Rapporteur's Report of the
Workshop on Radiological Characterisation for Decommissioning

Studsvik – April 17-19, 2012

1. Introduction

In April 2012, the Nuclear Energy Agency, in co-operation with Studsvik Nuclear AB, the Swedish Radiation Safety Authority (SSM), Swedish Nuclear Fuel and Waste Management Company (SKB) and AB SVAFO, held a Workshop on Radiological Characterisation in Decommissioning in Studsvik near Nyköping (Sweden). During three days, a wide range of presentations, posters, discussions and site visits brought together over 120 participants from 23 countries and 4 international organisations, the IAEA, the WNA, the European Commission and the OECD/NEA. Members of the Task Group on Radiological Characterisation for Decommissioning (RCD) of the WPDD were involved in the preparation of the workshop.

Many decommissioning projects of all types of nuclear installations have progressed substantially and/or have been completed to brown field or green field conditions, so that it was the right time to bring together operators, regulators, scientists, consultants and contractors to exchange information and views and to evaluate the information on radiological characterisation gained from this multitude of projects. The outcome will be valuable for the large number of decommissioning projects about to start in the near future.

The Workshop consisted of 5 topical sessions and a poster session. The topical sessions were complemented by discussions in the plenary and in smaller groups. This report provides a short summary of the various presentations and discussions. It concentrates on the outcome of the presentations, posters and discussions than giving an account of the spoken word.

2. Opening Session

The seminar was opened on Tuesday, April 17, 2012 by Anders Jackson, CEO of Studsvik Group. He underlined that this seminar has an important role to play and comes timely, as there are a large number of NPPs entering decommissioning, which need standard and well-applicable methods for decommissioning, of which radiological characterisation is an important aspect. As the nuclear renaissance is nevertheless going on and many new NPPs coming on line can be expected for the next decades, it is even more important for the nuclear industry to demonstrate its ability for carrying out efficient and safe decommissioning. International cooperation is an important means to achieve this objective. This is underlined by the large number of countries and international organisation being represented in this workshop.

Ivan Rehak of the OECD/NEA in Paris pointed out the important role that the OECD/NEA plays in assisting the OECD Member States in the use of nuclear energy. The NEA works as a forum for sharing experience and promoting international cooperation. There are several groups inside NEA, including the WPDD (Working Party on Decommissioning and Dismantling, installed under the umbrella of the RWMC, the Radioactive Waste Management Committee) and the CPD (Co-operative Programme on Decommissioning), covering various aspects of the decommissioning like regulatory implications, waste management, optimisation, funding and costing of decommissioning, lessons learnt from decommissioning, clearance of material, release of sites etc. The RWMC and the WPDD have responded to the needs of Member States to establish a Task Group on radiological characterisation (RCD). Since its establishment, the RCD Task Group has made significant progress, including disseminating and evaluating a questionnaire on this topic, staging the Topical Session on radiological characterisation in Paris in November 2011 and this Workshop in Studsvik.

The **IAEA perspectives on radiological characterisation** were presented by Patrick O'Sullivan of the IAEA, Vienna. He described radiological characterisation as an important prerequisite for achieving the objectives of the IAEA Safety Fundamentals. Special care concerning radiological characterisation needs to be taken in certain cases, e.g. at plants with fuel failures, buried waste, unplanned ending of operation, site release etc. The IAEA document TRS 389 provides large amount of information on radiological characterisation methods and issues. The characterisation data is used for developing the strategy for decommissioning, radioactive waste management and cost estimates. Data need to be collected not only on the radiological status, but also on the chemical and physical side. More information from the IAEA side on radiological characterisation is also available in documents on the transition phase. - The discussion following this presentation was centred on costs for radiological characterisation and references for this that might be available at the IAEA. It was pointed out that there is little international experience, but that it would be necessary to tend to individual projects to gain a broader understanding of costs for radiological characterisation.

Rateb Abu-Eid of the U.S. NRC gave a **generic overview of the status of characterisation and guidance for decommissioning**, concentrating on the approach used in the USA. There, the site release process is risk-based and uses a level of 0.25 mSv/a for the total effective dose equivalent as a target. In order to demonstrate that this target is complied with, radiological characterisation is necessary. In this approach, the DQO (Data quality objective) process is very important for the successful implementation of radiological characterisation. It covers planning, implementation, assessment of implementation and finally decision. The uncertainties during characterisation have to be properly taken into account. The approaches used for radiological characterisation have to be differentiated between various types of nuclear installations. The MARSSIM methodology governs the process. DCGLs (derived concentration guideline levels) are based on the results of the characterisation as well as dose analyses and are used as upper boundary values for the activity in the release of the facility. – In the ensuing discussion, the timeframe for the radiological evaluation for the license termination criteria of 1000 years was debated. A timeframe of 1000 years is deemed reasonable to account for all contaminants to be transported to the drinking water. Furthermore, the rationale for the risk based criterion 0.25 mSv/a was discussed. This value was derived from the consideration that ICRP, IAEA and other international bodies have agreed on a limit of 1 mSv/a for individual doses to members of the public, so that the criterion for site release needed to be a fraction of this dose limit.

The work of the RCD Task Group was briefly presented by Arne Larsson of Studsvik Nuclear AB in his presentation **OECD/NEA radiological characterisation - A WPDD Task Group**. This Task Group needs input from the international community to complete its work. A project team assists the Task Group, consisting of members from Sweden, France, Germany, Spain and UK; corresponding members are from France, Japan, Sweden, UK and USA. The Task Group performed data collection by a questionnaire, prepared a topical session at WPDD-12 meeting in 2011 and organised this workshop in 2012. The RCD Task Group will prepare the final report in early 2013. Until then, further work in selected topics will be performed. - Arne Larsson is also chairman of the RCD Task Group.

Arne Larsson's presentation was directly followed by an account of the evaluation of the questionnaire inside the RCD Task Group, given by Stefan Thierfeldt of Brenk Systemplanung GmbH, Aachen (Germany), in his presentation **Strategies for radiological characterisation in decommissioning – Evaluation of the questionnaire**. In the first half of 2011, the RCD Task Group had prepared a questionnaire on the characterisation of nuclear facilities that has been circulated among nuclear installations in various OECD countries, to gather information on the approaches and methods used for radiological characterisation of systems and components, buildings and for sites. - The discussion following this presentation concentrated on the question of how the results of such a survey on radiological characterisation could be incorporated in the design of new NPPs. It was pointed out that the process of taking account of the experience from decommissioning in nuclear new-build is already going on.

3. Session A: Decommissioning, general issues

Frederic Tardy of EDF / CIDEN (*Centre d'Ingénierie de Déconstruction et Environnement*, Lyon, France) acted as session chair. He introduced the session and CVs of five presenters.

The **history of radiological characterisation in Studsvik** was **presented by** Robert Hedvall of AB SVAFO (Nyköping, Sweden). He pointed out that the various decommissioning projects where Studsvik was involved (the underground research reactor R1, the Van de Graaff accelerator, the Ågesta purification plant and the ACL Nuclear Lab) reflect the development of radiological characterisation as a function of time: the number of samples taken from building surfaces, the number of single measurements and the effort used for radiological characterisation have increased considerably. The in-situ gamma spectrometry, now widely used, has the advantage that it covers virtually the whole surface. – In the following discussion, questions were asked mainly on the criteria used for clearance, e.g. 10 kBq/m² Co-60 for the ACL laboratory. These values were taken from the EU recommendation RP 113 on clearance of buildings, based on the 10 µSv/a criterion. Other values like 8 kBq/m² used for the research reactor R1 were not derived from first-hand dose levels.

Bill A. Westall of MAGNOX Ltd. (Oldbury, Gloucestershire, UK) presented the **radiological characterisation experience with MAGNOX reactors**. There are many points where radiological characterisation is needed in such types of reactors. A few types of measurements are e.g. the verification of the radioactive inventory of the biological shield derived from the irradiation history, the neutron flux and the elemental composition, gamma spectrometry of in-core items, bioshield drilling cores, which show generally good agreement between calculations and measurements, or in-core dose measurements. The cooling ponds show pronounced contamination by Cs-137, which can be reduced considerably by stripping off the coating of the ponds. The assay system is based on measurements of Co-60 and Cs-137, while the other nuclides are correlated via the fingerprint method. It has been found that good characterisation allows better segregation of waste and reduces radioactive waste volume. – The only question asked in the discussion related to the avoiding diffusion of H-3 while taking drilling cores. It was pointed out that careful sampling is needed here.

The **radiological characterisation and decommissioning in Denmark** was presented by Thomas Kjøller Nellemann of Danish Decommissioning (Risø, Denmark). The various nuclear installations at the research centre in Risø are currently under decommissioning. Decommissioning work is currently scheduled until about 2018. Decommissioning of the largest of the three research reactors, DR3, has been started. As this is a heavy-water reactor, H-3 contamination plays an important role. It was generally found for activated structures and components that sampling has proven to be more accurate and easier than modelling. Furthermore, these structures and systems are complex, so producing accurate models is hard. The best approach is a combination of sampling and modelling. Methods for calculating the induced activity and corresponding scaling factors have been given in the presentation. In this simplified approach, the neutron flux cancels out in the formula for calculation of scaling factors, which means that an estimate of these factors can be calculated without knowledge of the flux distribution. – The discussion centred on sampling methods. The samples from the biological shield were analysed with gamma spectrometry including scaling factors. The scaling factors agreed with measured values. H-3 was analysed in the concrete. For some of the samples, liquid nitrogen was used for freezing the water in the concrete, preventing H-3 from escaping.

A presentation on the characterisation of a very large nuclear site was given by Eberhard Thurow of Energiewerke Nord GmbH (EWN, Lubmin/Greifswald, Germany) with the title **Radiological Characterisation of Ground Areas at the Greifswald NPP Site**. The NPP site at Greifswald at the Baltic Sea was equipped with 5 WWER-440 reactors (with a planned total of 8 blocks), a 1.2 km long turbine hall and many unique features. The project is now in a very advanced decommissioning phase, so that large parts of the site with a total area of about 1.7 km² (170 ha) have already been cleared and there is large experience. The licence for clearance together with clearance levels was issued in 1999. The site was classified into 3 categories: 3: contaminated – 2: potentially contaminated – 1: free of contamination. The type and level of detail of the radiological characterisation varies for these categories: Category 1 requires spot checks to confirm the absence of contamination (contamination only possible via airborne activity, indicated by Co-60; required detection limits: 0.015 Bq/g or 0.1 Bq/cm²). For Category 2 and 3, clearance levels as provided in the German Radiation Protection Ordinance are used. The measurement density is derived from site-specific considerations or set to 100 %. The measurements are performed by in-situ gamma spectrometry (1 – 6 m² with collimator, 100 m² uncollimated). Background of Cs-137 is subtracted, based on quantification of Chernobyl fallout in the vicinity of the site. More than 1.1 km² have already been released. – The discussion underlined that the main experience from the KGR decommissioning project is that fast and efficient site release is possible. The clearance levels applied for the site are unrestricted, i.e. also agricultural use would be possible.

The last presentation of the first day was given by Rateb Abu-Eid of the US NRC (Washington, USA) on **Decommissioning survey and site characterisation - Issues and lessons learnt**. The focus of this presentation lay on issues from the regulator’s viewpoint. Subsurface contamination is deemed to be an important issue, because one must be sure that there is no contamination below the surface, in particular when pipes were buried below the surface. For subsurface contamination, sampling is a problem. Furthermore, DCGLs cannot be easily formulated, as the exposure is different from cases with normal (surface) contamination. Statistical analysis is also problematic, as samples from different levels do not belong to the same statistical population. The characterisation for the site including the subsurface situation is an iterative process, starting with a small number of samples which is eventually increased. The software tool MARSSIM3D is available for layers of different thicknesses with different physical characteristics. Release of sites in the USA is generally based on risk or dose. The approach with effective dose of 0.25 mSv/a is converted to DCGLs via the dose model (based on 1000 a). Software tools like MARSSIM, MARSAME or RESRAD are available for planning sampling and clearance. The paper also presented a collection of lessons learnt from the regulator's viewpoint from many decommissioning projects. – In the discussion, the interesting question on how to deal with contamination resulting from authorised releases (discharges) from the operational phase was raised. It was pointed out that these releases have already been restricted (see 10 CFR 20 App. B) and that today the limits are compatible with site release levels. In particular, the releases from the operational phase disperse. A further question on clearance levels for materials in the USA was answered that clearance is dealt with on a case-by-case basis and that there are no generic regulations.

The **discussion** that ended Session A centred on various topics, as outlined in the following:

- When planning a characterisation campaign, what are the main strategic considerations? What are the critical parameters?

The importance to be able to go back to records, documents etc. was pointed out. However, in actual decommissioning projects, documentation from the construction or operational period has often been disposed of. This was underlined by the importance to collect all historical information and do some radiological characterisation (scoping characterisation) to check the correctness of this information. This will then affect the level of detail of the subsequent radiological characterisation. In addition, the DQO process in radiological characterisation was pointed out as being very important. The radiological characterisation is determined to a large extent by the levels against which the characterisation has to take place. One has to be realistic about what is practical to achieve. It may not always be the textbook procedure concerning statistics or other aspects. The outcome needs to be compatible to what is achievable.

- How can radiological characterisation be optimised? What are the levers?

The principles for DQO need to be followed. The effort needs to go in up front to understand what needs to be achieved.

- How to take care of lessons learned?

Patrick O'Sullivan of the IAEA pointed out that the IAEA considered a database for lessons learnt, but it was doubted whether this would be viable (high effort for maintaining such a database and for inputting and updating its contents). Networks and fora have been deemed a better approach, being much easier to manage. The basis is networking itself, making people want to share information.

Communication of lessons learnt needs to take place to all parties involved, i.e. regulators, operators and other stakeholders. There are already webpages on nuclear decommissioning that really have a valuable and comprehensive content. It was also pointed out that regulators have an obligation for maintaining lessons learnt by asking the licensee to provide an appropriate summary of their projects.

- How to split characterisation efforts between the different phases of decommissioning projects to get best value for money?

It is essential to plan what to do with the waste and where to store it. This determines the effort for characterisation.

Finally, no comments were raised on the question whether and how radiological characterisation should be considered already at design stage of a facility.

4. Session B: Characterisation of Materials and Systems

Henrik Efraimsson of the Radiation Safety Authority (SSM, Stockholm, Sweden) acted as session chair. He introduced the session and CVs of four presenters.

Chris Hope of Sellafield Ltd. (Sellafield, UK) presented the **characterisation of metal in support of decommissioning a reactor site**, performed by Sellafield Ltd. at the Calder Hall Site, UK. Material was removed in a systematic way, and was divided into three characterisation groups: gas pipework connecting reactor to the top of heat exchanger; pipework exiting heat exchangers and linking to turbine halls; and finally stairways, walkways and access platforms painted with numerous layers. Characterisation objectives were defined for each group, based on expectations of contamination and activation. The presentation also informed on characterization execution for each group and sentencing decisions on consequent material management. – In the discussion, questions concerned the impact of the change of the exemption order; further dealing with painted structures; parameters of sampling; and measured nuclides.

Kristína Krištofová of AMEC Nuclear Slovakia s.r.o. gave an overview of the **radiological characterization of V1 NPP technological systems and buildings – activation**. She presented part of the project on physical and radiological inventory database development to support the decommissioning of V1 NPP, Bohunice, Slovakia, focusing on material activation data. Dose rate measurements and sampling were performed for civil structures, reactor shafts, reactors, reactor internals stored in the HLW storage, and storage grids of the spent fuel cooling ponds. Evaluated data of activation, nuclide vectors and dose rates were imported to the decommissioning database. Specific data on sampling procedures and results for groups of activated components were presented, accompanied by short videos of sampling. – In the discussion, questions were raised on comparison of measured data, having been reported in this presentation, and calculation performed by other member of the project consortium; reference dates of measurements; parameters of the camera; and personal doses relating to the project performance.

The **sampling of reactor pressure vessel and core internals** was presented by Ralf Oberhäuser of Areva NP GmbH (Erlangen, Germany). He pointed out that the main reasons for sampling are radiation protection, optimisation of dismantling and packaging strategy and minimisation of the radioactive waste volume, resulting in reduction of cost. Goals of activation calculations were presented, underlining the need to compare calculated and measured data. Detailed planning of sampling optimises the sampling process itself. Examples of sampling techniques and sampling positions were given. Intelligent choice of sampling positions has to support the most realistic activation model. Considerations on accessibility studies for sampling as well as handling and analysis of samples were also presented. - In discussion, questions concerned further technical information on the lens sampling device designed by AREVA; applicability of lens sampling; and radioactivity measurements of the lens samples. A proper balance between satisfactory number of samples and sampling cost needs to be considered. The number of samples and their positions are based on the expert judgement, they are site specific and depend on the design, operational history and other aspects.

The last presentation of this session concerned **validation of activity determination codes and nuclide vectors by using results from processing of retired components and operational waste**, given by Arne Larsson and Klas Lundgren of Studsvik Nuclear AB (Nyköping, Sweden). Arne Larsson summarised well-developed areas in the characterisation for decommissioning and the areas with potential for further development. He pointed out the importance of good understanding how the operational history and waste treatment influence a nuclide inventory and he underlined key issues necessary for successful validation of nuclide model. Klas Lundgren briefed on current knowledge of inventory of Swedish reactors, and source terms and nuclides considered in the activity calculation. Examples of validation of specific cases by comparison with measurements were given. It was proposed to form an international project on build up the industrial knowledge base on activity assessment in metals to support validation and optimisation of activity assessment codes. – The discussion centred on the importance of nuclides in a repository perspective (Cl-36 and C-14). It was clarified that the referred Fe-60 was only calculated, and explained that the number of nuclides considered in calculation has been later extended to achieve more comprehensive information on decommissioning waste.

The discussion on **Session B** dealt with various topics presented in the following:

- Can a best practice be identified?

The participants expressed the view that methods for characterisation (sampling and measurement) are defined in parallel in many different projects, so that there is the risk that "the wheel is invented" several times. National and international exchange of experience is therefore essential. In addition, standards or guidelines were desired by some participants.

A good characterisation strategy should rely on a graded approach (adjusted to the various phases of a decommissioning project) and should consist of an iterative process. This means that characterisation during the general scoping phase does not need to be as comprehensive as during the decommissioning implementation. The detailed characterisation strategy can be developed on the basis of a smaller number of samples.

A well-structured sampling strategy will also try to exploit additional information, like rotational symmetry around the reactor core or use of data obtained from similar areas of the facility.

- Are there potential bottlenecks and cost drivers?

In most countries experience shows that the time for laboratory analysis of samples will usually amount to 6 to 8 weeks and that laboratory capacity is limited. It was recognised that there is a trade-off between the costs for radiological characterisation and the number of samples, forming the basis for good knowledge of the facility.

Other important factors in this direction include effective project management. There is a need for a small staff of well-skilled people to perform these tasks. However, this may result in elevated project management costs. It was argued that the costs of radiological characterisation are not very significant in comparison to the costs caused by unnecessary prolongation of project duration.

5. Session C: Characterisation of land and groundwater

This session was chaired by Katherine Eilbeck of Sellafield Ltd. (Sellafield, UK). She introduced the session and the CVs of four presenters.

Robert Meck of Science and Technology Systems (Bethesda, Maryland, USA) gave a presentation entitled **Approaches used for Clearance of Land from nuclear Facilities among Several Countries: Evaluation of Regulatory Input**. In the underlying study, performed in co-operation with SSM, he evaluated the processes used in various countries to verify that a site conforms to release criteria (the report will be published, the work was performed to develop Swedish regulations and guidance). Sources of information came from France, Germany, Spain, UK, and USA. It was the aim to understand how site clearance is actually implemented in the various countries. The countries' approaches were compared with respect to the regulatory basis (revealing the large variety of criteria and methods applied), the flexibility of the approach, the roles that authorities and operators play, and the mathematical approach. There are trade-offs between the regulatory effort vs. inspection effort as well as costs to the authority vs. costs to the facility. Technically defensible processes have been published in general guidance documents, e.g. MARSSIM and EURSSEM. - The discussion dealt with terminology, suggesting that the term "clearance" is confusing in relation to sites. USA tends to call this "decommissioning criteria" or "license termination rules", while clearance is only used for equipment and materials. A question on the risk level seeming to be much higher in the USA than in many EU countries was answered pointing out that amongst the US agencies, the levels vary in terms of risk. The NRC, EPA and DOE have their own reasoning, to balance between the various approaches, but 10^{-4} is often used.

Julian Cruickshank of Sellafield Ltd. (Sellafield, UK) gave a presentation on **The Sellafield Contaminated Land and Groundwater: Characterisation of a Complex Nuclear Facility**. The Sellafield land quality management programme is used to cope with this large nuclear industrial complex in a rural area. In the history of the site, leaks, burials and spills occurred, resulting in contamination of land and groundwater. A programme is dedicated to control this contamination and remediate the land. The situation at Sellafield is a mixture of decommissioning, operation and new-build, making it more complex than many other purely decommissioning sites. The legacy in the ground is estimated as 3 billion GBP for dealing with soil and groundwater contamination. The presentation concentrated on sampling of ground and groundwater by drilling and other geophysical techniques (ground conductivity, metal detection, radar etc.) as well as monitoring of groundwater. Lateral migration of nuclides in the unsaturated zone has been found to be very limited (only few 10 m). Most of the unsaturated area is therefore uncontaminated or with low contamination. The following conclusions were drawn: Characterisation of an operating nuclear site is very difficult, as not all parts are accessible, and it may take long. Use of existing knowledge must be maximised. Use of less intrusive investigation techniques would be preferred, but the results to date have been disappointing. Innovative techniques are needed to investigate sources. – The discussion concentrated on Tc-99 and H-3 as tracers, making them unsuitable for defining release concentrations for the site.

A **comparison between ex situ and in situ measurements methods for the assessment of radioactively contaminated land** was presented by Peter Rostron of the University of Sussex (UK). The site studied for this presentation was Dounreay in Scotland. The presentation compared various measurement techniques that were all applied in this project. Ex-situ analysis can be expensive, in particular for alpha radiation. In situ techniques are much less expensive, but will deliver only poor quantification, while allowing high-resolution mapping. In-situ measurement techniques need to demonstrate fitness-for-purpose. In situ gamma spectrometry cannot determine between the various distributions of contamination in the measured volumes. The measurement uncertainties are therefore large. They are not suitable for the identification of "hot spots". Various criteria and approaches for detecting "hot spots" were presented. – The discussion dealt with sampling patterns according to MARSSIM, calibration procedures and uncertainty approaches as well as specific aspects of the measurement devices used.

Cristina Correa of ENRESA (Spain) gave a presentation of **soil radiological characterisation and remediation at CIEMAT**. The CIEMAT research centre comprises various nuclear facilities. Dismantling was completed by ENRESA in 2010. Since then, soil remediation has been performed.

The so-called Lenteja incident in the 1970s led to contamination of the area by pipe leakage from the reprocessing plant, releasing 40 l liquid contamination (Sr-90 and Cs-137) to the ground. While the soil was removed and filled with clean material and concreted, parts of the contamination remained in the ground and have been removed in the scope of this work. Surveys were performed from boreholes around leakages and in the unaffected areas (surface 415 m², volume 3000 m³, depth up to 8 m). Clearance levels were taken from RP 122 (for soil) and RP 113 (building rubble and structures). Release criteria for land (15 cm depth) were based on 100 µSv/a for an industrial worker scenario and 1 mSv/a for resident farmer scenario, performing calculations with RESRAD. Clearance measurements were performed in bulk monitors (box counter, 4 gamma spectrometers, shielded). – The discussion mainly dealt with the application of the MARSSIM model, that is also recommended to be used by Spanish regulator (but not prescribed), and the costs for this project, which were estimated to be less than 2 % of the budget for remediating the entire contaminated area.

The **discussion** to Session C dealt with various topics presented in the following:

- Characterisation optimisation with unknown clearance conditions / end-state

A first characterisation step must deliver the radiological status of the site. This is then the basis for the remediation objective. This means that the end-state should not be decided a priori. The scoping survey according to MARSSIM brings up which nuclides have to be dealt with, how they are distributed etc. MARSSIM defines the methods to calculate uncertainties. In terms of optimisation there is payoff between well understanding of the site and effort for sampling.

- Can a best practice be identified?

A best practice for radiological characterisation varies: the properties of the site and the available budget must be taken into consideration. Very simple surveys can be the optimum for simple sites.

When considering best practice for radiological characterisation, the category of the site should be taken into account, which in turn determines the DQO process. A peer-review process is important, as no single expert can keep up with all changes in technology. Therefore, input from the community may be helpful.

Learning from best practices derived from other projects is without doubt useful but there is a need to ensure that the lessons learnt are not overly cautious. It must also be taken into account that these lessons might be specific for a particular country or even a particular site only. In addition, advances of technology must be taken into consideration: An approach dismissed several years ago as impossible for technological reasons might today be viable.

- Stakeholder involvement – who and at what stage?

A very important point concerning stakeholder involvement is the need for early discussions on the end-uses of a site with all stakeholders, especially regulators, as this will shape the characterisation requirements. It was noted that problems can occur if requirements change during the execution of a project.

The stakeholder involvement in the US is comprehensive. The license termination plan is discussed with all stakeholders. The costs vs. risk of the facility for the whole process is an important factor. The decommissioning plan may change if the costs were found to increase considerably as a consequence of radiological characterisation. The plan could then change from unrestricted to restricted release, but then stakeholder involvement increases.

In Germany, this conflict is avoided by applying clearance of sites only for general purposes, i.e. unconditionally. Potential exposure is evaluated until peak values are reached, which may be a few 1000 years. A similar approach is used in the UK. The question was raised whether people can understand such an impact on future generations, and whether it is worthwhile to include such long periods. The public needs to understand that the risk is very low associated with 10 µSv, therefore the risk communication is quite important. Finally, it was pointed out that the IAEA has never recommended that clearance of sites should be based on the 10 µSv/a criterion. The IAEA tends more to use the range of a few hundreds of µSv/a, as there is a fundamental difference between material and sites. In any case, the corresponding dose constraint should take into account multiple pathways of exposure and should not exceed 300 µSv in a year above background

- Potential bottle necks

The delays caused by the regulatory process are often seen as a problem, as the authorisations for certain actions within the general decommissioning license need to be given by the authorities. In the CIEMAT Research Centre in Madrid, the stakeholder groups also participated in the strategy selection for remediation, e.g. in this case the cleared material was not allowed to be backfilled into the pit. This material had to be disposed of and new material had to be bought. In the USA, bottlenecks are often seen in the final status survey, i.e. the survey for confirmation that release levels have been met for the site. This is particularly true for contamination below ground, when contamination is found after the clearance process has been finished.

- Cost drivers

It may be necessary to change the endpoint of site remediation or the remediation process if this process will turn out to be more expensive than expected. In this case, the level of detail for the radiological characterisation needs to be adjusted. In the USA, there is often a fixed amount of money assigned to a site, which helps focussing the approach.

6. Session D: Characterisation of Rooms and Buildings

This session was chaired by Yvon Desnoyers of Geovariances (France), who introduced the session and the CVs of four presenters.

The **radiological characterisation of V1 NPP technological systems and buildings - contamination** was presented by Richard Hanzel of AMEC Nuclear Slovakia. This site consists of 2 WWER-440/230 units that were shut down in 2006 and 2008. A radiological inventory database has been developed to support V1 decommissioning. It covers nearly 100 civil structures or technological items and 175 technical systems. The methodology was based on MARSSIM, including the definition of survey items, preliminary categorisation of the items in the decommissioning database, number of measurements, and the sampling plan. Small locally contaminated areas outside the NPP controlled area were identified, as a consequence of leakages and temporary storage of contaminated equipment. This also included the turbine hall. Radiological parameters included dose rate at contact and at 1 m distance, surface contamination, volume / mass contamination. Rooms in controlled area were assigned to groups based on average and maximum dose rate levels, average surface contaminations of floor and walls, and the identification of “hot spots”. The survey for buildings consists of direct dose rate measurements, contamination measurements of wall and floor surfaces, wipe tests and samples, on-site gamma spectrometric measurements, and drilled concrete samples. Each sample is measured for total α, β, γ activity, selected samples for γ spectrometry and hard-to-detect nuclides (α and β spectrometry). – The discussion dealt with the MARSSIM approach, recommending an initial and a more in-depth characterisation. The later characterisation confirmed the results of the initial characterisation. In addition, the nuclide vectors were addressed. There were 8 nuclide vectors derived altogether (also for materials). All these nuclide vectors were determined using a complex derivation process.

The **radiological mapping and characterisation of the NPP Barsebäck** was presented by Leif Spanier of Scandpower AB (Sweden). The Barsebäck NPP has two blocks of 600 MWe boiling water reactors of Swedish design. As there were very few fuel damages, very few control rod leaks and full filtration of releases, the site is very clean and is therefore planned to be released for free use. The KAKA project (*KArtläggning och KAtegorisering*, characterisation and categorisation) forms the basis for decommissioning of Barsebäck NPP, waste and cost estimation, hazard evaluation etc. The mapping relates to all hazards (radioactive and environmental). It is carried out by sampling and in-situ scanning of radiation. The sampling and scanning strategy was biased by historical events. It comprises surface soil samples, drill cores between 100 and 570 cm length, groundwater samples, vegetation samples, settling pond samples and sea bed samples. The main radionuclides that could be identified are Co-60 and Cs-137 (Cs-137 originating mainly from Chernobyl fallout) in only part of the samples, of which only very few are above 0.1 Bq/g. This value was derived as a limit for free release from RESRAD. Further sampling programmes were carried out in the buildings. – The discussion clarified points on the sampling and measurement processes as well as on the RESRAD approach used here.

Robert Hedwall of AB SVAFO (Sweden) and Feng QuanHong of Multiinfo 3D Laser Scan Solution AB (Sweden) gave a presentation on **radiological characterisation by means of 3D laser modelling and positioning of measurements**. This project serves a better presentation and visualisation of the positions of measurements making use of laser scanning. This technique can give 3D visual images with high accuracy. Scans of various rooms can be connected by reference points, providing a model of the entire facility. A 3D CAD model can then be created from the scans. Laser scanning data can be combined with colour images. This has been presented here for a facility for treatment of ILW. There are different methods to link 3D visualisation of radiation measurements, e.g. classification of surfaces with colours according to the radiological results, while different symbols can represent different types of measurements and their size different values. – The discussion dealt with various technical aspects of the 3D laser scanning process and the methods to convert the data into a 3D CAD model.

The **radiological characterisation of buildings at the Ranstad Uranium Works** was presented by Jonatan Jiselmark of Studsvik Nuclear AB (Nyköping, Sweden) and Tommy Norberg of Chalmers Univ. of Technology (Sweden). The Ranstad facility for uranium mining, milling and extraction is under decommissioning and has already been removed partly. In the main characterisation project, about 110,000 measurements have been performed, mainly with beta scintillation measurements on surfaces. A number of nuclide vectors have been defined for different parts of the plant. Comparisons with the natural activity in concrete show that the largest part of the activity originates from the concrete itself. Differences in the activity ratios indicate presence of activity from U processing. The ratio Ra-226 / U-238 gives an indication about the ratio for leaching U concentrate to the residual material. The evaluation of measurements requires handling of uncertainties, as the measurements cover only a small percentage of the surfaces. A Bayesian Approach is used, calculating probability densities based on expert judgement. Reasonable upper bounds for the distributions are represented by the 95th percentile and are used for comparison with clearance levels. Stratification of sampling strategies helps covering a larger portion of the overall surface to be measured and to distribute the samples more evenly. – The discussion only dealt with the question why the MARSSIM methodology had not been used to reduce the number of samples (about 3 % of the area were covered by measurements).

The **discussion** to Session D dealt with various topics presented in the following:

- Regulatory framework, good health physicist practise and characterisation by using statistics – how to optimise and balance?

With respect to this topic, the question was discussed whether the processes for deriving nuclide vectors in Germany differ from those in the USA. The procedures are different, but the uncertainty is assessed in both cases. The German Commission on Radiation Protection has made a requirement on this, and the German DIN standards take this into account.

Spain reports that the guidance and approaches for radiological characterisation are well developed, but that there remains room for improvement with respect to soil and groundwater. Slovakia has regulations with release criteria, specific for each type of material. Canada has issued guidance on clearance of buildings.

The fact that US guidance is used in many other countries (MARSSIM, RESRAD etc.) was generally regarded as positive, but concern was also raised that it must be made sure that this guidance is really compatible with the needs in the particular country or facility (pathways, measurement equipment etc.).

- Key factors with regards to competence, attitude and resources?

The indiscriminate use of waste fingerprints is a dangerous approach, even if these are re-validated every few years. It is not considered a good approach to derive the activities for e.g. 30 nuclides just from a single dose rate measurement.

The best way for the derivation of nuclide vectors is to take a sufficiently large number of samples over a large activity range. It will then be possible to detect correlations between easy-to-measure and difficult-to-measure radionuclides. An important prerequisite is to have a clear idea why there could or should be a correlation between two radionuclides.

It is essential to apply the necessary experience, for which often the money may not be available. It may be necessary to hire experienced consultants.

Large uncertainties can be accepted as far as the values are far below the exemption limit / clearance levels / waste acceptance criterion. When older measurements are taken into account it usually needs to be determined whether these are reliable and have been made to the same standards as the current measurements. The example of the Ågesta NPP decommissioning project was given, where the question arises how to use data for decommissioning taken in the 1970’s. There might be a need to perform new measurements and characterisation before decommission will start. It might also be possible to accept a higher level of uncertainty because the Ågesta NPP was a small plant.

- Can a best practice be identified?

As stated before for characterisation of systems and components, the optimisation of the radiological characterisation process for buildings needs to find a balance between increasing the number of samples for gaining a better understanding of the radiological situation and the increase of the required costs and effort. The best approach might be iterative, taking a small set of samples in the beginning (which however cover the whole facility) and afterwards concentrating on more complex areas needing more refined characterisation.

There may be reluctance in sharing commercial solutions (intellectual property, approaches). It may be the case that a company is not willing to share the whole background of novel processes and approaches. In the UK, however, nearly all documents are in the public domain. However, expert consider that such reports today are written more cautiously providing less amount of proprietary knowledge than e.g. 10 or 20 years ago.

- How are non-radiological contaminants managed? Integrated or separated?

PCB has been identified as a large problem in Germany, Switzerland etc. where it has been used in decontamination coatings. The same applies to asbestos material in Switzerland, Spain, Sweden and elsewhere. Radiological and chemical hazards have to be analysed simultaneously, and often the radiological characterisation is a good time to identify other hazardous materials as well. In a few cases, e.g. in Canada and Germany, the characterisation for chemical contaminants was done separately, as this has been carried out by specialists and not by internal staff.

Material needs to be cleared first, then it can be disposed of without problems. As long as it is still classified as radioactive, handling is very expensive. In the USA, both hazards are generally treated together. However, different regulators are responsible here, so that their interaction may be a problem. Authorities have to work together. In the UK, the number of laboratories accepting samples with asbestos contamination for non-radiological analyses is currently very small.

- R&D needs in development of tools and methods

Tools and methods strongly depend on the criteria, e.g. clearance measurements from large distances etc. Switzerland does not see any needs for new tools and methods currently. A few items have been discussed, like measurements of scaffold poles that have not been capped, the use of ICPMS for clearance, the derivation of fingerprints from swabs, the analysis in an external laboratory etc., but also taking core samples from the concrete shield, the need for radiation-hardened cameras.

- How to consider the future waste management and waste characterisation information in the characterisation of systems and buildings?

For building rubble, averaging quantities are crucial. The characterisation has to be commensurate with this approach. For some areas, RADSCAN techniques could also be used, but only where there are rather high radiation levels. Especially here, distinction has to be made between characterisation, determination of the extent of decontamination and clearance. Measurements on the standing structure are a good choice, but there are situations where the building rubble must be characterised as well.

The long-term aspect of radiological characterisation was addressed with respect to radioactive waste characterisation. In this case, safety has to be demonstrated for periods of several

10,000 years or beyond, so that also the very long-lived radionuclides need to be appropriately analysed.

An issue was identified concerning the transfer of knowledge between current decommissioning projects and new-build to make use of lessons learnt in the past. Furthermore, in cases of transfer of ownership of a facility for decommissioning (as in Spain with ENRESA), transfer of plant knowledge also needs to be managed carefully.

- How can the nuclear industry be made interesting?

Several examples were given, e.g. from France, where the concept relies on new training and master courses, apprenticeships at EDF (half work, half education), or from Slovakia, where the pool of interested students is still large. It was also pointed out that in a project orientated organization it is not possible to perform also training and education. Russia has made the experience that the university study is concentrated too much on the theoretical side and will not impart knowledge to graduated engineers how to deal with nuclear facilities undergoing decommissioning.

7. Poster Session

The poster session covered a number of posters. Only a few of them can be presented in more detail here.

Jan van Wickeren of Studsvik Nuclear (Sweden) presented the system **BOLERO, a flexible decontamination system for walls and ceilings**. Measurements for determination of the decontamination success can be carried out immediately after the treatment process.

Patrick Konnéus, Veronica Andersson and Maria Lindberg of Studsvik Nuclear (Sweden) presented **clearance measurements as a tool for waste minimization during decommissioning**. A former cell for whole body measurements was used as a shielded compartment for sensible gamma spectroscopy measurements of materials.

The poster entitled **Systematic handling of requirements and conditions** by Peter Keyser, Anita Helander of FAVEO Projektledning (Sweden) gave an overview of requirements management as part of configuration management, supporting decisions and changes in a project development, and its application to decommissioning.

Alojz Slaninka and Ondrej Slávik of VUJE (Slovak Republic) presented **Characterisation of buildings concrete surfaces for decontamination and free-release at NPP A-1, Slovakia**, concentrating on measurements of the dominant nuclide Cs-137+ with hand-held gamma spectrometry assembly with scintillation LaBr 1.5” x 1.5” detector.

A poster on **Optimized determination of the radiological inventory during different phases of decommissioning** was presented by Matthias Hillberg and Detlef Beltz of TÜV NORD EnSys and Oliver Karschnick of the Ministry for Justice of the Land Schleswig-Holstein (Germany). It dealt with the role of radiological characterisation in the licensing procedure for obtaining a decommissioning license for nuclear facilities.

Jamie Townes of WNA (World Nuclear Association, London) presented **Radiological Characterisation and its Role in the Efficient Management of Low-Level Radioactive Material**, calling for – with a special emphasis on metallic components – further international standardization and implementation, constructive discussions toward this important international objective and facilitation of its practical implementation at the national level.

The **Characterisation of SVAFO's legacy, low level waste using non-destructive gamma assay and X-ray examination techniques** was presented by Fredrik Ekenborg of AB SVAFO (Sweden), describing how characterisation of about 7000 drums was achieved using a combination of non-destructive techniques via mobile equipment located in a building at the Studsvik site.

New Swedish regulations for clearance of materials, rooms, buildings and land were presented by Henrik Efraimsson of the Swedish Radiation Safety Authority (SSM) under the title **The Anatomy of Clearance**. This poster gave an overview of recent publications of regulations including their origin.

8. Session E – Software support, record keeping, quality assurance and logistics

This session was chaired by Nieves Martin Palomo of ENRESA (Spain).

Veronica Lindow of Vattenfall R&D (Sweden) gave the presentation **Radiological Characterisation – Know Your Objective**. The objectives of radiological characterisation are varying and cover waste handling logistics, waste packaging and other waste management aspects. The decommissioning logistics for NPP Barsebäck 1 and 2 are planned based on the radiological characterisation. Full decommissioning will start in 2020. The waste amount, types of packages etc. are affected by the radiological characterisation. In addition; waste acceptance criteria also influence the planning. This in turn will affect the size of the SFR repository. Radiological characterisation also triggers cost estimates and influences the dose estimates. These aspects were also discussed with respect to the Ågesta reactor. Radiological characterisation should be optimised, or at least an optimisation should be attempted: schedule for performing the radiological characterisation, access to areas (dose rates), added values with more samples, required precision etc. – The discussion focussed on the radiological characterisation required for the Ågesta reactor. The presented radiological characterisation aimed at cost estimates only. There will be a much more comprehensive radiological characterisation later for decommissioning of this reactor. A further question dealt with the DQO process applied for Ågesta.

New software tools for dynamic radiological characterisation and monitoring nuclear sites were presented by Istvan Szöke of IFE (Norway). One important aspect of radiological characterisation is the use of the data with the help of software tools, e.g. for dose rate and dose calculation, etc. The Halden project (which is hosted by IFE, a project for decommissioning of the Halden research reactor) uses a number of software tools, covering radiological conditions and tracking changes, accidents requiring quick intervention, realistic easy-to-understand user interface communication with the stakeholders and authorities and decisions regarding health and financial consequences. The “Halden Planner” is a real-time 3D software tool for characterising radiological features, exposure conditions, planning sequence of activities, teaching and rehearsing, producing job plan reports and post-work review reports. It can model all types of sources in 3D representation of the plant. Dose rates are calculated from these sources. With the work plan (including paths, times, activities), the exposure can be modelled. – The extensive discussion concentrated on visualisation of radiation fields from measurements in 3D, technical platforms and devices on which these tools can be used, aspects of positioning inside nuclear installations (e.g. local GPS), the time required for preparing 3D models etc. Sub-surface modelling is not yet included. The uncertainties for mapping of dose rates may be high, as the results are calculated from data which in turn have been derived with uncertainties.

The final presentation was entitled **Data analysis for radiological characterisation: geostatistical and statistical complementarity**, given by Yvon Desnoyers of Geovariances (France). The three pillars on which radiological characterisation rests are: evaluation objective, sampling design, and data processing. The design of the sampling campaigns vary between probability-based (systematic or random) and judgmental, with the possibility to mix both approaches. An iterative approach is recommended. The data analysis with geostatistical approaches is presented, an approach having been used for a long time in the mining industry. This approach takes account of historical and functional analysis, followed by a surface radiation survey (radiation mapping) and finally used for radioactive waste segregation. The approach was illustrated with a Uranium workshop where several incidents had occurred. It could be shown that appropriate data analysis leads to a probability-based decision on compliance with activity criteria in rooms. The method also allows a statistical optimisation. – In the discussion, NRC codes for similar tasks were mentioned.

The **discussion** to Session E dealt with various topics presented in the following:

- How to keep data up-to-date?

Tools have to be updated regularly to keep up with changes in the IT surroundings. In addition, archives need to be kept, often archived in paper form. National or other types of archives may keep the data themselves, but another issue is to make these data accessible and searchable also after long timeframes. In some countries, it is made part of the license to keep old data readable, including conversion to new formats if it becomes necessary.

A database must be easy to access, and data must be easily retrievable, if it is to be used regularly and with good efficiency. It should be avoided to keep data in more than one system or database, as then cross-referencing and duplicate changes to data may become a problem. Direct logging of data (avoiding manual typing) is considered very important.

The visual representation of the extent and height of contamination on building surfaces was considered to be advantageous. Furthermore, it would be desirable to see the evolution of the contamination situation as a consequence from decontamination. In order to obtain good time series, it is important to perform at least part of the measurements on the same locations.

- QA in radiological characterisation – critical parameters?

Techniques for 3D visualisation currently emerge. 2D is sometimes favoured, in particular when it comes to decision making, as it is much easier to present in paperwork. However, 3D models are much easier to understand and interpret. As an example, in the NPP Forsmark (Sweden), a first approach in 3D modelling of the plant and representation of data has been made already in the 1980s but has never been used. Today, 3D modelling is the common approach for all Swedish nuclear installations. It also helps avoiding unnecessary entries to the plant, thus reducing doses.

3D coupled with radiation measurements is a valuable tool for planning for dismantling. The tools presented here may be good planning tools, but cannot be used for the actual execution of the work. There needs to be a good link between engineering understanding of the work and computer skills to produce meaningful results.

- Data Quality Objectives

The experience reported from various countries show that there is no uniform approach how data quality objectives are managed. In general it is the concern of the regulator that the operators have understood their objectives.

- Aspects of Knowledge Management

The question of how to maintain the relevant knowledge of a facility during all phases of its lifecycle was discussed. As a large part of the staff will leave before the end of a decommissioning project, it is essential to recruit new staff in all phases, avoiding a large wave of release and new hire of staff. In Sweden, with the current transitioning into decommissioning, the change of mentality of staff from operation to dismantling becomes important.

9. Final Discussion

A short final discussion was conducted where each session chair gave a short statement.

Frederic Tardy: For radiological characterisation of systems and components, techniques are available, but sampling techniques require more sharing of experience. Methodologies for radiological characterisation for soils for clearance are well established (MARSSIM), but similar programmes could be developed for systems and components.

Yvon Desnoyers: For radiological characterisation of buildings and rooms, some issues are similar to components, e.g. sampling and decontamination. The techniques need to be kept to the needs of the project, and uncertainties of the analysis need to be quantified. The contamination level is generally lower in buildings than for systems and components, but there are much larger areas involved. Therefore, the cost-benefit analysis is different and needs to be carried out with careful consideration of the objectives.

Katherine Eilbeck: More joint research projects are required in order to pool resources. This would achieve much more than pursuing single approaches. As an example, directional drilling for subsurface characterisation was mentioned.

Nieves Martin Palomo: With respect to data management and similar aspects, identification of the gaps in the radiological characterisation process and solving any problems as early as possible is very important. In the future, the analysis and update of data and results in "real time" to give much faster overviews of changes will be more important.

Henrik Efraimsson: Share experience in a structured manner and making information available to everybody is important: networking, fora for Q&A, standardised project reports, databases etc.

10. Closing Remarks

When closing the workshop, Arne Larsson thanked the speakers for presentations of an outstanding quality, the audience for a lively input to the discussions and the staff of Studsvik as well as the RCD Task Group for planning and preparation of the workshop. In the afternoon of the last day, tours of the Studsvik site led the participants to the R2 reactor decommissioning project, the hot cell laboratory, the melting facility, the incineration facility and various other installations, providing first-hand insight into the tasks and methods of modern decommissioning and waste management processes.