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A Survey of User Requirements for a UK Radioactivity Measurement Infrastructure for Nuclear Decommissioning

J C J DEAN
AND S M JEROME

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J.C.J.Dean and S.M.Jerome
Quality of Life Division

ABSTRACT

The UK nuclear industry is in transition from operation to decommissioning. Many of the nuclear stations built in the latter half of the last century are now reaching the end of their useful lives, and the industry is having to deal with the many technical challenges of decommissioning and site remediation. One of these challenges is the need to measure very low levels of radioactive contamination bound to (or within) any of a wide range of physical matrices (e.g. building materials) for which compositional data is often not available. Some organisations within the nuclear industry had expressed concern over the lack of standards and Reference Materials in this area. Consequently, NPL is to establish a Measurement Infrastructure for Nuclear Decommissioning to address this problem and related needs. In order to define the priorities for the infrastructure, NPL has carried out a survey of users and stakeholders. A limited review of current guidance and training initiatives has also been carried out. The outcome of this project is summarised.

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National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

Approved on behalf of the Managing Director, NPL,
by Dr T D MacMahon, Knowledge Leader (Radioactivity and Neutron Metrology),
Quality of Life Division

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1. INTRODUCTION

Many of the UK's older nuclear facilities are now reaching the end of their working lives, and the industry as a whole is in transition from operations to decommissioning and site remediation. The scale of the clean-up task facing the industry in the coming decades is enormous and is reflected in the establishment of the Nuclear Decommissioning Authority (NDA), which will address the management of what is termed the UK's 'Nuclear Legacy'.

Accurate radioactivity metrology is one of the many technical challenges of this phase of the nuclear cycle. A very wide range of physical matrices (e.g. building materials) require radioassay; very often, the distribution of the radioactivity present is not known and can comprise a mixture of radionuclides with various decay modes and particle/photon energies. The physical nature of the matrix can present further difficulties for the analyst. A major consequence of inaccurate assay of these materials is that waste which is on the 'borderline' of two disposal categories may be needlessly assigned to the higher category, thus incurring large additional costs – a point which has been strongly made to NPL by many organisations active in the field.

The industry itself is starting to address these analytical problems through various initiatives but there is also a need for the establishment of a robust metrological base for this work consisting of traceable standards and Reference Materials and validated sampling and measurement protocols – what is termed a 'measurement infrastructure'. Such an infrastructure would also engender greater public confidence in the industry.

In response to this pressing need, NPL recommended to the DTI NMS-PU that a project be included in its Ionising Radiation Metrology programme for 2004-2007 to establish a Measurement Infrastructure for Nuclear Decommissioning. The draft scope of this project, based on initial discussions with selected key users, was:

(i) to provide Reference Materials to support the 'Nuclear Industry Code of Practice'[1,2];
(ii) to organise a Workshop on 'Metrology for Decommissioning and Site Clearance';
(iii) to participate in the development of the Nuclear Industry Code of Practice.

It was felt by NPL that the objectives of such a project must be more clearly defined to ensure that available resources are being efficiently used and that the industry's needs are being met. It was felt that this could best be achieved via a survey of users and other stakeholders prior to the 2004-2007 programme, and that it would also be useful to identify available guidance and training at the same time. Accordingly, NPL ran such a survey under its 2001-2004 Ionising Radiation Metrology programme. This report summarises its findings.

2. BACKGROUND

The decommissioning of nuclear facilities represents a major task for governments worldwide. The rapid growth of nuclear energy during the latter half of the last century has resulted in a large global stock of operational or shut-down facilities which will require decommissioning over the coming decades. The International Atomic Energy Agency (IAEA) estimates the total cost of this task will be of the order of US $900 billion (approximately £500 billion) over the next fifty years[3].

In the UK, the government will address the management of the nuclear stock via the establishment of the Nuclear Decommissioning Authority (NDA), which became operational in April 2005. This will impact significantly upon many of NPL's customers in the nuclear industry. The functions, duties and powers of the NDA are set out in the Energy Act 2004[4]. Working with the site licencees and the regulators, the NDA will oversee the decommissioning of the UK's public sector nuclear liabilities (known as the 'Nuclear Legacy'). This legacy consists of:

(i) those nuclear sites and facilities which were developed by UKAEA and BNFL in the 1940s, 1950s and 1960s to support government research programmes, along with spent fuel, wastes and other materials arising from this work;
(ii) those Magnox stations built in the 1960s and 1970s and now operated by BNFL (including plant and facilities at Sellafield for the reprocessing of Magnox waste, along with associated wastes and materials);
(iii) liabilities arising from the UKAEA's Joint European Torus (JET) facility at Culham.

The NDA will contract out the management of legacy site decommissioning to other organisations. Although BNFL and UKAEA will continue to manage their own sites for the next few years, they will have to bid for such work in the future.

The estimated cost of dealing with the Nuclear Legacy is estimated at £1 billion per year for the next 10 years and some £48 billion in total. This represents a significant burden on the taxpayer and efficient use of available resources will be important.

A major aspect of this work will be the radioassay and disposal of waste – not only the nuclear fuel itself but also the far greater volumes of potentially contaminated materials arising from building demolition and site clearance. These materials present particular measurement problems in that the material containing or supporting any contamination (the matrix) is often unfamiliar or uncharacterised and the activity levels are frequently very low. If these problems could be overcome and the materials more accurately assayed, potentially large quantities of waste could be correctly classified as being below the LLW category with very significant cost implications for the users. Consequently, some users have asked NPL for advice and for standards and Reference Materials which will improve measurement accuracy. This led NPL, in turn, to seek funding from the DTI to establish a measurement infrastructure to support work in this field. The user survey and review of guidance described herein were carried out in order to better define the initial objectives of this infrastructure project.

3. OVERVIEW OF MEASUREMENT TECHNIQUES

A variety of techniques are used by the industry for the measurement of radioactivity in waste arising from decommissioning work. These will be covered in more detail in

Issue 1 [1] of the Nuclear Industry Code of Practice, which is due for publication in June 2005.

The techniques can be subdivided into two broad categories: those appropriate for measuring activity located within the bulk of a sample, and those appropriate for surface activity measurements.

3.1 BULK MONITORING

Bulk monitoring of α-emitters is difficult because of the short ranges of the emitted particles. Sometimes, the analyte is chemically extracted from a representative sample of the matrix to produce a high-efficiency source which is then measured by α-counting. This enables the user to calculate a detection efficiency, for that particular matrix, for a suitable portable detector (e.g. a ZnS scintillation probe). Bulk monitoring of β-emitters can be carried out using a similar approach, although the higher background count-rates of β-detectors mean that the method is only practical for the higher-energy emitters.

The assay of ß/γ-emitters in bulk material is a very widely used technique. It can be done using small portable detectors (e.g. a NaI(Tl) counter) or trolley-mounted hyperpure Ge detectors. Again, detection efficiencies for a particular geometry can be determined by comparing the response of the instrument with true activity concentrations determined by γ-spectrometry of a representative sample, but, more often, modelling techniques are used to determine such efficiencies. For ground monitoring (e.g. to measure activity in soil over a large area), detectors can be vehicle-mounted.

For repetitive measurements of waste in a particular format (e.g. 200 L drums), an alternative to a portable detector is to use a fixed detector positioned adjacent to a rotating loading platform supporting the sample. This has several advantages and makes the use of a hyperpure Ge detector more practical. Many commercial detectors work on this principle. An example of this is the Segmented Gamma Scanner (or SGS), which uses a moving, collimated γ-detector to measure the activity in horizontal 'segments' of the sample. Another method appropriate for large sample volumes is to transfer the (crushed) sample to a hopper and thence to a conveyor belt which moves under a detector. This makes it easier to locate 'hot-spots' in the sample. A further method is to completely surround the sample with a large-volume detector (usually a plastic scintillator). Plastic scintillators are also used for vehicle monitors which, although not appropriate for clearance and sentencing, are sometimes used as a final check on material leaving site, or to ensure that material is acceptable for recycling.

3.2 SURFACE MONITORING

Surface α-emitters are measured using instruments such as ZnS scintillation detectors, gas proportional counters, silicon diode detectors and ion sensors (which work by drawing air across the sample and into an ionisation chamber, which measures the ions produced by any surface α-emissions). Surface ß-activity is measured using detectors such as thin β-scintillators and large-area proportional counters, whereas surface X-rays and low-energy γ-rays can be assayed using, for example, thin NaI(Tl) and CsI(Tl) scintillators or proportional counters. Surface monitoring is sometimes carried out using portable instruments but is also done using arrays of detectors in the form of 'tables' to hold the samples. Conveyor belt systems are also used.

Surface tritium is sometimes measured, but such measurements are of limited value because of the high mobility of this radionuclide.

Surfaces are sometimes monitored indirectly using wipes, and several detector types (e.g. scintillation counters and GM tubes) are used depending on the particles emitted, the wipe material and the conditions.

3.3 FINGERPRINTS

An important aspect of metrology in decommissioning is the fingerprint. This is a set of ratios which indicate the relative proportions of the radionuclides present in a particular operational area. The fingerprint is determined by γ-spectrometry and/or radiochemical analysis of several samples from the area of interest. Often, some of the radionuclides in a fingerprint are not detectable using a given monitor, and one or more of the radionuclides which are detectable will be directly measured and the activities of the others inferred from the ratios. The stability of the fingerprint is sometimes a concern, and this sometimes requires checking, either by full radiochemical analyses or by more direct methods.

4. OVERVIEW OF CURRENT GUIDANCE AND TRAINING

A number of documents are already available providing guidance on metrology in this area. Some of these are summarised below.

4.1 NUCLEAR INDUSTRY CODE OF PRACTICE

The principal guidance document currently available to the nuclear industry on the 'clearance' (see below) and sentencing of articles and materials is the interim version[2] of the 'Nuclear Industry Code of Practice on Clearance and Exemption Principles, Processes and Practices' (n.b. This will be superseded by Issue 1 [1] in June 2005.). The background to this document, and its content, are summarised below. The interim version is currently available online[2].

The need for guidance in monitoring for the clearance of radioactive items and substances was recognised in 1992 by the UK's Health and Safety Policy Exchange Meeting (HASPEM), which set up an intra-industry working group to develop a document for use by the industry which subsequently became known as the 'HASPEM document'[5]. The document specified industry-agreed values for the clearance of surface-contaminated materials and took account of the Exclusion and Exemption limits specified in the then current Radioactive Substances Act 1960[6], the Radioactive Substances (Substances of Low Activity) Exemption Order 1986 (as amended 1992)[7] and other Exemption Orders.

A detailed review and revision of the HASPEM document was undertaken in 2001, beginning with a workshop (organised jointly by the industry's Clearance and

Exemption Working Group (C&EWG) and Health Physics Operational Liaison Meeting (HPOLM)) attended by all the large nuclear organisations and the regulators. The workshop took account of recent directives and regulations[8-12] and the shift of UK policy towards clearance of materials whenever practicable. It was recognised that clearance should involve minimising the possibility of materials becoming contaminated in the first place and documenting the history of such materials whenever possible. The conclusions of the workshop were developed (in the context of parallel discussions with the regulators) to produce a document which, by agreement within the industry, was designated as the Nuclear Industry Code of Practice, with the full title given above. For convenience, this document is referred to hereinafter as the CoP. Its development and production are the responsibility of the Clearance and Exemption Working Group, and NPL staff regularly attend meetings of this group.

It should be noted that, although the proper application of the methods given in the CoP should result in compliance with relevant legislation, it is compliance with the legislation itself rather than the CoP that is required. It should also be noted that the CoP is not itself a working-level procedures document but rather an aid for the development of such procedures.

The CoP comprises:

(i) clarification of the nuclear industry's interpretation of relevant legislation;
(ii) agreed good practice where legislation is imprecise or unclear;
(iii) a standard management framework for safe and efficient clearances;
(iv) agreed guidance on required principles, processes and practices.

These broad sections are summarised below

4.1.1 The nuclear industry's interpretation of relevant legislation

The most widely applied legislation in radiological clearance is the Radioactive Substances Act 1993[8], the Radioactive Substances (Substances of Low Activity) Exemption Order 1986 (as amended 1992)[7] and the Radioactive Substances (Phosphatic Substances, Rare Earths etc.) Exemption Order 1962[13] (n.b. These are referred to hereinafter as RSA 93, SoLA and PSRE respectively.). RSA 93 requires disposals of radioactive materials to be carried out only under authorisation from the Environment Agency (EA) or Scottish Environmental Protection Agency (SEPA) unless they are <u>excluded</u> by the act itself or <u>exempted</u> by SoLA or PSRE. The processes of exclusion and exemption usually involve radioactivity measurements (to determine whether the activity concentration is below specified limits) and meeting other requirements, and articles or substances which have been excluded or exempted are termed as <u>cleared</u>. The CoP provides the best currently-available guidance on the treatment and clearance processes, including the <u>sentencing</u> stage, where the article or substance is designated as clean, excluded, exempt or radioactive.

<u>SoLA</u> specifies that waste is exempt if:

(i) it is substantially insoluble in water and has an activity concentration < 0.4 Bq g^{-1};

(ii) it is organic liquid waste containing only ^{3}H or ^{14}C and its activity concentration is < 4Bq ml^{-1};
(iii) it is gaseous waste in which none of the radionuclides present has a half-life > 100 s.

PSRE specifies that solid waste is exempt if it is substantially insoluble in water, is radioactive solely due to the presence of one or more elements specified in Schedule 1 of RSA 93 and that the activity concentration of none of these elements exceeds 14.8 Bq g^{-1}.

The CoP describes how to apply SoLA and PSRE activity limits and how background and insolubility criteria are defined.

4.1.2 Agreed good practice

This section specifies policies and practices to adopt where legislation/guidance are considered by the authors to be imprecise or unclear. It covers the applicability of the clearance process in the CoP, the general applicability of RSA 93, SoLA and PSRE, limitations on dilution and bulk sampling, confidence levels and sampling volumes for the sentencing of solids, consideration of adsorption effects when measuring certain radionuclides on surfaces, and the need for reference surface clearance levels.

4.1.3 Management frameworks

This section sets out waste management objectives aimed at achieving sustainable development, and the management principles and arrangements necessary to support those objectives. These include principles relating to safety, the environment and plant operation, and arrangements for Quality Assurance and the clearance and sentencing process.

4.1.4 Guidance on principles, processes and practices

This constitutes the vast bulk of the CoP. It includes the measurement scenarios for which Reference Materials may be required.

The possible scenarios are described and presented as a series of flow-charts which guide the user to the correct sentencing outcome via a sequence of measurements, actions and decisions. Details of sampling and measurement procedures are not given at this stage. The sentencing of solids is more complex than that of liquids or gases and consequently most of the scenarios relate to solid matrices.

The first three scenarios describe the clearance of:

(i) solid items and materials believed to be clean;
(ii) potentially surface-contaminated items;
(iii) high surface-area-to-volume items, materials and clothing.

Scenarios (i) and (ii) can lead to any of a further nine scenarios describing the sentencing of:

(iv) potentially activated solids;
(v) potentially tritiated solids;
(vi) potentially contaminated loose solids;
(vii) potentially contaminated porous solids;
(viii) potentially contaminated impervious solids with accessible surfaces;
(ix) potentially contaminated impervious solids with inaccessible surfaces;
(x) potentially contaminated aqueous or non-aqueous liquids containing sludges and/or suspensions;
(xi) potentially contaminated aqueous or non-aqueous liquids not containing visible amounts of any insoluble solids;
(xii) potentially contaminated gases or vapours (including aerosols if present).

Subsequent chapters of the CoP do not appear in the interim version. Issue 1 [1] will include these. A chapter on the statistical basis of sampling will recommend sampling and data analysis protocols for situations in which surface or and bulk measurements are needed and where it is not possible or practical to measure 100 % of the surface or material. The chapter on measurement practices will cover the principles of monitoring, wiping and sampling, including important considerations and limitations in their use. The areas covered will include:

(i) bulk α-, β- and γ-monitoring;
(ii) surface α-, β-, X-ray- and low-energy γ-monitoring;
(iii) surface monitoring by wipe;
(iv) radioassay via sampling and radiochemical methods.

4.2 GOOD PRACTICE GUIDES

NPL measurement Good Practice Guides (GPGs) enable users to improve measurement quality. They describe current best practice and are compiled by specialists in the particular subject area covered. Five GPGs have particular relevance to measurements for clearance and sentencing, namely:

(i) GPG014: The Examination, Testing and Calibration of Portable Radiation Protection Instruments[14];
(ii) GPG029: The Examination, Testing and Calibration of Installed Radiation Protection Instruments[15];
(iii) GPG030: Practical Radiation Monitoring[16];
(iv) GPG034: Radiometric Non-destructive Assay[17];
(v) GPG049: The Assessment of Uncertainty in Radiological Calibration and Testing[18].

GPG014 recommends procedures for the general examination, testing and calibration of the types of portable instruments often used in clearance work. Although the testing regimes contained within GPG014 have no actual legal standing, they have been compiled on the basis of HSE guidance, additional research and discussions of experts at NPL's Ionising Radiation Metrology Forum (IRMF), and it is the view of IRMF that use of these regimes will enable users to comply with legal requirements.

This document includes some guidance on calibration. Large-area sources are available for calibrating surface-contamination monitors and these should conform to the specifications outlined in ISO 8769, Part (1)[19] and Part (2)[20]. They should reflect the types and energies of the radiation likely to be encountered in the workplace. For α-particle measurements, suitable calibration radionuclides are ^{241}Am, ^{238}Pu and, as a low-energy standard, ^{238}U. For ß-particle and photon measurements, one of the radionuclides selected for the test should have an energy equal to or less than that of the minimum photon energy expected to be found in the workplace. Problems can arise with multi-energetic photon emitters because of the variation of detection efficiency with photon energy; best practice in such cases is to use a calibrated source of the radionuclide concerned.

GPG029 provides similar guidance for installed radiological protection instruments.

GPG030 recommends methods and procedures for the practical monitoring of a facility. It covers surface-contamination and dose-rate monitoring only and does not include advice on the monitoring of waste; however, much of the advice may be applicable in decommissioning scenarios, for example:

(i) gathering information on the area, such as the processes which have been carried out and the radionuclides likely to be present;
(ii) defining the monitoring strategy, particularly the selection of monitors and methods appropriate for the measurement of various radionuclide types on surfaces, determining detection efficiencies for various analytes and taking account of surface coating such as paint.

GPG034 provides general guidance in Non-Destructive Assay (NDA). It was compiled by a working group of experts from across the industry and is applicable to measurements in many different areas and can undoubtedly be applied to measurements in decommissioning, covering as it does a range of neutron counting, γ-spectroscopy and other techniques. It includes guidance in areas such as calibration, standards and the treatment of uncertainties.

According to GPG034, guidance on calibration of NDA equipment is available from ANSI standards[21] and other documents such as Sampson and Goldman[22]. Essentially, calibration is achieved either by recording the response of the detector to an appropriate reference standard or by using modelling techniques to calculate the response to a theoretical standard. In practice, a combination of the two is usually adopted (i.e. the response of a standard different from the sample is recorded, and the response of the sample is adjusted by use of factors to correct for sample geometry, matrix density, etc.). The variation of response with source position is often measured by recording the response of a point source located at various places within the measurement container (appropriate corrections having been applied for sample density, etc.). These data can be used to derive a mean efficiency for the container volume as a whole, and this may be applicable to homogeneous samples. Where the sample is heterogeneous, it may be prudent to weight the calibration towards the areas of minimum response and thus avoid underestimating the activity; however, this may well introduce a bias to some readings which may in turn have implications for disposal costs.

GPG034 also points out that standards should ideally have the same chemical and physical composition as the material to be assayed. If this is not the case, then it is essential that the relevant correction factors and their associated uncertainties are accurately known. The standards must be traceable to national standards of radioactivity.

The treatment of uncertainties is covered in definitive documents such as the Guide to the Expression of Uncertainty in Measurements[23]. For NDA measurements, the following are just some potential sources of uncertainty which may contribute significantly to the overall uncertainty and must therefore be accurately measured or estimated:

(i) Instrument reading
(ii) Background
(iii) Calibration
(iv) Sample geometry
(v) Matrix effects
(vi) Isotopic composition
(vii) Radionuclidic interferences

GPG049 complements the guidance given in M3003[24] by illustrating how uncertainties may be evaluated in various radioactivity measurement situations (e.g. the calibration of surface contamination monitors).

4.3 OTHER GUIDANCE

The International Atomic Energy Agency (IAEA) introduced the subject of decommissioning into its programme in the 1970s, and since 1980 over twenty publications have appeared in its catalogue. A limited number of these are described below. Others[25-30] appear relevant but had not been obtained at the time of writing. Many are available on-line at the IAEA website[31]. It is understood that new IAEA documents relevant to this area are in preparation.

IAEA Technical Report 334 [32] is a planning document which provides an overview of all the factors to be considered when establishing a monitoring programme for unrestricted releases of materials. It briefly covers the derivation of release criteria (in dose-equivalent terms) and the derivation of other quantities (such as activity concentration limits) from these criteria, and summarises unrestricted release practices used in different countries. It recommends that, in determining a monitoring programme, one should consider the type, history and age of the facility and then make decisions regarding which radionuclides to analyse for and in which locations. It points out that statistical sampling is sometimes necessary, and provides some basic guidance and references. Choice of instrumentation is discussed. Although details of instruments are not given, it provides guidance on instrument selection: for example, the monitor must have a sufficiently low Minimum Detectable Activity (MDA) for the measurand; it may be necessary to measure radionuclides not encountered during normal reactor operations; and instruments must be calibrated for the geometry of the measurand. Theoretical calculations of activity (e.g. from compositional and neutron flux data) are mentioned as useful for supplementing actual measurements in some cases.

This report recognises that the control of low-level decommissioning waste is a major issue for both operators and regulators. It is interesting to note that this document appeared twelve years ago, suggesting that this is a more established subject at the international level than in the UK.

Technical Report 389 [33] is also pertinent. Primarily, it covers characterisation as a precursor to decommissioning, but the radiometric methods and techniques described are also applicable to measurements made during the actual decommissioning process. A comprehensive list of radionuclides encountered in decommissioning scenarios is given, along with some basic nuclear data[*], information on how and where the radionuclide arises, and basic guidance on appropriate measurement procedures.

Three documents in the IAEA Safety Standards Series [34-36] address the planning and safe management of the decommissioning of a wide range of facilities (e.g. nuclear power plants, research reactors, medical, industrial and research facilties) and mention the importance of the waste characterisation aspect of the process. Final plans should include a description of waste management practices, including characterisation and criteria for segregation. It is pointed out that ‘national regulatory authorities should provide guidance on radiological criteria for the removal of regulatory controls over the decommissioned installations and sites and should ensure that an adequate system is in place for properly managing the removal of controls’. Decontamination (leading to clearance, recycling or reuse) can minimise waste volumes, and decontamination strategies should include ‘an ability to demonstrate by measurement that the target decontamination level has been reached’. Two documents[37,38] in the Safety Series discuss exemption principles and their application, and Technical Report 376 [39] and IAEA-TECDOC-864 [40] provide guidance on the quality assurance of waste packages.

A limited search of the ISO website[41] revealed a few relevant documents in addition to the ISO standards[19,20] cited above. ISO 11932:1996 [42] provides guidance on activity measurements for materials to be cleared or recycled, and ISO 14850-1:2004 [43] describes a procedure for the assay of γ-emitters in unconditioned waste in a range of matrices and containers. Additionally, an ISO draft[44] of a standard guide for γ-spectrometric measurements of waste packages using Ge detectors has been obtained.

4.4 SRP WORKSHOPS

The Society for Radiological Protection (SRP), via its Practical Radiological Protection Topic Group, has run two workshops on the Practical Aspects of Radiological Clearance in response to the increased amount of work in this field. They have provided perspectives from various groups (e.g. the nuclear industry, the regulators, pressure groups, the scrap metal industry and waste companies) and have given practitioners the opportunity to discuss problems during informal workshop sessions on specific aspects of the subject (e.g. ^{3}H measurements, surface and bulk activity measurements, sampling and radiochemical analysis). It was clear from these workshops that meetings of this type fulfil a valuable role in the decommissioning community by keeping industry members informed of developments, by providing feedback to stakeholders and by providing a forum for discussing measurement issues.

[*] Note that NPL-recommended nuclear data may differ from that cited in this Technical Report.

5. USER SURVEY

5.1 OVERVIEW

In order to determine the exact needs of the user community in the UK in respect of standards and services for decommissioning, several site visits were made to organisations currently active in the field. The visits were also useful in forming contacts for NPL and in obtaining an overall picture of the 'decommissioning industry' in the UK. Many of these meetings involved representatives of more than one organisation, or more than one function within an organisation (see below). Some organisations (both operators and contractors) were represented at more than one site.

Discussions were held with the following site operators:

- AWE Aldermaston
- BNFL, Risley and Sellafield
- G E Healthcare (formerly Amersham Health), Amersham
- UKAEA, Dounreay, Harwell and Windscale

Similarly, meetings were held with the following service providers:

- AEA Technology Analytical Chemistry Team, Winfrith
- NIRAS (NNC Independent Radiation Assessment Services), Warrington
- NNC Limited, Winfrith
- RWE NUKEM, Harwell and Winfrith

The individual contacts canvassed in the survey represented a variety of work areas. These included:

(i) Operations
(ii) Decommissioning
(iii) Waste management
(iv) Health Physics
(v) Radiation Protection
(vi) Instrumentation design
(vii) Non-Destructive Assay
(viii) Radiochemistry
(ix) Quality Assurance
(x) Consultancy

Finally, meetings were held with some instrument manufacturers to identify current technology in radioactive waste characterisation and to obtain their perspective on the metrological problems faced by the industry. The manufacturers were:

- BIL (formerly BNFL Instruments), Sellafield
- Canberra Harwell Ltd, Harwell

n.b. The above organisations are known to NPL and were together felt to represent a reasonable 'cross-section' of the industry. However, it should be noted that their inclusion in this study is not meant to imply that NPL prefers their services/products to those of other service providers and manufacturers.

Details of all the individuals consulted, and full addresses, are given in Appendix 1.

5.2 SAMPLE TYPES

The users were asked to cite the matrices they typically encounter in their decommissioning activities. Figure 1 summarises the responses obtained. The responses were not based on actual documented records but were estimates from their recent experience.

As one might expect, the matrices of greatest interest are those arising from building structures (e.g. concrete, steel, brick and timber), substructures (e.g. soil) and contaminated items arising from system decontamination and dismantling (e.g. Personal Protective Equipment and non-specific metals). Graphite, Zinc Bromide, oils and sludges were also cited by more than one organisation.

Similarly, the users were asked which radionuclides or radionuclide categories they typically have to measure. The responses are summarised in Figure 2.

Tritium was cited more than any other radionuclide. This reflects its increasing importance, as evidenced by the recent establishment of the Tritium Users Group in the UK. This radionuclide can be produced by several mechanisms. Its low-energy ß-emission and high mobility in many matrices can lead to significant measurement difficulties.

Not surprisingly, other activation products, and also fission products and actinides, were frequently cited as well; ^{60}Co, produced by activation of trace levels of stable ^{59}Co in steels, translocates and deposits throughout reactor systems. It is readily detected by γ-spectrometry and is often used in conjunction with a fingerprint. The radionuclide ^{14}C can generate a significant contribution to the radioactive inventory, particularly in concrete and graphite, and ^{90}Sr and ^{137}Cs are well-known as being among the most abundant fission products.

The radionuclide ^{226}Ra is ubiquitous in soils and in building materials, and was cited by two organisations. The importance of this radionuclide may grow as more organisations reach the site remediation stage of the decommissioning process.

The activity levels of materials encountered in decommissioning vary considerably, and it was difficult for the users to provide an accurate estimate of these levels. Many of them gave an estimate by reference to waste categories. Most of these users are measuring materials with activity concentrations corresponding to a range from the 'Free release' category up to the Intermediate-Level Waste (ILW) category, although one user was categorising most material as Low-Level Waste (LLW) or ILW.

The term 'Free release' has been used historically to indicate that an article or material has been released from controls on the basis of radioactivity measurements;

however, this process is subject to stringent controls, so the term 'Controlled clearance' is preferable.

LLW has an activity concentration limit of 4 kBq g^{-1} for α-emitters and 12 kBq g^{-1} for ß/γ-emitters; non-heat generating waste with concentrations above these limits is classified as ILW. If waste is heat generating, it is classified as High-Level Waste (HLW).

5.3 DETECTOR TYPES

A wide range of instruments of the types described in Chapter 3 above is commercially available in the UK. Detector types include:

(i) Low-resolution γ-detectors (e.g. NaI(Tl) crystals)
(ii) High-resolution γ-detectors (e.g. Ge crystals)
(iii) Ion sensors

These can be used in various formats, e.g.:

a) Portable γ-imagers (for locating 'hot-spots')
b) Basic in-situ monitors
c) Segmented/tomographic scanners

They can be used for a variety of commonly-encountered waste packages (e.g. crates and 200 L drums). Some units are 'integrated' (e.g. combining more than one detector type). The more elaborate systems have conveyor-belt systems to facilitate rapid sample assay.

The detector types actually deployed by the users surveyed in decommissioning situations are summarised in Figure 3. Of the bulk NDA techniques, γ-spectrometry appears to be the most widely used. However, many measurements are carried out using other instrument types, such as portable surface contamination monitors and scintillation probes (e.g. for post-decontamination checks in the field) and techniques used following radiochemical processing, such as Liquid Scintillation Counting, α-counting and ß-counting.

Detectors are used for any of the following:

- sentencing measurements;
- radionuclide fingerprint determination;
- screening measurements.

Most of the organisations are, of course, sentencing materials themselves or making measurements to support such decisions elsewhere, and most of the instruments cited are used for this purpose. Often, fingerprints (derived by radiochemical analysis or mass spectrometry) are used in conjunction with the responses of portable monitors, although one organisation uses radiochemical analysis alone for sentencing decisions. The uncertainty on fingerprint ratios are assumed to be small compared with overall uncertainties on actual measurements. Radiochemical analysis is sometimes used if the material under study is thought to be porous.

One organisation carries out screening measurements to categorise waste as LLW or ILW, but does not do so for clearance purposes. They use a variety of instruments, such as scintillation probes, gas-filled detectors, high-resolution γ-spectrometers and passive neutron counters. Another organisation uses screening for initial characterisation of soil surfaces using low-resolution γ-spectrometry.

5.4 CURRENT CALIBRATION PROCEDURES AND USER REQUIREMENTS

There is apparently no common practice for the calibration of low- or high-resolution γ-spectrometers for clearance work. In some cases, ‘point’ sources are used in conjunction with inert matrices to derive correction factors for absorption within the matrix. Indeed, one manufacturer provides calibrations for its SGS systems (prior to shipment) using a series of test drums, each containing a series of mixed-radionuclide calibration ‘rods’ in an inert matrix of known density. These standards are from the USA and the accuracy of these calibrations is claimed to be approximately ± 3 %. Some instruments provide an external γ-emitting ‘transmission source’ which enables the user to correct for self-absorption. Some users X-ray and weigh drums to determine fill height and weight, and therefore density.

Others use commercial software to derive an efficiency calibration. A common example of this is ‘ISOCS’ (In-Situ Object Counting System) which calculates the detection efficiency of radionuclides from a source when provided with details such as source shape, composition and counting geometry.

One laboratory submits sub-samples of assayed material to an outside laboratory as an alternative.

For portable instruments such as surface contamination monitors, calibrations are carried out using single nuclide sources of α-emitters and ß-emitters, in either ‘point source’ or large-area formats.

This initial survey has revealed a wide range of customer requirements for standards and reference materials. This is probably due partly to the limited number of organisations canvassed – a larger survey would have perhaps better revealed the ‘dominant requirements’ of the industry. The wide range of requirements also reflects the sheer diversity of the work being carried out in this field.

Some organisations felt that the needs of the industry would best be served by the provision of comparison exercises, proficiency tests, etc. rather than by the provision of ‘off-the-shelf’ Reference Materials. One felt that Reference Materials would not be practical because of the large volumes of matrix involved, and another felt that the use of point-sources, solid matrices and transmission sources as above would be the best approach. Four of these organisations between them suggested a range of radionuclides, matrices and sample formats. These were:

- ^{3}H
- ^{14}C
- ^{36}Cl

- ^{54}Mn
- ^{55}Fe
- ^{90}Sr
- ^{137}Cs
- ^{226}Ra
- Other fission products
- Other activation products
- Actinides

- Aqueous solutions
- Concrete
- Graphite
- Liquid scintillants
- Naturally-Occurring Radioactive Material (NORM)
- Oil
- Sludge
- Soft wastes
- Soil
- Steel

- 200L drums
- 1m^3 'Jencons' bags
- 80-90L cylinders
- HEPA filters

Two laboratories suggested that suitable activity concentrations would be around the SoLA Exemption Order limit of 0.4 Bq/g, although one laboratory suggested that 10 Bq/g for α-emitters, and 1 kBq/g for ß- and ß/γ-emitters, would be more suitable for the industry as a whole.

One organisation suggested it would actually be useful to prepare Reference Materials using some of the above radionuclides, matrices and formats. They also felt that NPL should consider the need for standards for the radionuclides which BNFL require waste consignors to quantify before they will accept the waste at their Drigg site.

Another suggested that, if NPL were to develop Reference Materials, perhaps it would be most advantageous to prepare just one or two based on the commonly-encountered matrices (e.g. concrete, steel or gloves). They also suggested that it would be useful to develop some Reference Materials specifically to validate efficiency calibrations derived from ISOCS. Another laboratory suggested that an instrument calibration 'pad' (e.g. γ-emitters in a layer of concrete) would be useful for type-testing purposes.

Other suggestions for standards include:

- Low-energy standards for α-emitters
- Standards which 'mimic' true samples (e.g. large-area sources with coated surfaces)
- Large-area sources with activities at the sentencing levels

5.5 OTHER USER REQUIREMENTS

A number of requirements additional to the provision of Reference Materials were raised during the user survey. It is clear from these requirements as a whole that there is a need for NPL to provide guidance, procedures or training in a number of areas.

(i) There is a need for guidance in the sampling and analysis of a range of radionuclides/radionuclide types (e.g. ^{3}H, ^{226}Ra, α-emitters and γ-emitters). A lot of this expertise has been developed by senior analysts in the industry but has not been formally documented and there is concern that this will be lost as these more experienced analysts retire.

(ii) There is a need to develop radioanalytical procedures for the unusual matrices now being encountered by analysts. These must take into account the safety problems arising from analysing large volumes of material (e.g. when using combustion methods).

(iii) A problem with 'decommissioning waste' is that the activity levels are often extremely low and the issue of distinguishing 'activity' from 'background' has been raised. This is particularly difficult with a moving detector (e.g. when screening a surface with a surface contamination monitor), and guidance here was requested.

(iv) The need to quantify radionuclide 'pick-up' factors for various materials used for swabbing various surfaces was also mentioned.

(v) Another issue raised was the need for training of key groups and stakeholders within the industry. Some users feel that groups such as the client base and the regulators lack expertise in key aspects of radioactivity metrology and that NPL should address this.

(vi) Several users raised concerns about the methodology of sampling. There is a shortage of guidance on this subject and it is apparently difficult to identify a definitive document; however, as mentioned in Chapter 4 above, this will be included in Issue 1 [1] of the CoP.

6. DISCUSSION

Several key issues have arisen from this study.

It is clear that the CoP is a key document for the industry and a major aid to project managers in planning clearance work. It may become an 'industry standard' in this area and it is therefore essential that the specialist metrological advice that NPL can provide continues to influence its development. Some users see this as an important aspect of NPL's decommissioning initiative.

In addition to the CoP, this study has revealed a number of other extant documents relevant to this area, such as NPL Good Practice Guides and the growing list of IAEA publications relating to nuclear decommissioning. It is also evident that the users canvassed have requirements for additional guidance in a number of areas. Input from a larger number of users would help to clarify the predominant needs of the industry as a whole, and it may therefore benefit the industry if NPL were to canvass the delegates at the NPL workshop on this issue with a view to developing proposals for new guidance documents, etc.

The SRP workshops were an important industry initiative and their experts have much valuable experience in this field. Their involvement in planning and running the NPL workshop would be invaluable.

The main objective of the study had been to gain an overview of the status of metrology in the industry and the needs in terms for standards and Reference Materials. In the time available, it was possible to canvass only a relatively small number of organisations, but it was felt that those consulted represented a reasonable cross-section of industry stakeholders. Sufficient data was obtained to reveal some predominant measurands, matrices and detector types, but the priority user requirements were less clear and it was felt that another function of the NPL workshop should be to clarify the industry's priorities here also.

By the completion of this study, the draft of the NPL infrastructure project (see Introduction above) for 2004-2007 had been approved by the DTI, and funding for the project had been confirmed.

7. RECOMMENDATIONS

In conclusion, it is recommended that NPL should:

(i) hold its workshop on Metrology for Decommissioning and Site Clearance early in the 2004 – 2007 programme with the aim of better defining the priorities for required standards, Reference Materials, guidance and training;
(ii) develop (as planned) one or more priority Reference Materials, comparison exercises, etc. as identified by the workshop;
(iii) define, and seek funding for, additional NPL projects identified by the workshop;
(iv) continue to contribute to the ongoing development of the CoP, as planned;
(v) continue to develop its knowledge of the UK nuclear decommissioning industry with a view to addressing future needs in radioactivity metrology.

8. ACKNOWLEDGEMENTS

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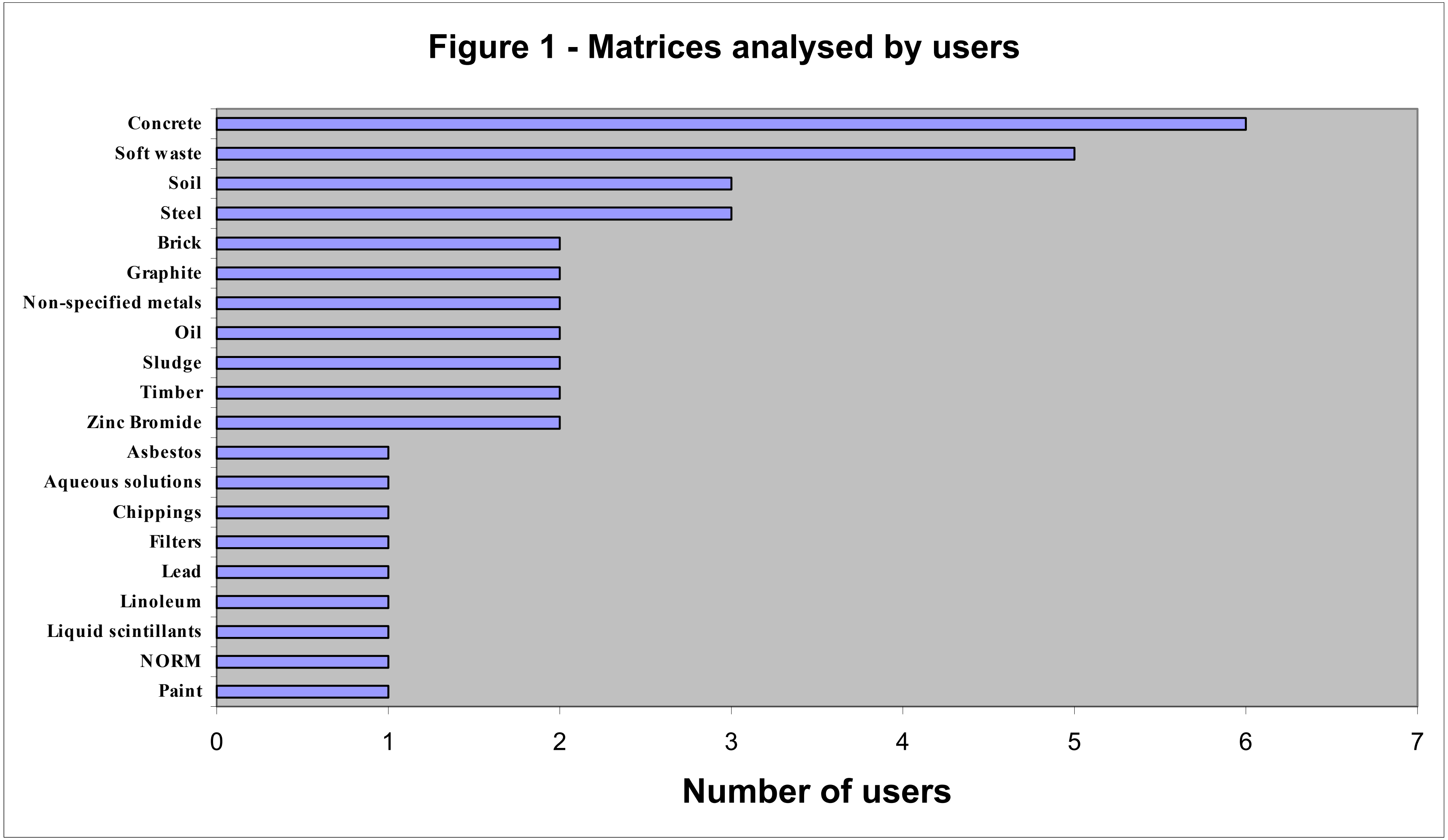


Figure 1 - Matrices analysed by users
Concrete
Soft waste
Soil
Steel
Brick
Graphite
Non-specified metals
Oil
Sludge
Timber
Zinc Bromide
Asbestos
Aqueous solutions
Chippings
Filters
Lead
Linoleum
Liquid scintillants
NORM
Paint
0
1
2
3
4
5
6
7
Number of users

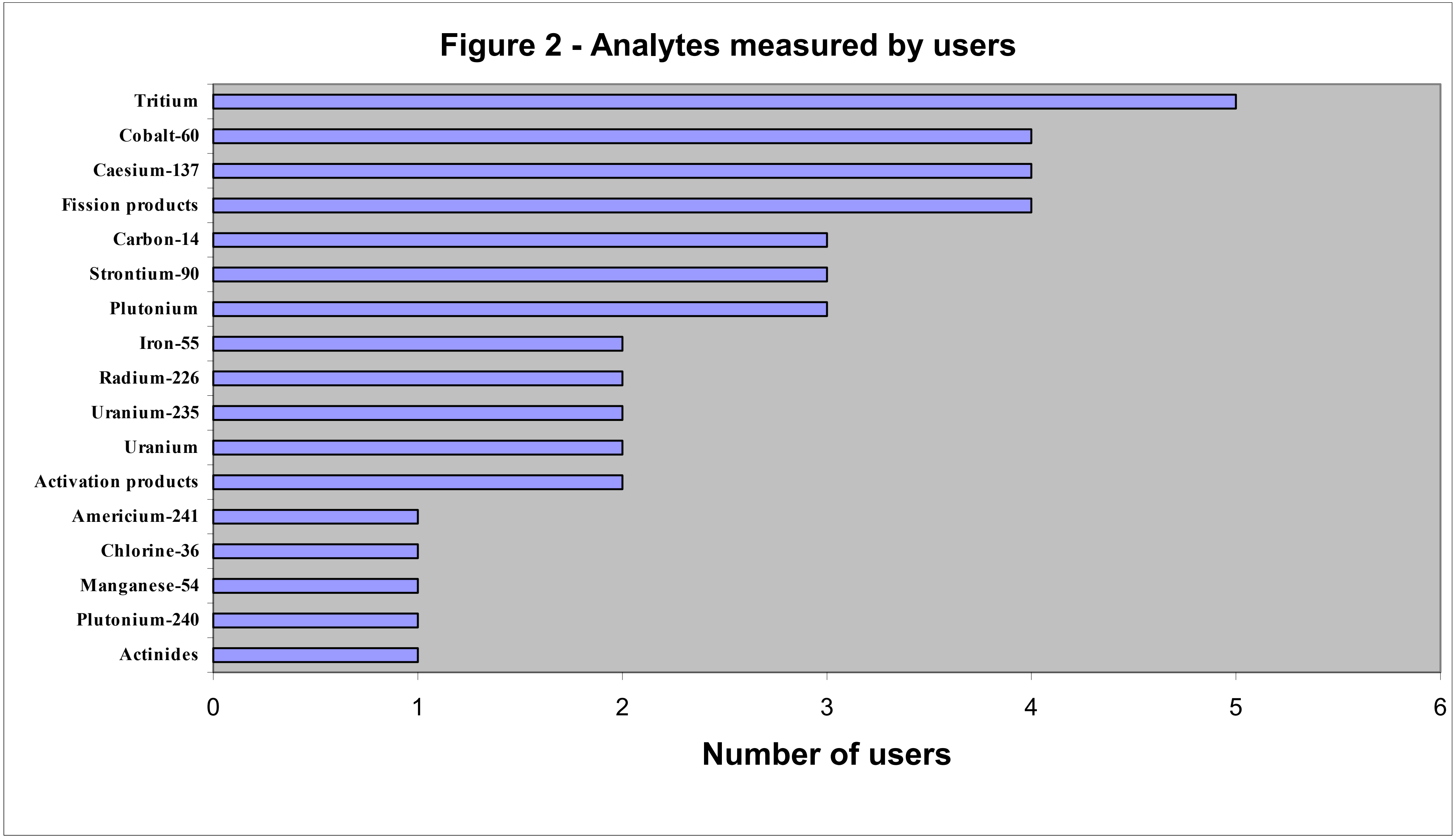
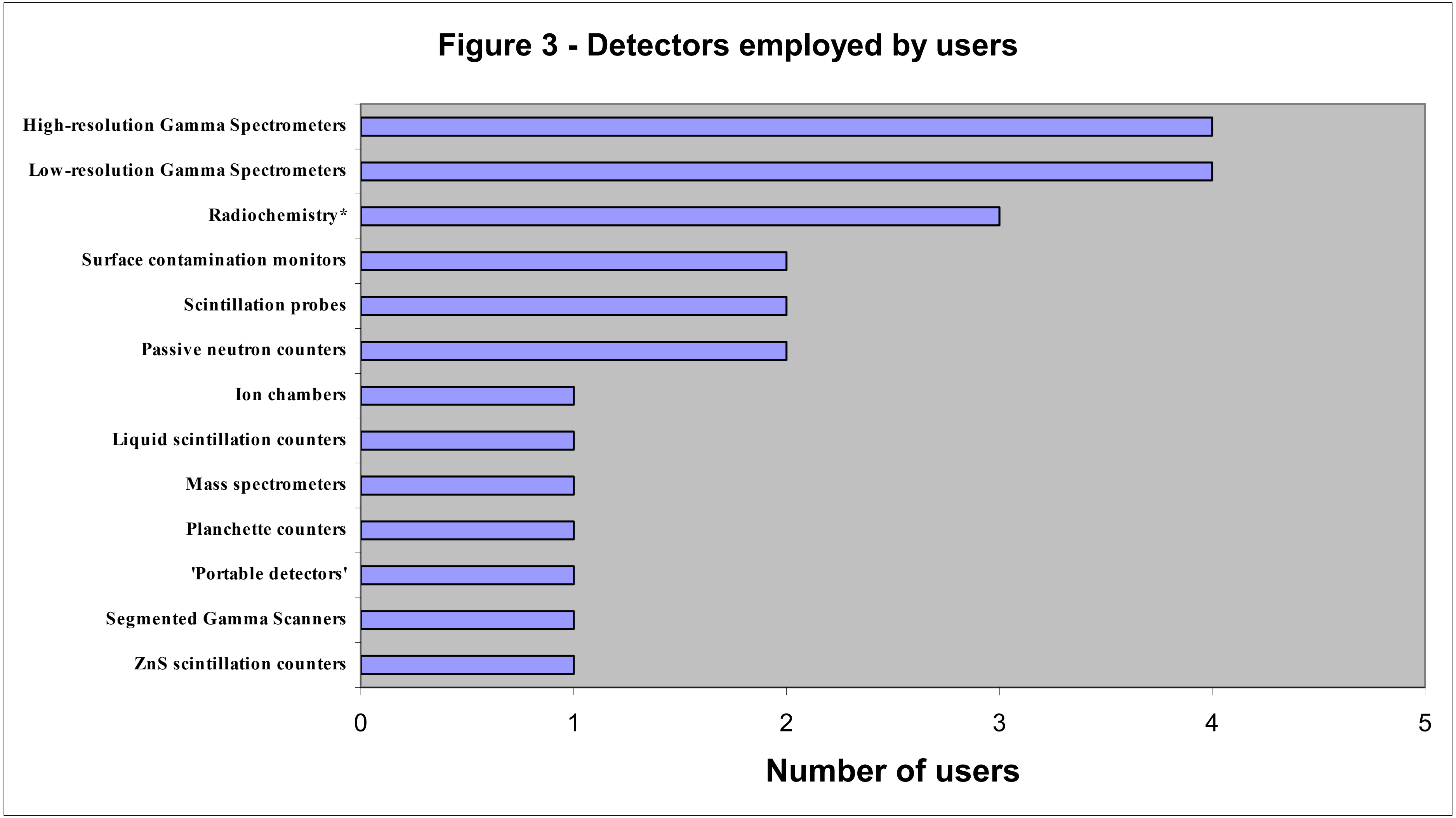


Figure 2 - Analytes measured by users
Tritium
Cobalt-60
Caesium-137
Fission products
Carbon-14
Strontium-90
Plutonium
Iron-55
Radium-226
Uranium-235
Uranium
Activation products
Americium-241
Chlorine-36
Manganese-54
Plutonium-240
Actinides
0
1
2
3
4
5
6
Number of users



* i.e. detectors used subsequent to radiochemical separations

APPENDIX 1

LIST OF CONSULTEES

Mr I Adsley
RWE NUKEM
Harwell International Business Centre
Harwell
Didcot
Oxon. OX11 0TA

Mr N Ardern
AWE
Aldermaston
Reading
Berkshire RG7 4PR

Mr D Baker
NIRAS
NNC Ltd
The Renaissance Centre
601 Faraday Street
Birchwood Park
Warrington WA3 6GN

Ms J Barnes
NIRAS
Warrington

Mr M Bennett
UKAEA
Dounreay
Thurso
Caithness KW14 7TZ

Mr P Booroff
AWE
Aldermaston

Mr K Bradshaw
NIRAS
Warrington

Mr P Burgess
UKAEA
Harwell International Business Centre
Harwell
Didcot

Oxon. OX11 0TA

Mr J Cobb
NIRAS
Warrington

Mr S Cripps
NIRAS
Warrington

Mr C Dale
NNC Ltd
Winfrith
Dorchester
Dorset
DT2 8WG

Ms H Day
AWE
Aldermaston

Mr G Druce
AWE
Aldermaston

Mr S Fell
AWE
Aldermaston

Mr B Handy
NIRAS
Warrington

Mr M Harker
AWE
Aldermaston

Mr K Hughes
BIL
Sellafield
Seascale
Cumbria CA20 1PG

Mr D Hull
AWE
Aldermaston

Mr M Jackson
G E Healthcare (formerly Amersham plc)
The Grove Centre

White Lion Road
Amersham
Bucks. HP7 9LL

Mr A Laker
UKAEA
Sellafield
Seascale
Cumbria CA20 1PG

Mr R Major
NIRAS
Warrington

Ms O Marsden
NIRAS
Warrington

Dr P McClelland
UKAEA
Dounreay

Mr P Mountford-Lister
UKAEA
Harwell

Mr D Owen
BNFL
Risley
Warrington WA3 6AS

Mr C Pearman
AWE
Aldermaston

Mr I Pearman
RWE NUKEM
Harwell

Mr G Pugh
BNFL
Sellafield
Seascale
Cumbria CA20 1PG

Mr M Renouf
BNFL
Sellafield

Mr J Simpson

RWE NUKEM
Winfrith
Dorchester
Dorset DT2 8WG

Mr I Smith
AWE
Aldermaston

Mr A Spour
UKAEA
Sellafield

Mrs S Vallet-Thomas
Canberra Harwell Ltd
Harwell International Business Centre
Harwell
Didcot
Oxon. OX11 0TA

Mr R Wilkins
AWE
Aldermaston

Mr D Wickenden
AEA Technology
Winfrith
Dorchester
Dorset DT2 8WG

Mr M Wormald
Canberra Harwell Ltd
Harwell