

## **Approaches used for Clearance of Land from Nuclear Facilities among Several Countries: Evaluation for Regulatory Input**

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**Abstract.** The purpose of this report is to describe, compare and evaluate the pros and cons of different methods for radiological characterisation of land areas after decommissioning of nuclear facilities. Specifically, it describes and examines the applied methods for the final status survey used in France, Germany, Spain, the United Kingdom (UK), and the United States (US). The Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten, SSM) has authorised this comparison and evaluation for dissemination to industry and other interested parties. The information from the five countries in the study came from several kinds of sources. Professional network referrals identified subject matter experts in each of the five countries who were then contacted. The contacts provided electronic documents or online links to the publicly available information. The online links often led to additional world-wide-web searches and more information. In addition, some information was provided by private communication in e-mails. Other experts provided electronic proceedings of a conference or symposium.

The information was compared and evaluated on for each country according to each of ten attributes:

1. Regulatory basis;
2. Scope;
3. Applicability;
4. Flexibility;
5. Transparency;
6. Roles and responsibilities of parties involved;
7. Quality program;
8. Detail of measurements descriptions;
9. Mathematical approaches;
10. Available assessment tools.

A summary comparison across all countries for each attribute is presented in a table. Overall, it appears that each country has a goal of clearing lands from nuclear facilities at a risk of a fatality from residual radioactivity of on the order of one-in-a-million per year. However, their approaches vary in a number of aspects, and evaluation of these different approaches should take into account the regulatory culture of the respective country.

High level considerations for developing regulations and guidance for implementation of final status surveys take into account the regulatory framework, stakeholder involvement, and the Data Quality Objectives structure for the development. Concluding remarks note that development of such guidance does not require starting anew. Rather, established guidance that has proven effective, efficient and useful such as MARSSIM and EURSSEM can be adopted or at least used as a starting basis.

**Presentation.** Good Morning!

To the Session Chair and colleagues, thank you for the opportunity to speak to you about a topic of mutual interest. The subject of this presentation is Site Clearance. Specifically, it is a comparison of processes used to verify that clearance criteria have been met and thus that the site can be released for general use—at least from a radiological point of view. This work was done under a contract with the Swedish Radiation Safety Authority, SSM, and it is based on a report entitled, *Approaches used for Clearance of Land from Nuclear Facilities among Several Countries: Evaluation for*

*Regulatory Input.* SSM plans to publish this report electronically and in hardcopy. The presentation has five parts: the purpose; the methods used; the results; concluding remarks; and, discussion.

As a result of a number of international meetings and professional information exchanges, the staff at SSM was aware that site clearance is not approached in the same way among countries. So, SSM initiated a comparative study to examine the various approaches in more detail. The thought is that: a better understanding of the alternatives for clearing nuclear facilities would be valuable to SSM in developing their own regulations and guidance. In addition, Swedish industry could potentially benefit from this information from other countries by understanding the importance of different attributes that characterise those various approaches. With this understanding, better and more informed planning for the facility's clearance approach could be implemented. So, the purpose of this presentation is to describe major parts of the report that was prepared for SSM to compare and evaluate different methods for radiological characterisation of land areas at the end of decommissioning nuclear facilities.

I compared the approaches used in France, Germany, Spain, the UK and the US. The sources of information were from official documents that were readily available on the internet, from public information provided by contacts in the respective countries, and from personal communications with colleagues in these countries. From this information, I identified important attributes of the approaches to investigate in more detail for the report. These attributes will be listed in the next two slides. **It is important to keep in mind that the focus of the report and this presentation is to examine in detail and to understand how the clearance of a nuclear site is actually implemented and verified in these countries.** To do this, it is necessary first to understand the objectives of the regulations and the regulatory environment.

These are the first five attributes that I examined and compared.

- First is the *Regulatory basis*—It is the identification of exactly what is the legal statement that leads to the regulatory requirements. Does it specifically lead to the regulations and guidance? Or is it a general connection that describes the implementation or outcome with general principles.
- The *Scope* attribute refers to the topics of the regulations, policies, and guidance. Are they general or specific? For example, do they include instrumentation and uncertainties? Does the guidance describe the entire process? Or is it limited to clearance approval? Does it address surfaces and sub-surfaces; etc.
- *Applicability* means do the regulations, policies and guidance specifically address authorisation of clearance and how it is finally accomplished? Is there a general statement of compliance for clearance? Or are specific criteria stated that have to be met?
- *Flexibility* addresses whether the processes are prescriptive or outcome based. Are various interpretations of the requirements possible? Is there an ability to modify requirements? Is there a specific operational authority for all sites, or is it on a case-by-case basis?
- *Transparency* means that descriptions of verification processes are explicit and detailed. Are the respective requirements and guidance clearly understood? Transparent implies that most technically qualified persons would be able to reproduce the results from the data that are used to make the decision. Are the processes that are used readily available to the public?

The remainder of the attributes of the site clearance processes that were compared are on this slide.

- The first one addresses the *Roles and responsibilities of parties involved*. Are they stated as specific requirements of authorities? Specifically, what are the responsibilities of facility operators? What are the roles of various implementers of clearance procedures; what are the roles of various stakeholders? In other words, who does what? Which other stakeholders have a role?

- A *Quality program* requires control of processes and documentation. Is there one required in the regulations, policies or guidance? Are Data Quality Objectives stated and followed or required?
- The next attribute examines how do the requirements or guidance address the *Details of measurement descriptions*? This would include types of instruments, calibration, use of radionuclide vectors, quantitative uncertainty calculations.
- Are *Mathematical approaches* provided? If so, are they rigorous mathematically or are they of general technical defensibility? Are there explicit or general details of mathematical procedures given?
- Finally, does the guidance lead to *Available assessment tools*—For example, statistical software applications for clearance; data logging of measurements; mapping software?

Following a detailed description of each attribute for each country, I combined a summary of the information in a table. The table is too large to show you in this presentation, so I am showing you only four rows from the table. Each row is for the comparison of a single attribute.

This slide is for the first attribute, regulatory basis. Please recognise that in such a summary table, there must be some tolerance for generalising sometimes complicated legal and regulatory language. I made my best attempt to represent each attribute from the available information.

In the report, there are comparisons for all the attributes from each of the respective countries in the summary table.

- The regulatory basis in France for site clearance comes, at least in part, from two acts, a decree, and a policy. Central to the implementation of clearance is the 2006 Act. The Act defines materials on a site that is undergoing decommissioning as either conventional or radioactive waste. Radioactive waste is defined as the activity or concentration of which warrants a radiation protection control. Radioactive waste includes any radioactive substance for which no further use is prescribed or considered. ASN guides number 14 and 6 identify the manager as the one who makes the determination of the objective concentrations. Further, it is the responsibility of the operator to plan and ensure that all hazardous waste, including radioactive waste is removed.
- The regulatory basis for clearance of nuclear facilities in Germany lies in the German Radiation Protection Ordinance. The clearance criteria are prescribed in comprehensive detail by this Ordinance.
- Spanish guidance appears mostly to use methods and procedures adopted by international organisations and other countries, such as from the European Commission (EC) and the US. In 1984 the Parliament decided to set up a public company to manage the radioactive wastes generated in Spain. Enresa is also responsible for the dismantling of nuclear power plants when their service lifetime has come to an end and for the environmental restoration of disused uranium mines and facilities.
- In the UK, the Health and Safety Executive (HSE) is the regulator for nuclear facilities as well as for other work places. The Nuclear Installations Act 1965 contained wording that set a criterion of “no danger” for decommissioned nuclear facilities. The “no danger” criterion drove HSE to define its meaning. In 2005, HSE published its radiological criterion for the delicensing of a nuclear facility. For practical purposes, HSE will consider the satisfactory demonstration of a risk from radionuclides above background less than one in a million would normally mean the site could be allowed to be delicensed. HSE is of the view that doses to members of the public that are of the order of 10  $\mu\text{Sv}$  or less per year broadly equates to the 1 in a million per year ‘no danger’ criterion. The Energy Act 2004, enacted by Parliament, established a public corporation, the Nuclear Decommissioning Authority (NDA). NDA owns the civil nuclear facilities. Its purpose is to deliver the decommissioning and clean-up of the UK’s civil nuclear legacy in a safe and cost-effective manner. NDA contracts out the delivery of site programmes through management and operation contracts with licensed operators, Site Licence Companies (SLCs), at each site. SLCs manage sites, including preparing site plans, performing and sub-contracting work. There is another layer of responsibilities in between.

Parent Body Organisations (PBOs) own shares in SLCs for the duration of their contract with the NDA. The PBO is responsible for managing the delivery of site programmes.

- The principal enabling US law that authorises the Department of Energy (DOE), the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) is the Atomic Energy Act (AEA) as amended. Clearance criteria vary among these agencies. However, the DOE, EPA, NRC, and the US Department of Defense endorse the processes and methods in MARSSIM for demonstrating compliance with clearance criteria for surfaces of structures (buildings, etc.) and lands with radionuclides from licensed operations.

This is the row addressing flexibility.

- There is considerable flexibility in the implementation left to the judgment of the facility operator in France. However, the details of the implementation must be documented in the decommissioning plan and approved by the regulator, ASN. Thus, within the framework, the implementation and final judgment, both, are on a case-by-case basis.
- Both the German Radiation Protection Ordinance and the DIN standard are prescriptive in nature. Upon request, the authority may find that the dose-based requirement for clearance may be met in a specific situation by the use of different criteria, e.g., different radionuclide concentrations. [See Part 2, Chapter 2, Section 9, §29 (2).] Notable flexibilities arise in the DIN for areas of statistical treatment of log-normally distributed radionuclide concentrations and also for the level of detail in implementation plans.
- The reviewed Spanish documents allow a great deal of flexibility and appear to be oriented to clearance on a case-by-case basis.
- The details for implementing delicensing in the UK appear to be highly flexible. Not only are they developed on a site-specific basis, but apparently they can be progressive during the decommissioning processes and finalised shortly before the survey for verification of the Site End State.
- In the US, MARSSIM methods and processes are non-binding, and other alternative methods may be used to comply with clearance criteria. MARSSIM processes are endorsed as methods and processes that the regulatory authorities find acceptable to verify compliance. As such, they are highly prescriptive, but generally applicable to a variety of final states of the site, e.g., green field or structures remaining.

This slide shows the row comparing roles and responsibilities of parties involved.

- In France, the ASN Policy includes a statement that the statutory procedure for obtaining authorization to decommission requires consultation between the relevant parties: the public, the public authorities concerned (national or European) and the local information commission. ASN recommends that operators form an active partnership with them during the final shutdown and dismantling authorization application procedure. The organisation and roles of teams for the operator's facility were not mentioned in the documents that I reviewed.
- The German Atomic Energy Act, abbreviated AtG, clearly specifies the roles of the authorities and requirements of the operator of the facility, and persons who perform various functions must be qualified. In terms of stakeholders from the public or groups, the (AtG) requires that decommissioning be licensed; however, the requirement for a public hearing may be waived.
- The roles of Spanish authorities are very well established and clear. The roles of the various implementers of the final radiological study at the facility were not found. Nothing in the reviewed documents mentioned a role for members of the public or of organisations in the clearance process. However, the autonomous communities do have opportunity for input.
- In the UK documents I reviewed, and in general for the UK, there appears to be a very complex inter-woven and inter-linked constellation of roles. There may be overlapping requirements by authorities and blurred responsibilities among facility operators, on-site implementers, and various stakeholders--including government-industry groups. These roles

and responsibilities seem likely to evolve on a case-by-case basis as the site-specific strategy and plans develop.

- The US MARSSIM guidance states specific responsibilities of a planning team for the design and implementation of the surveys. A different team may perform the analysis. The decision may be made by still another team or individual. There are a number of places where consultation with the regulatory authorities, and perhaps other stakeholders, is recommended.

This last slide on attribute comparisons addresses the guidance on the mathematical approaches. Please recall that the full table in the report compares all ten attributes.

- Requirements and guidance from ASN apparently do not indicate specific mathematical approaches to provide the technical basis for clearance of French nuclear facilities. Rather, they recommend the best available technology. In support of using the best available technologies, CEA actively conducts research as demonstrated in the Sampling and Characterization II symposium in April 2010. Geospatial statistics are promoted. I must note that for sites with simple situations, the best available technology may not be the optimal technology to reach the desired end results at lower costs.
- There are specific statistical instructions, with examples, in the German DIN standard that describe a method to calculate the number of samples needed to confirm that clearance requirements have been met with 95% probability. The method uses the binomial distribution and the calculation of a confidence interval with the inverse F-distribution. The DIN requires that if measurements exceed the clearance level, the adjacent grid areas are to be measured and perhaps the survey unit be re-designated to exceed clearance levels. There is also flexibility to use other mathematical distributions, and an annex provides a procedure for using a log-normal distribution to make the decision.
- In Spain the details of the statistics needed to demonstrate that clearance criteria in the Site Restoration Plan were met are left apparently for ENRESA to describe and defend. I did not find specific guidance on accepted statistical approaches in the documents I reviewed.
- In the general case, acceptable mathematical approaches were not found in the UK documents I reviewed. However, in a specific case, apparently from the Dounreay site, I found rigorous, technically defensible and explicit mathematical procedures.
- In MARSSIM, rigorous mathematical approaches are essential for ensuring that the implementation, data analysis, quantified combined standard uncertainty, and the decision are technically sound and defensible. The statistical approach is to use the non-parametric Wilcoxon Rank Sum test or the Sign test to calculate the number of samples needed and to verify that the desired Type I error rate is met. For data logging data sets random samples are taken from the data to make the statistical samples. These tests have an underlying assumption that the measurements are spatially independent. Geospatial statistics account for spatial correlation and are not included at present. The explanations in MARSSIM are explicit and accompanied with illustrative examples.

It is clear that there are wide-ranges of approaches for each attribute among the countries. Please recall that the focus of the report is to examine how the site clearance processes are actually implemented and verified. For some countries, the guidance and even the regulatory basis is clearly prescriptive. That is, by carefully following specific instructions, step-by-step, the site will be cleared. In other countries, the guidance is based on the final outcome or objective with the demonstration of compliance that is subject to approval. In some cases, the case-by-case approach may result in different end states from site to site within a country, while in others, the end state is relatively uniform throughout the country.

It appears that the regulatory climate in the country itself is a very significant factor in the implementation of site clearance. The degree of rigor and acceptable uncertainty required by the

regulatory climate starts with the regulations and carries through to the policies and guidance, and on to the characterisation of the end state clearance.

For example, the processes leading to de-licensing of a site in the UK appear to incorporate a significant amount of stakeholder input and an evolutionary development of the end state criteria. In the end, there appears to be a general convergence between the stakeholders, the facility, and the regulators that the de-licensing decision can be made.

This UK example, illustrates the trade-offs among the various approaches. A dynamic set of criteria or a case-by-case approach can require significantly more regulatory effort and inspections than an approach that requires that a prescriptive set of criteria to be met. In the case of prescriptive criteria, wide acceptance is likely to require detailed examination of those criteria and wide stakeholder input and approval before they are adopted. A prescriptive approach can lead to uniform end stages throughout the country, but they are somewhat inflexible in their character. So case-by-case changes may be more difficult to obtain in the prescriptive regulatory climate.

In all approaches for site clearance, the implementation needs to be technically defensible. The treatment of uncertainties in the verification appear to be weak in the documentation I examined, except for the US case. There are sound documents based on the Data Quality Objectives process that are publically available and address how to quantify uncertainties. These processes do not have to be re-invented. Examples are MARSSIM and EURSSEM.

With that thought, I end this presentation.  
Thank you!