduction of enhanced beach monitoring, using improved detection techniques, radioactive particles continue to be found on (and removed from) local beaches; work continues on identifying their precise origin, but it is likely that the finds are related to past events and incidents at Sellafield. The health risks to the public from contact with these particles have been assessed by the UK's Health Protection Agency, and are unlikely to be significant. In May 2007 the Environment Agency required Sellafield Ltd to review the application of best practicable means (broadly equivalent to BAT) to exclude solids in aqueous effluents prior to discharge to the environment (a pre-existing discharge authorisation requirement) and to develop an improvement programme to address the findings of the review. As part of this, Sellafield Ltd is continuing to review both the prevention and minimisation of solids in effluents at source and the final filtration system prior to discharge.

6.1.8 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.

During the review process for the 2004 authorisation, a comparison was made between discharge abatement techniques used at Sellafield and the COGEMA Cap La Hague reprocessing plant. COGEMA operates two spent oxide fuel reprocessing plants at this site which have a total fuel throughput capacity of 1700 tonnes (te)/year. In comparison, the Magnox Reprocessing Plant (1750 te/year) and THORP (1200 te/year) have a total design fuel throughput capacity of 2950 te/year.

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

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

Schedule 9 of the 1 October 2004 Sellafield Authorisation required a report on national and international developments in best practice for minimising waste disposals and a strategy for achieving reductions in discharges. A review undertaken on behalf of the site Operators concluded that, “Sellafield Ltd’s minimisation practices for airborne, liquid and solid radioactive wastes are mainly consistent with those recognised as BPM or best practice in comparable national and international situations” (RMC, 2007).

6.2 Calder Hall

Liquid effluent discharges from the Calder Hall Magnox nuclear power station are considered within the overall Sellafield site authorisation. The impact of discharges from Calder Hall is indistinguishable from other discharge streams. Calder Hall ceased operating in March 2003 and the cooling towers were demolished in September 2007. Fuel remains within the reactors and it is currently planned to commence defuelling in 2012.

The majority of spent fuel previously discharged from Calder Hall has been reprocessed through the Sellafield site. Remaining fuel, awaiting reprocessing, 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.

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7. RESEARCH AND DEVELOPMENT

The UKAEA is decommissioning the majority of its former nuclear research establishments, at four licensed nuclear sites at Dounreay, Windscale, Harwell and Winfrith. The reactors located on these sites have been closed down and are at various stages of decommissioning. Ownership of the sites (with the exception of Harwell) was transferred to the NDA in April 2007. UKAEA now operates the sites at Harwell and Winfrith. Licensee responsibility for the Windscale site has been transferred to Sellafield Ltd (although the site will continue to operate under its own nuclear licence) and the Dounreay site has transferred to a new company, Dounreay Site Restoration Limited (DSRL), a wholly owned subsidiary of UKAEA. These sites are operated by the respective companies on behalf of the NDA.

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

Over the last twenty to thirty years, radioactive discharges from the research sector have reduced substantially, as research and prototype reactors have ceased operation, and as abatement has been applied to the remaining discharges.

Over the next 20 years, the main activities leading to discharges of radioactivity into the environment from licensed 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.

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

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

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

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. In October 2004, the authorised liquid waste discharge limits were reduced to reflect the change of activity on site from reprocessing to decommissioning.

7.1.1 Sources of liquid effluent

The principal radionuclides discharged are: tritium, total beta (including ^{22}Na and ^{40}K), total alpha (excluding ^{242}Cm), ^{90}Sr, and ^{137}Cs. Liquid α and β discharges are mainly associated with the decommissioning of the reprocessing facilities and fuel cycle areas. Liquid tritium discharges are mainly from the dissolution of alkali metals (sodium and potassium) formerly used as fast reactor coolant.

During the period 2004 to 2007 destruction of the liquid sodium coolant from the Prototype Fast Reactor was progressed (and completed in August 2008), with the exception of the non-recoverable portion at the reactor base. This process involved treatment of sodium metal with sodium hydroxide solution and subsequent neutralisation with hydrochloric acid. The resultant solution of sodium chloride was contaminated with various fission and activation products, the principal examples of which were: tritium, ^{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.

The aqueous solution resulting from sodium destruction operations was treated by filtration and passage through ion exchange material to remove the majority of the ^{137}Cs. In 2008 the destruction of the NaK from the DFR Reactor primary coolant commenced with active commissioning of the destruction plant. This is expected to be completed by 2011.

During early operation of Dounreay, intermediate level waste was placed in a Shaft that was originally built as a temporary access route for the removal of earth and rocks during the excavation in the 1950s of a 600 metre long liquid waste discharge pipeline. The 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 there would be higher levels of discharged radioactivity 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 the ground water ingress to the Shaft.

Prior to discharge of effluents to the site active drain system and subsequently to the Low Level Liquid Effluent Treatment Plant (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.

7.1.3 Trends in discharge over the 2002-2007 period

A detailed breakdown of the discharges over this period is provided in Table 2.89 and illustrated in Figure 1.14. In all cases, the liquid discharges are a small fraction of the authorised limits. The discharge of tritium has fluctuated over the period as a consequence of the dissolution of alkali metals, while the discharge of ^{90}Sr has decreased steadily. Between 2004 and 2007, discharges of other radionuclides remained at or below the minimum detectable activity (MDA) of the individual nuclides concerned.

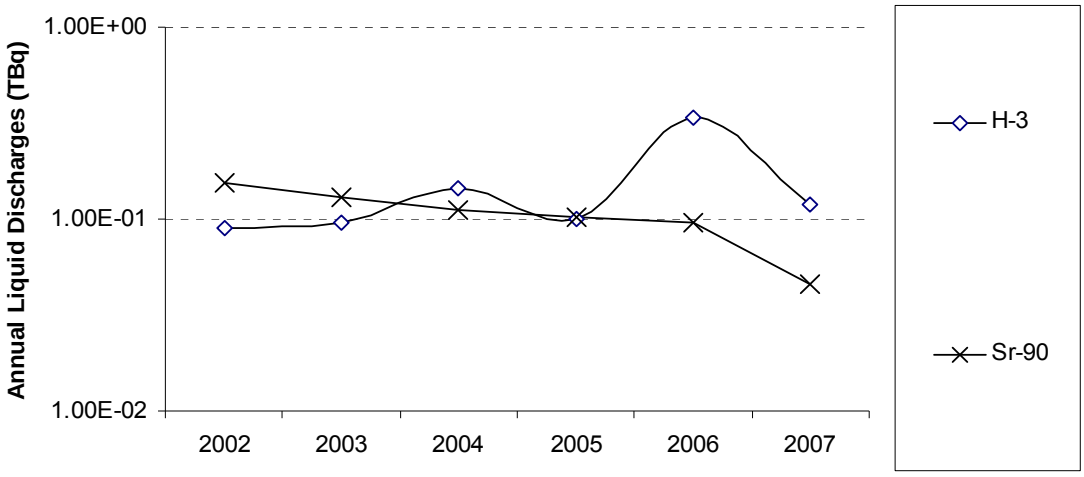

Figure 1.14 Annual Liquid Discharges from Dounreay

The actual site annual emissions to air for total beta, total alpha and individual radionuclides are presented in Table 2.89 and illustrated in Figure 2.48. These demonstrate that the levels have remained fairly constant throughout the 2004-2007 reporting period.

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 Part 2 Table 2.90.

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

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

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 relevant reference group consists of adults with a mean consumption rate of 0.5 kg per year of winkles, resulting in an annual dose of around <5 μSv/y (Table 2.91). Other exposure pathways considered are:

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

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

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, was put in place to ban the taking of sea foods in an area of 2 km radius centred on the end of the outfall pipe some 0.6 km from the shore, and advisory signs were erected at Sandside Bay. These measures are still in place and particles continue to be found. In the year 2000, the Dounreay Particles Advisory Group (DPAG) was established to provide scientific advice to SEPA and UKAEA on this issue and has since made considerable progress in understanding:

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

DPAG released their most recent report on these issues in 2008 and may be accessed from the SEPA website[23]. A BPEO for dealing with the particles already in the environment has been completed and practical trials commenced on recovery.

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 tritium recovery is not currently considered BPM in alkali metal destruction as the high salt content in the effluent and the presence of gamma emitting radionuclides

[23] http://www.sepa.org.uk/radioactive_substances/publications/dounreay_reports.aspx

makes 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 (currently estimated to cost £400 million for very little benefit over the rest of the Dounreay Lifetime Plan). An updated BPEO is in preparation which is due to be completed in 2009.

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 world wide, UKAEA maintains contact with relevant plants in Europe and the US, to share experience and information regarding international best practice. The details of operation and impact may differ between sites. For example, the PFR and, more significantly, the DFR sodium coolant contains more ^{137}Cs (due to fuel and coolant contact as a result of fuel pin cladding failure) than similar plants elsewhere such as EBR2, Phenix and SuperPhenix.

7.2 Harwell

The Harwell site is operated and owned by UKAEA, with the licensed site leased to the NDA. As part of UKAEA restructuring, UKAEA formed Research Sites Restoration Ltd (RSRL), during in order for RSRL to take on responsibility for the operation of the Harwell site on behalf of NDA in early 2009.

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

- Medium level active liquors are collected in carboys and monitored before being sent to the LETP,

- Low level active liquors, generally in volumes of about 5 to 10 m^3, are held in delay tanks at the individual buildings before being transferred to the LETP by way of either the site active drainage system or by tanker, and

- Trade wastes, which are of very low radioactivity content, go direct to the LETP and are generally discharged, following monitoring, with no treatment.

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

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

7.2.3 Trends in discharge over the 2002-2007 period

A detailed breakdown of the discharges over this period is provided in Part 2 Table 2.93. Discharges have generally reduced in both volume and activity terms over the past 5 years with the gradual progression of decommissioning. Liquid discharges have declined significantly in volume terms (41,000 m^3 to 16,000 m^3 between 2003 and 2007). Authorised annual discharge limits for liquid effluents at the Harwell site were also significantly reduced in 2003, reflecting the reductions in the volume and activity of liquid waste arisings. In all cases, the liquid discharges remained within the authorised limits throughout the period. As illustrated in Figure 1.15, the discharge of tritium decreased substantially (to around 4% of the previous value) in 2003 mainly due to reduced receipts of tritiated wastes from organisations on site and has remained relatively steadily at the lower level since that time. The discharge of ^{60}Co has decreased by around 80% of its value in 2002, while that of other radionuclides have also generally decreased, albeit by a less significant fraction. This is due to reduced levels in the input waste streams from consignors.

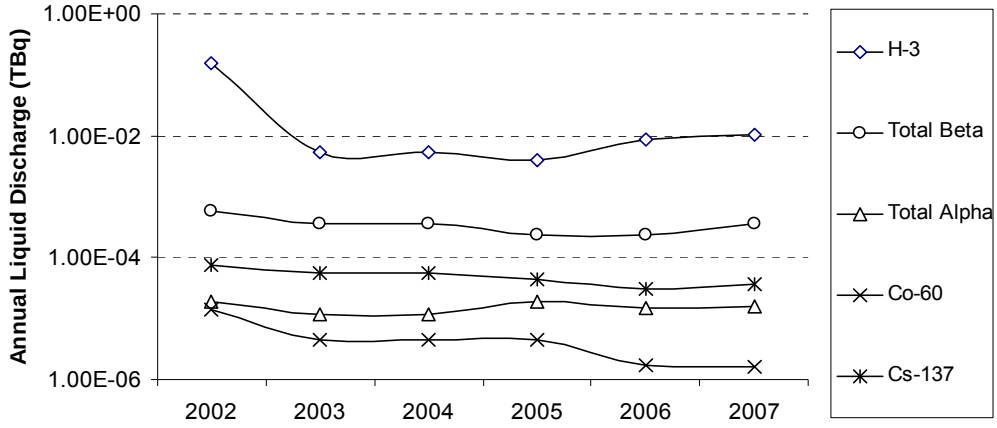

Figure 1.15 Annual Liquid Discharges from Harwell

The emissions to air also show a general downward trend over the reporting period, as indicated in Part 2 Table 2.93 and Figure 2.50. In 2003, Harwell began reporting iodine, ^{220}Rn, ^{222}Rn and ^{85}Kr discharges as part of the requirements in its revised authorisation. The discharges of radon and iodine have remained relatively constant, while there have been short-term increases in the discharge of ^{85}Kr as a consequence of waste handling and decommissioning operations. It is anticipated that emissions of these radionuclides will decrease in the long-term.

7.2.4 Radiological impact of liquid discharges

UKAEA makes discharges to the middle reaches of the River Thames which then flows into the Thames estuary. No marine monitoring is undertaken. Samples taken from the Thames region cover radionuclides in fish, lilies, water and silt representative activity concentrations data are presented in Table 2.94. 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). 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.

UKAEA has identified a hypothetical critical group for modelling and assessing the impact of discharges to the Thames estuary. Modelling includes consideration of consumption of fish, crustaceans, molluscs and seaweed plus exposures due to inhalation and sediment exposure via beach occupancy. Pathways are added together where applicable, *e.g*. consumers of foods are also assumed to spend time along estuarine beaches. Modelling includes effects from past discharges. The resulting estimated doses are presented in Table 2.95, which demonstrates that annual effective doses to the critical group from this site have remained around or less than 10 μSv throughout the reporting period.

7.2.5 The application of BAT

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

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.

Work has been implemented over the last 5 years to prevent unnecessary dilution of effluents prior to treatment in order to improve the efficiency of the subsequent treatment methods.

Following this work, the organisation 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 over the next two to three years. 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 UKAEA 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.

Liquid residues would be subject to cementation, such that the removal fraction for liquid effluents 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 will be discharged either direct to the Thames or to local sewer. The evaporator condensate would also be directed to this route.

7.2.6 Comparison with performance of similar plants world-wide

There are difficulties is 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 with equivalent evaporators, to those proposed at Harwell, in nuclear applications could not be found. However, before deciding on the evaporator choice, UKAEA reviewed evaporators from a variety of sources, some within the nuclear industry (AWE evaporator) and some industrial evaporators from the non-nuclear sector. The AWE evaporator was too large a plant for the small effluent volumes arising at Harwell. Two non-nuclear sector evaporators that were considered were of an appropriate size and would deliver very good DFs, especially allowing that residual effluent volumes should be sufficiently small to allow direct cementation (therefore giving total removal of this part of the active component from the liquid effluent stream).

7.3 Windscale

The Windscale site was operated by UKAEA, under the ownership of the NDA, until operation of the site was transferred to Sellafield Ltd in 2008.

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 reactors at Windscale have been closed for many years. The main activities carried out on site include: decommissioning (and the associated ILW storage) of the Windscale Advanced Gas-Cooled Reactor (WAGR) and Pile reactors and waste remediation work. A separate facility carries out post irradiated examination (PIE) of nuclear fuel along with the receipt and processing of surplus sources from across the UK, which are subsequently dispatched to the miscellaneous beta gamma waste store at Sellafield for safe long term storage pending disposal.

7.3.1 Sources of liquid effluent

The liquid waste arisings from Windscale are very small and contain activity principally from waste remediation, PIE work and general cleaning operations (active side sinks, emergency shower and floor washings) carried out in controlled areas. These are transferred to the Sellafield site for treatment and discharge and are therefore included in the reported discharges presented in Section 6.

7.3.2 Liquid effluent treatment and discharges

Management controls are in place across the site to ensure the production of liquid and aerial effluents are minimised throughout all decommissioning or operational

activities. The emphasis is placed upon keeping the radioactive inventory of any waste produced in the solid form in preference to liquid wastes, and liquid waste in preference to gaseous waste (as far as is reasonably practicable) as this simplifies containment and in the majority of cases will represent the BPEO.

Production of liquid effluent from the hand washing facilities at the active side barrier are limited through the use of foot pumps or knee valves. This prevents excess water being transferred into the low level liquid effluent system.

At WAGR, the fuel handling and examination facility and PIE, liquid effluent is collected in storage vessels, as part of a liquid effluent handling facility, prior to sampling and transfer. Additional local management controls are in place to allow monitoring of the collection tanks and subsequent transfer to bowser. The bowsered liquid is transferred to the Sellafield site effluent treatment plant (SETP). When transferring liquid from storage tank to bowser, an in-line filter (self-cleaning) is fitted on the transfer line to remove particulate material (duty and standby filters are also incorporated into the system). In all cases authorisation for transfer to the SETP is requested and received prior to dispatch.

7.3.3 Trends in discharge over the 2002-2007 period

Liquid effluents from Windscale are transferred to Sellafield Ltd for treatment and discharge and are therefore included in the discharge data and trend analysis for that site, provided in Section 6.

The annual emissions to air from the Windscale site are presented in Part 2 Table 2.97. These emissions have exhibited a decreasing trend, as illustrated in Figure 2.51, with the most significant reduction being in the discharge of ^{85}Kr, which has decreased by two orders of magnitude over the reporting period. The discharge of tritium has also decreased to such an extent that the reported values for 2006 and 2007 were zero.

7.3.4 Radiological impact of liquid discharges

As the Windscale site does not discharge to controlled waters, sampling relating to liquid discharges is not required. Sellafield Ltd carry out environmental sampling in respect of its liquid discharges and the aerial discharges from both the Windscale and Sellafield Ltd facilities. These data are presented and discussed in Section 6.

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

7.3.5 The application of BAT at the Windscale site

Waste characterisation, and filtration to remove solids, is carried out prior to transfer via tanker to the Sellafield SETP.

Due to the small volumes of liquid waste produced, limited technological systems can be implemented to reduce volumes further. The Windscale site has reviewed the application of BPEO and BPM, to liquid discharges at a facility level and concluded that the volumes and nature of the site liquid effluent do not necessitate any change at this time. As part of the decommissioning safety case, any future activities will be subject to a BPEO/BPM assessment.

7.3.6 Comparison with performance of similar plants worldwide

The site does not conduct specific comparisons of Windscale activities with other plants worldwide. As part of the Sellafield Ltd organisation, however, the site maintains a general watching brief on international best practice and comparisons of waste minimisation and prevention techniques.

7.4 Winfrith

The Winfrith site is operated by UKAEA and owned by NDA. As part of UKAEA restructuring, Research Sites Restoration Ltd (RSRL) will become responsible for the operation of the site in 2009.

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 in 2004.

The current focus of work on the site is surveillance and maintenance of remaining reactors, decommissioning of remaining reactors, with storage of intermediate level waste prior to transfer to off-site interim storage or disposal to a national repository. All liquid discharges are made via a pipeline to the English Channel.

7.4.1 Sources of liquid effluent

Current operations at Winfrith are concerned primarily with surveillance and maintenance activities, which give rise to significantly lower discharges than when reactors were running on-site. Liquid effluents arise at a number of the buildings on the site used for commercial research and development purposes by tenants. These are transferred to UKAEA. The principal radionuclide discharged is tritium, which arises from the waste processing work of Waste Management Technology Ltd (WMT Ltd). The bulk of the volume of the discharge arises from the on-site sewage works operated by UKAEA.

7.4.2 Liquid effluent treatment and discharges

In accordance with standard UKAEA practice, waste arisings are minimised at source and by the application of BPM. 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 range 8.0-8.5. 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) and the effluent is mixed and discharged.

It is expected that the active liquid effluent system (ALES) will be decommissioned after 2034. Further liquid discharges to Weymouth Bay will not be made after it has been decommissioned.

The active liquid effluent system which collects liquid waste for discharge to the sea is expected to close after decommissioning of the SGHWR primary circuit is complete around 2034. Work will be undertaken to reduce effluent volumes.

7.4.3 Trends in discharge over the 2002-2007 period

Discharge and emission data for Winfrith are presented in Part 2 Table 2.99 and Figures 1.16 and 2.53. Discharges of radionuclides from Winfrith remain low. There has, however, been an increase in liquid discharges of tritium as a result of processing work carried out by WMT Ltd on tritium-containing equipment and materials such as telephone dials and exit signs. There has also been a short-term increase in the other radionuclides discharged due decommissioning operations at the Winfrith site. All discharges are a very small fraction of the authorised discharge limits.

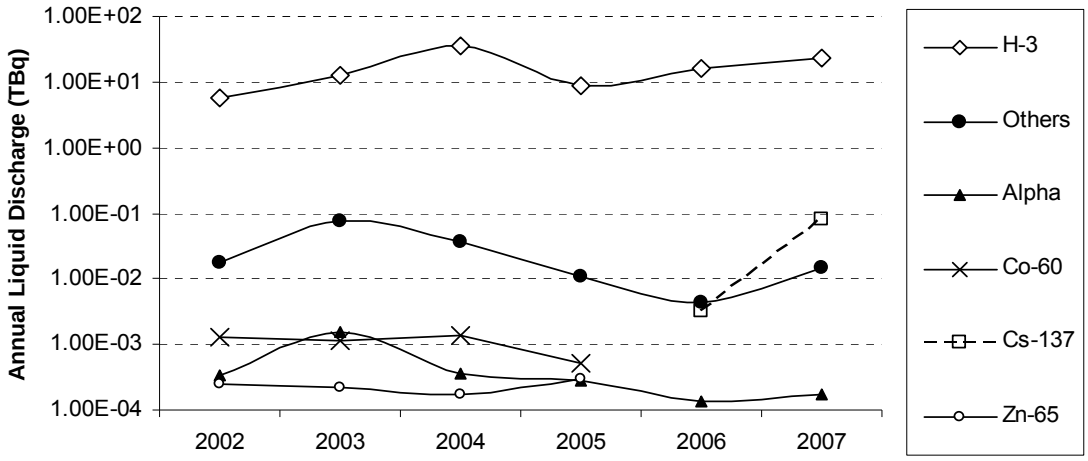

Figure 1.16 Annual Liquid Discharges from Winfrith

After 2005 no specific Co-60 limit was placed on Winfrith hence no specific reported data for 2006/7. A new authorisation was granted in 2006 which placed specific limits on Cs137, hence data available from this date

In 2007, the rate of decommissioning decreased which resulted in a decrease in aerial emissions of some radionuclides.

7.4.4 Radiological impact of liquid discharges

UKAEA undertakes environmental monitoring in the vicinity of the Winfrith site and representative environmental concentration data collected over the reporting period are given in Table 2.100. Activity concentrations of radionuclides in environmental media are typically 0.01%-1% of the relevant Generalised Derived Limits, published by the Health Protection Agency.

At Winfrith a hypothetical critical group is assumed to be consumers of seafoods caught in Weymouth Bay. The exposure pathways included in calculations of critical group doses are: consumption of seafood, exposure to contaminated beach sediment and inhalation of resuspended beach sediment and seaspray. The critical group for liquid discharges from Winfrith has been defined by FSA, on the basis of habit surveys, as those people who consume the following: 210 g/day fish; 110 g/day whelks; 70 g/day crabs. The mean activity concentrations found in edible parts of seafood have been used to calculate a corresponding annual effective dose. This has reduced over the reporting period, from 7 μSv in 2002 to <5 μSv for each year since 2004 (Table 2.101). In fact, the critical group doses arising from liquid discharges and emissions to air in 2007 were each estimated to be of the order of 0.2 μSv in 2006.

7.4.5 The application of BAT at UKAEA Winfrith

A recent study to consider the optimum approach for managing radioactive wastes on the site concluded that the current disposal routes represent BPEO. The application of BPM at UKAEA Winfrith to liquid waste is based on management controls and minimising arisings at source. In addition, liquid wastes from WMT Ltd and other tenants are handled by the site Active Liquid Effluent System and are included in the UKAEA disposals.

Discharges to sea are very small and have remained so throughout the reporting period. Although UKAEA has taken the decision that additional improvements to reduce the levels of radioactivity in the effluent are not economic, since the critical group dose is already well below 20 μSv per year, substantial effort has been put into

minimising ingress of rainwater in to the Active Liquid Effluent System in order to minimise volumes of effluent.

The principal radionuclide discharged is tritium, primarily from the recycling of tritium phone dials, from WMT Ltd. At present, there is no realistic treatment by which discharges of tritium (which has low radiological impact) can be reduced. Tritium recovery, using a dehumidifier or scrubber is currently being investigated for the decommissioning of the primary containment at SGHWR. This may have an impact on liquid discharges in the future.

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. This plant cemented the first batch of SGHWR sludges in 2006 and is expected to remain in operation until 2009.

7.4.6 Comparison with performance of similar plants world-wide

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

7.5 References

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.

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8. THE DEVELOPMENT AND APPLICATION OF BAT

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

Since the last report, the changes made to the authorisation process, with the aim of ensuring, among other things, that the objectives of the OSPAR Strategy with regard to Radioactive Substances and the UK Strategy for Radioactive Discharges 2001-2020 are adhered to, have been consolidated. The authorisations to dispose of radioactive substances are reviewed in a transparent, consultative and integrated approach periodically. Integrated multi-media authorisations have largely replaced the range of single medium authorizations in place previously. The decision and explanatory documents associated with authorisations 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 included in these multi-media authorisations 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), in 2003. To date, the Group has focused on the generic waste minimisation requirement included in the 'additional information and improvement requirements' (AIIRs), issued with the multimedia authorisations on the basis that EARWG considered that the 'national and international review of waste minimisation techniques' is a common task that could be undertaken jointly by members of the group. The group reviewed national and international minimisation information. The information gained is included on a web-based data base. This best practice reference is expected to be of assistance to operators in determining suitable options for BAT or BPM/BPEO studies[24].

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.

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

The choice of filter media depends on the characteristics (generally, the particle size) of the material to be removed and the operational constraints; there is invariably a balance between filter rating (DF – decontamination factor) and the required liquid throughput. Improved efficiencies are often achieved by placing filters of varying pore size in series. The principal area of development has been in regard to fine particulates (~0.001 to 0.1µm), filtration of which by fine pore media would normally require high pressure drops and low throughputs, and are therefore appropriate for removing low levels of activity from pre-treated liquid effluents.

Cross-flow filtration is receiving increasing attention, both for direct filtration of liquids and for the removal of solids formed by co-precipitation/flocculation treatments. The process stream is passed tangentially across the surface of the filter medium and a high cross-flow velocity is required if the formation of a filter cake is to be avoided. A clarified permeate passes through the filter and leaves a liquid with a greatly increased level of suspended solids/activity on the primary side of the filter – which can be removed as a separate mobile waste stream as required. An advantage of this technique is that it can operate on a 'bleed-and-feed' basis in a continuous loop; in this mode of operation, the primary side of the cross-flow filters works as a closed loop but is fed by new liquor at the same rate as the accumulated solid/active materials are bled off. It is possible to achieve a level of 10% solids in secondary waste bled from such a cross-flow loop and this is suitable for solidification in cement. The Enhanced Actinide Removal Plant (EARP) at Sellafield 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, the ion exchange resin IONSIV IE911 has been used for this purpose in fuel ponds and a number of Magnox stations and similar materials have been installed at a number of AGR sites. However, plant trials at Sellafield of the application of an ion-exchange pre-coating on existing filtration systems to reduce discharges of ^{60}Co proved unsuccessful.

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

8.1.2 Caustic scrubbers

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

In contrast to the Magnox Reprocessing Plant, THORP is designed to drive-off ^{14}C into the dissolver off-gas (DOG) treatment system and to minimise the amount of the

radionuclide that is transferred into the uranium chemical separation process. In the DOG system, ^{14}C passes through an acid recombination column, an iodine desorber column and finally through a caustic scrubber, where it is removed from the gas stream. ^{14}C is then removed from spent caustic scrubber liquor in a barium carbonate precipitate that is subsequently encapsulated in cement grout in the Waste Encapsulation Plant.

8.1.3 Ion exchange and adsorption

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

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

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

8.1.4 Hydrocyclone centrifuge

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

8.1.5 Electrochemical and electrophysical processes

Most of the techniques 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 International reports related to BAT

8.2.1 The NEA EGRO Report

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

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

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

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

Reverse osmosis, ultrafiltration and evaporation are used to remove very low levels of contaminants from liquid effluents. As indicated above, reverse osmosis and ultrafiltration rely on passing clean effluents through a sensitive permeable membrane under pressure. The membrane removes particulates and allows dissolved salts to pass through. In combination with evaporation, extremely low discharges result.

8.2.2 IAEA-TECDOC 1336

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

- Use of inorganic sorbents in combination with other treatment processes;

- Use of sorbent mixtures;
- Combined processes for treatment of solutions containing complexing agents and organics;
- Multiple processes for treatment and immobilization of organic wastes.

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

8.3 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:

- Internal effluent management arrangements (*e.g.* conditions for acceptance and internal authorisations for materials transfer) prevent, minimise and control effluents at source.
- Abatement of ^{99} Tc discharges from treatment of stored MAC by use of TPP in EARP and the continued use and combination of SETP, SIXEP and EARP plants at Sellafield;
- Abatement of ^{99}Tc discharges from treatment of current MAC arisings by processing through the HALES plant at Sellafield, prior to vitrification;
- Use of the Salt Evaporator, in combination with other treatment plants at Sellafield, has reduced discharges of plutonium and in various short lived fission products, such as ^{95}Zn, ^{95}Nb and ^{106}Ru;
- The Solvent Treatment Plant at Sellafield, which destroys solvents currently stored on site (producing an aqueous residue which can be processed through EARP) is now fully operational;
- The development and increased application of Submersible Caesium Removal Units (IONSIV IE-911) in Magnox fuel storage ponds;
- Measures to prevent dilution of radioactive effluents and the consideration of evaporation technologies at Harwell.

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. Explicit within the new multi-media authorisations is a requirement that operators keep abreast of new abatement and treatment technologies (and report within stipulated timescales). 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.

8.4 References

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

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

9. ACRONYMS AND KEY DEFINITIONS

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

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

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

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

v. the economic feasibility of such techniques;

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

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

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

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

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

The **BPEO** is the outcome of a systematic consultative and decision making procedure which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term.

BPM is a term used by the Environment Agency and the Scottish Environment Protection Agency in authorisations issued under the Radioactive Substances Act. Essentially, it requires operators to take all reasonably practicable measures in the design and operational management of their facilities to minimise discharges and disposals of radioactive waste, so as to achieve a high standard of protection for the public and the environment. BPM is applied to such aspects as minimising waste creation, abating discharges, and monitoring plant discharges and the environment. It takes account of such factors as the availability and cost of relevant measures, operator safety and the benefits of reduced discharges and disposals.

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)

ACRONYMS

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
Cm2919	Command 2919, Review of Radioactive Waste Management Policy, Final Conclusions (July 1995)
COS	Carbonyl Sulphide
CRU	Caesium Removal Unit
DECC	Department of Energy and Climate Change
DEFRA	Department of the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (predecessor to DEFRA)
DF	Decontamination Factor
DOENI	Department of the Environment, Northern Ireland
EA	Environment Agency of England and Wales
EARP	Enhanced Actinide Removal Plant
EHS	Environment and Heritage Service Northern Ireland
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
FASSET	Framework for Assessment of Environmental Impact
FSA	Food Standards Agency
HEPA	High Efficiency Particulate Air
HLW	High Level Waste (waste containing >4 GBq α and/or 12 G Bq β/γ and with heat generating properties).
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
ISTA	Inter Site Transfer Authorisation
LCBL	Life Cycle Base Line
LETP	Liquid Effluent Treatment Plant
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low Level Waste (<4 GBq α and/or 12 G Bq β/γ)
LMU	Liabilities Management Unit
MAC	Medium Active Concentrate
MRP	Magnox Reprocessing Plant
MXD	Magnox Dissolution Plant
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NII	Nuclear Installations Inspectorate

ACRONYMS

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

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