For Official Use **NEA/RWM/WPDD(2002)8**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

27-Nov-2002

English - Or. English

NUCLEAR ENERGY AGENCY
RADIOACTIVE WASTE MANAGEMENT COMMITTEE

NEA/RWM/WPDD(2002)8
For Official Use

Working Party on Decommissioning and Dismantling (WPDD)

TOPICAL SESSION ON BUILDINGS & SITES RELEASE AND REUSE

Karlsruhe, Germany
17-18 June 2002

English - Or. English

JT00135892

TABLE OF CONTENTS

INTRODUCTION ... 3

SUMMARY OF THE PRESENTATIONS ... 5

SUMMARY OF DISCUSSIONS ... 7

APPENDIX 1:

Papers and Extended Abstracts

Modeling for the Derivation of Levels for the Release of Buildings and Sites ... 9

Development of Software Tools for Supporting Building Clearance and Site Release at UKAEA ... 15

Development of Radiation Measurement Technology for Low-level Contamination ... 39

Barsebäck after Barsebäck - a Case Study on the Conflicting Issues Concerning Land use after a Total Clean-up (decommissioning) of a Nuclear Facility ... 43

Building and Site Release and Use ... 47

Buildings & Site Release and Reuse The Spanish Regulator’s View ... 50

Clearance of Buildings and Certification for Reuse as Non Nuclear Industrial Building at SCK•CEN, Mol ... 58

Approach to Decommissioning at AECL’s Laboratories ... 62

Approach to, and Experience in, the Release & Reuse of Building and Sites ... 70

Regulatory Aspects of Radioactive Waste Management and Decommissioning in the UK ... 79

Decommissioning – a Regulatory View ... 93

INTRODUCTION

Set up by the Radioactive Waste Management Committee (RWMC), the WPDD brings together senior representatives of national organisations who have a broad overview of Decommissioning and Dismantling (D&D) issues through their work as regulators, implementers, R&D experts or policy makers. These include representatives from regulatory authorities, industrial decommissioners from the NEA Co-operative Programme on Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects (CPD), and cross-representation from the NEA Committee on Nuclear Regulatory Activities, the Committee on Radiation Protection and Public Health, and the RWMC. The EC is a member of the WPDD and the IAEA also participates. This ensures co-ordination amongst activities in these international programmes. Participation from civil society organisations is considered on a case by case basis, and has already taken place through the active involvement of the Group of Municipalities with Nuclear Installations at the first meeting of the WPDD.

At its third meeting, in Karlsruhe, 17-19 June 2002, the WPDD held a topical session on Buildings and Sites Release and Reuse.

Manfred Schrauben, Head of Decommissioning, ONDRAF/NIRAS, Belgium, served as Session Chair. Juan Luis Santiago, Head of Projects Dept, ENRESA, Spain, served as the rapporteur of the Topical Session.

Presentations during the topical session covered key aspects of the release of buildings and sites and provided the basis for exchange of information and experience, including:

Standards

- What are the release standards for site release?
- Do the same release standards apply to soil and the grounds as apply to the buildings?
- Are release standards dose-based, or concentration-based?
- Are there different release standards for different types of radionuclides (e.g. are Uranium and Thorium treated in the same manner as other radionuclide contaminates)?
- What are the standards for groundwater?
- Do implementors use surface contamination standards for cleaning interiors of buildings, or volumetric contamination standards?

Standards Setting

- What types of modelling do regulatory agencies perform before site release?
- What types of modelling are performed for buildings that are to be reused? What are the exposure scenario assumptions? Are the models based on ICRP 60 methodology or earlier exposure models?

Experience

- What has been the international experience with respect to groundwater monitoring and contamination?
- How is the site determined to be "clean?" Through monitoring? In-process inspections?
- What types of final surveys are conducted? By whom (regulator or implementor)?
- How are the final surveys conducted? Are they based on statistical sampling?
- How do countries address discrete, low-level sources (e.g., slag) on a site if the overall site meets dose-based release standards?
- Are there follow-up monitoring requirements for buildings and facilities that are reused?
- In case of building reuse, what are the “rights” of the new user? How long does the former nuclear operator/owner keep the liability? (or is the building released “once and forever”?)
- Which are situations where release of site and buildings has been restricted to other nuclear uses, and what issues does this entail from the point of view of licensing?

Opinion

- Does the release of site need to be “harmonized” internationally?

Local Community (LC)

- what would local communities like to know?
- what issues had arisen from local communities in implementation and follow on use?
- Does greater confidence need to be established in LC's and how is this done?

At the end of each presentation time was allotted for discussion of the paper. Integral to the Topical Session was a facilitated plenary discussion on the topical issues identified above. The rapporteur briefly reviewed the main points at the end of the topical session.

The Topical Session is documented as follows. First a summary of the presentations is given along with the questions that were asked to each speaker; then follow a summary of the plenary discussions and the main points made. The extended abstracts or full papers supporting each presentation are given in Appendix 1.

As a follow-on to the Topical Session it was agreed that the Task Group on Material Management should be expanded to include the topic of buildings and sites release and reuse.

SUMMARY OF THE PRESENTATIONS

The presentations in this session were divided into four groups as follows:

R & D Community Voices

Three presentations were given in this group, one on dose modelling for the release of buildings and sites, a second on software tools to address data management from surveys, and a third on new measurement technologies for low contamination.

In the first of the three presentations in this group, S. Thierfeldt described the radiological modelling performed in Germany for the derivation of clearance levels on the basis of 10 µSv/year individual dose. For each nuclide and each clearance option, a radiological model is developed which covers all relevant exposure situations and pathways.

In the second paper, G. Jessop described the UKAEA’s approach to meeting the delicensing criteria for buildings and sites at Harwell and Winfrith, and M. Pearl gave a presentation on a software package (IMAGES) that enables the systematic collection, collation, interpretation and visualisation of all information (building and land usage, plans of buildings, radiological monitoring, geological and hydrogeological environment, radiometric surveys, intrusive surveys, ground-water quality, etc) that is required to justify that the delicensing criteria have been met.

In the third paper, S. Yanagihara presented a high-sensitive double-layer detector developed for the measurement of surficial contamination on building surfaces and inside pipes embedded in building structures. The detector is very sensitive to β-rays emitted by Co-60 and Cs-137 and has a minimum detectable level of about 0.1 Bq/cm^2 for a 60 seconds counting time.

Local Community Voices

Philip Moding made a presentation on the case study of Barsebäck and the conflicting issues concerning land use after the decommissioning of a nuclear facility. He stressed the right of the municipalities to decide over the future local planning and land use and discussed the conflicts which may arise between national decision and local interests. He emphasized the importance of the EIA process and the active role which should be played by the local population during the first stage of the process. Finally he indicated that municipalities need financial resources to engage independent experts who can provide advice during the dialogue with the implementer and education/training of local politicians and civil servants.

Regulator’s Voices

In the first of two papers in this group, Scott Moore described the dose-based release standards used in the USA and the process to demonstrate compliance with the license termination rule. An effective dose of 0,25 mSv/year must not be exceeded for unrestricted release. He emphasized the importance of dose modelling to derive concentration levels and the need to perform final status surveys, following the MARSSIM (Multi-Agency Radiological Survey and Site-Investigation Manual) methodology. Future challenges, from a regulator's perspective, include: dose modelling for future use scenarios, clean-up standards by the states or other agencies, clearance criteria for release of materials and developing the restricted release option (i.e. how to ensure that institutional controls will last for 1,000 years).

In the second paper, J. L. Revilla explained that no general clearance standards are available in Spain and that release criteria have been authorised only on a case by case basis. In the case of Vandellós 1 decommissioning project, the values recommended by the EU in documents RP89 and RP113 are being used for building and rubble release. These values have been derived on the basis of an effective dose less than 10 µSv/year and a collective dose less than 1 man Sv during one year. In the case of site release, a criteria of 100 µSv/year has been used in uranium mill and mine decommissioning projects and is being proposed by the implementer for Vandellós 1.

Implementer's Voices

Three different experiences for the clearance of buildings and sites were discussed. The first was presented by V. Massaut, who described the process for decommissioning and clearance of some radiological laboratories for unrestricted reuse. Contamination levels were below 500 Bq/cm^2 for beta gamma emitters and 0.5 Bq/cm^2 for alpha emitters. Clearance limits were established as 0,4 Bq/cm^2 surficial contamination for beta and gamma emitters and 0.04 Bq/cm^2 for alpha emitters. Residual radioactivity should be of the same order of magnitude as that of a non-nuclear building on site. Methods used to demonstrate compliance with the limits were the radiological monitoring of the entire wall and floor surfaces, radiological analyses of the washwater from walls and floors, and measurement of selective core samples.

The second presentation by B. A. Lange described AECL's approach to decommissioning and release of building and building rubble, land and groundwater. AECL's interim criteria for building and materials is 0.2 Bq/cm^2 (0.2 Bq/g) for alpha emitters and 1.0 Bq/m^2 (1.0 Bq/g) for beta and gamma emitters. For the release of lands, the approach involved demonstrating that the residual radioactivity is not statistically different from that of off-sited lands. Several options are under consideration for free release: full off-site release, no off-site release, and partial off-site release (only non-detectable contamination is released off-site and other wastes are disposed on-site).

The last presentation from Luis Valencia described the experience in release of buildings and sites at FZK, Germany. He discussed the process of characterization, zoning, decontamination and decision survey for the release of rooms and explained the frequency of measurements for different categories of rooms. Release values used were those established by the previous Radiation Protection Ordinance, which are less conservative than the present ones.

SUMMARY OF DISCUSSIONS

Following the presentations, the WPDD members discussed the released of buildings and sites in an open manner led by the Topical Session Chair, Manfred Schrauben. The discussion was organized towards addressing some of the questions that the WPDD Core Group had proposed for this session.

Standards

A dominant theme emerging from the discussions was the significant difference in release standards among the various countries. Most standards are dose-based rather than concentration-based but it was felt that there is need for a greater uniformity. It was mentioned that IAEA is working on achieving unification among exclusion, exemption and clearance levels and that a draft document will be available for comments before the end of the year.

Release standards are defined for different types of radionuclides and it was discussed whether naturally occurring radionuclides should be treated or not in the same manner as other radionuclides.

Standards Setting

Concentration levels, complying with the dose requirement, are derived through dose modelling. It was recognized, as for the dose criteria, the great diversity and inconsistencies in derived concentration levels among different countries. However, it was realized that this may be explained by the different assumptions/methods used in any of the four elements of the dose modelling process: source term, exposure scenarios, mathematical model and parameter values and their uncertainty.

Experience

It is necessary to perform surveys to demonstrate compliance with the clearance standards. The presentations indicated that the general framework for performing these surveys include planning, implementation and assessment phases. It was recognized the importance of determining the history of usage of buildings and sites, as well as defining the natural background activity and the radiological conditions of buildings and sites, through scan surveys and sampling. Data management, including statistical analysis, was also emplasized as a key aspect in the assessment phase.

Another issue that was discussed was the term “detectable contamination” and its implications on the free release options. It was felt that clearance standards should not be based on detectable limits.

Remediation of those areas above the clearance limits is also part of a site release plan and it was agreed that this topic should be elaborated further in a task group.

Local Community

It was recognized the key role of municipalities in local planning and land use and the need for their active involvement in the decommissioning process from the early stages of planning.

Further discussion by WPDD is needed to address in more detail the questions proposed for this Topical Session and it was agreed that the Task Group on Material Management should be expanded to include Release and Reuse of Buildings and Sites.

MODELING FOR THE DERIVATION OF LEVELS FOR THE RELEASE OF BUILDINGS AND SITES

S. Thierfeldt
Brenk Systemplanung GmbH, Germany

Introduction

The Radiation Protection Ordinance [1] (RPO) (Strahlenschutzverordnung / StrlSchV) has been issued on July 20, 2001. This Radiation Protection Ordinance transforms the EURATOM Basic Safety Standards [2] into national legislation. It contains for the first time detailed regulations on clearance including nuclide specific sets of clearance levels (CL) for all clearance options: unconditional clearance, clearance of building rubble (> 1000 Mg/a), clearance of buildings for demolition and for reuse, clearance of metals for recycling, clearance of nuclear sites, and clearance for disposal or incineration.

All clearance levels are based on the concept of triviality of dose, i.e. the clearance levels have been derived on the basis of 10 µSv/a individual dose. In addition, the assessments of collective dose for each clearance option show that the criterion of 1 man-Sv/a is well fulfilled. The clearance levels in Germany have always been derived in such a way to achieve maximum compatibility with the international development, especially in the European Union, but also with recommendations of the IAEA.

All sets of clearance levels are based on detailed radiological assessments which rely on comprehensive investigations and studies taking into account the distinctive features of the clearance options and the types of materials involved. Each radiological model consists of a variety of scenarios which take into account external irradiation, inhalation, direct and secondary ingestion and skin contamination and a number of pathways (workplaces, home, foodstuff, water pathways etc.). For each nuclide and each clearance option, a separate clearance level value exists in the German RPO.

Clearance Options in the German Radiation Protection Ordinance (StrlSchV)

The clearance options are defined in § 29 together with Annex III Table 1 of the German RPO [1]. They consist of options for "unconditional clearance" (category 1 in the following list) where no restrictions exist concerning the destiny of the material exist after clearance, i.e. the material need not be traced to a final destination, as well as clearance for a specific purpose (category 2 in the following list) where it must be guaranteed that the material will be brought to the pre-defined destination. This latter category of clearance options is often called "conditional clearance" (a term which is no longer used in German legislation).

Clearance options are:

1. unconditional clearance
   - a of all solid materials for reuse, recycling or disposal including building rubble of less than 1000 Mg per year,
   - b of building rubble and soil of more than 1000 Mg per year,
   - c of buildings for reuse or demolition,
   - d of nuclear sites (after removal of the buildings);

2. clearance
   - a of solid materials for disposal on landfills or for incineration,
   - b of buildings for demolition only,
   - c of metal for melting only.

The following presentation deals with the clearance options, which are marked in bold in this list. **Table 1** provides an overview of CL for a short selection of nuclides.

Table 1: **Examples for CL in Annex III Table 1 of the German Radiation Protection Ordinance**

Nuclide	**Exemption level**		**surface specific activity**	**Clearance**						
	activity in Bq	activity concentr. Bq/g	Bq/cm²	**unconditional clearance of**				**clearance of**		
				solids, liquids* Bq/g	rubble, soil of > 1000 t/a Bq/g	sites (land) Bq/g	build-ings for reuse Bq/cm²	solids, liquids for dis-posal* Bq/g	build-ings for demo-lition Bq/cm²	metal scrap for recyc-ling Bq/g
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*10a*
H 3	1E+9	1E+6	1E+2	1E+3	6E+1	3	1E+3	1E+3	4E+3	1E+3
C 14	1E+7	1E+4	1E+2	8E+1	1E+1	4E-2	1E+3	2E+3	6E+3	8E+1
Fe 55	1E+6	1E+4	1E+2	2E+2	2E+2	6	1E+3	1E+4	2E+4	1E+4
Co 60	1E+5	1E+1	1	0.1	9E-2	3E-2	4E-1	4	3	0.6
I 131	1E+6	1E+2	1E+1	2	6E-1	2E-1	1E+1	2E+1	6E+2	2
Cs 137	1E+4	1E+1	1	5E-1	4E-1	6E-2	2	1E+1	1E+1	6E-1
U 234	1E+4	1E+1	1	5E-1	4E-1		1	9	1E+1	2
Pu 242	1E+4	1	1E-1	4E-2	4E-2	4E-2	1E-1	1	2	3E-1
Am 241	1E+4	1	1E-1	5E-2	5E-2	6E-2	1E-1	1	3	3E-1
**) for col. 5 and col. 9: only for material which does not fall under column 6*										

Modeling for the derivation of clearance levels

Clearance of Building Rubble

Scope: The CL for building rubble and soil of more than 1000 Mg/a are valid for larger amounts of rubble and soil, e.g. from large decommissioning projects. They apply to

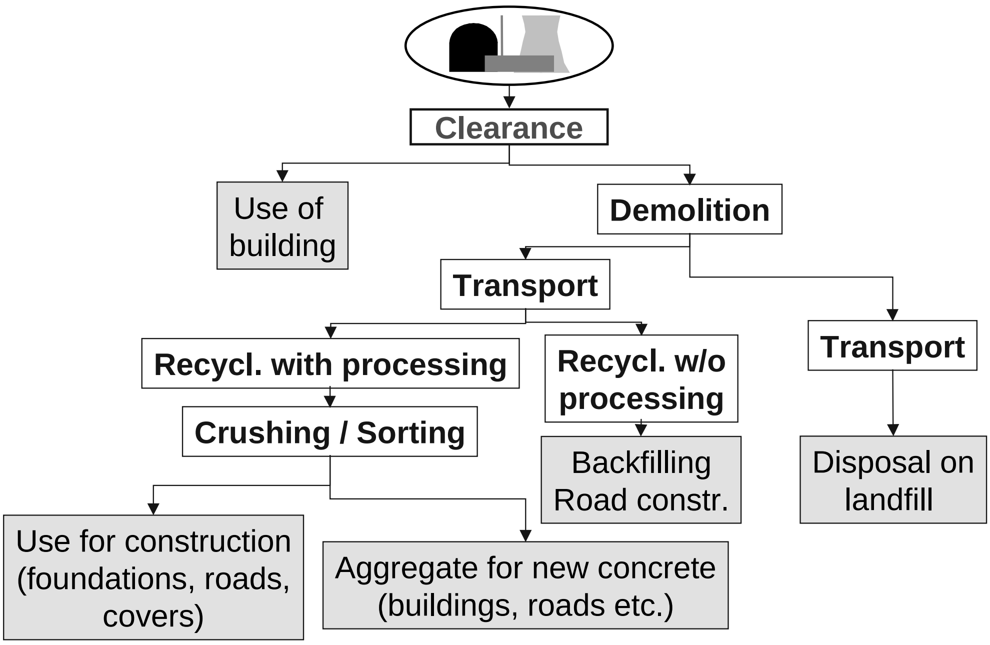
- building rubble which arises prior to the demolition of the buildings, e.g. from demolishing walls in the controlled area to gain access to larger components;

- soil which arises prior to the release of the entire site (or parts thereof), e.g. because building structures had to be removed from the ground or new buildings have to be erected.

The scenarios which describe exposure situations for large material quantities are different from those applying to unconditional clearance (column 5 in **Table 1**). Therefore, the mass limit was introduced. The preferred option for clearance of buildings is, however, to make the release measurement at the standing building structure. In this way deliberate mixing of uncontaminated and contaminated portions of rubble are avoided. This is why separate CL for buildings exist (see below).

Model: The model used for deriving the CL for rubble covers the following steps: building demolition (conventional demolition), recycling with various options (with and without processing), various exposure pathways (external irradiation, dust inhalation, direct ingestion, secondary ingestion via water pathways etc.), various options for the final use of the recycled material (e.g. use in new buildings, in road construction or as filling material). This model is an adaptation of the model used for deriving the corresponding CL developed by the Article 31 Group of the European Union [3], [4]. An outline of this model is shown in **Figure 1**.

Figure 1: **Outline of the model used for derivation of CL for buildings and building rubble**



Examples: CL values for the clearance of rubble and soil of more than 1000 Mg/a are shown in column 6 of **Table 1**. It should be noted that those CL are generally lower than or equal to those for unconditional clearance (column 5) which reflects the larger masses involved in this case.

Clearance of Buildings

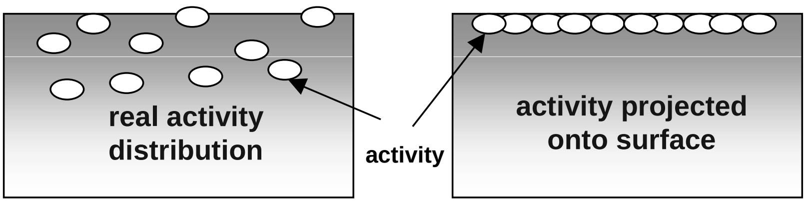
Scope: The CL for the unconditional clearance of buildings for reuse or demolition apply to clearance of the standing building. It does not matter whether the building will be reused or demolished after clearance.

Model: The same model assumptions are used as the one described above for building rubble. However, the CL are expressed as surface specific values because the measurement will take place at the surface structure. CL values include the entire activity on the surface (removable and fixed contamination) as well as the activity which has penetrated the surface and entered the volume. This can be understood as the "projection" of the activity onto the surface as shown in

Figure **2**. This is an elegant method to avoid simultaneous application of mass and surface specific values and it corresponds to various commercially available measurement techniques like the collimated in situ gamma spectrometry.

The model contains specific exposure situations which apply to the reuse of the building e.g. as a store house, an office or other purposes. In these circumstances, external irradiation over longer time periods is an important pathway, but also inhalation due to dust from building renovation.

Figure 2: **Application of surface specific CL as the projection of the activity onto the surface**



Examples: CL values for unconditional clearance of buildings are shown in column 8 of Table 1. Those CL have been applied already in a few licensing procedures in Germany for buildings or parts thereof.

Clearance of Sites

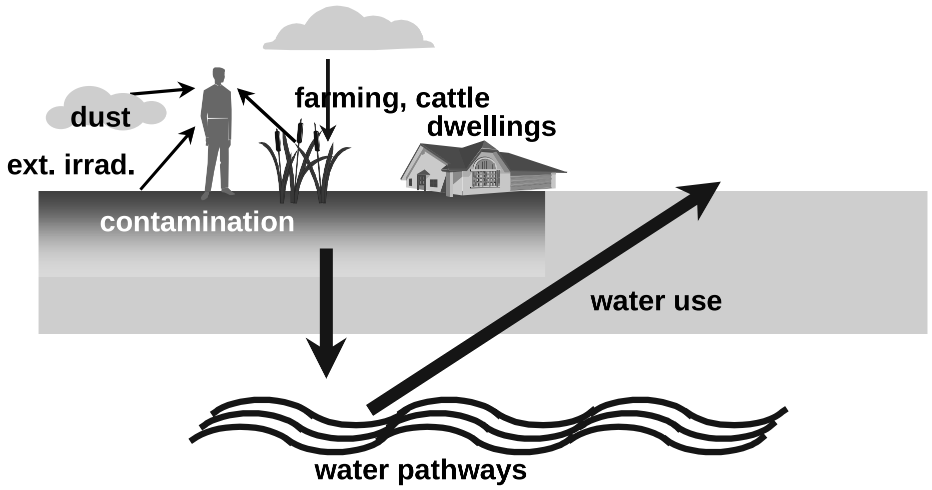
Scope: The CL for the unconditional clearance of nuclear sites apply to (entire or parts of) sites which belong to a nuclear installation (nuclear power plant, research reactor, fuel cycle installation etc.). The area in question must be free of buildings (exception: building foundations might be left in the ground, depending on circumstances). The CL are valid for sealed surfaces (concrete, bitumen) as well as for open ground. The averaging area is set to 100 m². Measurements need not cover 100% of the surface. Instead, stochastic measurement distributions with a pre-determined measurement density may be used [6].

Model: A rather complex model [5] has been used which cannot be discussed here in detail. It is based on the fact that the contaminated site has a finite size and that the contamination is supposed to be in the upper part of the soil or on the soil cover. From there nuclides might be resuspended into the air during work (construction of new buildings, gardening etc.). Nuclides will, however, also be washed away by rain to a river (surface water pathway) or will migrate to deeper parts of the soil under the influence of rain and infiltrating water, where they will reach a ground water layer (ground water pathway). From the surface or ground water they may enter the human food chain if the water is used for drinking or irrigation. This leads to the following pathways:

- external irradiation from nuclides in the top layers of the soil (e.g. a few 10 cm) on the cleared site,
- inhalation of contaminated dust from the soil of the cleared site,
- direct ingestion of contaminated soil from the cleared site,
- ingestion of vegetables that are grown on the cleared site,
- ingestion of drinking water, vegetables, meat and milk which have been contaminated by nuclide migration from the soil to surface or ground water (unlike the other pathways, this pathway is possible to happen on and in the vicinity of the cleared site) - drinking water, irrigation of plants, water for cattle.

A very simplified outline of this model is shown in **Figure 3**.

Figure 3: **Outline of the model used for derivation of CL for nuclear sites**



Although the model made a distinction between unconditional clearance of the site for any use (i.e. for dwellings, for industrial purposes, for recreational areas etc.) and clearance for industrial use only (i.e. no dwellings, gardens, agriculture etc. are allowed on the site), only the first option has been included into the German RPO.

Examples: CL values for unconditional clearance of sites are shown in column 7 of **Table 1**. They are provided in Bq/g for the top layer of soil but can be converted into surface specific values (e.g. for measurement with collimated in situ gamma spectrometry) by using the penetration depth and the density of the soil. The fact that the CL values are rather low in comparison e.g. to unconditional CL for rubble and soil may be understood from the fact that rather large areas may be affected. Modern measurement techniques are capable of detecting especially Co 60 and Cs 137 even to much lower levels.

The model and the derived CL have been applied for the first time at the nuclear power plant KGR at Greifswald, Germany. It has become clear that the clearance measurements can be based solely on the two nuclides Co 60 and Cs 137.

Application of clearance levels in German decommissioning projects

The CL which have been described in section 0 are most relevant for decommissioning projects in Germany. The preferred decommissioning variant is early dismantling to green (or brown) field without a safe enclosure period. Therefore, a number of decommissioning projects already have reached a stage where clearance of buildings and/or part of or the entire site is approaching or has already taken place. Some larger reactors (KKN Niederaichbach, HDR Heißdampfreaktor Kahl) have already been completely removed.

References

[1] German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Bonn): Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung – StrlSchV) – (*Radiation Protection Ordinance*), Bundesgesetzblatt Teil 1, p. 1714, Bonn, July 20, 2001.

[2] Council of the European Communities: Council Directive 96/29/Euratom laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation, Official Journal of the European Communities, ISSN 0378-6978, L 159, Vol. 39, 29.06.96.

[3] Group of experts established under the terms of Article 31 of the Euratom Treaty: Recommended radiological protection criteria for the clearance of buildings and building rubble from the dismantling of nuclear installations; Radiation Protection 113; European Commission, Luxembourg, 2000.

[4] A. Deckert, S. Thierfeldt, E. Kugeler, I. Neuhaus: Definition of clearance levels for the release of radioactively contaminated buildings and building rubble; Radiation Protection 114, European Commission; Brenk Systemplanung, Aachen, 1999.

[5] Thierfeldt, S.; Nüsser, A.; Deckert, A.; Schramke, M.; Neuhaus, I.: Stillegung von Kernanlagen - Freigabe von Bodenflächen kerntechnischer Standorte; report on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, res. project SR 2271, Brenk Systemplanung, Aachen, 1999.

[6] German Institute for Standardisation (DIN): DIN 25457 part 7: Aktivitätsmeßverfahren für die Freigabe vom radioaktiven Reststoffen und kerntechnischen Anlagenteilen, Bauschutt und Gebäude, Teil 7: Bodenflächen (draft), Berlin, 1999.

DEVELOPMENT OF SOFTWARE TOOLS FOR SUPPORTING BUILDING CLEARANCE AND SITE RELEASE AT UKAEA

G. Jessop and **M. Pearl,**
UKAEA

Abstract

UKAEA sites generally have complex histories and have been subject to a diverse range of nuclear operations. Most of the nuclear reactors, laboratories, workshops and other support facilities are now redundant and a programme of decommissioning works in accordance with IAEA guidance is in progress.

Decommissioning is being carried out in phases with post operative activities, care and maintenance and care and surveillance periods between stages to allow relatively short-lived radioactivity to decay. This reduces dose levels to personnel and minimises radioactive waste production. Following on from these stages is an end point phase which corresponds to the point at which the risks to human health and the environment are sufficiently low so that the buildings / land can be released for future use. Unconditional release corresponds to meeting the requirement for 'delicensing'.

Although reaching a delicenseable end point is the desired aim for UKAEA sites, it is recognised that this may take hundreds of years for parts of some UKAEA sites, or may never be attainable at a reasonable cost to the UK taxpayer. Thus on these sites, long term risk management systems are in place to minimise the impact on health, safety and the environment.

In order to manage these short, medium and long term liabilities, UKAEA has developed a number of software tools based on good practice guidance. One of these tools in particular is being developed to address building clearance and site release. This tool, IMAGES (Information Management and Geographical Information System) integrates systematic data capture, with database management and spatial assessment (through a Geographical Information System).

Details of IMAGES and its applications are discussed in the paper.

1. Introduction

UKAEA sites generally have complex histories and have been subject to a diverse range of nuclear operations. Most of the nuclear reactors, laboratories, workshops and other support facilities are now redundant and a programme of decommissioning works in accordance with IAEA guidance is in progress.

Thus UKAEA's mission is to restore the environment of its sites in a way that is:

- safe and secure
- environmentally responsible
- value for money
- publicly acceptable

Decommissioning is being carried out in phases with post operative activities, care and maintenance and care and surveillance periods between stages to allow relatively short-lived radioactivity to decay. This reduces dose levels to personnel and minimises radioactive waste production. Following on from these stages is an end point phase which corresponds to the point at which the risks to human health and the environment are sufficiently low so that the buildings / land can be released for future use. Unconditional release corresponds to meeting the requirement for "delicensing".

Because some parts of the site reach the criteria for an "unconditional release" end point earlier than others, land is being released in packages so that an income stream can be generated from the purchase of this land for development.

Although reaching a delicenseable end point is the desired aim for UKAEA sites, it is recognised that this may take hundreds of years for parts of some UKAEA sites, or may never be attainable at a reasonable cost to the UK taxpayer. Thus on these sites, long term risk management systems are in place to minimise the impact on health, safety and the environment.

This paper (i) introduces the UK legislative standards for 'delicensing' and discusses UKAEA's approach to meeting the end point criteria for buildings and land on its sites; (ii) presents details of the development and use of a software tool called IMAGES (Information Management and Geographical Evaluation System) which is used to collect, collate, interpret and systematically manage the data required to meet these criteria and (iii) discusses delicencing experiences on UKAEA's Winfrith site.

2. Building and Land Clearance Criteria

2.1 UK Legislative Requirements

Within the United Kingdom a licence is required for all nuclear sites that undertake prescribed processes such as the operation of nuclear reactors; the storage, processing or disposal of nuclear fuel or other materials produced or irradiated as a consequence of the production of nuclear fuel (excludes fusion).

The requirement and conditions for this licence are given in the Nuclear Installations Act.

Within the UK regulation of licensed facilities is undertaken by the Nuclear Installations Inspectorate (NII), a division of the Health and Safety Executive (HSE), who are responsible to the Government of the day.

The NIA (65) Act includes the requirement for Licensing Conditions specific to that site and also for the Variation or Cessation of a Licence (referred to as delicencing).

The requirements for Variation or Cessation are the same, and are both considered by the NII who must satisfy themselves that there are no prescribed nuclear processes in that area, and that there is no danger from ionising radiations from anything on that part of the site (NIA65, S3(6)).

2.2 UKAEA Criteria to meet Legislative Requirement

To demonstrate "no danger" from ionising radiation the following criteria has been applied on UKAEA's Harwell and Winfrith sites:

- Confirmation that, there are no current or future planned prescribed activities within area for delicensing, and that as 'licensee' we no longer require the area licensed.

and that,

- Levels of radioactivity will be below the exemption levels given in the UK Radioactive Substances Act (Schedule 1) and the Substances of Low Activity Exemption Order (SoLA).
- Levels of contamination on hard surfaces will be below 0.4 Bq/cm^2 (alpha) and 4.0 Bq/cm^2 (beta / gamma).
- Levels of radiation will, so far as is reasonably practicable, be consistent with that of the background levels for land and in buildings.

The levels given in the Substances of Low Activity Exemption Order are in addition to background radioactivity levels. Thus, natural background levels should be determined to ensure that any areas of elevated natural activity are not misinterpreted as being above the delicensing criteria.

3. UKAEA's Approach to Meeting the Delicensing Criteria

The work required to meet the delicensing criteria involves:

- determining the history of usage for buildings and land within the target zone
- the determination of the radiological characteristic and condition of buildings and land to be delicensed and the surrounding areas;
- the determination of natural background activity;
- establishment of potential migration routes from, and to, the area to be delicensed (through groundwater and/or air);
- assessment of the data and comparison of the radiological condition of the area to the delicensing criteria (taking into account natural background activity and taking into account possible contaminant migration from adjacent areas);
- remediation of those areas above the delicensing criteria, or of those areas which impact on the delicensing area;
- validation of the remedial measures.

The first four points above are initially ascertained by reference to existing records. These include records relating to:

- building and land usage throughout the history of the site (not just its current use) including identification of any waste transfer routes and waste storage areas;

- plans of buildings and services (drains) to those buildings,
- routine monitoring such as those associated with routine operations, room clearance, groundwater monitoring, environmental monitoring (e.g. air sampling);
- incidents particularly those relating to spills and leaks, also subsequent clean-up records;
- geological and hydrogeological environment and other potential migration pathways (e.g. through air).

The results from this initial desk based survey is used to:

- establish a radiological fingerprint of potential source areas of contamination and also ascertain potential chemical contaminants and based on the radiological fingerprint to determine the appropriate radiological monitoring technologies and techniques;
- determine the characteristics of any sources of contamination e.g. size and possible extent of a contaminant source;
- conceptualise potential migration pathways for the contamination.

This knowledge of the likelihood of contamination occurring, the likely types of contaminants, their likely extent and potential migration pathways are used to steer and target the subsequent surveying campaigns. Thus, radioactive contamination which has a gamma fingerprint that has arisen as a consequence of aerial discharges or surface spills is likely to be "spotty" in distribution but should be readily detectable using surface monitoring techniques using appropriate instrumentation (see Box 1).

Conversely, contamination that has arisen as a consequence of a liquid leak from a drain may only be present at depth, but is likely to be relatively evenly distributed over a particular area. The detection of this contamination requires intrusive investigation together with sampling and radiochemical and chemical laboratory analysis of the samples. The pattern used for sampling and the depth of sampling will depend on the understanding of the potential subsurface migration routes. Thus, as a precursor to intrusive investigation, the desk study and non-intrusive geophysical surveys can be used to identify preferential drainage pathways (e.g. service channels, preferential geological horizons etc).

4. Development of the IMAGES software tool

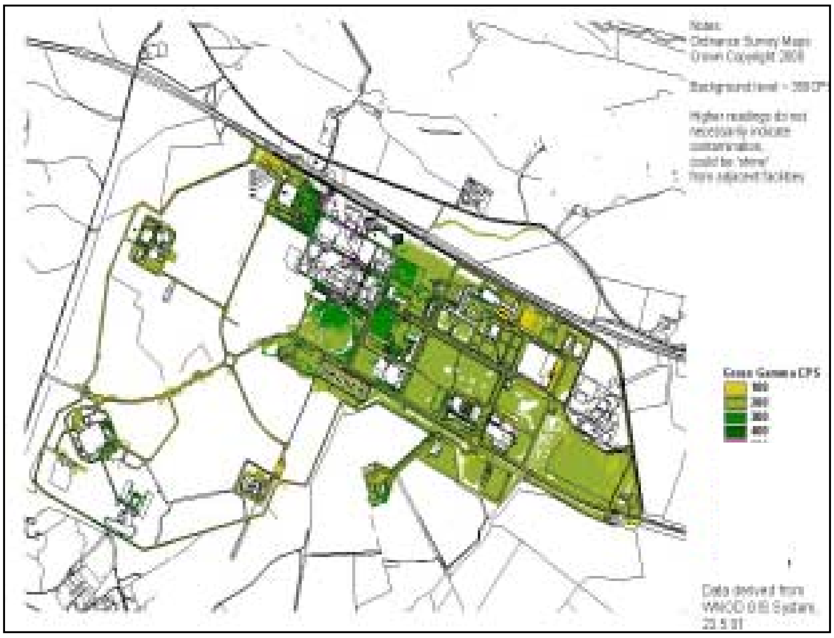
The background information presented above illustrates that in order to delicense a facility, a large amount of information is required to justify that the "no danger" criteria have been met. To ensure that this information was managed methodically, an integrated software tool was developed. Called IMAGES - Information Management and Geographical Evaluation System – the tool enables the systematic collection, collation, interpretation and visualisation of relevant data.

Key aspects of the system include data management and spatial interpretation and visualisation.

Although it was realised at the outset that as such a system could not be purchased "off the shelf", it was a desire that the system should use, as far as possible, standard software products to collect the data. This enabled UKAEA users and contractors to be able to collect information in familiar software products (e.g. Excel).

Box 1: **Surface Monitoring of Land**

In recent times these have been undertaken using high sensitivity, low resolution gamma detectors supported by either Global Positioning Satellite (GPS) systems or laser tracking systems. The data gathered is captured by data logging systems such that many measurements can be made over an extensive area relatively cheaply and with very good Quality Assurance. The output can then be displayed within a Geographical Information System (GIS) and overlaid on relevant maps which can be held in an electronic database. An example is shown below.



5. The components of IMAGES

IMAGES integrates data capture and data management system with a Geographical Information System (GIS).

The key components of IMAGES are:

- A series of proformas (templates) mostly using MSExcel for data capture,
- an ORACLE database system for storage, searching and reporting,
- the ADMiT data management system for controlling data from a number of sources,
- ArcView GIS for geographical analysis and presentation of information.

As a consequence the integrated package enables:

- consistent data capture
- quality controls on data (e.g. identification of data custodians, data quality marking, revision control, updateability, archivability and traceability)
- data selection through database querying, filtering, and searching
- integration with GIS
- control of data modifications and distribution

IMAGES has been developed as a number of integrated modules. These are shown in Table 1. Further details are presented in the sections below.

Many of the QA aspects built into IMAGES are controlled through a workflow process – which controls input, access, editing and revision. This is illustrated in Figure 1. Thus in revising data, new versions receive a higher revision number. Reasons for the revision are noted, together with the date and person who made the revision. Old versions are kept as lower numbered versions – this ensures that any conclusions about land condition status refer to the data as it was at the time of the writing of the land condition record.

Figure 1: **Workflow Process**

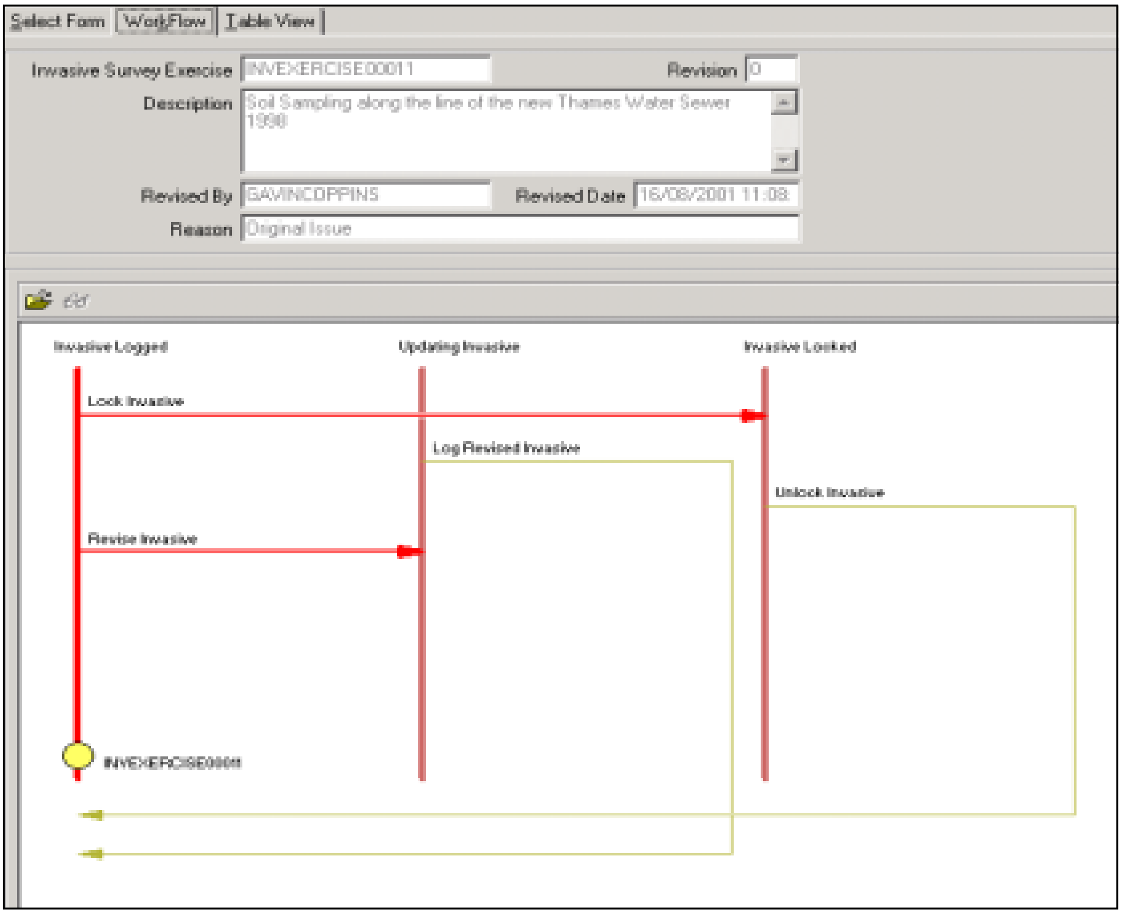


Table 1: **IMAGES Modules**

Module	**Comments**
Document Register	Captures electronic reference documents (e.g. reports etc), records details about the documents (including document owner). This links to the Buildings Module and the Assessment database
Photograph Register	Captures electronic photographs, records details and links to the Buildings Module and the Assessment database.
Buildings	A collation of the history of building usage, incidents, construction details and fabric, and radiological classification. Links to the Document Register and Photograph Register within IMAGES. Buildings information can be queried through the database and the result displayed in GIS (e.g. show all buildings where oil was stored and highlight corresponding buildings on a map [within GIS]).

Health Physics Form	An MSExcel Spreadsheet which records monitoring data collected using health physics instrumentation. Mainly used for application within buildings.
Health Physics Database	The repository for all the Health Physics spreadsheets. This enables querying and searching and delivery of the result to the GIS for spatial interpolation, or to MSExcel for further analysis.
Intrusive Survey Form	An MSExcel Workbook which records information about intrusive surveying. This includes logging details for different lithologies, in-situ measurements, samples taken (solid, groundwater or free phase liquid), laboratory analysis of the samples, preservation methods and analytical methods.
Intrusive Survey Database	The repository for all the intrusive survey workbook. On capture by the database, quality marks can be added to reflect the quality of specific aspects of the data e.g. location, analytical technique. Once in the database then the data can be queried and searched with the result being delivered to the GIS for spatial interpolation, or to MSExcel for further analysis (and possibly subsequently to GIS). In addition, logging descriptions can be dumped into a borehole logging package to give a downhole display.
Groundwater Quality Form	An MSExcel Workbook which records information about groundwater surveying. This includes in-situ measurements, samples taken (groundwater or free phase liquid), laboratory analysis of the samples, preservation methods and analytical methods.
Groundwater Quality Database	The repository for groundwater monitoring workbooks. On capture by the database, quality marks can be added to reflect the quality of specific aspects of the data e.g. location, analytical technique. Once in the database then the data can be queried and searched with the result being delivered to the GIS for spatial interpolation, or to MSExcel for further analysis (and possibly subsequently to GIS). A routine has been developed which enables a display of the variation of specific contaminants in groundwater through time.
Block Data Store	A database for blocks of data not otherwise captured in the other parts of the system. This is subdivided according to data type. This is the repository for Geophysical Data and for intensive GPS based survey (Groundhog) data.
GIS Project Database	A database to log GIS based information i.e. GIS Projects and GIS Themes (within GIS Projects). This enables ownership and revisions/amendments to be controlled.
Land Assessment Database	Uses the information above to assess the land condition. Includes a qualitative risk assessment and captures information on any qualitative risk assessment.

5.1 Historical Information Associated with Buildings

This information establishes the types of contamination likely to arise and those parts of the building or its infrastructure likely to be contaminated. Of particular interest are those activities which could have caused releases to air or drainage systems and which could cause contamination of specific parts of the building fabric, adjacent facilities or the subsurface below and around the building. It should be noted that the review of building usage is not only about identifying potential radioactive material and discharges, but is also about identifying chemical usage, storage and discharges.

Within IMAGES the Buildings Database records summary information of usage, incidents and construction details (Figure 2).

Specific reference documents and photographs can also be attached to provide supporting information and as well as an audit trail back to the original information sources. As well as specific documents (paper or electronic), these sources may also be other databases such as a Building Manual Database, an Asbestos Register, and an Incident and Accidents database.

An important aspect of these data sources is that the“owner” or “custodian” of the information is identified and informed that their data is being used within IMAGES. They are then requested to inform the IMAGES administrator of any updates or revisions to the information supplied.

A link from the “Buildings Module” to ArcView GIS allows useful presentation of historical queries. For example, a database query showing all buildings that contained active laboratories can be viewed in GIS, providing a clear indication of their location on site as well as any spatial relationships that exist with other data held within the system.

5.2 Radiological Surveying of Buildings

Following a historical review, radiological surveying of buildings is carried out using appropriate health physics instrumentation. Results are recorded in the Health Physics MSExcel template within IMAGES (Figure 3). The template itself is an electronic version of a recording sheet that has been used for many years within UKAEA. The sheet records instrument type, serial number, operator and readings. Because dates and serial number are recorded, the results can be traced back to the calibration history of the instrument.

Because locational (e.g. room number) and positional (position of activity relative to a room reference point) data is recorded then it is possible to visualise the findings in the GIS as an overlay to a building layout plan or to geo-referenced photographs of particular room layouts.

In addition, once captured within the database, trends can be queried and viewed within GIS maps and cross correlated to the building histories database for those facilities which meet the search or query criteria.

Figure 2: **Illustration of the Building History module of IMAGES**

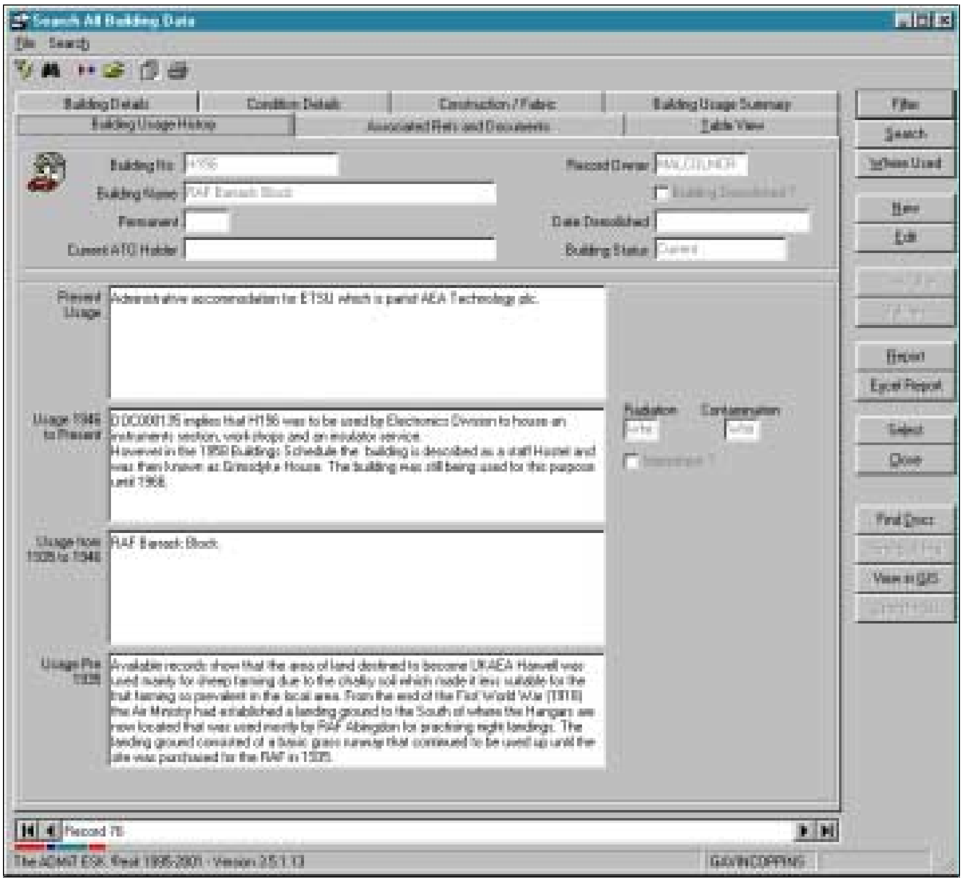
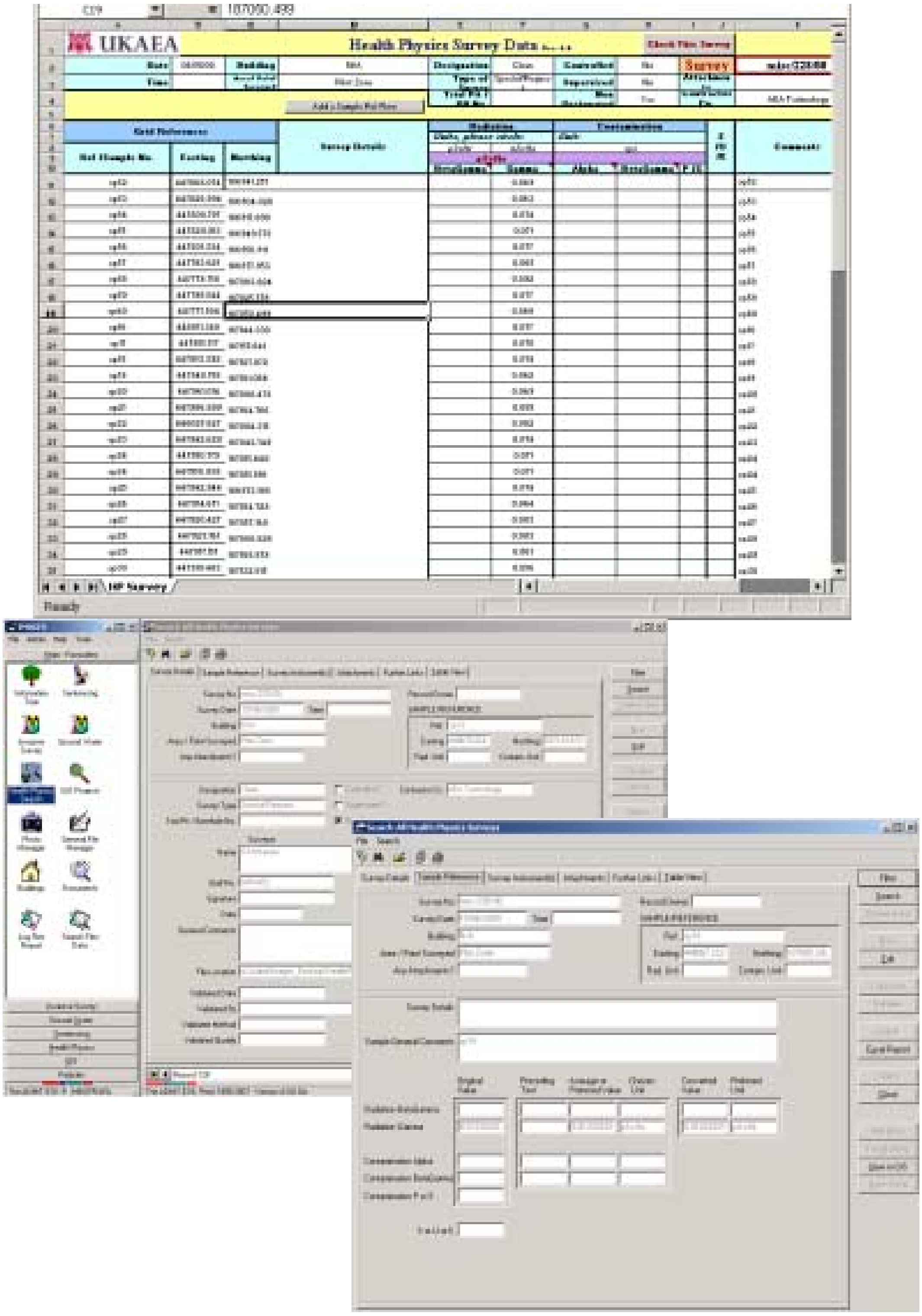


Figure 3: **Health Physics Survey of Building Showing Excel Template and the Database**



5.3 Information Associated with Land Quality

Information associated with land quality captured and stored within IMAGES includes:

- Maps, photographs, service paths, building history, incidents, monitoring records, geology, hydrogeology;
- Geophysical survey information to identify subsurface features;
- Surface radiological measurements using high sensitivity, low resolution gamma detectors supported by Global Positioning Satellite (GPS);
- Intrusive sampling data (where the sampling points have been decided based on all the information above);
- Groundwater monitoring data;
- Data evaluation and interpretation (through a structured Land Assessment Database);
- Records of remedial actions and/or monitoring requirements.

Details of some of these collection templates and databases are presented below.

5.3.1 Intrusive Land Surveys

Where there is the possibility of subsurface contamination intrusive coring or trial pitting with discrete sampling is carried out. Standard electronic input forms associated with these types of survey have been developed which can be uploaded into IMAGES. Figure 4 shows information capture, processing and GIS visualisation.

By collecting data on a standard input form, consistency of data capture is assured.

In addition, when completed input forms are logged into IMAGES they can be quality marked against a set of predefined criteria which relate to locational accuracy, and the radiochemical and chemical analytical methods (e.g. traceability to known standards) and laboratories used. The data can then be queried and spatially assessed in GIS – for example, interrogating the analytical data for levels of contamination above a particular level and visualising the result in GIS.

5.3.2 Groundwater Monitoring

In the context of delicensing, down-hydraulic gradient groundwater monitoring boreholes may be required as evidence that there is no subsurface contamination. In the context of contaminated land management, groundwater monitoring boreholes can also be used to show that subsurface contamination is being contained or that remedial measures are required to deal with contamination migrating in groundwater.

IMAGES contains input templates for groundwater monitoring information. Once captured with IMAGES then the data can be viewed (Figure 4):

- patially - using GIS functionality, and also
- with time where variations in groundwater quality can be viewed relative to the time of the year to assess seasonal variation (which may be related to water table level) as well as over longer periods of time to assess gradual trends.

5.3.3 The Land Assessment Database

The Land Assessment Database within IMAGES enables the systematic assessment of land quality. This assessment database is a series of forms which relate to various aspects of the land and also link to supporting data, photographs, maps and documents.

Figure 5 shows the structure of the database. Three levels of information can be stored about the land on a site – Site (regional), Zone (subsection of the site), Area (specific part of the site where land quality is assessed). At the site level is a link to high level strategic documents as well as general documents on site history and geological setting. Sites are divided into Zones, which contain selected Areas to which detailed land quality information is attached. A qualitative risk assessment section considers sources of contamination, its potential migration and its potential impact to human health and the environment. Following on are recommendations for mitigating measures. The database is a "living" record and can be updated as new information becomes available. Updating records is a revision exercise and the reasons for updating are recorded. For completeness, old versions of the record are kept as a lower version number. This enables users the ability to revisit previous decisions – which may be required to substantiate progressive decision making.

Figure 4: **Example of data capture, query and GIS analysis using intrusive survey data**

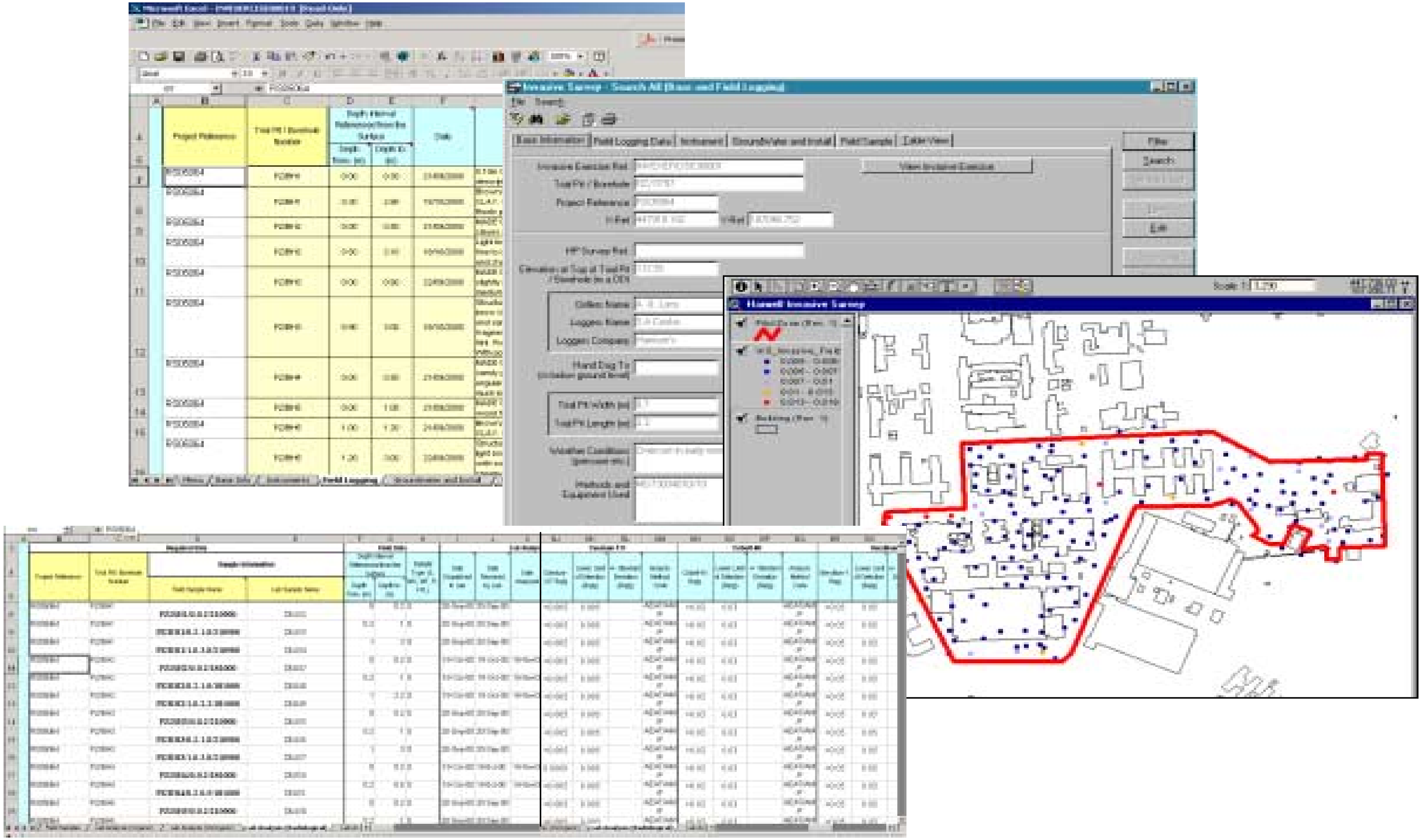


Figure 5: **Illustrated example of data capture and spatial and temporal analysis using groundwater data within IMAGES and GIS**

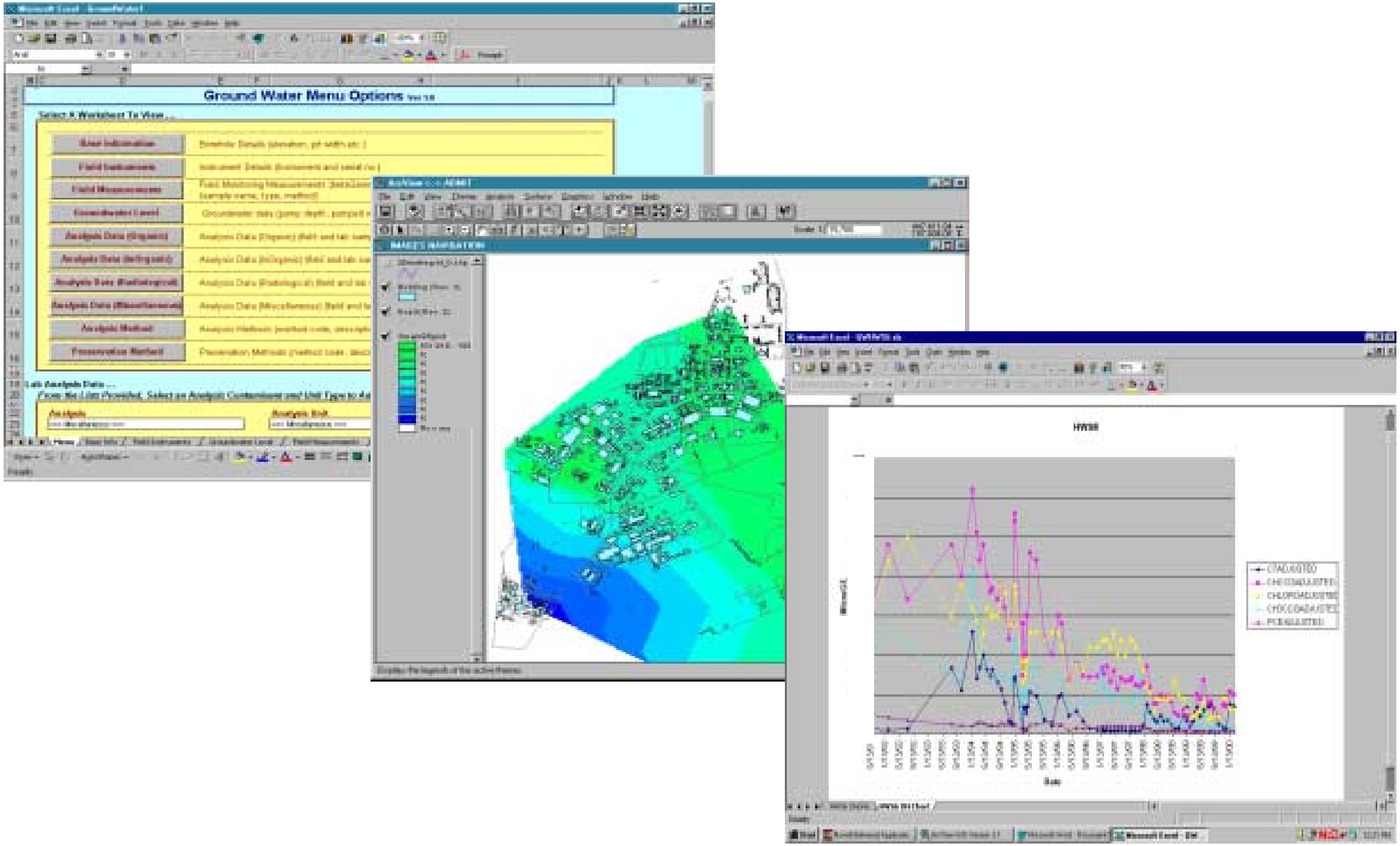
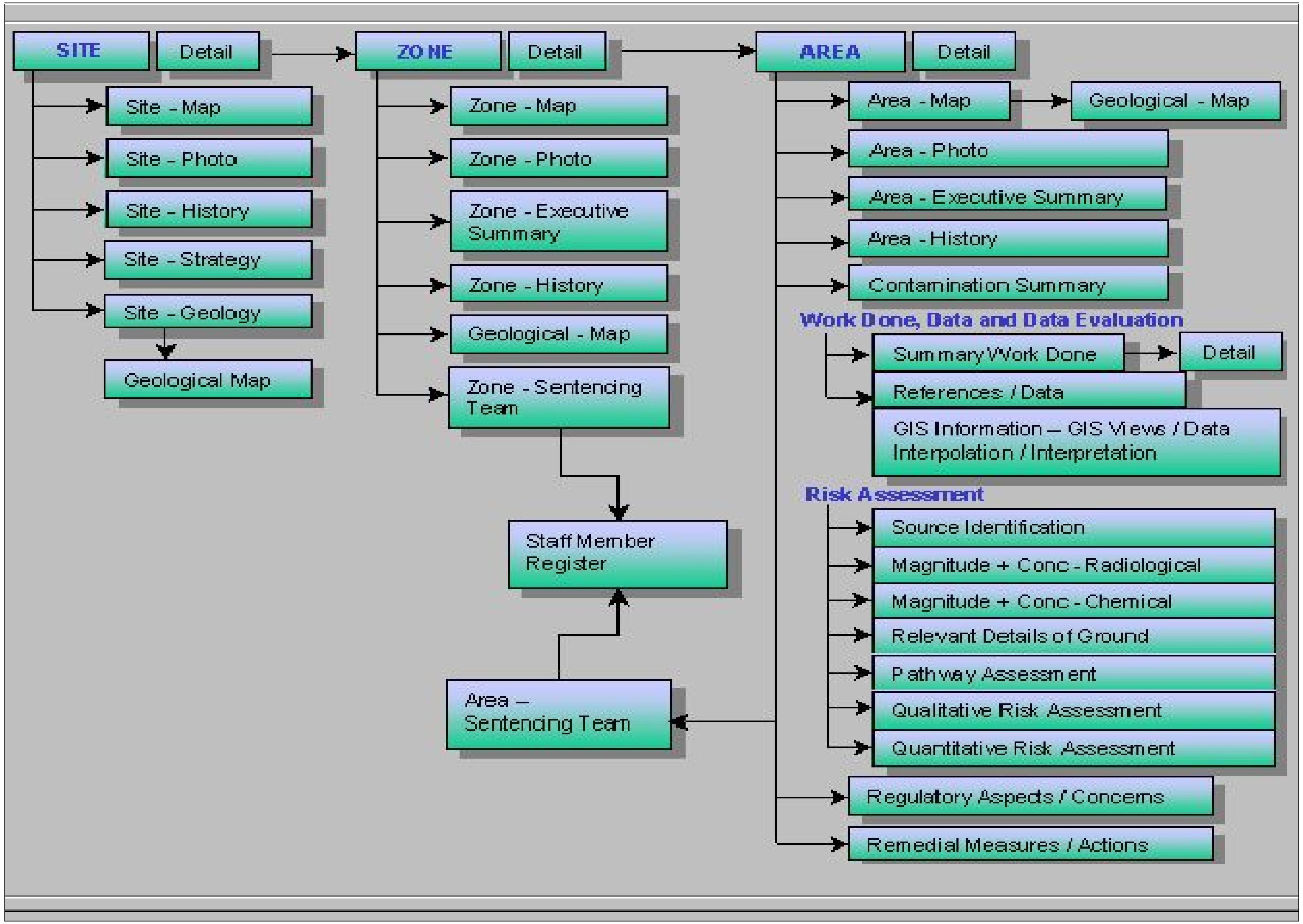


Figure 6: **Structure of the IMAGES Assessment Database**



5.4 Drain Surveys

Decommissioning and site clearance activities may require drain monitoring to ensure integrity and to ensure that there is no residual internal radioactive contamination. This can be carried out using a monitor that incorporates both a video recording device as well as a gamma spectrographic detector. Results can be processed and visualised through a GIS interface (Figure 7). Drain data can also be linked to intrusive survey results – where subsurface contamination might be associated with a breach in the drain system.

Figure 7: **Drain Radiological and Physical Monitoring System**

6. Winfrith Delicensing

6.1 The Winfrith Site

The Winfrith site when compared to other sites within the UKAEA portfolio is unique, as it is the only site purpose designed and built for nuclear research, and is built on land with no prior industrial and limited military activity. The site was designed as the UKAEA Prototype Reactor Test Site, and originally had provision for seven major reactors with numerous other material test reactors or source generators. The fenced area of the site occupies some 340ha, of which 216ha forms the 'licensed' area. The most notable reactors at Winfrith were SGHWR, DRAGON and ZEBRA. The site also housed fuel fabrication and storage facilities, active chemistry facilities and post irradiation examination cell facilities and active waste stores. Today all these facilities are shutdown, most are already removed with the three main reactors, the PIE cell facility and active store remaining, although even they are in an advanced stage of decommissioning.

The principle driver for the decommissioning and delicensing project at Winfrith was the realisation of a commercial objective to release land and buildings at the site for future development, and to reduce UKAEA liability costs to the UK Government.

To support these activities within UKAEA a number of software support tools have been established which include ***SPS*** a strategic planning system, and ***PRICE*** a parametric cost estimating system. This presentation does not address these tools, however further information is available from the UKAEA data packs which can be collected from the UKAEA team.

Currently the site is changing from a former research centre to high technology science park whose population is drawn mostly from non nuclear industry related tenants.

6.2 The Winfrith Delicensing Case

In developing the project process the following steps were identified:-

⇒ Definition of Area and criteria for the variation
  ⇒ Current and historic operations
    ⇒ Un-planned occurrences
      ⇒ Sampling and surveying
        ⇒ Data assessment
          ⇒ Formal issue of application to the regulator

The Winfrith delicensing case was interesting because it occurred at the end of significant nuclear decommissioning phases on differing plant and facilities. These included wet active chemistry labs, bulk item external storage areas and below ground services.

The land area and building involved in the delicensing case was identified early in the project and is shown in Figure 8.

Figure 8: **Definition of land for delicensing**

Extensive 'current' documentation existed on the status of the buildings and associated areas. Some difficulty was initially encountered when identifying and accessing historical data. Eventually significant amounts of data from diverse areas such as the Local and National Public Records Office and UKAEA Archives were examined. From the data gathered a detailed picture was built of the delicensing area and its usage over time.

Possibly the most significant data identified was the extensive array of aerial photographs of the area. This allowed the team to form a robust view that aside from the existing structures, the external land areas were untouched (no building excavations) from the day construction work on the site ceased in that area late in 1959.

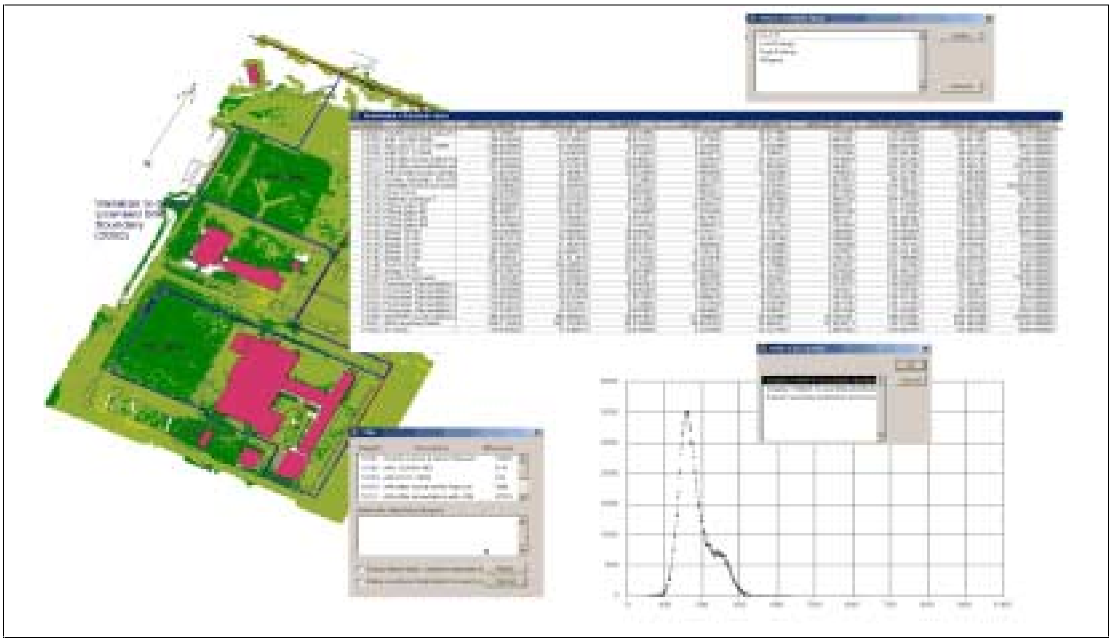
This was a critical issue as the project team were then able to concentrate on gathering near surface radiological data, with physical sampling and analysis being utilised to underpin and substantiate the surface data.

UKAEA determined that it was appropriate to survey 100% of the available land surface utilising a high sensitivity, low-resolution gamma surveying and mapping technique. The data (Figure 9) from this survey further confirmed earlier views that the land area was at or below natural background radiation levels for this part of Dorset. Physical sampling undertaken on the site also confirmed this view.

Figure 9: **Land surface gross gamma map**

To further enhance UKAEA's ability to interpret the surface radiological data a new module was written for use within the IMAGES / GIS system. The GHCDAW module allows data input, extraction and analysis within a controlled QA environment. Some of the system capability is shown in figure 10.

Figure 10: **Tools available within the GIS Module GHCDAW**

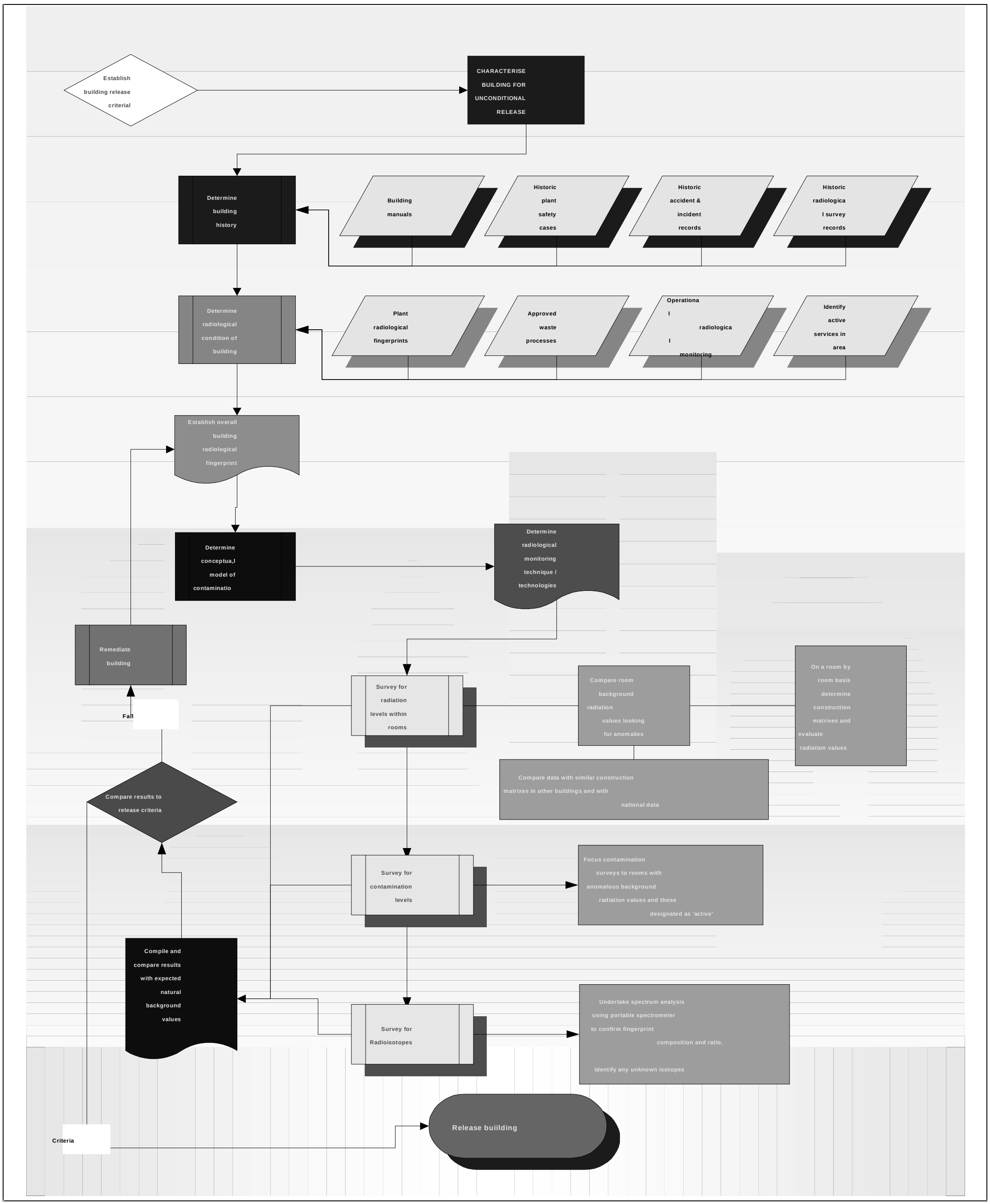


To ensure that both the technology behind the gamma surface monitoring system and the analysis algorithms used within the module were appropriate the system was independently assessed by the National Radiological Protection Board.

Building interiors were surveyed using a range of environmentally sensitive radiation and contamination instruments, including sodium iodide scintillation radiation detectors (PRM7) and DP6 / Electra contamination monitors. Some areas were then also surveyed in detail using a hand held Exploranium mini gamma spectrometer.

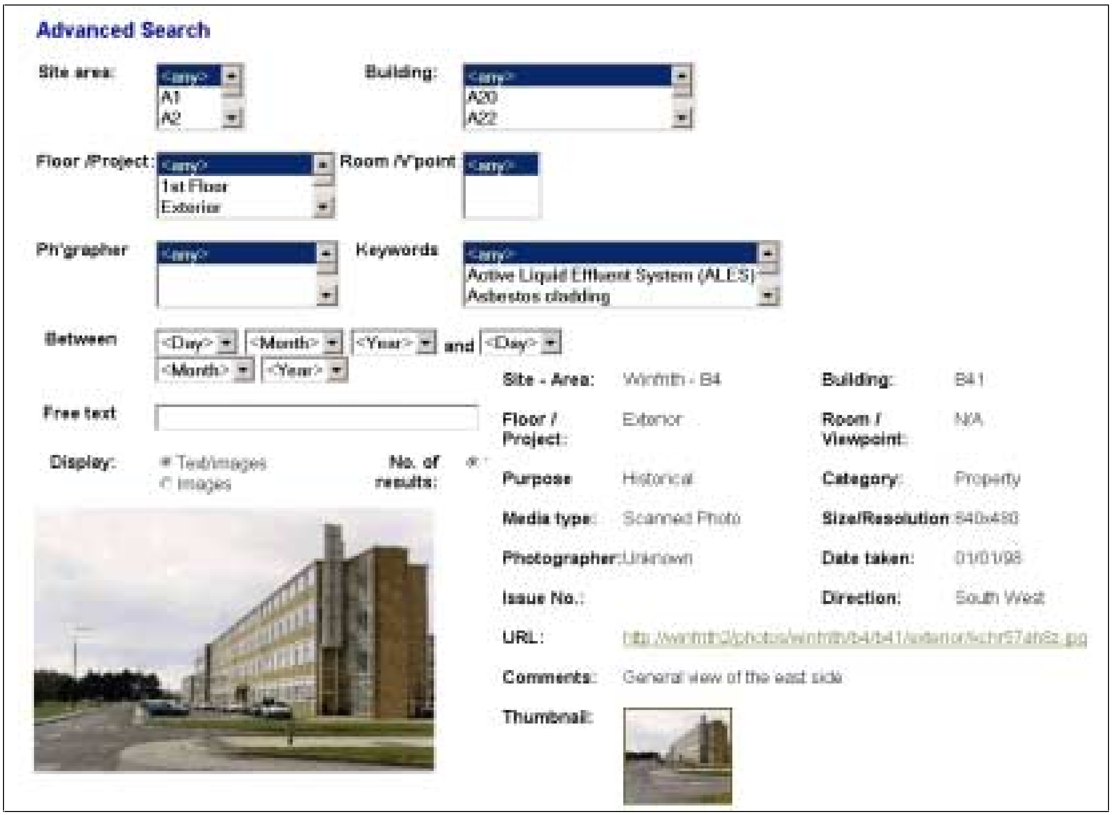
The process for building clearance is outlined in Figure 11.

Figure 11: **Process for building clearance**



Photographic data gathered during building evaluation is gathered in electronic format and is accessed via a custom viewing system (Figure 12) created by UKAEA. The viewing system is networked to allow multi-user access to the data, and is controlled to prevent multiple copies being created without appropriate QA control.

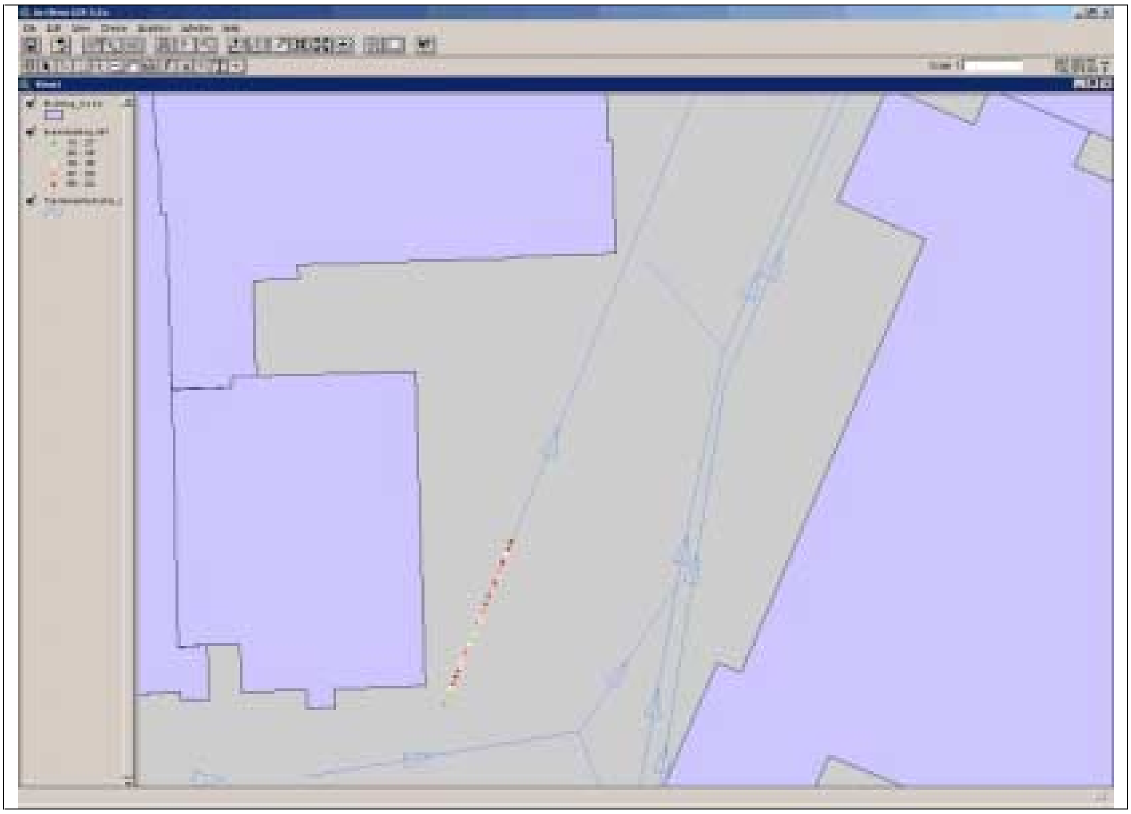
Figure 12: **Photographic Database Viewer**



Below ground active effluent services and their associated ducts were fully removed. Soils samples taken from around the excavations confirmed no leakage to the ground. Effluent pipelines were mostly removed following surveying using the ROV fitted with cctv and gamma probes, not because of activity greater than the acceptable criteria, but because they were redundant. A single effluent pipeline was grouted in-situ as the cost of removal was significant as it was well below the water table of the site, again no radiological issues were associated with the decision to fix the pipe-work with grout. This was a simple engineering solution to prevent surface ground collapse if ever the drain material failed in the future.

The output of the drains ROV radiological system was merged with spatial data and CAD maps derived from within IMAGES and then visualised within the GIS system (Figure 13).

Figure 13: **IMAGES / GIS Visualisation of drain radiological data**



During the course of the project work contact was maintained with the Nuclear Installations Inspectorate. At this point in time the NII were supported by experts from the National Radiological Protection Board (NRPB). The regulator undertook various on -site audits. These included a physical survey of the delicensing area by NRPB.

UKAEA established an internal review panel to adjudicate on the prepared application. Following minor adjustments the application was forwarded to the regulator in May 2000. On the 1st December 2001 UKAEA were advised that consent had been given to vary the nuclear licensed site boundary at the defined area of the Winfrith site.

Although decommissioning and delicensing represented the nuclear endpoint for the buildings and land, the overall project included the requirement to refurbish and fit out of a major building. This phase of the project was undertaken in partnership with the planned tenant. Figure 14 shows the extent of the work undertaken and the final end product.

Figure 14: **Fully Realised Project**

9. Conclusions

This paper has outlined the approach being adopted by UKAEA for building and site release and the integrated software system, IMAGES, being used to capture, collate, interpret and report results. The key to UKAEA's strategy for building clearance and land quality management is a consistency of approach where records supporting the main tasks are systematically managed.

Dedicated data tools such as IMAGES are the key to ensuring compliance with our project requirements, and to enable UKAEA to meets its mission objectives of site restoration that is safe, secure, environmentally and publicly acceptable, and value for money.

DEVELOPMENT OF RADIATION MEASUREMENT TECHNOLOGY FOR LOW-LEVEL CONTAMINATION

S. Yanagihara
Japan Atomic Energy Research Institute

Introduction

In the final stage of dismantling nuclear facilities, radiological survey may be required to confirm radioactivity levels on building surfaces for releasing the buildings. The final radiological survey was applied to the Japan Power Demonstration Reactor (JPDR) dismantling project to demolish the buildings as the first case in Japan. It was found from the project that the radiological characterization and the final radiological survey were time-consuming and costly activities, since some additional tasks such as evaluation of radioactivity of embedded piping in building structures and confirmation of background levels in each area were required in addition to survey all building surfaces. The JPDR dismantling project completed successfully 1996 to accumulate experience and data for future decommissioning projects. After completing the major dismantling activities in the JPDR, the research and development program started to utilize the experience for other decommissioning projects. The radiation measurement technology for low-level contamination was one of the key items in the program.

The study was focused on development of a new radiation detector and automated movable unit regarding the measurement of low-level radioactivity on building and pipe inner surface. Two movable units are developed, which are equipped with new type detectors for measurement of radioactivity in building and pipe inner surfaces, respectively. The outline of the developed technology is described in this paper.

Background

Clearance levels of nuclear wastes have been studied for a long time and certain levels are decided in nuclide base by the nuclear safety commission in Japan. However, the methodology of confirmatory survey is now under development. Although the confirmatory survey on building surfaces is important for clearance of buildings, a present applicable way for releasing buildings is to confirm that the radioactivity is less than background levels. The delectability around 0.3 Bq/cm^2 may be a certain meaning level for the confirmatory survey. This is a basic level to be considered in development of technologies for radioactivity measurement necessary for clearance of materials as well.

Double Layer Detectors

A high-sensitive detector to measure low-level radioactivity was designed for remote measurement of radioactivity on building surfaces and inside pipes embedded in building structures. To achieve high sensitivity under natural background conditions, double-layer detectors were first developed for flat and cylindrical surfaces, respectively. The detector is characterized to be sensitive to β-rays emitted by such nuclides as ^{60}Co and ^{137}Cs. It has two detectable layers with a β-ray shielding plate between the layers. The lower layer counts both γ and β rays emitted by contaminated objects; the upper layer counts only γ rays due to the shielding plate. The system evaluates only β ray counting rate by processing the counting by both lower and upper layers. Since the background radiation is basically caused by γ ray countings, the discrimination of β rays results in high sensitivity to real radiological contamination. Figure 1 shows schematic diagram of the double-layer detectors. It was confirmed by the tests that the minimum detectable level achieved was approximately 0.1 Bq/cm^2 for 60 second in counting time.

RAPID and MISE

The radiation measuring pilot device for surface contamination (RAPID) was develop for automated measurement of radioactivity on building surfaces. The RAPID consists of an omnidirectional mobile mechanism, a radiation detector (size 856 x 208 mm), and a self-position identification system. Figure 2 shows the appearance of RAPID. A dual-wheeled caster-drive mechanism was adopted for RAPID as the mobile mechanism. It was designed for RAPID to move without restriction against the moving direction and to allow prompt omnidirectional movement. The marker unit, which has a digital mark pattern of a circle at its top part, was prepared for self-position identification. The CCD camera installed at the top of the RAPID obtains the image of the digital mark pattern of the circle. After processing the image, a distance and an angle on the polar coordinate, of which the origin is located in the center of the circle, are calculated to identify the present position. The mobile robot has a capability to correct its position if an orbital error is detected by the self-position identification system.

The pipe crawler (MISE) was also fabricated to measure radioactivity on inner surfaces of piping. The MISE consists of driving wheel, steering mechanism, observation devices and the double-layer detector. The power and signal are transmitted through a 15 m long cable. A flexible micro actuator is applied to the steering mechanism, of which size is 24 mm in outer diameter and 130 mm in length. Inside of the actuator, three rooms are located separately; steeling is controlled by differentiation of pressure in each room. The driving power is transmitted through a worm gear from the electric motor to wheels. It is possible for MISE to move bent or branching portions in piping. The MISE was designed for 3-8 inch pipes in inner diameter. Figure 3 shows the appearance of MISE.

Concluding remarks

A great amount of wastes is expected to be produced in dismantling nuclear power plants if dismantling to be green field conditions is chosen as an option of the decommissioning project. Effective segregation of non-radiological parts of wastes might be a key factor in successful completion of a decommissioning project. Various devices and systems have been developed for clearance measurement of wastes in Japan. Based on the experience of the JPDR dismantling project, radiation measurement technology was developed in consideration of automatization and elimination of background counting in measurement of low level radioactivity on building or pipe inner surfaces. The developed technology has been verified to be useful for future use in decommissioning nuclear power plants in Japan.

Figure 1: **Conceptual diagram of double-layer detector**

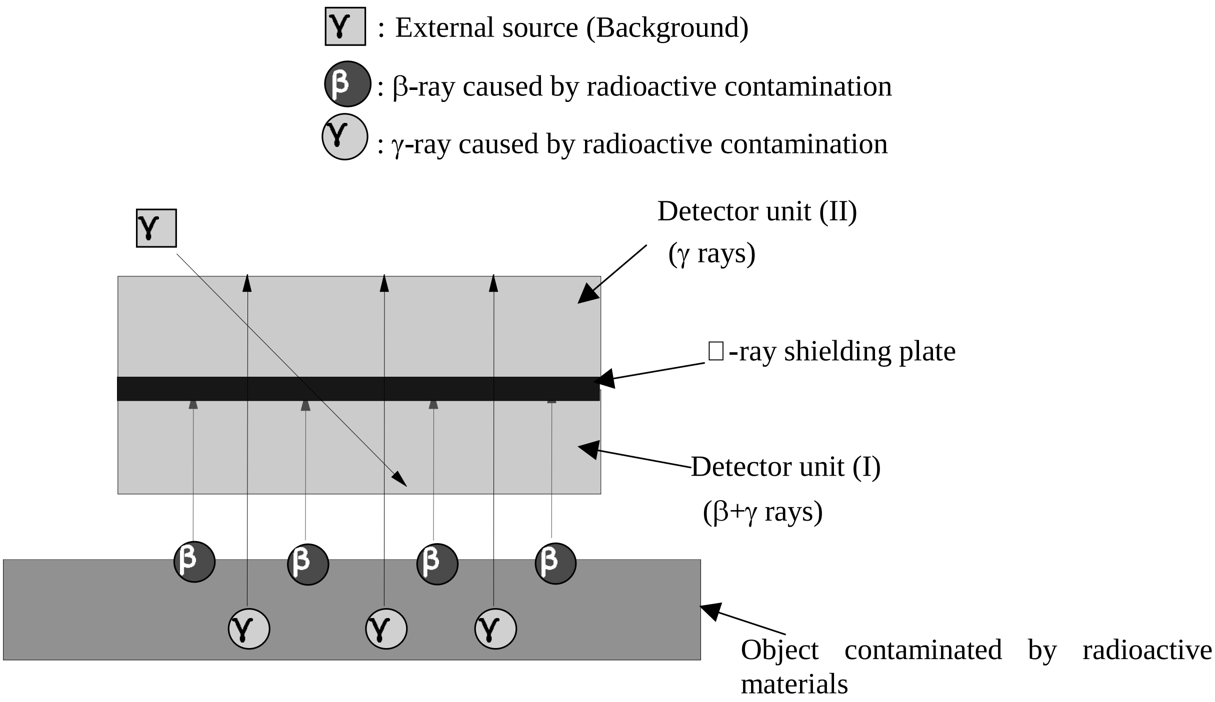


Figure 2: **Appearance of radiation measuring pilot device for surface contamination (RAPID)**

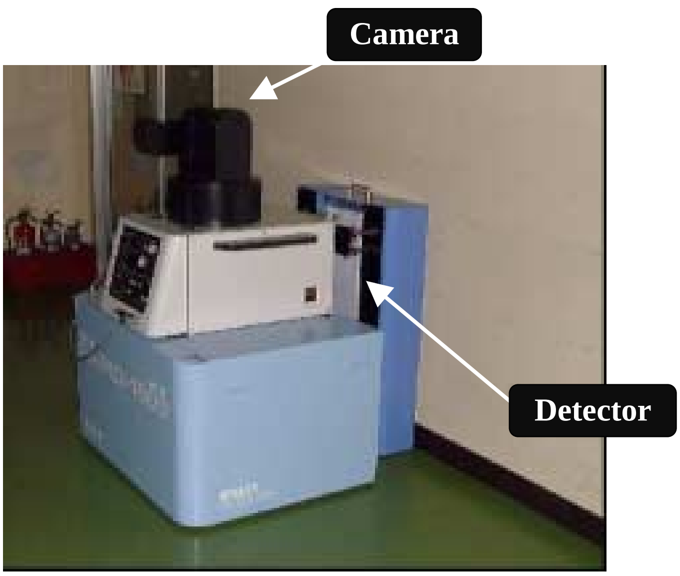
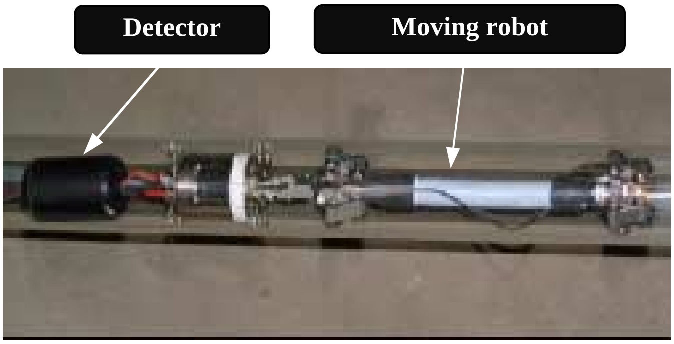


Figure 3 **Appearance of measuring device for inner surface of embedded piping in building structures (MISE)**



BARSEBÄCK AFTER BARSEBÄCK - A CASE STUDY ON THE CONFLICTING ISSUES CONCERNING LAND USE AFTER A TOTAL CLEAN-UP (DECOMMISSIONING) OF A NUCLEAR FACILITY

P. Moding
KSO, Sweden

1. Barsebäck in the Scandinavian (Nordic) context, a brief background

With the help of a map of Scandinavia showing the nuclear facilities the differences between Sweden's first attempts to phase out nuclear power and the contrasting situation in Finland (and Russia!) can be observed. The Finnish government and parliament have recently decided to construct a new, larger reactor! Denmark (with its grand Niels Bohr) was, from the outset, positively inclined towards not only the Barsebäck facility but also towards developing its own nuclear power resources. During the 1970s opinion in Denmark swung back and forth eventually developing into today's very negative attitude. The Danish view has strongly contributed to Sweden's decision to begin the process of shutting down the Barsebäck facility, which faces Greater Copenhagen across the narrow stretch of water, the Öresund, that separates the two countries. B1 was closed in 1999 and the Swedish government, with strong support from the Danish government, wishes to close B2 next year, i.e. 2003! This is on the condition that the supply of electricity is guaranteed in Sweden even if Barsebäck is completely closed down. B1 and B2 are thus to be closed down for political reasons after negotiations with the power company's owners concerning financial compensation from the State etc.

2. Barsebäck in the regional context

As seen in the pictures Barsebäck is situated on the coast of the Öresund. The facility's first reactor (B1) began operations in 1977 and was shut down in November 1999. The other reactor (here called B2) began operations in 1977 and is still in operation. The state-owned company, Vattenfall, has according to the agreement between the government and Sydkraft, the owner at the time, taken over the Barsebäck facility. Today, as is well known, Sydkraft is owned by the German company E.ON Energie and the Norwegian company Statkraft.

Barsebäck is located in the municipality of Kävlinge, an important factor when considering the future use of the land. This municipality, along with the neighbouring municipalities, would much prefer a continued, safe operation as the main alternative for the facility. Should the government and the power company decide that, for primarily political reasons, to close even B2, the Kävlinge council requests that the nuclear facility is cleaned up, dismantled and properly decommissioned as soon as possible. The municipality aims to plan for a new housing area along the shoreline where the nuclear facility is presently situated. In western Scania there are many recently built and successful examples of coastal housing areas, for example in Helsingborg, in the neighbouring municipality of Lomma and in Malmö. The remainder of the Kävlinge municipality coastline, as with other unexploited coastal areas along the Öresund, is unsuitable for building purposes as there are strict rules concerning nature conservancy that protect the remaining, unexploited parts of the coast. Out at sea in the Öresund and also on the land there is much interest in building wind power units with the substantial governmental grants now available. A majority in Kävlinge municipality are against these windmills, both on land and in the adjacent sea. Further, the municipality does not appreciate the views of the governmental authorities, especially Energimyndigheten, to maintain the Barsebäck site as a possible location for alternative energy production (i.e. not nuclear power) in the future. Their argument is that the power lines and infrastructure are already in place. The State's present declaration concerning Barsebäck after Barsebäck thus clashes head on with the municipality's declared intentions as expressed, for example, in its latest Municipal Comprehensive Plan. A Swedish municipality has a very strong position in questions of future land use as it has a so-called municipal planning monopoly. Each municipality, according to Swedish law, has the right, in most cases, to decide over the future use of the land within its own boundaries, even in a case such as this.

3. Barsebäck in the international context

The municipality trusts that a number of critical questions will be answered in international forums (fora) such as this. We can still leave the interesting question of a neighbouring country's right to be able to influence and intervene in cases such as Denmark has done in the Barsebäck case. Similar border conflicts have occurred in various places in Europe such as the border between Germany and Switzerland, Germany and France to say nothing of Austria and the Czech Republic. The technical questions are of particular interest for, in this case, Kävlinge municipality. How quickly can the total clean-up and dismantling process be done? When can the former nuclear facility premises be declared suitable for other uses such as housing, green zones, sport facilities, marinas etc?

Within the EU the question of compulsory environmental sequence analyses is being considered, which will precede the closing down of all nuclear power facilities. Such an environmental study was, nonetheless, never made for Barsebäck 1. The Swedish municipalities hosting nuclear facilities underline the importance of such environmental inquiries. Especially a first, strategical phase is of enormous interest for the affected local population as well as the employees working on site. During this phase the applicant and the responsible energy and environmental authorities must clearly answer the questions:

- What environmental gains and losses will accompany the planned close down?
- How and where will the diminished electricity supply, caused by the close down, be compensated for?

This picture emanates from the publics' assumed diminishing interest for a dialogue concerning the exact technical procedures in the clean-up and dismantling operations as the questions become increasingly more technical and difficult to understand. Nonetheless, in order for the concerned municipalities to continue to participate actively in such a dialogue the applicant, or preferably the State, must grant the municipality financial resources to engage or employ independent expertise and organise the continued education of those affected local politicians and civil servants. This method is currently used with great success in connection with the extensive initial studies in Sweden that concern the location of a final repository. When it comes to the difficult placement of new waste sites the chances are that the main interested party, i.e. the concerned power companies as well as the State, is interested in supporting the municipality. Unfortunately it is not as easy for the affected municipalities to mobilise financial compensation from the State and power companies for decommissioning purposes as it is with new buildings and running costs!

The State and power company should therefore carefully examine the aspect of providing a fair amount of financial compensation to those nuclear facility municipalities which are unable to find a sufficient number of replacement jobs as compensation for the losses of nuclear power employees and the technical know-how etc, which are lost locally and regionally due to the phasing out of nuclear power. The nuclear power municipalities would like to see that the State and power companies act in a socially responsible manner when preparing for phasing out! In the case of Barsebäck and its shut down the former owner, Sydkraft Co, acted very social and responsible by giving the employees a five year job guarantee after the decision was taken on closing the reactor ! May this example serve as a good model in the future!

4. The European network GMF - what are its goals?

The European nuclear power municipalities have been cooperating for some years in a network called GMF (the Group of European Municipalities with nuclear Facilities). The network's core consists mainly of the Spanish municipalities' national network AMAC, which has a Secretariat even for the whole of Europe. The Swedish nuclear power municipalities are included within this inner network through our corresponding KSO and the French municipalities ARCICEN. As a common denominator for our cooperation the following key words are used:

- Nuclear safety (the most important)
- Transparency (the opportunity for municipality insight and in good time)
- Local consequences (the opportunity for municipality influence)

GMF strives to get European organs such as the EU, OECD/NEA, IAEA etc to harmonise the national rules for nuclear power and in so doing increase the respect which should be observed for those parties with specific and major interests, such as the concerned local population, the municipalities and also the regional representatives. GMF has made the responsible EU commissioner and Vice President, Mrs Loyola de Palacio aware of this. In this connection we also reminded her of the unfair capacity tax put on Swedish nuclear power.

GMF tries in many different ways to increase the exchange among the local actors in Europe. As a part of this activity GMF arranges an annual conference (the next event being in Prague on 30-31 October 2002). GMF's main target group is the principal officials of the nuclear power municipalities. These are, after all, the elected representatives for the local, greatly affected population. In such a way GMF follows the European community's main principle concerning SUBSIDIARITY and applies local and regional democracy. Subsidiarity means that decisions should be taken as close to the grassroots level as possible; a principle, which has by no means characterised either nuclear power expansion up to now, or the approaching phasing out. In the Swedish municipalities that have been studied and closely examined in the field as possible location alternatives for a final repository for high level waste, the municipality leaders have initiated and permitted extensive dialogues to take place directly with their local citizens. In particular Östhammar and Oskarshamn and their nearest neighbours have thereby completed extensive attempts to improve the dialogue with their inhabitants. All the citizens in an area which may be considered for the location of a final repository, must have a real opportunity to be both informed in an objective way and be guaranteed that their views and opinions are taken into consideration in the decision making process by the municipality, the applicant and the authorities. Both the remaining principal Swedish candidates for a final repository, Oskarshamn and Östhammar, also actively participate in a special network (the COWAM project) where even a number of other potential European final repository candidates are included. The methods of reaching the grassroots which Oskarshamn, in particular, is well known to be applying, have become the subject of enormous international attention.

The representatives for the European nuclear power municipalities feel that far too many decisions in large scale investments, e.g. within nuclear power, have been taken " from the top and down," often using the method "DAD" (decide, announce and defend). This we wish to change and it is hoped that GMF will find it appropriate to make a supportive recommendation at this conference. Remember that almost every decision concerning the expansion or phasing out of energy production has its clear, concrete geographical consequences. Many citizens, a site and a municipality will be affected for a long time, often for many generations, by such a decision. Therefore it is reasonable and democratically correct that the affected local people and their elected representatives, the local political leaders, at an early stage are not only prepared for the opportunity to join in a dialogue concerning the expected huge changes and investment decisions that may take place. More that they understand and are fully assured that they will have the opportunity to influence decisions. The EU principle of subsidiarity has to be practically applied and put in the driving seat in connection also with a phasing out of nuclear facilities. It must be developed methodologically and systematically at the local level. The GMF network is not satisfied with this just being well formulated, well-meaning advice from above.

BUILDING AND SITE RELEASE AND USE

S. Moore and **E. Pogue**
United States Nuclear Regulatory Commission

The current U.S. Nuclear Regulatory Commission (NRC) site release criteria, the License Termination Rule (LTR), went into effect on July 21, 1997. The LTR, located in Subpart E of 10 CFR Part 20 (*see* http://www.nrc.gov/reading-rm/doc-collections/cfr/), provides dose-based criteria for the release of sites for either unrestricted or restricted use. This paper discusses the LTR and dose modeling and survey techniques employed to demonstrate LTR compliance.

1. Release standards

Prior to 1997, NRC licensees were required to meet the criteria provided in the "Action Plan to Ensure Timely Cleanup of Site Decommissioning Management Plan Sites" (SDMP Action Plan), located in 57 FR 13389. The 1992 SDMP Action Plan consolidated existing criteria and guidance on license termination (e.g., the 1981 NRC Technical Position "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" and Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors"). Under the SDMP Action Plan, sites were remediatied to concentration-based criteria, which varied for different radionuclides. Furthermore, remediation generally included the use of different criteria/guidance for different media. For example, a "typical" uranium and thorium contaminated facility would have used the surface contamination criteria in Regulatory Guide 1.86 for release of buildings and equipment, while applying the soil concentration criteria from the 1981 Technical Position for remediation of outdoor areas.

In order to provide for more efficient use of NRC and licensee resources, to facilitate consistent cleanup across all types of licensees, and to create a predictable basis for decommissioning planning, the NRC developed and codified the dose-based LTR. The LTR encompasses cleanup of all of the media (i.e., soil, buildings, and groundwater) and radionuclides at a site, and provides two release options.

A. Unrestricted Use

The LTR provides for the termination of the NRC license and release of a site for unrestricted use, if the criteria in 10 CFR 20.1402 are met. For unrestricted release a licensee must demonstrate that the residual radioactivity (i.e., from all NRC regulated radionuclides and from all media) results in a total effective dose equivalent to an average member of a critical group that does not exceed 0.25 milliSievert per year (mSv/yr). Furthermore, the regulation provides that licensees must also demonstrate that the residual radioactivity at the site has been reduced to levels that are as low as is reasonably achievable (ALARA).

B. Restricted Use

In addition to unrestricted use criteria, the LTR also provides for license termination under restricted conditions. The LTR generally provides that license termination can be achieved if a licensee demonstrates that the dose to an average member of the critical group would not exceed the unrestricted use dose criterion, with restrictions in place (e.g., engineered barriers, institutional controls), and would not be higher than 1 mSv/yr if those restrictions were to fail.

2. Demonstrating compliance

A. Dose Modeling

Dose modeling is almost always necessary for licensees to demonstrate compliance with the LTR. Additionally, dose modeling is a tool used by the NRC staff in reviewing licensee submittals. NRC's review plan for materials decommissioning (NUREG-1727, available at https://www.orau.com/PTP/pdf/1727.pdf) contains the methodology employed by NRC staff when evaluating licensee submittals, and also includes guidance and references on dose modeling in general. In summary, NRC's review process includes an assessment of: 1) source term assumptions; 2) the exposure scenario; 3) the mathematical model/computational method used; and, 4) the parameter values and their uncertainty. While a number of computer codes are available for dose modeling, licensees and NRC staff commonly use RESRAD and DandD. Information and a downloadable version of RESRAD are available at: http://web.ead.anl.gov/resrad/home2/index.cfm.

Information regarding DandD is available on NRC's website at: http://www.nrc.gov/what-we-do/regulatory/research/comp-codes.html#rt-dc.

B. Surveys

Similar to dose modeling, it is necessary for licensees to perform surveys to demonstrate compliance with the LTR. While the LTR is dose-based, compliance is still based on demonstrating that the concentrations of radionuclides at licensed facilities are reduced to appropriate levels. Specifically, NRC guidance requests that licensees develop and demonstrate compliance with derived concentration guideline levels (DCGLs), which are concentration equivalents to the dose requirement, derived through dose modeling.

Prior to 1997 NRC's primary guidance document for final status surveys was NUREG/CR-5849: Manual for Conducting Radiological Surveys in Support of License Termination. This was a prescriptive methodology, which was designed for demonstrating compliance with concentration-based criteria. In 1997, NRC in cooperation with the U.S. Environmental Protection Agency, the U.S. Department of Defense, the U.S. Department of Energy, and other agencies on a multi-agency working group, developed the Multi-Agency Radiological Survey and Site Investigation Manual (MARSSIM). MARSSIM is a performance based survey methodology, which is designed for conducting surveys to demonstrate compliance with dose- and risk-based criteria, rather than concentration-based standards. The MARSSIM document and information regarding the methodology are available at: http://www.epa.gov/radiation/marssim/.

3. Ongoing challenges

Implementation of the LTR has created several challenges to NRC as a regulating agency. These challenges include: dose modeling (e.g., developing and modeling adequate future use scenarios); additional cleanup standards by States and other Federal agencies; clearance (e.g., what is the appropriate pre-license termination criteria for release of material for decommissioning sites); and making the LTR's restricted release option viable (e.g., solving the problem of how to provide for the long-term custodianship of restricted use sites).

NRC is making steady progress in resolving many of these challenges facing the U.S. decommissioning industry and the American public. Participation in the international decommissioning community, through meetings such as this, offer us the opportunity to learn how other nations and regulatory agencies have addressed similar challenges.

BUILDINGS & SITE RELEASE AND REUSE THE SPANISH REGULATOR'S VIEW

J. L. Revilla
CSN Project Manager for the Vandellós-1 NPP Decommissioning Program

Decommissioning of nuclear power plants causes an enormous amount of residual materials with very low level of contamination. A risk optimisation analysis would indicate that some of these residual materials need not to be handled, processed or disposed of with any reference to their radioactivity content in order to allow more beneficial allocation for the limited social resources. The same analysis could also be applied to the site release once a particular facility is decommissioned. Remedial or restoration actions in pieces of land to be released should be subjected to a similar radiological optimisation process for selecting the best strategy of remedial actions.

In order to make this release from regulatory control possible, it is often necessary to establish conditions for the site or for these materials to be managed during their later reuse or final disposal. Authorisation for this release or clearance of control is a responsibility of the competent authority and, in the case of Spain, it is carried out by the General Directorate for Energy and Mining Policy of the Ministry of Economy taking into account the safety report of the Spanish Nuclear Safety Council (CSN). Up to now, all clearance or release criteria applied in Spain have been issued on a basis of "ad hoc" case by case decisions.

The Spanish Royal Decree 1836/1999 of 3 December, whereby new regulations on nuclear and radioactive facilities are approved, address for the first time a specific administrative framework for licensing the decommissioning process for nuclear facilities. An official document addressed in this regulation is the "Radioactive Waste Management Plan" which should contain the criteria adopted for material declassification or clearance. Another official document addressed in this new regulation is the "Site Restoration Plan" which must contain the clean up criteria to release the site once the decommissioning process has finished.

Up to now, the Ministry has not yet implemented any clearance levels for residual materials or any clean up criteria for lands or sites to be applied in a general way. However, there have been particular ministerial authorisations linked to decommissioning projects for certain facilities (Andujar uranium mill factory, Uranium mining sites restoration projects, etc.) which lay down declassification levels for residual material and radiological criteria for site release that are only valid for these projects.

The Vandellós 1 Nuclear Power Plant decommissioning project has already three authorised basic possibilities for the application of clearance of residual materials: the unconditional clearance (N_1 level); the generic conditional clearance (N_2 level); and the specific conditional clearance (N_3 level). Different sets of radionuclide specific figures for unconditional clearance levels (N_1) and for generic conditional clearance levels (N_2) have already been established for some generic materials, building and concrete demolition debris among them.

On the contrary, it does not exist yet any official clean up criteria for the release of the site of Vandellós 1 NPP. Up to 60 % of the nuclear site will be released at the end of the current decommissioning phase leaving the remaining 40 %, including the reactor building, under regulatory control in a latent facility.

As part of the licensing procedure of the decommissioning program, ENRESA has recently submitted the "Site Restoration Plan" for the partial release of Vandellós 1 nuclear site. CSN technical staff is currently reviewing the radiological criteria and different scenarios considered in the proposal.

Radiological analysis

Any free release of former regulated material or site has to demonstrate that the radiological detriment it causes in the environment is as low as reasonable achievable. We find here, as a particular case of the radiological optimisation process, the so-called general protection principles for exemption:

- Radiological risk to the individuals caused by the cleared material must be sufficiently low as not to be of any further regulatory concern.
- The exempted sources must be inherently safe, with a very low likelihood of scenarios that might lead to failure to meet the criteria previously mentioned.
- The collective radiological impact of the cleared policy must be sufficiently low as not to warrant regulatory control under the prevailing circumstances.

In any case, the individual-related dose limits for members of the public have to be accomplished to prevent unacceptable individual detriment:

- Individual effective dose < 1 mSv in a year
- < 15 mSv per year for lens
- < 50 mSv per year averaged over 1 cm^2 of skin

A dose constraint in the range of 1/100 to 1/10 of the individual effective dose limit is usually applied to the average individual of the critical group of the affected population when clearing residual materials. The use of these constrains simplify the formal radiological optimisation process and try to avoid the possibility that cumulative exposures due to several and non related sources exceed the established individual limits.

The radiological protection philosophy when releasing lands or sites that are currently under regulatory control is essentially the same. The sites should be remedied to reduce the residual risk as far as reasonable to do so, taking into account the cost and risks associated with the remedial measures.

Building release

European Basic Safety Standard require national competent authorities to take into account, when establishing clearance levels, technical guidance provided by the Article 31 Group of Experts under the EURATOM Treaty. The current Vandellós 1 decommissioning authorisation states the acceptability, as generic conditional clearance levels (N_2) for metallic scrap and building rubble, of the figures recommended by the Article 31 Group of Experts in the documents RP 89 and RP 113. Higher specific conditional clearance levels (N_3) can also be issued by CSN in consideration to some future route to be proposed by licensee (¿rubblization?).

Accepted radiological criteria for the clearance of buildings and building rubble assume that the effective dose to be incurred, by any individual member of the public, is of the order of 10 µSv or less in a year, and the collective dose committed during one year is no more than about 1 man Sv. For an unforeseen future use a very conservative scenario is considered yielding a worst case dose of 1 mSv. In addition to the dose criterion for the effective dose a limiting equivalent dose to skin of 50 mSv/a has been introduced to exclude the possibility of deterministic effects.

Three main situations are considered in three different generic conditional clearance levels (N_2):

Clearance of building for any purpose (reuse and future demolition).

The clearance levels relate to the total activity in the structure per unit surface area. After clearance, the building can be use for non-nuclear purpose or demolished. The surface specific clearance levels apply to the total activity on the surface to be measured divided by its area. The total activity is the sum of the fixed and non-fixed activity on the surface plus the activity that has penetrated into the bulk.

Clearance of buildings for demolition only.

Buildings at a decommissioned nuclear site will often be demolished and the resulting rubble either recycled or conventionally disposed of. Either the standing structure of the building to be demolished can be cleared using surface contamination clearance criteria or the building rubble resulting from the demolition can be cleared using mass specific clearance criteria. The advantage of clearing the standing structure is that high level surface contamination is not mixed with the uncontaminated interior of the building structure. The clearance levels are expressed as total activity in the structure per unit surface area, and are generally greater than those proposed for reuse.

Clearance criteria for building rubble.

Provided measures are taken to remove surface contamination a possible option is to clear the material after the building or major part of it has been demolished. In this case mass specific clearance levels can be applied. Records should be kept of the dismantling operations in order to demonstrate that highly activity and contaminated materials have been kept separate.

Site release

As it has been mentioned previously, there is not a general applicable radiological criterion to support the clean up restoration or site release in Spain. Some decommissioning projects already finished, like the stabilisation of some uranium concentrate mill tailings and the restoration of old uranium mines sites have been governed by particular criteria included specifically in the licence or authorisation granted to each individual holder to whom the clearance or release applies.

The criteria that governed the decommissioning program at the Andujar mill tailings stabilisation project were taken from the standards given by US EPA for the rehabilitation of uranium mill tailing in the UMTRA program and the Spanish groundwater protection regulation. These criteria can be summarised as an effective equivalent dose to individual in the critical group below 100 µSv and an additional reduction of residual concentration of Ra-226 on land, so the background level is not exceed by more than 0,2 Bq/g (in the upper 15 cm of soil) and 0,6 Bq/g (in the 15 cm thick layers of soil more than 15 cm below the surface).

It is worth noting here the establishment in 1995 of a CSN working group to derive radiological criteria for the decommissioning and restoration of uranium ore processing sites. The report, which included the criteria for site restoration and site release, was never come into force and never went beyond the draft stage. The proposed criteria were, nevertheless, subsequently included in later authorisations granted for new restoration and remediation projects.

The document indicated, basically, that intervention to decontaminate the site was justified if the effective dose to individual in the critical group is above 100 µSv/a. Intervention was not justified in any case below an effective dose of 10 µSv/a. Intervention in the range of 10 to 100 µSv/a will be necessary if the individual exposure in any hypothetical and conservative scenario implies an individual effective dose above 1 mSv/a, the dose limit for the public.

Consideration was given to the suitable options for using the land after clearance, which must be realistic for the location in question, as well as to the relevant exposures pathways. This analysis stated that the agricultural/residential scenario (family farm) was the most restrictive scenario resulting in a guideline concentration for soil contamination of 0,1 Bq/g of U-238 in equilibrium with all the radionuclides of its natural decay chain. Higher values derived from other generic exposure assessments, requiring some special additional conditions, were established for three restricted and more plausible scenarios:

- Agricultural/residential (up to 0,1 Bq/g)
- Forestry/grassland use (up to 1 Bq/g)
- Recreational area (up to 1 Bq/g and H < 0,1 Gy/h)
- Industrial use (up to 1 Bq/g and H < 0,3 Gy/h)
  (Closed building only in soils < 0,1 Bq/g)
  (Radon concentration inside buildings < 200 Bq/m^3)

Radiological criteria for the partial release that is being considered for the Vandellós 1 nuclear site have been proposed in the "Site Restoration Plan" submitted by ENRESA to the CSN. The main features of the proposal can be summarised as follows:

- Relevant radionuclides that are considered in the analysis are ^{3}H, ^{14}C, ^{59}Ni, ^{63}Ni, ^{60}Co, ^{90}Sr, ^{94}Nb, ^{125}Sb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{239}Pu and ^{241}Am.
- Industrial scenario in the next 30 years: external exposure, inhalation and soil ingestion pathways.
- Residential scenario after 30 years: external exposure, inhalation and limited ingestion of vegetables and water including inadvertent soil ingestion.

Dose release criteria (100µSv/year) has been translated into corresponding derived concentration guideline levels using the RESRAD code for the two different scenarios. Site specific parameters have been used in the calculations and, for each radionuclide, the most restrictive concentration obtained in both scenarios is taken as the proposed concentration level. Typical values obtained for key radionuclides are as follows: 0,4 Bg/g for ^{60}Co, 0,3 Bq/g for ^{137}Cs, 0,15 Bq/g for ^{90}Sr, 0,3 Bq/g for ^{14}C.

The radiological surveys to be conducted to demonstrate compliance with the derived concentration limits are based on the MARSSIM approach (NUREG-1700 and NUREG-1727) and includes the planning, implementation, assessment and decision making phases required for a final status survey.

An historical site assessment and a scoping survey are initially performed to provide the necessary information to design the characterisation survey. The characterization survey integrates scanning surveys with direct measurements and sampling and includes the classification of areas, the definition of survey units and the determination of the required data points. Appropriate statistical tests are finally used to demonstrate compliance for each survey unit.

Radionuclide specific clearance levels for building reuse or demolition:

Nucleido	Nivel de Desclasificación Redondeando (Bq/cm^2)
H3	10000
C 14	1000
Na 22	1
S 35	1000
Cl 36	100
K 40	10
Ca 45	1000
Sc 46	1
Mn 53	10000
Mn 54	1
Fe 55	10000
Co 56	1
Co 57	10
Co 58	10
Co 60	1
Ni 59	100000
Ni 63	10000
Zn 65	1
As 73	1000
Se 75	10
Sr 85	10
Sr 90	100
Y 91	1000
Zr 93	1000
Zr 95	1
Nb 93m	1000
Nb 94	1
Mo 93	100
Tc 97	100
Tc 97m	100
Tc 99	100
Ru 106	10
Ag 108m	1
Ag 110m	1
Cd 109	100
Sn 113	10
Sb 124	1
Sb 125	1
Te 123m	10
Te 127m	100
I 125	100
I 129	10
Cs 134	1
Cs 135	1000
Cs 137	1
Ce 139	10
Ce 144	10
Pm 147	1000
Sm 151	10000
Eu 152	1
Eu 154	1
Eu 155	10
Gd 153	10
Tb 160	1
Tm 170	1000

Nucleido	Nivel de Desclasificación Redondeando (Bq/cm^2)
Tm 171	1000
Ta 182	1
W 181	100
W 185	1000
Os 185	10
Ir 192	10
Ti 204	1000
Pb 210	1
Bi 207	1
Po 210	10
Ra 226	1
Ra 228	1
Th 228	0,1
Th 229	0,1
Th 230	1
Th 232	0,1
Pa 231	0,1*
U 232	0,1
U233	1
U234	1
U 235	1
U 236	1
U 238	1
Np 237	1
Pu 236	1
Pu 238	1
Pu 239	0,1
Pu 240	0,1
Pu 241	10
Pu 242	1
Pu 244	1
Am 241	1
Am 242m	1
Am 243	1
Cm 242	1
Cm 243	1
Cm 244	1
Cm 245	0,1
Cm 246	1
Cm 247	1
Cm 248	0,1
Bk 249	100
Cf 248	1
Cf 249	0,1
Cf 250	1
Cf 251	0,1
Cf 252	1
Cf 254	1
Es 254	1

* Si este radionuceido contribuye en más del 10%, se usará el valor no redondeado (0,013).

Radionuclide specific clearance levels for building demolition.

Nucleido	Nivel de Desclasificación Redondeando (Bq/cm^2)
H 3	10000
C 14	10000
Na 22	10
S 35	100000
Cl 36	100
K 40	10
Ca 45	100000
Sc 46	10
Mn 53	10000
Mn 54	10
Fe 55	10000
Co 56	10
Co 57	100
Co 58	10
Co 60	1
Ni 59	100000
Ni 63	100000
Zn 65	10
As 73	10000
Se 75	100
Sr 85	100
Sr 90	100
Y 91	100000
Zr 93	1000
Zr 95	10
Nb 93m	100000
Nb 94	10
Mo 93	1000
Tc 97	1000
Tc 97m	1000
Tc 99	100
Ru 106	100
Ag 108m	10
Ag 110m	10
Cd 109	10000
Sn 113	100
Sb 124	10
Sb 125	10
Te 123m	100
Te 127m	10000
I 125	10000
I 129	10
Cs 134	10
Cs 135	10000
Cs 137	10
Ce 139	100
Ce 144	100
Pm 147	10000
Sm 151	10000
Eu 152	10
Eu 154	10
Eu 155	100
Gd 153	100
Tb 160	10
Tm 170	10000

Nucleido	Nivel de Desclasificación Redondeando (Bq/cm^2)
Tm 171	100000
Ta 182	10
W 181	1000
W 185	1000000
Os 185	10
Ir 192	100
Ti 204	1000
Pb 210	1
Bi 207	10
Po 210	100
Ra 226	1
Ra 228	10
Th 228	1
Th 229	1
Th 230	1
Th 232	1
Pa 231	0.1
U 232	1
U233	10
U234	10
U 235	10
U 236	10
U 238	10
Np 237	10
Pu 236	10
Pu 238	1
Pu 239	1
Pu 240	1
Pu 241	100
Pu 242	1
Pu 244	1
Am 241	1
Am 242m	1
Am 243	1
Cm 242	100
Cm 243	10
Cm 244	10
Cm 245	1
Cm 246	1
Cm 247	1
Cm 248	1
Bk 249	1000
Cf 248	10
Cf 249	1
Cf 250	10
Cf 251	1
Cf 252	10
Cf 254	10
Es 254	10

Radionuclide specific clearance levels for building rubble.

Nucleido	Nivel de Desclasificación Redondeando (Bq/g)
H 3	100
C 14	10
Na 22	0,1
S 35	1000
Cl 36	1
K 40	1
Ca 45	1000
Sc 46	0,1
Mn 53	1000
Mn 54	0,1
Fe 55	1000
Co 56	0,1
Co 57	1
Co 58	0,1
Co 60	0,1
Ni 59	1000
Ni 63	1000
Zn 65	1
As 73	100
Se 75	1
Sr 85	1
Sr 90	1
Y 91	100
Zr 93	100
Zr 95	0,1
Nb 93m	1000
Nb 94	0,1
Mo 93	100
Tc 97	10
Tc 97m	10
Tc 99	1
Ru 106	1
Ag 108m	0,1
Ag 110m	0,1
Cd 109	100
Sn 113	1
Sb 124	100
Sb 125	1
Te 123m	1
Te 127m	100
I 125	100
I 129	0,1
Cs 134	0,1
Cs 135	1000
Cs 137	1
Ce 139	1
Ce 144	10
Pm 147	1000
Sm 151	1000
Eu 152	0,1
Eu 154	0,1
Eu 155	10
Gd 153	10
Tb 160	0,1
Tm 170	100

Nucleido	Nivel de Desclasificación Redondeando (Bq/g)
Tm 171	1000
Ta 182	0,1
W 181	10
W 185	1000
Os 185	1
Ir 192	0,1
Ti 204	100
Pb 210	0,1
Bi 207	0,1
Po 210	1
Ra 226	0,1
Ra 228	0,1
Th 228	0,1
Th 229	0,1
Th 230	0,1
Th 232	0,1
Pa 231	0,1* [a]
U 232	0,1
U233	1
U234	1
U 235	1
U 236	1
U 238	1
Np 237	0,1
Pu 236	0,1
Pu 238	0,1
Pu 239	0,1
Pu 240	0,1
Pu 241	1
Pu 242	0,1
Pu 244	0,1
Am 241	0,1
Am 242m	0,1
Am 243	0,1
Cm 242	1
Cm 243	0,1
Cm 244	0,1
Cm 245	0,1
Cm 246	0,1
Cm 247	0,1
Cm 248	0,1* [b]
Bk 249	10
Cf 248	1
Cf 249	0,1
Cf 250	0,1
Cf 251	0,1
Cf 252	0,1
Cf 254	0,1
Es 254	0,1

* Si estos radionucleidos contribuyen en más del 10%, se usará el valor no redondeado: a: 0,0035 Bq/g
b: 0,026 Bq/g

CLEARANCE OF BUILDINGS AND CERTIFICATION FOR REUSE AS NON NUCLEAR INDUSTRIAL BUILDING AT SCK•CEN, MOL

L. Noynaert and **V. Massaut**
CEN•SCK, Belgium

Introduction

In the past, the SCK•CEN was involved in both nuclear and non-nuclear research programs. In the early nineties, the Belgian government decided to restrict the operational scope of the SCK•CEN to the strictly nuclear programs. A new research centre, the Vito (Flemish Institute for Technological Research) was founded and took over all non-nuclear activities. The Vito is housed in former SCK•CEN buildings. In addition to well-equipped non-nuclear laboratories and offices, these buildings contain laboratories and installations with a radiological history [1], [2]. The buildings have to be decontaminated and cleared for unrestricted reuse prior to transferring them to the Vito.

Definition of the unrestricted release and/or reuse limits

In the absence at that time of clearance criteria in the Belgian regulation, the SCK•CEN Health Physics department, in association with the recognised Inspection Organisation (AVN), specified the following clearance limits:

- 0.4 Bq/cm² surface contamination for $\beta\gamma$ emitters;
- 0.04 Bq/cm² surface contamination for α emitters.

The residual radioactivity of the radionuclides present in representative samples of the building material had to be of the same order of magnitude as that of similar building material from a non-nuclear zone at the site.

SCK•CEN and the recognised Inspection Organisation defined the methods that had to be used to analyse and monitor the radioactivity from the start of the decommissioning until the final release, namely:

- Monitoring the entire wall and floor surfaces;
- Radiological analyses of the washwater of walls and floors;
- Measurement of selective core samples.

When the results of these measurements and analyses were below the above-mentioned limits, the Health Physics department established the certification of unrestricted reuse and submitted it for approval to the recognised Inspection Organisation.

Then the certification of unrestricted reuse of the building was sent to the new operator. Based on the certification and his own control, the new operator send us an official letter declaring that he accepts the property of the building without any restrictions.

Description of the buildings concerned

The buildings that needed to be decommissioned were the Physics Building, the Metallurgy Building, Bloc 3 of the Chemistry Building and two Radiobiology Buildings.

The Physics Building consists mainly of laboratories, offices and a waste storage room. Only a few laboratories were used for experiments and measurements with radioactive materials such as ^{14}C, ^{137}Cs, ^{60}Co, ^{133}Ba and ^{90}Sr. The total wall and floor surface of these laboratories covers approximately 700 m². Average contamination levels were below 2.5 Bq/cm² with hot spots up to 30 Bq/cm² for β-γ emitters and 0.1 Bq/cm² for α emitters.

The decommissioning of the Metallurgy Building was, compared to the Physics Building, somewhat more complicated. Besides a number of conventional laboratories, a large hall for material testing, some cellars and a storage room were contaminated. In these laboratories, characterization programs were carried out on different kinds of fuel, fissile material and waste, resulting in contamination with Thorium and Uranium isotopes. The total wall and floor surface of potentially contaminated areas is approximately 4800 m². Average contamination levels were below 2 Bq/cm² with hot spots up to 60 Bq/cm² for β-γ emitters and 0.5 Bq/cm² for α emitters.

Block 3 of the Chemistry Building consists mainly of laboratories and offices. The laboratories were used for experiments and measurements with radioactive materials, fuel, and fissile materials. The total wall and floor surface of these laboratories covers approximately 4300 m². Average contamination levels were below 500 Bq/cm² for β-γ emitters and 0.12 Bq/cm² for α emitters.

Two Radiobiology buildings needed to be decommissioned, namely the Bio-lab and the Bio-animals 1. Both buildings contain laboratories, offices, and storage rooms. In addition, the Bio-animals 1 building contained several animal cages. Extensive experiments and measurements of the impact of radiation and contamination on plants and animals were carried out in these laboratories. A whole range of isotopes, including ^{3}H, ^{14}C, ^{32}P, ^{238}U, ^{239}Pu and ^{241}Am, were used. The total wall and floor surface of these laboratories and cages covers approximately 3500 m². Average contamination levels for the surfaces were below the limits for unrestricted release/reuse. Hot spots of 1.5 Bq/cm² for β-γ emitters and 0.15 Bq/cm² for α emitters were found.

Decommissioning

The specific strategy used for decommissioning the above-described facilities followed multiple steps. The zone to be decommissioned was first isolated from the rest of the building and equipped with hand/foot monitors and an air-monitoring device. In this zone, an area was set up for decontamination, material reduction (see Fig. 1), and sorting and packaging of the waste produced during the dismantling and demolition activities.

Figure 1: **Reduction of contaminated material**

The first step in the decommissioning process consisted of scanning for α, β and γ contamination on loose materials and equipment inside the controlled area. Non-contaminated objects were released from the controlled zone. Suspect or contaminated items were brought to the decontamination area and treated.

Next, the devices anchored in the walls and floors such as ventilation pipes (see Fig. 2), fume hoods, waste-piping etc., were demolished and removed to the decontamination area for treatment.

Figure 2: **Dismantling of ventilation pipes**

Based on the results obtained by scanning the dismantled and/or decontaminated items, the agent of the Health Physics Department decided whether the objects could be freely released or released with restrictions (*i.e.*, whether they have to be disposed of as industrial waste on a public dumping ground). Materials that could not be decontaminated were treated as radioactive waste following the specifications of NIRAS/ONDRAF.

The next step included vacuum cleaning and washing the floors and walls, followed by mapping all surfaces to identify which parts were contaminated. The contamination was removed by scabbling, shaving and/or drilling. This sequence of washing, mapping and decontamination was repeated until the radioactivity has been removed.

Then, all the surfaces were washed again. The washwater was collected and analysed by α and γ spectroscopy. Core samples were taken at random from floors and walls for further measurement by α and γ spectroscopy. Once the spectroscopy results proved that the release criteria have been achieved, the demarcation of the zone was removed.

Results

The decommissioning of the Physics Building, executed by the decontamination crew of the SCK•CEN, was used as a test case. During the decommissioning, the daily activities in the non-contaminated parts of the building went on as usual. The decommissioning activity caused some stress for personnel not familiar with radioactivity. Therefore, it was very important to hold an information meeting for the employees before each decommissioning phase.

No major problems were encountered during the decommissioning of the building itself. Nevertheless, the contamination level of some parts of the infrastructure such as window ledges and doors was higher than expected.

The Metallurgy Building, Block 3 of the Chemistry Building, and the two Radiobiology Buildings were decommissioned by an external company selected on the basis of a call for proposals. The SCK•CEN Technical Liabilities team and the Health Physics Department supervised all the activities. Before each decommissioning phase, a meeting was held to inform the employees of the Vito about the decommissioning activities and the safety conditions.

After complete decommissioning of the buildings, the transferable $\alpha\beta\gamma$ contamination was below 0.001 Bq/cm^2. The core samples have a similar radionuclide spectrum as corresponding material coming from a non-nuclear zone. The total $\alpha\beta\gamma$ activity measured on those samples was below 1 Bq/g.

The decommissioning certifications were obtained in 1993 for the Physics building, in 1994 for the Metallurgy Building and in 1995 for Bloc 3 of the Chemistry Building. The certification for the Radiobiology Buildings was obtained at the end of 1996. At the time of each certification, the Vito has formalized its agreement for the transfer of the decommissioned buildings.

References

[1] Noynaert L, Marien J., Cornelissen R., Harnie S., Unrestricted reuse of decommissioned nuclear laboratories, Topseal '96, Stockholm, June 9-12, 1996.

[2] Cornelissen R., Noynaert L., Harnie S., Marien J., Unrestricted reuse of decommissioned nuclear laboratories, Topical Day on Site Remediation, SCK•CEN, Mol, September 18, 1996.

APPROACH TO DECOMMISSIONING AT AECL'S LABORATORIES

B. A. Lange
Director, Decommissioning Planning and Operations, Atomic Energy of Canada Ltd

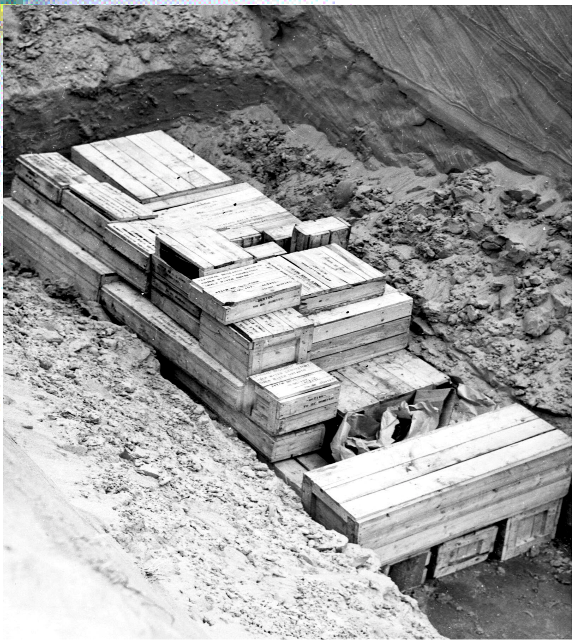
PRESENTATION TOPICS

- **Chalk River Laboratories - Overview**
- **Decommissioning Organization**
- **Waste Management Strategy**
- **Integration of Waste Management and Decommissioning**
- **Free Release Criteria**
- **Issues for Discussion**

Pg2

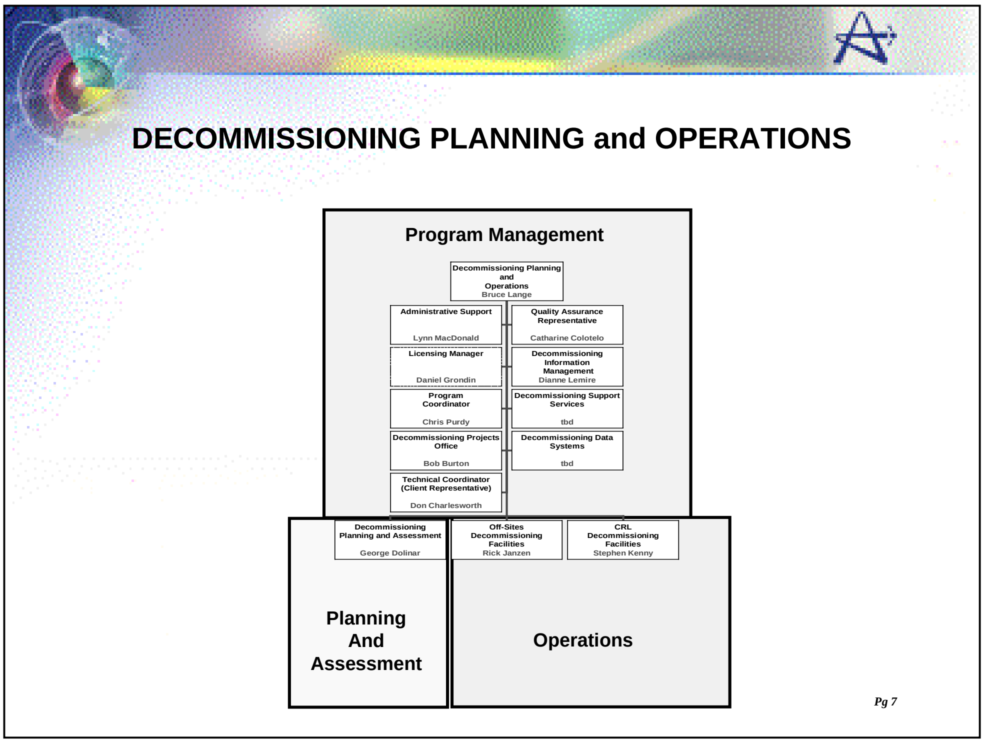
CRL Facilities

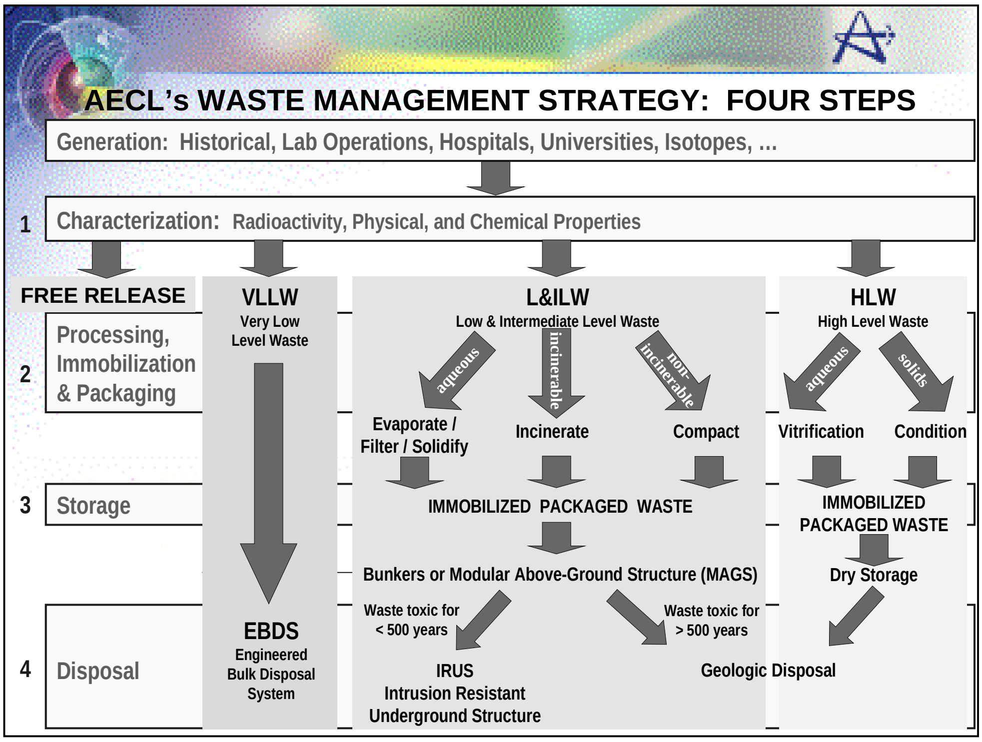
Pg 4

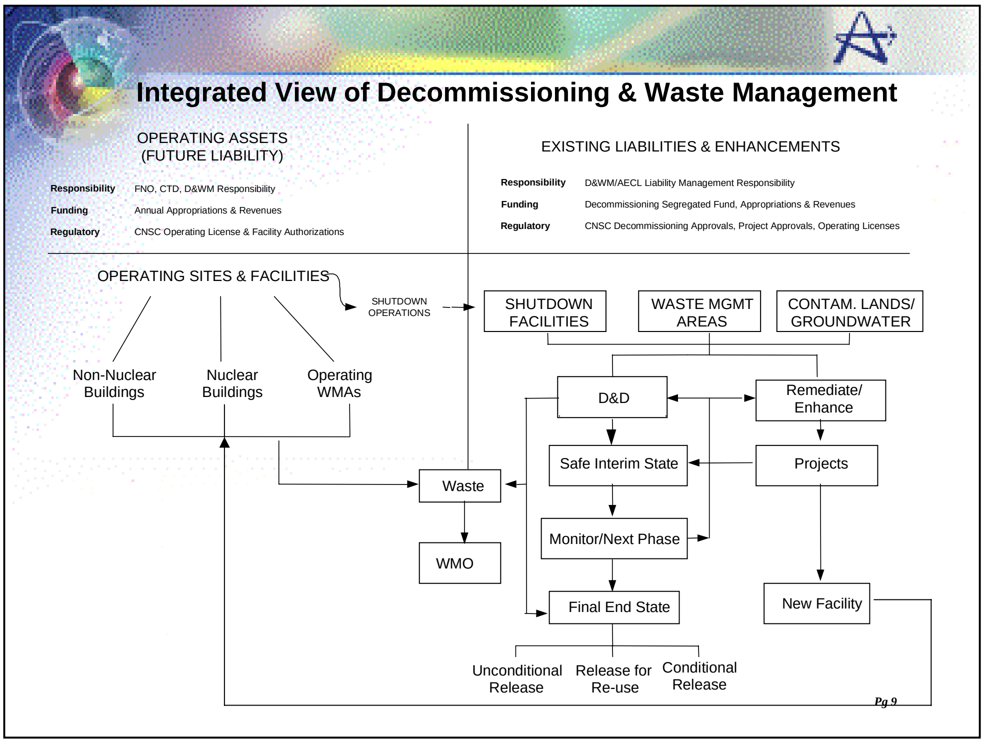


First “disposal” of waste at CRL in February 1946.

Pg 5


DECOMMISSIONING PLANNING and OPERATIONS
Program Management
Decommissioning Planning and Operations
Bruce Lange
Administrative Support
Lynn MacDonald
Quality Assurance Representative
Catharine Colotelo
Licensing Manager
Daniel Grondin
Decommissioning Information Management
Dianne Lemire
Program Coordinator
Chris Purdy
Decommissioning Support Services
tbd
Decommissioning Projects Office
Bob Burton
Decommissioning Data Systems
tbd
Technical Coordinator (Client Representative)
Don Charlesworth
Decommissioning Planning and Assessment
George Dolinar
Off-Sites Decommissioning Facilities
Rick Janzen
CRL Decommissioning Facilities
Stephen Kenny
Planning And Assessment
Operations
Pg 7


AECL's WASTE MANAGEMENT STRATEGY: FOUR STEPS
Generation: Historical, Lab Operations, Hospitals, Universities, Isotopes, ...
1 Characterization: Radioactivity, Physical, and Chemical Properties
FREE RELEASE
VLLW
Very Low Level Waste
L&ILW
Low & Intermediate Level Waste
HLW
High Level Waste
2 Processing, Immobilization & Packaging
aqueous
incinerable
non-incinerable
aqueous
solids
Evaporate / Filter / Solidify
Incinerate
Compact
Vitrification
Condition
3 Storage
IMMOBILIZED PACKAGED WASTE
IMMOBILIZED PACKAGED WASTE
Bunkers or Modular Above-Ground Structure (MAGS)
Dry Storage
Waste toxic for < 500 years
Waste toxic for > 500 years
4 Disposal
EBDS
Engineered Bulk Disposal System
IRUS
Intrusion Resistant Underground Structure
Geologic Disposal



RELEASE CRITERIA

- **STATUS in CANADA**
  - o **AECL, Regulator (CNSC), Nuclear Utilities, Private Sector are "Evaluating" the Free Release Criteria Issue**
  - o **Approach Is Likely to Be Based on the Use of the 10 μ Sv/a Public Dose Limit**

Pg 10

RELEASE CRITERIA (2)

- **AECL OFFICIAL CRITERIA**
  - **Radiation Protection Program : Developed for Movement of Material from One Radiological Zone to Another**
  - **Primarily for On-Site Equipment Re-Use**
  - **Disposal of Large Volumes Not Considered**
  - **Based on Simple, Conservative Pathway Modeling (1962)**

Radionuclide	Removable (Bq/cm^2)	Total (Bq/cm^2)
α emitters	0.01	0.4
U-nat, depleted U, LE, Th-nat	0.2	4.0
^{90}Sr, radioiodines	0.05	4.0
β -γ emitters	0.2	4.0

Pg 11

RELEASE CRITERIA (3)

- **AECL INTERIM CRITERIA**
  - **Proposed for Decommissioning based on ALARA**
  - **Scaling Down of Official Criteria**

Radionuclide	Removable (Bq/cm^2)	Total (Bq/cm^2)
α emitters	0.01	0.2
U-nat, depleted U, LE; Th-nat	0.2	1.0
^{90}Sr, radioiodines	0.05	1.0
β -γ emitters	0.2	1.0

Pg 12

RELEASE CRITERIA (4)

- **Comparison of AECL Interim Criteria to International Criteria for <u>Surface Contamination</u>**

	β/γ Criteria (Bq/cm^2)			α Criteria (Bq/cm^2)		
Material	Minimum	Maximum	Typical	Minimum	Maximum	Typical
International Criteria						
Generic	0.05	1.0	0.4	0.02	0.3	0.04
Building Rubble	n/a[1]	n/a[1]	5.0	n/a[1]	n/a[1]	2.0
Equipment (Re-Use)	0.4	1.0	n/a[2]	0.02	0.1	n/a[2]
AECL						
Generic			1.0			0.2

Pg 13

RELEASE CRITERIA (5)

- **Comparison of AECL Interim Criteria to International Criteria for <u>Volumetric Contamination</u>**

	β/γ Criteria (Bq/g)			α Criteria (Bq/g)		
Material	Minimum	Maximum	Typical[3]	Minimum	Maximum	Typical[3]
International Criteria						
Generic	0.05	10.0	0.1	0.02	0.3	0.1
			0.3 - 0.4			0.03 - 0.04
						0.01
Building Rubble	n/a[1]	n/a[1]	0.1	n/a[1]	n/a[1]	0.1
Metals (Recycling)	0.1	1.0	n/a[2]	0.1	2.0	n/a[2]
AECL						
Generic			*1.0[4]*			*0.2[4]*

Pg 14

RELEASE CRITERIA (6)

- **AECL PRACTICES – Release of Lands**

  The approach involved demonstrating that the level of radioactive contaminants in the land proposed for release was not statistically different from that of off-site lands (Non-Distinguishable).

RELEASE CRITERIA (7)

- **AECL PRACTICES – Groundwater Monitoring**

  REGULATORY: Off-Site Discharges Compared to Derived Release Levels (Dose-Based)

  NON-REGULATORY: Concentrations Compared to Drinking Water Standards As a "Convenient Measure"

Pg 15

RELEASE CRITERIA (8)

- **Approaches Under Consideration for Free Release**
  - **<u>Full Off-Site Release</u> - Release of All Clearable Waste Off-Site Using Single Criteria Set Based on Pathway Analysis (Detectable Contamination <u>but</u> < Clearable Criteria)**
  - **<u>No Off-Site Release</u> – Dispose of All Wastes in CRL Waste Management Facilities**
  - **<u>Partial Off-Site Release</u> - Using Tiered Criteria Set:**
    - **Release "Non-distinguishable" Wastes Off-Site (Non-Detectable Contamination – Criteria Determined by Background Levels)**
    - **Dispose of Other "Clearable" Waste in On-site Inactive Landfill (Detectable Contamination <u>but</u> < Clearable)**

Pg 17

RELEASE CRITERIA (9)

- Actions
  - o Determine Proportion of Waste between "Non-Detectable" and "Clearable" Using Actual Waste
  - o Assess Implications of Using Background as a Basis for Release Criteria

Pg 18

ISSUES FOR DISCUSSION

- What are the release standards?
- Do the same release standards apply to soil and the ground as apply to the buildings?
- Are release standards dose-based, or concentration based?
- Are there different release standards for different types of radionuclides?
- What are the standards for groundwater?
- Are surface contamination or volumetric standards used?

Pg 19

APPROACH TO, AND EXPERIENCE IN, THE RELEASE & REUSE OF BUILDING AND SITES

L. Valencia
KƒZ Karlsruhe, Germany

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Experience in Release & Reuse of Sites

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Areas for Release Measurements in [m²]

Building	Metal	Concrete	Soil	Total
Reactor Building	11,734	17,002	-	28,736
Aux. Building	2,190	7,137	-	9,327
Work. Build. C.A.	182	510	-	692
Working Build.	1,050	7,447	-	8,497
Build. outs. C.A.	8,930	9,808	-	18,738
Areas outs. C.A.	233	3,159	3,169	6,561
Total	24,319	45,063	3,169	72,551

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

KKN Areas for Release Measurements

	Clearance Areas	Number of Measurements
Control Area (CA)	26,000 m² Walls, Floors and Roofs	200,000 with Portable Monitors 5,000 Samples
Outside CA	19,500 m² Buildings, Roads and Soil	2,300 with Portable Monitors 300 Samples

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Preparation for Clearance

- Characterisation Based on „Finger Prints“ from Operational History and Contamination Paths from Dismantling
- Determination of Room Sequences, Areas, Coding and Enumeration of Measurement Sections
- Removal of Floor Mortar Layers or Coating
- Identification of Hot Spots and Presumably Uncontaminated Sections
- Demarcation of Sections, Rooms and Stories to Prevent Spread of Contamination

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Clearance Procedure

- Sampling to Determine the Penetration Depth of Contamination
- Determination of Decontamination Steps Based on Hand-Held Monitor Measurements, Smear Tests and Samples
- Decontamination and Control Measurements
- Final Vacuum of Dust, Cleaning and Room Sealing
- Decision Measurements and Evidential Back Sampling

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Some Release Values from the old Radiation Protection Ordinance (RPO)

Nuclide	Exemption Level [Bq]	$5 \cdot 10^{-5}$ of Exemption Level [Bq/g]
Co-60	5 E + 5	25
Cs-137	5 E + 4	2.5
Eu-152	5 E + 5	25
Fe-55	5 E + 5	25
Ni-63	5 E + 5	25
H-3	5 E + 6	250

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Clearance Values from the new RPO

uclide	Exemption level		surface specific activity	Clearance						
				unconditional clearance of				clearance of		
	activity in Bq	activity concentr. Bq/g	Bq/cm²	solids, liquids* Bq/g	rubble, soil of > 1000 t/a Bq/g	sites (land) Bq/g	build-ings for reuse Bq/cm²	solids, liquids for dis-posal* Bq/g	build-ings for demo-lition Bq/cm²	metal scrap for recyc-ling Bq/g
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*10a*
H 3	1E+9	1E+6	1E+2	1E+3	6E+1	3	1E+3	1E+3	4E+3	1E+3
C 14	1E+7	1E+4	1E+2	8E+1	1E+1	4E-2	1E+3	2E+3	6E+3	8E+1
Fe 55	1E+6	1E+4	1E+2	2E+2	2E+2	6	1E+3	1E+4	2E+4	1E+4
Co 60	1E+5	1E+1	1	0.1	9E-2	3E-2	4E-1	4	3	0.6
I 131	1E+6	1E+2	1E+1	2	6E-1	2E-1	1E+1	2E+1	6E+2	2
Cs 137	1E+4	1E+1	1	5E-1	4E-1	6E-2	2	1E+1	1E+1	6E-1
U 234	1E+4	1E+1	1	5E-1	4E-1		1	9	1E+1	2
Pu 242	1E+4	1	1E-1	4E-2	4E-2	4E-2	1E-1	1	2	3E-1
m 241	1E+4	1	1E-1	5E-2	5E-2	6E-2	1E-1	1	3	3E-1

) for col. 5 and col. 9: only for material which does not fall under column 6

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Release Values for unrestricted Reuse

Concrete Structures	Mass Specific [Bq/g]	Surface Specific [Bq/cm²]
Biological Shield	0.038 (Eu-152)	0.475 (Cs-137)
Reactor Building (RB)	-	0.475 (Cs-137)
Structures outside RB) Auxiliary Buildings	-	$5 \cdot 10^{-5}$ of RPO Exemption Level

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Release Values for unrestricted Reuse

Steel Structures	Mass Specific [Bq/g]	Surface Specific [Bq/cm²]
Biological Shield, Reactor Building (RB), Structures outside RB and Auxiliary Buildings	$5 \cdot 10^{-5}$ of RPO exemption level averaged over 100 Kg	$5 \cdot 10^{-5}$ of RPO exemption level

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Release Values for Unrestricted Reuse of Buildings, Soil and roads

Steel Structures	Mass Specific [Bq/g]	Surface Specific [Bq/cm²]
Buildings, Pavement and Roads	-	0.5 (Cs-137 + Co-60)
Soil	0.03 (Cs-137 + Co-60, Co-60: Max. 0.01)	-

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Nuclide Vector for Biological Shield

Nuclide	Correlation Factors Co-60	Correlation Factors Eu-152	Activity Distribution [%]
H-3		2.34	58.74
Fe-55	2.40		7.23
Co-60	1		3.01
Ni-63	0.90		2.71
Eu-154		0.075	1.89
Eu-152		1	25.12

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Nuclide Vector RB Concrete Structures

Nuclide	Correlation Factors Co-60	Correlation Factors Cs-137	Activity Distribution [%]
Fe-55	24.35		3.65
Co-60	1		0.15
Ni-63	168.83		25.33
Sr-90		0.02	1.30
Y-90		0.02	1.30
Cs-137		1	66.48

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

HDR Nuclide Vector for Steel Structures outside RB and Auxiliary Buildings

Nuclide	Correlation Factors Co-60	Correlation Factors Cs-137	Activity Distribution [%]
Co-60	1		0.05
Cs-137		1	99.69

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Frequency of Measurements for HDR

Category	Vector	Frequency Monitor	Frequency Samples	Building
B0	Concr.	1/100 m²	1/500 m²	Outside RB
B1	Concr.	1/10 m²	1/500 m²	Outside RB
B2	Concr.	1/5 m²	1/Section	Outside RB
B1	Cs-137	1/10 m²	1/500 m²	Inside RB
B2	Cs-137	1/5 m²	1/Section	Inside RB
B3	Cs-137	1/1 m²	1/Section	Inside RB

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Frequency of Measurements for KKN

Radiological Category	Building	Frequency of Measurement
I	Control Areas (CA)	Roofs and Walls: 1/m² Floors: 100%
II	Areas Outside CA (Cont. Possible)	Floors: 1/10 m² Min: 1/Room

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Frequency of Measurements for KKN

Radiological Category	Building	Frequency of Measurement
III	Areas Outside CA (Cont. Possible)	Floors: 1/10 m² Others: 1/50 m² Min: 1/Room
IV	Areas not Contaminated During Operation and not Used During Decommissioning	Floors: 1/10 m² Min: 1/Room Soil: 1/500 m²

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Sampling Procedure

Forschungszentrum Karlsruhe
Bereich Stilllegung nuklearer Anlagen

Averaged Activity Measurements

Building	In-Situ Un-collimated	Hand-Held Monitor	Sample	HDR Hand-Held Monitor
	Cs-137			Nuclide Vector
	Bq/cm²	Bq/cm²	Bq/cm²	Bq/cm²
Reactor Building	0.087	0.086	0.149	0.094
Reactor Building	0.027	0.056	0.039	0.116
Aux. Building	0.022	0.063	0.090	0.103
Work. Build. C.A.	0.008	0.048	0.003	0.110
Working Build.	0.008	0.050	0.009	0
Build. outs. C.A.	0.013	0.050	0.013	0.014

REGULATORY ASPECTS OF RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING IN THE UK

F. Taylor, and **S. Blakeway,**
Health and Safety executive, HM Nuclear Installations Inspectorate, UK

Summary

This paper covers the regulation of radioactive waste management and decommissioning on nuclear licensed sites in the United Kingdom (UK) by HM Nuclear Installations Inspectorate (NII), which is part of the Health and Safety Executive (HSE). The role of HSE is described together with the legislation which it is responsible for enforcing, and the nature of the regulatory regime.

HSE has recently issued guidance to its nuclear Inspectors on the regulation of radioactive waste management and decommissioning activities on nuclear licensed sites. This guidance outlines HSE's expectations for the arrangements that licensees should have in place for the safe and effective management of their radioactive waste and for the decommissioning of their nuclear facilities. A number of specific aspects from the guidance are selected for discussion in this paper. For radioactive waste management the topics chosen include strategic planning, the content of safety cases, passive safety for long-term storage, the preservation of records and the management of contaminated land. For decommissioning the topics chosen include the current position with respect to delicensing, strategic planning, the factors that influence the timing of decommissioning and the maintenance of appropriate organisations.

Finally, the regulators perspective is given on some of the most important challenges that the nuclear industry currently faces in this area.

Introduction

The paper explores, from the point of view of nuclear Inspectors in HSE, some of the issues and challenges associated with radioactive waste management and decommissioning at the nuclear sites in the UK. It describes the relevant legislation, including the recent regulations on Environmental Impact assessment for reactors, and the regulatory regime within which HSE operates, which is generally non-prescriptive.

In order to provide a consistent regulatory framework in this area, the HSE has developed, and recently issued, guidance for its nuclear Inspectors, which essentially sets down expectations for the arrangements that licensees should have in place for the safe and effective management of their radioactive waste and for the decommissioning of their nuclear facilities. A number of specific topics of particular relevance are selected from the guidance for further discussion.

Regulatory background

HSE is the executive arm of the Health and Safety Commission which is appointed by the Secretary of State for the Environment, Transport and the Regions; it aims to ensure that the risks to people's health and safety arising from work activities are properly controlled. NII, which is part of HSE, aims to secure the maintenance and improvement of standards of safety at licensed nuclear installations. In carrying out its regulatory role HSE takes UK Government policy [1] into account.

The main legislation covering the safety of workers and the general public at nuclear installations in the UK, is the Health and Safety at Work Act 1974 (HSWA74) and associated statutory provisions, which include the Nuclear Installations Act 1965 (as amended) (NIA65). Under NIA65, no site may be used for installing or operating any nuclear installation unless a site licence has been granted by the HSE. NIA65 allows HSE to attach such conditions to the site licence as may appear to HSE to be necessary or desirable in the interests of safety, or as it may think fit with respect to the handling, treatment and disposal of nuclear matter, including radioactive waste. It is largely through this route that we achieve our regulatory aims. The conditions, which are attached to a licence, are essentially non-prescriptive and generally require the licensee to make and implement adequate arrangements. The arrangements that the licensee develops constitute elements of a safety management system. The non-prescriptive nature of the licence conditions enables a continuous and flexible form of regulation that can be applies throughout all stages in the operation of a nuclear installation, including decommissioning. Of particular interest is the requirement of NIA65 for the licensee's responsibility under the licence to continue "until there has ceased to be any danger from ionising radiation from anything on the site". The delicensing of nuclear sites is a challenge to both HSE and the licensees and the current position is discussed later.

There are 36 standard licence conditions. These are described in more detail in the HSE publication, Notes for Applicants [2], with the exception of licence condition 36 (LC36), which was added in 2000. LC36 concerns arrangements for the control of organisational change by licensees. The licence conditions cover topics such as the production of safety cases, records, control of operations, maintenance and changes to the plant, ensuring staff are suitably qualified and experienced, managing organisational change and dealing with incidents and emergencies. There are specific licence conditions related to the control of nuclear matter, the accumulation, containment and disposal of radioactive waste, and another covers the arrangements to be made for decommissioning including the production of decommissioning programmes.

HSE has about 155 nuclear Inspectors all of whom are based at Bootle in Liverpool. Each nuclear site has at least one designated Site Inspector and the largest sites may have several Site Inspectors. The Site Inspectors role is to check compliance with the conditions of the site licence, for which they can call on the support of specialist Inspectors for technical assessment or for advice on strategy matters. The enforcement powers of nuclear Inspectors derive principally from the general powers bestowed on HSE Inspectors under the HSAW74.

The Ionising Radiations Regulations 1999 (IRR99), made under the HSAW74, aim to ensure that the radiological exposure of workers and the public to ionising radiation arising from work activities are kept as low as reasonably practicable. These regulations are enforced on nuclear licensed sites, and on certain Ministry of Defence sites, by NII and on non-licensed sites by other parts of HSE.

HSE is responsible for administering the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 (EIADR99) recently enacted in the UK. These regulations require an Environmental Impact Assessment (EIA) to be carried out by the licensee before HSE considers granting consent for the decommissioning of nuclear reactors (above 1 kW thermal power). It does this by consulting relevant bodies and the public on an Environmental Statement (ES) provided by the licensee, the results of which are taken into account when considering consent. HSE may attach conditions to any consent to start the decommissioning project as may appear desirable in the interests of limiting the impact of a project on the environment. Decommissioning projects that were in progress when the regulations came into effect do not need to comply with the regulations, unless there are changes to the projects, which may have significant adverse environmental effects. The nuclear power stations at Bradwell and Hinkley Point 'A' are the first decommissioning projects to fall completely under the requirements of the EIADR99 process.

The disposal of radioactive waste and discharge of radioactive material in airborne and liquid discharges from any facility, including nuclear licensed sites, is regulated, under powers derived from the Radioactive Substances Act 1993 (RSA93), by the Environment Agency (EA) in England and Wales and the Scottish Environment Protection Agency (SEPA) in Scotland. Liaison is maintained between HSE and the two environment agencies, through interdepartmental agreements, with the aim of ensuring that waste management aspects are regulated in a consistent manner. HSE and EA have set down their responsibilities and joint working arrangements within a Memorandum of Understanding (MoU). A similar MoU is being developed with SEPA. These agreements aim to ensure that the regulators' actions are co-coordinated and do not conflict.

Governments are required to make submissions to the European Commission, under Article 37 of the Euratom Treaty, for any new project that has significant radioactive waste management implications and this includes decommissioning projects. This submission covers the potential impacts on other member states. DETR or the Scottish Executive takes the lead on this submission.

Government policy

Government policy on radioactive waste management was reviewed in 1994/95 and the conclusions of that review were set out in "Review of Radioactive Waste Management Policy, (Cm 2919)" [1]. Following the publication of the report of the House of Lords Select Committee Enquiry into Nuclear Waste Management [3], issued in March 1999, the Government has announced a review of this policy [4], it has made clear that it wishes to "take account of the Committee's views and undertake wide consultation before announcing how it wishes to proceed". The Government (and devolved administrations in Scotland and Wales) plan to publish a wide-ranging consultation paper to "discuss the processes that would be involved in the various management options for radioactive waste, rather than the relative merits of the options themselves" in the near future.

The OSPAR/Sintra agreement [5], which the Government signed in July 1998, commits the UK to a progressive and substantial reduction of the radioactivity in liquid discharges by adopting best available techniques, such that additional concentrations in the marine environment above historic levels, are close to zero by 2020. This agreement may have an impact on existing disposal routes and requirements for discharges during decommissioning.

HSE's expectations

As explained earlier the licensing regime is goal setting rather than prescriptive and therefore HSE does not generally issue guidance to the nuclear industry on its expectations. However it has published the Safety Assessment Principles [6] used by its Inspectors in assessing licensees' proposals. It also issues more detailed guidance to its Inspectors. Over the last few years HSE has been developing and consolidating its guidance on radioactive waste management and decommissioning taking account of Government policy. Because it realised that this was a topic of wide interest, HSE discussed the draft guidance with interested organisations and presented papers at conferences [7, 8, 9, 10] on its emerging thinking, and found this to be a very useful exercise. This work is now complete and the guidance [11, 12] has been placed on the Nuclear Safety Directorate section of the HSE website, www.hse/nsd/. The guidance will be reviewed regularly in the light of experience with its use. This section describes some of the topics covered in the guidance.

Radioactive Waste Management

The guidance starts with four fundamental expectations for the management of radioactive waste, which, should be met so far as is reasonably practicable, they are:

1. Production of radioactive waste should be avoided. Where radioactive waste is unavoidable, its production should be minimised.
2. Radioactive material and radioactive waste should be managed safely throughout its life cycle in a manner that is consistent with modern standards.
3. Full use should be made of existing routes for the disposal of radioactive waste.
4. Remaining radioactive material and radioactive waste should be put into a passively safe state for interim storage pending future disposal or other long-term solution.

Strategic Planning

Good strategic planning is essential if radioactive wastes are to be managed safely and effectively throughout their life cycle. HSE requires licensees to produce and maintain strategies providing an overview of their approach to the safe management of all their radioactive material. Where a licensee is responsible for a number of nuclear sites, then it may be appropriate to produce a corporate strategy supported by a series of site-specific strategies. The strategy should not be restricted to radioactive waste but should include other materials which may become or may lead to the generation of waste in the future, for example stocks of fissile material held prior to possible operational use or spent fuel. In presenting their strategy HSE would expect licensees to demonstrate that they have considered a full range of options and justify their selection of the preferred option, making clear the major assumptions and uncertainties. A range of factors will influence the selection of a strategy including technical issues, Government policy, availability of disposal routes etc. A strategy should include programmes showing significant milestones and the timescales on which they are planned to be achieved and against which progress can be reviewed.

Safety Cases

The nuclear site licence requires licensees to produce safety cases for all operations that may affect safety, including radioactive waste management, throughout all phases in the life of a facility, including construction, commissioning, operation and decommissioning. HSE has expressed the view [13] that it expects safety cases to be made on the basis that arrangements are consistent with modern standards, which are represented by sound engineering principles and current best practice. Furthermore it should demonstrate that the risks from the operations have been reduced as low as reasonably practicable (ALARP). Quantified or probabilistic risk assessment (QRA or PSA) can help to prioritise safety issues and investigate the benefits of further safety improvements. Risk estimates should be used with caution for radioactive waste management facilities where they often produce very low estimates, and they should never be used to justify poor practice.

If new facilities are to be designed and constructed then they are expected to be fully consistent with modern standards. However, in some cases licensees may choose to use or modify existing facilities. Justification of the safety of older plant [14] will require careful consideration of the current and future condition of the plant and the intended use. The standard approach is to establish the shortfalls against modern standards and investigate what safety improvements are reasonably practicable. A particular concern is that deteriorating facilities that fail to meet current standards will fall further behind in the future.

Licensees should carry out routine verification that the safety case is consistent with each plant and its operation, and in addition the licence conditions require licensees to carry out more comprehensive periodic safety reviews, typically every 10 years. These reviews are intended to consider operational history and provide a comparison with modern safety standards and justify any differences or concerns.

Characterisation and Segregation

If they are to be managed effectively then all radioactive materials must first be characterised in terms of their chemical and physical form, radioactive content, origin, and other relevant properties. Segregation involves accumulating together those materials with similar characteristics, and avoiding mixing those with different characteristics. Segregation is most efficient if it is taken into account at the process design stage and it should be done as close to the point of waste generation as is reasonably practicable. Experience has shown that characterisation and appropriate segregation can contribute significantly to the safe and economic management of radioactive materials, on the other hand it has also shown that failure to take these steps can restrict the options that are available and lead to significant difficulties and cost.

Passive Safety

The refusal to grant planning permission to Nirex, for an underground rock characterisation facility near Sellafield, has delayed the availability of a future national disposal facility for ILW, and some forms of LLW that are not suitable for disposal by existing routes. As a result licensees need now to plan for significant periods of interim storage of these radioactive wastes, the current situation in the UK indicates that this period should be at least 100 years taking account of the time to build a repository, time to emplace the wastes and a further period before a repository may be closed. Where long-term storage is anticipated there is a significant benefit from placing radioactive material and waste in a passively safe state. Passive safety requires the radioactivity to be immobilised and packaged in a form that is physically and chemically stable and which minimises the need for control and safety systems, maintenance, monitoring and human intervention.

In considering the attributes of passive safety HSE has developed a set of engineering principles [15], which can be achieved by a combination of the waste form, it's packaging and the storage building. These principles are listed in Table 1. In practice, in any particular case, it is intended that the principles should be met so far as is reasonably practicable. The more hazardous the waste and the more mobile its form, the greater the safety benefit from passive safe storage and the sooner this should be achieved.

Radioactive material and waste should be packaged in a form that is suitable for both long-term storage and ultimately for disposal. Nirex is the UK organisation that provides advice and maintains specifications for the packaging of radioactive waste, and they issue letters of comfort to licensees for those waste forms that they consider consistent with future disposal requirements. In some cases a conflict can arise between processing waste now to achieve passive safety and the foreclosure of future options, such as disposal. In such cases a licensee will be expected to demonstrate an appropriate balance has been achieved between current and future safety requirements, and in some cases the need for short-term safety improvements may be overriding. However, HSE believes that in the majority of cases it should be possible to place radioactive waste in a passive safe state that can also be shown to be acceptable for final disposal.

Records

Although the responsibility for managing existing radioactive waste safely rests with this generation, they may be stored in facilities for a considerable period, and in the future the responsibility will pass to future generations. In order to comply with the concept of sustainable development it will be necessary to provide the future generations with all the information they will need to manage the materials and facilities safely. The nuclear site licence requires licensees to make adequate records to demonstrate compliance with each condition of the site licence, and to ensure that such records are preserved for 30 years after a building or facility is decommissioned. This period of 30 years reflects primarily the requirements of NIA65 with respect to third party liability. However, the information relating to radioactive waste and the facilities that hold them will need to be retained for much longer periods in the future, until the waste is finally disposed off.

This generation holds a great deal of information on the characteristics of radioactive materials, and waste, and the facilities that hold them, but this information is often in diverse and relatively insecure locations. It needs to be assembled and maintained in a secure and accessible form for as long as it may be needed. HSE has been working with the nuclear industry, and other Government departments to develop an electronic database called the British Radwaste Information Management System (BRIMS) [16], which will provide a means of accumulating and storing relevant data. The joint development by the nuclear industry is allowing best practice to be shared and should ensure consistency in the nature and extent of the information that is retained.

Contaminated Land

There are a significant number of instances of radioactively contaminated ground on nuclear licensed sites. This contamination is the result of historical incidents involving spillage or leakage, or the placement of radioactive material in the ground. In the past, licensees have not always actively managed contaminated ground, but in recent years the profile has been raised as it has been appreciated that it represents a substantial liability and as a result, they are beginning to put in place measures to manage it.

HSE regards radioactively contaminated ground, or emplaced radioactive material, as an accumulation of radioactive waste and it requires licensees to manage it as such. The first priority is to prevent radioactive contamination of the ground through proper control and containment of radioactive material, the second priority is to recover any material that has leaked and, if this is not practicable, to contain it. In the longer term licensees should develop a strategy and safety case that cover the safe management of the ground including remediation, and the disposal of any radioactive waste. Dealing with contaminated ground is an important issue for licensees who are aiming to delicense their nuclear sites.

Decommissioning

The guidance starts with four fundamental expectations for the decommissioning of nuclear facilities, which, should be met so far as is reasonably practicable, they are:

- i) In general, decommissioning should be carried out as soon as it is reasonably practicable, taking account of all relevant factors.
- ii) Hazards associated with the plant or site should be reduced in a progressive and systematic manner.
- iii) Full use should be made of existing routes for the disposal of radioactive waste.
- iv) Remaining radioactive material and radioactive waste should be put into a passively safe state for interim storage pending future disposal or other long-term solution.

Delicensing

The ultimate end point of the decommissioning process is the return of the site to unrestricted use and its release from regulatory control or delicensing. According to NIA65 a nuclear licensee's period of responsibility only ceases when HSE has given notice in writing that, in its opinion, there has ceased to be any danger from ionising radiations on the site or the licence has been transferred to another corporate body. It is clear that the intention of NIA65 is that sites should be able to be delicensed but there is no definitive guidance on the appropriate criteria.

However, HSE has delicensed around 12 sites to date. These sites have involved relatively minor hazards and it has been possible to adopt a pragmatic approach in interpreting the requirement. In general terms HSE has expected licensees to demonstrate that radiation and radioactivity levels on their site are indistinguishable from background levels in the vicinity of the site. In the future licensees will seek to delicense more complex sites with a greater degree of radioactive contamination. There is therefore a need for more practical criteria, which HSE is currently developing. These will most likely be based on exemption levels defined in RSA93 or clearance levels defined in the European Community Basic Safety Standards [17]. HSE's experience and current thinking on delicensing has been reported in a number of conference papers [18, 19, 20, 21, 22].

Strategic Planning

Many decommissioning projects are large and complex; hence good strategic planning is essential to ensure that the work proceeds safely and efficiently. The strategy should identify the inventory of its liabilities and describe the means of dismantling each part of the facilities and the management of all the radioactive material and waste until it is ultimately disposed of. The timescales over which the different stages of decommissioning will take place should be defined. The strategy should be linked to, or integrated with, the strategy for the management of existing radioactive waste and waste which is produced during decommissioning. If a licensee is responsible for a number of nuclear sites then it may be appropriate to provide a corporate strategy supported by series of site-specific strategies.

In selecting a preferred strategy, licensees should demonstrate that they have examined a full range of options covering different timescales, technical factors, social factors and financial factors. Licensees should demonstrate that their strategy is consistent with Government policy and consider the extent to which it is consistent with the concept of sustainable development. The strategy should describe how the costs of implementing the strategy have been estimated and how the appropriate funds will be provisioned.

A detailed decommissioning programme will be required prior to the shutdown of each facility and it should include milestones and timescales on which they are to be achieved to enable progress to be monitored.

Safety Cases

The nuclear site licence requires licensees to produce safety cases for the operation of facilities at all stages of their life, including decommissioning. The safety case should show that hazards are being reduced in a systematic and progressive way. In general, the most active and potentially mobile radioactive material should be removed and processed, either for disposal or for passive safe storage pending disposal, on the shortest timescale. The elimination of the highest hazards should not diminish the consideration of the residual hazards.

During decommissioning, the safety case should be updated when necessary to reflect the impact of modifications to the facilities and to address the changing nature of the hazard. Some decommissioning activities may temporarily result in an increase in the risk in order to achieve an overall reduction in the hazard. In such instances, the safety case must identify the impact of the changes and demonstrate that the risks remain at an acceptable level whilst the work is undertaken. A final safety case will be required to support the delicensing of the nuclear site.

Timing

The justification of the timescale over which licensees plan to complete the decommissioning of each of their nuclear facilities is a topic that is currently receiving significant consideration by the regulators and licensees. In line with Government policy, HSE requires licensees to decommission their nuclear facilities as soon as it is reasonably practicable, taking account of all relevant factors. It will seek to ensure that licensees take steps to reduce the hazards associated with their facilities in a progressive and systematic manner, over an appropriate period. The rate at which work proceeds will be determined by several factors, each of which will exert a particular influence, and licensees will need to demonstrate that they have considered and balanced these influences in reaching and justifying their proposals on a case-by-case basis.

HSE has identified a number of factors that influence the timing of decommissioning and has concluded that many of the factors drive towards early decommissioning. A list of such factors, which is not intended to be exhaustive, is shown in Table 2.

HSE considers that decommissioning techniques are sufficiently developed and proven for licensees to undertake decommissioning of facilities in the short term but recognises that there are potential safety benefits from deferring dismantling of some installations containing short-lived radionuclides. In the particular case of reactors, where the principal form of radioactivity is Co-60 with a half life of 5.3 years, HSE recognises that there are safety benefits from deferring final reactor dismantling for several decades in order to reduce operator and public radiation exposure, and also in reducing the quantity and possibly the classification of radioactive waste that is produced. On the other hand, there are nuclear chemical facilities contaminated with plutonium, where the in-growth of americium leads to a radiological hazard that increases with time, and there is a detriment from delaying decommissioning.

In terms of costs, early dismantling of facilities will be more expensive initially, but this must be compared to the long-term costs of deferral, because of the need to maintain the facility in a safe condition, the increasing risk of unforeseen routes for environmental releases and other uncertainties associated with the future. In addition, where licensees use discounting techniques to compare costs incurred at different times this inevitably favours the options for delay, and HSE believes that such arguments should be used with caution in justifying the timescales for decommissioning.

In HSE's view, early decommissioning, particularly where there are few safety benefits from deferral, is more in line with the Government policy of sustainable development and the use of the precautionary principle. HSE's views in this area have been expressed at other conferences [10].

Management and the Organisation

A fundamental basis of UK nuclear regulation is that the licensee bears the sole and absolute responsibility for safety and that this cannot be delegated to another party. Decommissioning, coming after plant shutdown, can be a time of significant change for an organisation and its personnel. Licensees will be required to demonstrate appropriate management of the organisational change, in advance of shutdown, to ensure that safety standards are maintained. HSE will require licensees to prepare detailed programmes and describe their arrangements before each phase of decommissioning, including an appropriate management structure and staffing levels, both to fulfill key roles associated with licensees' responsibilities under the site licence and to provide the general infrastructure to support the project.

Contractors are of course used widely in decommissioning and contribute valuable skills and expertise. HSE has been considering the implications of the use and control of contractors, and other arrangements such as partnering, and has presented its views on a number of occasions [23, 24, 25]. In this context, the term intelligent customer has been in use for several years, and essentially it means that a licensee must take steps to retain an adequate capability within its own organisation to understand the nuclear safety requirements of all of its activities, and also those of any contractors; to take responsibility for managing safe operation; and to set, interpret and ensure the achievement of safety standards. The licensee cannot seek to discharge this role through the use of contractors and must itself be intelligent enough to do these things for the activities of its contractors.

In carrying out decommissioning work there are practical benefits, in terms of doses and costs, to be gained from using workers from the former operating team who have good knowledge of the facilities and the site. If decommissioning is deferred, then it is unlikely that this resource will still be available when dismantling starts. In that case, licensees must make arrangements to capture and maintain the knowledge base, and to assemble and train teams of workers to undertake activities when required, which might be a considerable time into the future.

Quinquennial reviews

Government policy [1] requires HSE, in consultation with the environment agencies, to carry out quinquennial reviews (QQRs) of licensee's decommissioning strategies. In its review HSE assesses the strategy as to whether it is reasonably practicable, consistent with existing legislation, technical knowledge, safety and environmental requirements, and Government policy which is to undertake decommissioning as soon as reasonably practicable, taking account of all relevant factors. HSE will seek to satisfy itself that the strategies remain soundly based as circumstances change. The review also examines the financial provisions to determine whether they are adequate to meet the costs of the decommissioning strategy, and also flexible enough to take account of changes and do not foreclose the option of carrying out decommissioning on an earlier timescale should that be required.

HSE expects licensees to produce a publicly available document setting out their decommissioning strategy, and HSE will in turn publish the conclusions of its review. The first round of QQRs is well underway and is covering all the UK licensees. HSE recognises that licensees have undertaken substantial studies to support their strategies, but the area is complex, and so it is not surprising that HSE has identified the need for further work in the identification of liabilities, the clarification of responsibilities and the justification of the timing of the dismantling of some facilities.

Current issues and challenges

The aim of this section is to introduce briefly, from HSE's perspective, some of the major challenges in the area of radioactive waste management and decommissioning that are currently being addressed by the nuclear industry and its regulators.

In recent years HSE has become increasingly concerned about the daunting legacies of radioactive waste that are accumulated in a raw form in unsatisfactory facilities on nuclear sites. HSE has encouraged licensees to condition such waste for passive safe storage and to move away from long-term storage of waste in mobile forms.

The nuclear sites with the largest accumulations of legacy radioactive waste are Dounreay and Sellafield. In 1998 HSE and SEPA published a joint report of a safety audit of UKAEA's operations at Dounreay [26]. The audit concluded that much needed to be done at Dounreay to enable the site to be safely decommissioned and made safe for future generations. Radioactive waste posing a particular challenge on this site includes, for example, 700 m3 of radioactive waste in the shaft that had been used as a disposal route between 1959 and 1971. One important recommendation from the audit highlighted the need for an integrated decommissioning strategy for the site. In response UKAEA has recently made public its strategy, termed the Dounreay Site Restoration Plan, which to be implemented will require the design and construction of a significant number of new waste treatment plant and associated stores. At BNFL's Sellafield site there are significant legacies of raw radioactive waste that arose during the early years of operation in the 1960s and 1970s. HSE wishes to see progress continue in the recovery and processing of this backlog of waste. For its part BNFL has fundamentally reassessed its approach to dealing with these wastes and raised the profile within the company, and is moving towards defining targets and timescales for their work. The same kind of challenges, albeit on a smaller scale, are being addressed by licensees on other nuclear sites.

In 1997 the refusal of planning permission for the Nirex RCF, and the consequential delay in the availability of an ILW disposal facility, meant that radioactive waste would need to be safely stored for much longer periods than previously envisaged. The current view is that storage periods could exceed 100 years before radioactive waste is emplaced in a repository. As a result HSE has carried out a review of ILW storage in the UK [27]. The conclusion was that although areas of immediate concern were being dealt with, many facilities do not meet modern standards, and that up to 20 new stores would be required for the waste currently accumulated. In the longer term the condition of other facilities would deteriorate, and because every facility only has a limited operational life, a programme of store refurbishment or replacement will be needed in the future. There is therefore a significant challenge to the licensees in designing and providing the storage facilities for the future.

We are all aware that decommissioning activities are increasing as more redundant nuclear facilities are dismantled and other facilities approach the end of their operating life. Each type of facility, whether a nuclear fuel cycle plant, a research or power reactor, or the UK's laid-up nuclear submarine fleet poses different technical, commercial and management challenges if decommissioning is to be achieved safely. HSE will continue to regulate these activities to ensure that they are carried out safely and in line with the legislation and Government policy. Notable issues that currently challenge the nuclear industry and the regulators for decommissioning projects, include the justification of timescales for dismantling different types of facilities, managing the changes in organisational structure that will occur during the projects, the remediation of contaminated ground on nuclear sites and ultimately the radiological criteria for delicensing and releasing sites from regulatory control.

Conclusions

Under the relevant legislation in the UK, HSE is able to regulate the safety of radioactive waste management and decommissioning activities on nuclear sites through the application of a flexible and non-prescriptive licensing regime. It seeks to do this in a manner that is consistent with Government policy. HSE has recently issued guidance in this area for the use of its nuclear Inspectors, which will assist in the application of a consistent regulatory approach.

References

[1] Cmnd 2919, Review of Radioactive Waste Management Policy Final Conclusions, London HMSO 1995.

[2] Nuclear Site Licences under the Nuclear Installations Act 1965 (as amended), Notes for Applicants, HSCG 120. ISBN 0-7176-0795-X.

[3] HL Paper 41, Management of Nuclear Waste, House of Lords Select Committee on Science and Technology, London HMSO 1999.

[4] The Government Response to the House of Lords Select Committee Report on the Management of Nuclear Waste, DETR, October 1999.

[5] "OSPAR Convention: Convention for the Protection of the Marine Environment of the North-East Atlantic - the United Kingdom became a signatory at Sintra, Portugal during the Ministerial Meeting of the Oslo/Paris ("OSPAR") Commission in July 1988.

[6] Health and Safety Executive, Safety Assessment Principles for Nuclear Plants, HSE Books 1998, ISBN 0-11-882043-5.

[7] DM Watson, Decommissioning in the UK, a Regulatory Perspective, poster presentation to WM '99 Conference (Abstract No. 892), Tucson, February 1999.

[8] DJ Mason, Regulatory Aspects of Decommissioning in the UK, a paper presented at a Joint NEA/IAEA/EC Workshop on the regulatory aspects of decommissioning, Rome, May 1999.

[9] DJ Mason and CE Temple, Regulatory Aspects of Decommissioning, IBC 6th International Conference on Decommissioning of Nuclear Facilities, London, June 1999.

[10] FE Taylor, The Regulation of Shutdown Licensed Facilities in the UK, IBC 7th International Conference on Decommissioning, London, October 2000.

[11] HSE/NII, Guidance for Inspectors on Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites, (web-site hse.gov.uk/nsd/).

[12] HSE/NII, Guidance for Inspectors on Decommissioning on Nuclear Licensed Sites, (web-site hse.gov.uk/nsd/).

[13] Evidence from the HSE to the House of Lords Select Committee on Science and Technology: Enquiry on the Management of Nuclear Waste, January 1998.

[14] Evaluation of the Safety of Operating Nuclear Power Plants built to earlier Standards: A common basis for judgement, IAEA Safety Series Report No 12.

[15] L Williams, D Mason, S Blakeway and C Snaith, A regulatory view of the long term passively safe storage of radioactive waste in the UK, Proceedings of an international conference on Safety of Radioactive Waste Management, IAEA Cordoba, 13-17 March 2000.

[16] British Radwaste Information Management System (BRIMS), AG Davies et al., pp 315 - 318, Proc. Sixth International Symposium of the Society for Radiological Protection, Southport June 1999.

[17] Basic Safety Standards for the Protection of the Health of Workers and the General Public against the Dangers arising from Ionising Radiation, European Community, Council Directive 96/29/Euratom, L159 Vol 39, June 1996.

[18] IF Robinson and DN Simister, A Regulatory View of De-licensing at UK Nuclear Sites. Proceedings of the 6th Society of Radiological Protection International Symposium, Southport, 14 June 1999.

[19] IF Robinson, A Nuclear Inspector’s Perspective on Decommissioning at UK Nuclear Sites, J Radiol. Prot. vol 19 no 3 p203-212, 1999.

[20] IF Robinson, Delicensing Nuclear Sites in the UK. Proceedings of the 10th International Radiation Protection Association Congress, Hiroshima, May 2000.

[21] IF Robinson, Regulatory experience of ALARA and decommissioning at UK Nuclear Sites, European ALARA Network Workshop, Saclay, France 1 December 1997.

[22] JS Griffiths and PH Burgess, Delicensing of Nuclear Sites in the UK, IRPA9:1996 Vienna.

[23] FE Taylor and D Turton, Regulatory Requirements for the use of Contractors on Nuclear Licensed Sites Nuclear Energy, 1998, 37, No 1, 55-58.

[24] FE Taylor and A Coatsworth, Partnering in the Nuclear Industry: A Regulatory Perspective, Proceedings of an International Conference in Alliancing, INE, Erskine, 9-11 June 1999.

[25] FE Taylor Regulatory View of the Nuclear Licensee as an Intelligent Customer Nuclear Energy, 2000, 39, No 3, June, 175-178.

[26] MISC 148, HSE and SEPA, Safety Audit of Dounreay 1998, HSE Books.

[27] HMNII, Intermediate Level Radioactive Waste Storage in the UK: A Review, HSE Books, 1999.

Table 1: Principles for achieving passive safe storage of radioactive waste

Principle
The radioactivity should be immobile
The waste form and its container should be physically and chemically stable
Energy should be removed from the waste form
A multibarrier approach should be adopted in ensuring containment
The waste form and its container should be resistant to degradation
Storage environment should optimise waste package life
The need for active safety systems to ensure safety should be minimised
The need for monitoring and maintenance to ensure safety should be minimised
The need for human intervention to ensure safety should be minimised
The storage building should be resistant to foreseeable hazards
Access should be provided for response to incidents
There should be no need for prompt remedial action
The waste packages should be inspectable
The waste packages should be retrievable for inspection or reworking
The lifetime of the storage building should be appropriate for storage period prior to disposal
The storage facility should enable retrieval of wastes for final disposal (or re-storing)
The waste package should be acceptable for final disposal

Table 2: Relevant factors to be considered in justifying the timing of decommissioning

Factor	Suggested Influence (reactors/Pu contaminated plant)
Risk to Operator	
Radiation dose rates	Deferral/early
Risk to Public	
Reduction in source term	Deferral/early
Probability of releases	
Deterioration of the structures	Early
Passive safe storage	Early
Radioactive Waste Management	
Volume of packaged waste	Deferral/neutral
Availability of disposal route	Deferral
Compatibility with disposal requirements	Neutral
Radioactive discharges	Early
Licensees Organisation	
Maintain an organisation capable of fulfilling the conditions of the nuclear site licence	Early
Maintain the supporting infrastructure	Early
Maintain corporate memory and records	Early
Use of experienced operators	Early
Regeneration of the organisation	Early
Costs and Financial Provision	
Dismantling costs	Deferral/neutral
Care & maintenance, infrastructure costs	Early
Insurance liabilities	Early
Investment returns on segregated funds	Unknown
Cost discounting	Deferral
Future uncertainties	
Changes to waste classification	Neutral
Changes to radiation exposure limits	Early
Changes to regulatory regime	Early
Climate change	Early
Organisation survival	Early
Cost increases	Early
Investment uncertainty	Early
International standards	
Current practice in other countries	Early
Social and Political factors – Government Policy	
Sustainable development	Early
Environmental impact	Early
Public perception of risk	Early
Precautionary principle	Early
Public acceptability	Early

DECOMMISSIONING – A REGULATORY VIEW

S. J. Blakeway and **F. E. Taylor**
HM Nuclear Installations Inspectorate, Health and Safety Executive, UK

Abstract

Decommissioning is the final stage in the life of a facility and is regulated in a similar manner to the operational phase. The nuclear regulatory regime is described including the new regulations on Environmental Impact Assessment for reactors. The Health and Safety Executive has recently issued guidance to its inspectors on the regulation of facilities being decommissioned. A number of aspects of this guidance are discussed including strategies, timetables, safety cases, management and organisation and finally delicensing.

1. Introduction

Decommissioning is the set of actions taken at the end of a nuclear facility's operational life to take it permanently out of service with the ultimate aim of making the site available for other purposes. As far as the regulator is concerned the expectation is that the process should have adequate regard for the health and safety of workers and the public and the protection of the environment. The actions taken should systematically and progressively reduce the level of hazard on a site, and will in most cases include the physical dismantling of the facilities. It is not necessarily a single step process and may involve work being done in stages over a significant period of time.

From a nuclear licensing point of view decommissioning is a continuation of the period of operation and therefore the existing regulatory framework, which is generally non-prescriptive, is applied to this type of work. The Health and Safety Executive (HSE) also takes account of Government policy, which was last stated in 1995 (1). As the nuclear industry matures many facilities have reached the end of their lives and have either been decommissioned or their decommissioning is being planned. There are many challenges to both the industry and the regulator as these complex projects get under way especially since many of the older plants were not designed with decommissioning in mind. This paper discusses some aspects of the regulatory framework and our expectations of nuclear licensees which have recently been made available as guidance to HSE inspectors.

2. Nuclear regulatory regime

The main legislation governing the safety of nuclear installations is the Health and Safety at Work etc Act 1974 and those sections of the Nuclear Installations Act 1965 (as amended) which are relevant statutory provisions. Under the Nuclear Installations Act no site may be used for the purpose of installing or operating any nuclear installation unless the operator holds a valid licence from HSE. Once a licence has been issued, there is a continuing period of responsibility of licensees under the Nuclear Installations Act throughout operation and decommissioning, until there is no longer any danger from ionising radiations from the site.

HSE may attach conditions to nuclear site licences which appear to it to be necessary or desirable, in the interests of safety, or with respect to the handling, treatment and disposal of nuclear matter. These standard licence conditions are essentially non-prescriptive and many of them require the licensee to make and implement adequate arrangements to address safety issues (2). The regime is flexible in that it can be used for all stages of the life of the plant and each licensee can develop arrangements which best suits its business. Consequently these conditions apply equally to decommissioning and operating sites and form a continuous process of regulation "from cradle to grave". The arrangements that a licensee develops to meet the requirements of the licence conditions constitute elements of a safety management system. HSE reviews the licensees' arrangements to check that they are clear and unambiguous and address the main safety issues adequately. It also carries out regular inspections to check compliance.

A particular requirement, under these conditions is that the licensee should produce and implement decommissioning programmes. The current expectation is that outline decommissioning programmes should be available for plants at the design stage and more detailed programmes would normally be produced some time before cessation of use of the plant. HSE has the option of approving these programmes which then cannot be changed without the approval of HSE. In addition, the arrangements for decommissioning should, where appropriate, divide decommissioning into stages and HSE has the power to specify that the licensee shall not proceed to the next stage without its consent. These powers under the licence can be used by HSE to give a high degree of regulatory control over decommissioning. Also of relevance to decommissioning are several licence conditions which relate to the management of radioactive waste and other material on the site, for which HSE has regulatory responsibility.

During the decommissioning period, of course all other health and safety legislation will apply and some will be prominent as the plant state changes and projects commence. The Ionising Radiations Regulations 1999 will remain important as it will be necessary to ensure that doses remain as low as reasonably practicable during different operations. Projects will need to be managed under the Construction (Design and Management) Regulations 1994. Other regulations such as the Provision and the Lifting Operations and Use of Work Equipment Regulations 1998 and Lifting Equipment Regulations 1998 will also be relevant.

This paper covers HSE's regulatory responsibilities, however it should be noted that discharges to the environment and the disposal of radioactive waste are regulated under the Radioactive Substances Act 1993 by the Environment Agency and the Scottish Environment Protection Agency. Close liaison is maintained between the HSE and the two environment agencies in addition to specific statutory consultation arrangements. This is to ensure that all aspects are properly regulated and licensees are not subject to conflicting requirements.

Licensees are also required to make submissions under Article 37 of the Euratom Treaty describing the potential radiological impact of decommissioning on other European Union States. These are Government documents and the environment agencies generally manage their preparation.

3. Environmental impact assessment

The recently amended European Directive on Environmental Impact Assessment covers decommissioning projects associated with nuclear reactors above 1 kW continuous thermal load. The aim is to ensure that the possible environmental effects of decommissioning reactors are properly considered before the project commences. The licensee should also consider the impacts of different ways of implementing the options. It is recognised that it is difficult to assess environmental impact in detail over the very long time span of some of these projects. Nevertheless the licensee is expected to identify the more significant effects.

This Directive has been implemented in the UK by the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 which are administered by HSE. They apply both to new decommissioning projects for nuclear reactors and nuclear power stations and also to changes in existing projects which may have a significant adverse environmental effect. Licensees will need to produce an Environmental Statement describing the Environmental Impact Assessment to support their applications for consent from HSE to commence the project. The public is given access to the Environmental Statement and is invited to make representations. Before granting consent, HSE is required to consult with a wide range of interested parties and must be satisfied that an adequate Environmental Impact Assessment has been performed. A decommissioning project is deemed to have started when action has been taken to permanently disable the reactor so it cannot return to service. Defuelling, as long as it is carried out using the normal operating procedures, is not included in the project.

An optional stage in the process is that a licensee can request a pre-application opinion from HSE of the proposed content of the Environmental Statement. This gives consultees the opportunity to comment and to suggest topics which should be considered. In particular local consultees are able to provide information on local issues. This process has been undertaken for the BNFL (Magnox Generation) stations at Bradwell and Hinkley Point A. HSE recognised that the scoping document could not give a complete picture of the intent but came to the view that BNFL would be covering most issues in its Statement. Therefore, taking account of the comments from consultees, HSE has provided its opinion on issues that need to be covered that were not explicitly described in the document. In particular it pointed out the need for BNFL to cover the whole project and discuss the impact of options. The full reports are expected later in the year will be sent out for wide consultation. HSE will assess the Statements taking into account the comments received and, if satisfied grant consent for the projects to commence.

4. Government policy

Government policy on radioactive waste management was reviewed in 1994/95 and the conclusions of that review were set out in "Review of Radioactive Waste Management Policy, (Cm 2919)" (1). This includes policy concerning decommissioning which has been taken into account by HSE in developing guidance for its inspectors. Following the publication of the report of the House of Lords Select Committee Enquiry into Nuclear Waste Management (3), issued in March 1999, the government has announced a review of this policy.

The OSPAR/Sintra agreement (4), which the government signed in July 1998, commits the UK to a progressive and substantial reduction of the radioactivity in liquid discharges by adopting best available techniques, such that additional concentrations in the marine environment above historic levels, are close to zero by 2020. This agreement may have an impact on existing disposal routes and requirements for discharges during decommissioning.

5. Decommissioning guidance

As explained earlier the licensing regime is goal setting rather than prescriptive and therefore HSE does not generally issue guidance to the nuclear industry on its expectations. However it has published the Safety Assessment Principles (5) used by its inspectors in assessing licensees' proposals. It also issues more detailed guidance to its inspectors. Over the last few years HSE has been developing and consolidating its guidance on radioactive waste management and decommissioning taking account of Government policy. Because it realised that this was a topic of wide interest, HSE discussed the draft guidance with interested organisations and presented papers at conferences on its emerging thinking. It found this to be a very useful exercise. This work is now complete and the guidance has been placed on the Nuclear Safety Directorate section of the HSE website. The guidance will be reviewed regularly in the light of experience with its use.

The guidance starts with four fundamental expectations for the decommissioning of nuclear facilities, which, should be met so far as is reasonably practicable, they are:

i) In general, decommissioning should be carried out as soon as it is reasonably practicable, taking account of all relevant factors.

ii) Hazards associated with the plant or site should be reduced in a progressive and systematic manner.

iii) Full use should be made of existing routes for the disposal of radioactive waste.

iv) Remaining radioactive material and radioactive waste should be put into a passively safe state for interim storage pending future disposal or other long-term solution.

It then goes on to discuss a number of aspects in more detail and some of these are described below.

5.1 Strategic Planning

Many decommissioning projects are large and complex, hence good strategic planning is essential to ensure that the work proceeds efficiently and the resultant radioactive wastes are managed effectively. The strategy should identify the extent of a licensee's liabilities, describe the means of dismantling each part of the facilities and the management of all the radioactive material and waste. The timescales over which the different stages of decommissioning will take place should be defined. The strategy should be linked to, or integrated with, the strategy for the management of existing radioactive waste and waste which is produced during decommissioning. If a licensee is responsible for a number of nuclear sites then it may be appropriate to provide a corporate strategy supported by series of site-specific strategies.

In selecting a preferred strategy, licensees should demonstrate that they have examined a full range of options covering different timescales, technical factors, social factors and financial factors. Licensees should demonstrate that their strategy is consistent with Government policy and consider the extent to which it is consistent with the concepts of sustainable development and the precautionary principle. It should be clear how the costs of implementing the strategy have been estimated and how the appropriate funds will be provisioned.

Licensees' strategies should take into account uncertainties in the future especially since decommissioning of nuclear facilities will continue for many decades in to the future. The next 50 to 100 years will undoubtedly see many social, political and environmental changes. Over recent years the perception of risk by society has changed and people are becoming more averse to those risks which are imposed upon them, are unevenly distributed, affect future generations or the environment. Other trends such as stricter regulation of radiation exposure, radioactive waste disposal, increased regulation from Europe may place further responsibilities on licensees in the future. The effects of climate change may challenge the design bases on which the plant and structures were originally designed.

In particular estimates of costs will be increasingly uncertain as they are projected into the future. As well as unforeseen influences and events that can lead to additional costs, there are a number of costs which are virtually certain to rise in the future such as those associated with waste management and disposal. Similarly, there is an uncertainty associated with the projection of investment returns into the future to demonstrate adequate financial provision.

5.2 Quinquennial Reviews of Decommissioning Strategy

HSE, in consultation with the environment agencies, has been carrying out quinquennial reviews (QQRs) of licensee's decommissioning strategies as requested by the Government (1). In its review HSE assesses the strategy as to determine whether it is technically feasible and in addition consistent with existing legislation, safety and environmental requirements. HSE will seek to satisfy itself that the strategies remain soundly based as circumstances change. The review also examines the financial provisions to determine whether they are adequate to meet the costs of the decommissioning strategy, and also flexible enough to take account of changes and do not foreclose the option of carrying out decommissioning on an earlier timescale should that be required.

HSE expects licensees to produce a publicly available document setting out their decommissioning strategy, and HSE will in turn publish the conclusions of its review. The first round of QQRs is well underway and it is covering all the UK licensees.

HSE recognises that licensees have undertaken substantial studies to support their decommissioning strategies. However, the area is complex and so it is not surprising that as a result of these reviews HSE has identified the need for further work in areas such as in the identification of liabilities, the clarification of responsibilities and the justification of the timing of dismantling.

5.3 Decommissioning Timetables

One of the key elements that will emerge as a result of strategic planning is a decommissioning timetable and a number of factors will influence the timescale over which decommissioning takes place. Some of these are discussed below. It also needs to be recognised that if necessary, in the interests of safety, HSE may require decommissioning to be completed on an earlier timescale than originally planned.

Government policy (1) states that decommissioning of nuclear facilities should be done as soon as it is reasonably practicable, taking account of all relevant factors and this is recognised in HSE's first fundamental expectation. The next expectation is that the hazards associated with shutdown facilities will be reduced in a progressive and systematic manner, over an appropriate period of time. The rate at which work proceeds will be determined by several factors, each of which will exert a particular influence, and licensees will need to demonstrate that they have considered and balanced these influences in reaching and justifying their proposals on a case-by-case basis. The Government's expectation is that timetables will be developed that were acceptable to the regulators. It follows therefore that decommissioning may proceed as a continuous activity, or if appropriate, as a series of sequential stages, the end result of each stage being a significant reduction in hazard. The order, timing and extent of each stage will be influenced by the hazard posed by a particular plant on a site with the priority being on those with the highest hazard or risk. It is recognised that in some circumstances, actions may be required which temporarily increase risk to enable hazard reduction to take place and this will clearly need to be justified.

Another of HSE's fundamental expectations is that full use should be made of existing routes for the disposal of radioactive waste. At present routes are only available for low level wastes but it is expected that at some time in the future routes will become available for other wastes and HSE will expect licensees to make use of them. In the meantime other wastes, which are potentially mobile should be removed and processed, for passive safe storage (6) pending disposal. In general priority should be given to the most significant hazards which are likely to be represented by the most active materials, radioactivity that is in a mobile form, and waste that is inadequately characterised, packaged, contained in nuclear facilities that do not meet modern standards, or that are deteriorating.

HSE considers that decommissioning techniques are sufficiently developed and proven for licensees to undertake decommissioning of facilities in the short term but recognises that there are potential safety benefits from deferring dismantling of some installations containing short-lived radionuclides. In the particular case of reactors, where the principal form of radioactivity is Co-60 with a half life of 5.3 years, HSE recognises that there are safety benefits from deferring final reactor dismantling for several decades in order to reduce operator and public radiation exposure, and also in reducing the quantity and possibly the classification of radioactive waste that is produced. However, the benefits in radiological safety and waste generation from deferral diminish with time and there will be a point at which there is little further gain. On the other hand, there are nuclear chemical facilities contaminated with plutonium, where the in-growth of americium leads to a radiological hazard that increases with time, and there is a detriment from delaying decommissioning.

The benefits of delay must be balanced against those of placing any hazardous material into a state of passive safety as soon as practicable. In addition, if periods of deferral are proposed, licensees will need to demonstrate that they can ensure long-term safety by maintaining an appropriate organisation, supporting infrastructure and corporate memory. There is also the risk that the physical structures will degrade leading to an increased possibility of leakage of radioactive materials.

In terms of costs, early dismantling of facilities will be more expensive initially, but this must be compared to the long-term costs of deferral, because of the need to maintain the facility in a safe condition, the licensees' infrastructure, the increasing risk of unforeseen routes for environmental releases and other uncertainties associated with the future. In addition, where licensees use discounting techniques to compare costs incurred at different times this inevitably favours the options for delay, and HSE believes that such arguments should be used with caution in justifying the timescales for decommissioning.

The *Precautionary Principle* describes a philosophy for addressing potentially serious risks subject to high scientific uncertainty, particularly where they are in the environmental field and where there are risks that could affect future generations. It basically prescribes that as uncertainty increases then emphasis should increase on reducing the hazard by cost-effective means.

In HSE's view, early decommissioning, particularly where there are few safety benefits from deferral, is more in line with the Government policy of sustainable development and the use of the precautionary principle. In addition, it is noted that, internationally, the approach is for early decommissioning; this is in marked contrast to the approach of some UK licensees.

5.4 Safety Cases

The nuclear site licence requires licensees to produce safety cases for the operation of facilities at all stages of their life, including decommissioning. Indeed the current expectation is that the safety aspects of decommissioning should be considered when the plant is designed. The licence conditions also require that the safety case should be regularly reviewed and HSE's expectation is that a major review should be carried out every 10 years. In addition during decommissioning, the safety case should be updated when necessary to reflect the impact of modifications to the facilities and to address the changing nature of the hazard. Some decommissioning activities may temporarily result in an increase in the risk in order to achieve an overall reduction in the hazard. In such instances, the safety case must identify the impact of the changes and demonstrate that the risks remain at an acceptable level whilst the work is undertaken. Examples of such activities could include partial dismantling of structures, removal of systems, post-operational clean out and radioactive waste retrieval and processing.

Many buildings, structures or equipment may have to remain in place for long periods of time during the decommissioning of a nuclear facility. In such cases the assessment of the continuing safety of the nuclear facility involves determining the current physical condition and establishing how it will change in the future. The safety case should describe the arrangements for the continued surveillance, maintenance and monitoring of the facilities that will ensure that any unexpected degradation will be detected. Similarly, adequate arrangements should be made for detecting leakage of radioactivity.

5.5 Management and Organisation

A fundamental basis of UK nuclear regulation is that the licensee bears the sole and absolute responsibility for safety and that this cannot be delegated to another party. Significant changes in organisational structure and personnel are likely to occur during decommissioning. One of the conditions attached to the site licence requires licensees to have arrangements for management of organisational change. These should be used in advance of shutdown and throughout the decommissioning process which, in some cases, may last for a very long period time. The licensee is expected to have in place an appropriate management structure and numbers of staff, both to fulfill the key roles associated with licensees' responsibilities under the site licence and to provide the general infrastructure to support the project.

Contractors are of course used widely in decommissioning and contribute valuable skills and expertise. HSE has been considering the implications of the use and control of contractors, and other arrangements such as partnering, and has presented its views on a number of occasions (7, 8, 9). In this context, the term intelligent customer has been in use for several years, and essentially it means that a licensee must take steps to retain an adequate capability within its own organisation to understand the nuclear safety requirements of all of its activities, and also those of any contractors; to take responsibility for managing safe operation; and to set, interpret and ensure the achievement of safety standards.

In carrying out decommissioning work there are practical benefits, in terms of doses and costs, to be gained from using workers from the former operating team who have good knowledge of the facilities and the site. If decommissioning is deferred, then it is unlikely that this resource will still be available when dismantling starts. In that case, licensees must make arrangements to capture and maintain the knowledge base, and to assemble and train teams of workers to undertake activities when required, which might be a considerable time into the future.

5.6 De-licensing

The ultimate end point of the decommissioning process is the return of the site to unrestricted use and its release from regulatory control or delicensing. According to the Nuclear Installations Act a nuclear licensee's period of responsibility for the site only ceases when HSE has given notice in writing that, in its opinion, there has ceased to be any danger from ionising radiations on the site or the licence has been transferred to another corporate body. It is clear that the intention of the Nuclear Installations Act is that sites should be able to be delicensed but there is no definitive guidance on the appropriate criteria. It should be noted that there is no facility in UK law for releasing the site for restricted use only.

HSE has delicensed a number of sites in the past. These were mostly research facilities and each case was assessed on its merits. In the most recent cases it was reasonably straightforward to demonstrate that the levels of radioactivity were indistinguishable from background. HSE is currently developing generic criteria for delicensing and a number of papers have been published describing its emerging thinking (10, 11). This will assist in its consideration of applications from more complex sites. In developing criteria HSE will need to take into account forthcoming regulations on radioactively contaminated ground being prepared by the Department of Environment, Transport and the Regions and the Scottish Executive.

As a first step the licensee will be expected to undertake a thorough survey of the site and identify radioactive material including any in structures or in the ground. HSE will generally wish to have an independent survey undertaken on its own behalf before being satisfied the site can be delicensed.

It is HSE's view that it would not be able to delicence a site if it fell above the exemption limits of other legislation such as the Radioactive Substances Act 1993 or the Ionising Radiations Regulations 1999. This implies, for example, that the concentration of most radioactive materials in soil would need to be less than 0.4 Bq/g. In addition HSE would expect the licensee to consider reducing levels further where this is reasonably practicable. HSE believes this approach is consistent with its general approach to risk reduction described in the document "Reducing Risk, Protecting People" (12).

6. Summary and conclusions

The flexible nature of the nuclear licensing regime enables HSE to regulate decommissioning as a stage in the life cycle of the plant. New regulations on the need for an Environmental Impact Assessment before the start of a reactor decommissioning project have recently come into force. Two major projects, at Bradwell and Hinkley Point A are starting to go through the process. HSE has recently issued detailed guidance to its inspectors which has been placed on its website. This will assist a consistent approach to the regulation of facilities being decommissioned.

References

[1] Department of the Environment Review of radioactive waste management policy: Final conclusions Cm2919 HMSO 1995 ISBN 0 10 1291922.

[2] Health and Safety Executive Nuclear site licences under the Nuclear Installations Act 1965 (as amended): Notes for applicants HSE Books 1994 ISBN 0 7176 0795X.

[3] The Government Response to the House of Lords Select Committee Report on the Management of Nuclear Waste, DETR, October 1999.

[4] "OSPAR Convention: Convention for the Protection of the Marine Environment of the North-East Atlantic - the United Kingdom became a signatory at Sintra, Portugal during the Ministerial Meeting of the Oslo/Paris ("OSPAR") Commission in July 1988.

[5] Health and Safety Executive *Safety Assessment Principles for Nuclear Plants,* HSE Books 1998, ISBN 0-11-882043-5.

[6] L Williams, D Mason, S Blakeway and C Snaith *A regulatory view of the long term passively safe storage of radioactive waste in the UK* Proceedings of an international conference on Safety of Radioactive Waste Management, IAEA Cordoba, 13-17 March 2000, IAEA 2000 ISBN 92 0 101700 6.

[7] F E Taylor and D Turton Regulatory Requirements for the use of Contractors on Nuclear Licensed Sites Nuclear Energy, 1998, 37, No 1, 55-58.

[8] F E Taylor and A Coatsworth *Partnering in the Nuclear Industry. A Regulatory Perspective* Proceedings of an International Conference in Alliancing, INE, Erskine, 9-11 June 1999.

[9] F E Taylor Regulatory View of the Nuclear Licensee as an Intelligent Customer Nuclear Energy, 2000, 39, No 3, June, 175-178.

[10] I F Robinson *De-licensing Nuclear sites in the UK* P-9-133 in Proceedings of the 10th International Congress Site International Radiation Protection Association May 14-19 2000 Hiroshima, Japan.

[11] I F Robinson A Nuclear Inspector's perspective on decommissioning at UK Nuclear Sites, J Radiol. Prot. 1999 Vol. 19 No. 3 p203-212.

[12] Health and Safety Executive *Reducing Risk, Protecting People* Discussion Document, HSE Books 1999.