Joint NEA / IAEA / EC Workshop
on
The Regulatory Aspects of Decommissioning

Rome, Italy

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EDITORIAL NOTE

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INTRODUCTION

As more nuclear installations begin to reach the ends of their useful lives, decommissioning projects have become more common, and the technical aspects of the decommissioning process have become better understood. With this better understanding of the technical issues, the decommissioning process has moved from "case-by-case" R&D programmes towards being a much more standardised industrial process, taking specific site characteristics into account as necessary. With this shift to more routine operations, interest has risen in more generically applicable regulations, guides and standards, both nationally and internationally.

In this context, discussions have begun concerning the regulatory aspects of Nuclear Installations decommissioning. In order to facilitate progress towards better mutual understanding of the rationale behind and the practical implications of decommissioning regulations, dialogue between regulators and implementers is seen as being particularly valuable.

To further the dialogue in this area, the OECD Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA), and the European Commission (EC) agreed to co-sponsor a Workshop to bring together regulators, implementers and waste receiving organisations to identify those regulatory issues of most concern.

This Workshop was held from the 19th to the 21st of May, 1999, and was hosted in Rome, Italy, by the Italian National Environmental Protection Agency (ANPA).

The scope of discussions at this Workshop included the decommissioning of all nuclear installations, but excluded mines, mills and mill tailings piles, as well as waste disposal facilities. Many of the issues raised in this context would be directly or partially applicable to the decommissioning of radioactively contaminated facilities not explicitly included in these discussions.

Within this scope, the objective of the Workshop was to assist regulators, implementers and waste receiving organisations to identify those regulatory issues still in need of some resolution and work towards a mutual understanding of roles and needs and the resolution of conflicts. More specifically, this Workshop was being held:

- to hold a focused dialogue among the organisations responsible for the regulation of decommissioning activities, the operational decommissioning of nuclear installations and for receiving and disposing of waste arising from the decommissioning process, in order to share views concerning the most significant regulatory aspects of decommissioning;
- to identify the points of international consensus regarding the regulation of decommissioning activities;
- to identify those issues where further discussion and work is needed in order to reach consensus among the various stakeholders; and
- to suggest processes by which consensus can be reached on the above issues.

Discussions at the national and international level have already begun in this area, and even before the Workshop it was possible to identify several issues which were gaining importance. These included:

- Decommissioning of a nuclear facility produces radioactive waste which cannot be released for uncontrolled use, but which requires ultimate disposal in a safe manner. Therefore, a national waste management system, including a regulatory basis, is a necessary condition for starting decommissioning. The system may be based on interim storage capability, or incorporate final disposal arrangements. It may vary from a centralised to a decentralised approach with respect to the sites and organisations involved.

- There has been much discussion of exemption, clearance and authorised release, both at the national and international levels. In 1996, NEA published the results of a questionnaire to its Member States on the management of very low level wastes which, inter alia, addressed the question of criteria being used for release from regulatory control.

- In 1997, the IAEA organised a Specialists Meeting on the application of the concepts of exclusion, exemption and clearance. The meeting concluded that, in future, it would be necessary to clarify terminology in the subject area and to address the whole range of regulatory mechanisms by which materials can be released from control. The NEA Liaison Committee Task Group on Recycling and Reuse has made proposals for a tiered system to be applied to the release of materials from regulatory control. Progress has been made in this area but more needs to be done

- With regard to the future enlargement of the European Union, decommissioning is an activity that is of growing importance in the field of nuclear safety and radioactive waste management. Therefore, the European Commission decided to concentrate more efforts on the regulatory, policy and strategy aspects of decommissioning during the upcoming years. As a starting point the EC prepared an expert report on decommissioning policies and is actively working on an official communication on the subject.

- Other aspects of the demonstration of compliance with national and international regulations are also of interest, for example, the technical aspects of release measurements. The regulatory aspects of compliance with clearance levels, and of regulatory certification for release, are influenced by the technical aspects of the process, but these, as with the other issues, should be discussed in a forum between regulators and implementers.

- Public acceptance of recycled materials from nuclear power plants is an issue of concern in some countries, and the problem of how to explain and provide a proper perspective for the release of these materials to members of the public needs to be addressed.

- Problems are occurring with the transboundary movement of very low activity materials, in particular metal scrap. Detection systems at borders are not an answer in themselves and often cause undue concerns because of false alarms. With more of such materials becoming available through decommissioning, an agreed international system for control should be established.

- Throughout the decommissioning process the use of specified decontamination and dismantling technologies depend on, and interact with, safety and regulatory aspects.

- The regulatory process of site "declassification" is of great interest to regulators and implementers alike. The phases of declassification of an operational facility involve some or all of the following: passage from operation to a cold-shutdown configuration, cold shutdown phase, passage from cold-shutdown to a safe storage phase, safe storage phase, dismantling phase, restricted and/or unrestricted site release. The regulatory process necessary for this declassification is most likely stepwise, but with larger or smaller steps depending on the national regulatory context. The definition of this process will be of interest to all stakeholders, and should be discussed in an international and national context to help assure consensus and understanding of national differences.

- As part of the declassification process it is essential to have in place the appropriate regulatory criteria and to be able to demonstrate compliance with them.

- Many decommissioning strategies involve maintaining a facility in a SafeStore status for long periods, perhaps over 100 years, prior to final demolition and return to "green field" status. Because of these long periods, the regulatory approach necessary to assure that financial liabilities are appropriately addressed becomes important.

- Once normal operation ends, until the spent fuel is completely removed from the reactor and fuel storage pool, there still exist nuclear safety concerns, particularly in terms of human factors. These concerns are related in the short term especially to the motivation of the staff involved to maintain high safety culture in their work, and in the long term to the availability of competent staff with adequate knowledge on all relevant issues. There are similar safety concerns for other nuclear installations in these same circumstances. An understanding of the significance of these issues, and of how they should be taken into account in the regulation of reactors during all phases of decommissioning, should be discussed.

To discuss these issues, as well as others identified by the various invited papers, the workshop was organised into seven sessions covering the following topics:

1. Introduction: Setting the Scene
2. The Current Situation: Keynote Papers
3. The Management of Materials from Decommissioning
   3.a The Management of Radioactive Waste from Decommissioning
   3.b Exemption, Clearance and Authorised Release
4. The Management of Site Decommissioning
5. Liability and Financial Aspects
6. Human Factors and Organisational Issues
7. Conclusions and Closure: Panel Discussion

A list of Programme Committee Members is provided in Annex 1, while Annex 2 lists the rapporteurs for the Workshop. Annex 3 contains the list of registrants for the Workshop.

These Proceedings include all the papers submitted as of the end of July 1999, as well as a summary of the final discussions and conclusions of the Workshop.

WELCOME ADDRESS

Giovanni Damiani,
Director of the National Agency for Environmental Protection (ANPA)

Good morning Ladies and Gentlemen, and welcome to Rome.

After NEA's invitation to the member states to host the Workshop on the Regulatory Aspects of Decommissioning, ANPA, the Italian National Agency for the Environmental Protection which, inter alia, is the National Technical Body responsible for Nuclear Safety and Radiation Protection and related regulatory procedures, did not hesitate to accept such an invitation, offering its support and assistance to organise this event in Rome.

We think that a meeting like this may offer an excellent opportunity to know, first hand, other countries' experience regarding the regulatory aspects of the decommissioning, the decommissioning safety assessment, as well as sharing such experience and opinions.

Taking into account the experience and the reputation of the speakers, we are sure that the technical level of this workshop will constitute an excellent and remarkable reference, with which next years' activities can be faced.

As all of us well know, several nuclear reactors in the world will reach, in the next decade, the end of their working lifetime, and as a consequence, will start the relevant decommissioning operations. Significant experience in these operations is today available, and, in particular, the NEA Cooperative Programme in Decommissioning offered an remarkable reference point for the exchange of information in this important area.

However, we think that the specific aspect of the regulatory framework, essential to ensure that decommissioning operation will be carried out safely and providing for an effective protection of individuals, society and the environment, needs a particular and special attention.

In this connection, the great interest shown in this workshop, clearly demonstrated by the level and number of participants, is a matter of satisfaction for ANPA.

Therefore, we express the wish that this workshop may be the starting point for further useful occasions, in view of the implementation of a forum for discussion on regulatory knowledge and experience in the field of decommissioning.

We are also convinced that the whole decommissioning process should develop with openness and transparency, with a rigorous process of information and participation, and in the frame of a clear and responsible regulatory regime; according to our experience, these conditions are essential in order to gain the public consensus, without which the decommissioning operations could hardly be performed and even started.

In Italy, a strong and complex programme for the ultimate management of post-closure nuclear heritage, including radioactive waste and decommissioning, is going to be launched by the Government; this is an additional reason why we are so happy to host this workshop in our country.

Actually, it is for us an honour and a great pleasure to have the opportunity, by hosting this workshop, to cooperate with the NEA, as well as with the IAEA and the EC, co-sponsors of this meeting, in promoting, now and in the future, the exchange of information and experience in this very important field.

In conclusion, Ladies and Gentlemen, I wish all of you a pleasant and fruitful meeting, and, at the same time, I hope you will enjoy the flavour and the atmosphere of the beautiful city of Rome.

Thank you very much for your attention.

OPENING ADDRESS

Luis Echávarri
Director General of the OECD Nuclear Energy Agency

Good Morning Mr.Chairman, Ladies and Gentlemen:

On behalf of the OECD Nuclear Energy Agency, I would like to welcome you all here today. The fact that you are so numerous, over 100 registrations, and that this workshop has been co-sponsored by five Standing Technical Committees of the NEA, as well as by the IAEA and the EC, attests to the importance of decommissioning to regulators, decommissioners, and waste handling organisations. I am sure that many very interesting aspects of decommissioning will be discussed during this workshop, and that we will succeed in clarifying issues for international consensus.

As you are aware, the world's current fleet of nuclear power plants continues, logically, to age, and the world around us continues to change, particularly in terms of the economic and policy context in which nuclear power regulators operate and, for that matter, the nuclear industry in general. These changes have led, in some cases, to decisions to decommission commercial nuclear power plants.

As of April 1998, there were 73 commercial nuclear power plants, in 10 countries, in some phase of decommissioning. These include 11 western-style PWRs, 14 BWRs, 11 PHWRs, 4 HTGRs, 3 HWGCRs, 3 FBR's, 2 GCRs, 14 Magnox Reactors, 1 SGHWR, 8 VVERs, and 2 RBMKs. As can be seen from the summary table, in general, these plants were closed down at an early age (18 years of commercial operation on average), and are generally relatively small (averaging only about 300 Mwe). What can also be seen from the table is that, in spite of the comparatively low number of years of commercial operation, the reactors which have thus far been decommissioned tend to be older plants in the sense that their construction began, on average, 35 years ago.

In view of this characterisation, it is certain that economic pressures have played a significant role in the decision to decommission these plants. Policy decisions, particularly for plants in former East Germany, in Italy, and some plants in the United States, have also played an important role in determining when plants should be decommissioned.

Statistics on those Commercial Nuclear Power Plants which were in some phase of Decommissioning as of April 1998 (IAEA 98)

Country	Average Number of Years of Commercial Operation	Average Age of the Reactor from Start of Construction Today (years)	Average Gross Power (Mwe)	Number of Reactors in Decommissioning
Armenia	9	25	408	1
Belgium	24	41	12	1
Canada	20	32	499	9
France	20	38	264	10
Germany	12	31	250	16
Italy	18	36	376	4
Japan	19	38	13	1
Netherlands	28	33	59	1
Russia	20	38	211	4
Slovak Republic	6	40	144	1
Spain	18	30	500	1
Sweden	10	41	12	1
United Kingdom	23	39	215	9
United States	18	36	383	14
Overall Average	**18**	**35**	**300**	**73 (Total)**

With such a wide variety of plant types, sizes, ages and locations, a great diversity exists in the characteristics of decommissioning projects, and in their mid- and long-term objectives. The design of decommissioning plans is, in general, the responsibility of the operator, but requires the authorisation of the national regulatory authority. In many cases, the objective of decommissioning is to return the site to a "green field" state, however, other, more restricted reuse of the site, often for other nuclear facilities, is also considered.

Variation is also evident in the periods of safe storage before full dismantling. For example, in Finland, plans for PWR decommissioning specify early dismantling (within 10 years), but 30 years of safe storage for BWRs. In France, decommissioning is planned to include 50 years of safe storage. In Japan, only 5 to 10 years of safe storage are proposed, followed by site decommissioning and cleanup generally for reuse as a licensed, nuclear facility. For GCRs in the UK, an initial period of 35 years is proposed for preliminary decommissioning activities, followed by 100 years of safe storage, after which full decommissioning can take place. Approaches and proposed time spans of operators in most other countries fall within these bands.

In a regulatory sense, decommissioning is relatively new. Although some countries have had comprehensive decommissioning regulations in place for many years, this is the exception rather than the rule. For example, regulations regarding the clearance of materials from regulatory control, specifically as applied to materials from decommissioning, are under development in most European countries in order to comply with the latest EU directives. Rulemaking in this area is also currently in progress in the United States. Internationally, the IAEA, together with the NEA and several other international organisations, is developing guidance on exclusion, exemption and clearance. These efforts attest to the current relevance of these issues and the level of interest, both nationally and internationally, by regulators, waste handling organisations and operators alike.

In terms of specific issues of interest, many of these are regulatory in nature, however public acceptance, technical and cost issues are also important. For example, an issue tied to all of these aspects is that of identifying criteria and regulations for the release of decommissioned materials for unrestricted use. This includes such matters as metals and concrete which can be recycled, as well as other materials which can be disposed of in normal waste repositories or through incineration. The resolution of this issue in a scientifically, politically, and publicly acceptable fashion is a key to successful decommissioning policy at national and international levels.

A short summary of some of the most significant projects, regulatory and public concerns includes the following:

Some Regulatory, Public Acceptance, Cost and Technical Issues in Decommissioning

Regulatory Issues:

- the status of a national waste management infrastructure, including temporary storage and ultimate disposal;
- national regulations regarding the clearance of materials from regulatory control;
- national and international regulations governing the transboundary movements of materials released from national regulatory control;
- the regulatory process declassification, from a regulated site to a released site;
- liability and financial considerations over very long periods; and
- nuclear safety considerations between the decision to shutdown and the removal of all fuel elements.

Public Acceptance Issues:

- public acceptance of materials released for disposal in municipal landfills;
- public acceptance of materials released for recycling; and
- public acceptance of sites released for unrestricted use.

Cost and Technical Issues:

- monitoring techniques for the release of large volumes of material to demonstrate compliance with regulatory requirements;
- decommissioning cost characterisation; and
- decommissioning schedule.

A development of great significance for decommissioning in particular, and the nuclear industry in general, has been the increasing awareness of naturally occurring radioactivity (NORM), which is technologically concentrated (and released) by many non-nuclear industries. Considering the large number of industries and quantities of material involved, the relative activity levels, and the collective doses actually being received by the population, the main message from the NORM issue is that radioactivity is not only a part of the human environment but needs to be viewed globally. In the area of radioactive low level waste, the nuclear industry represents just a small part of the many global radioactive waste generators. The way in which regulators address the disposal of NORM and of wastes from decommissioning activities is of great interest to the decommissioning community.

Since the mid 1980's, technical and project management progress in the area of decommissioning has been very significant, such that decommissioning has grown from the scale of demonstration and pilot projects, to full industrial scale (NEA 96). However, in spite of this, the fact that decommissioning has been a relevant issue since the very beginning of the nuclear industry, and that there are currently many decommissioning projects in progress, it has only been during the past few years that there has been a concerted attempt, both nationally and internationally, to address the questions whose answers are essential to the success of most decommissioning projects.

I feel that this workshop will be a significant step towards clearly defining the international consensus that currently exists in some of these important areas, and towards identifying a process to reach consensus, and mutual understanding of legitimate differences, in other areas.

I thank you for the efforts which you will make here this week, and I wish you luck in your discussions of this essential area of the nuclear fuel cycle.

Reference:

Nuclear Power Reactors in the World: Reference Data Series No.2 (IAEA, 1998)

WELCOME ADDRESS

Abel J. González
Director, Division of Radiation and Waste Safety, International Atomic Energy Agency

On behalf of the Director General of the IAEA, Dr. Elbaradei, I would like to welcome all of you to this workshop concerning regulatory aspects of decommissioning. Let my first words be of gratitude to the Italian Government for agreeing to host this meeting. We are particularly grateful to the Italian National Environmental Protection Agency for the work done in organising this event. Let me also express our recognition to our sister organisations the Nuclear Energy Agency of OECD and the European Commission who are jointly sponsoring this workshop with the IAEA. Last but not least, let me convey our thanks to all of you, the real *alma mater* of this event, as well as to the governments and organizations that are supporting your stay in Rome.

The IAEA

I would like first to say a few words about the organisation that I represent, the IAEA. Many of you are well acquainted with the Agency and its role, but many people working in decommissioning activities are not. I will therefore apologise to those who know the Agency well because I will repeat here concept that are not new for them but which could be of interest for others.

As you probably know, the IAEA is a constituent organization of the United Nations (UN) system. Its three essential functions are:

- the safeguarding of the peaceful uses of nuclear energy;
- the transference of nuclear techniques; and,
- the promotion of radiation safety and nuclear safety.

The IAEA has a membership of 128 Member States. It is served by more than 800 professional staff and 900 general support personnel. Its 'regular' budget (or direct expenses shared by Member States) is of US$ 225 million. The budget for technical co-operation, mainly for assisting developing Member States, is around US$ 90 million. A number of Member States make extra-budgetary contributions of more than US$ 10 million. In addition to these cash budgets, the IAEA benefits from a large amount of contributions in kind from its membership.

Within the UN family, the IAEA is the only Agency with specific statutory functions in the field of nuclear, radiation and waste safety. (I shall refer to this field just as 'safety'). It is authorized by its Statute:

- to establish standards of safety for the protection of health; and
- to provide for the application of these standards at the request of any State.

In recent years the IAEA has been given, *de facto*, an additional function, namely:

- to facilitate the undertaking by States of legally binding obligations in relation to safety, mainly in the form of international conventions.

By virtue of its functions, the IAEA, has - not surprisingly - become a catalysing global forum for safety, and the operator of the largest international safety programme.

We need to recognise that, during this decade, the world has experienced the emergence of a *growing international safety regime*. This regime will have -I am convinced- a large impact on the future of decommissioning. The regime can be construed to be constituted by three key elements, for all of which – I emphasise – the IAEA has primary responsibility, namely:

- legally binding international undertakings (conventions) amongst States, encompassing obligations on safety;
- globally agreed international safety standards; and
- international provisions for facilitating the application of those standards.

Conventions: Three important international conventions enforcing safety obligations have become operative under the auspices of the IAEA. They are:

- The Convention on Early Notification of a Nuclear Accident;
- The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency; and
- The Convention on Nuclear Safety.

Another important convention for safety, which will have an important impact in decommissioning, has been approved, but has not yet been adopted as the number of countries that have ratified is not enough; this is:

- The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

I should underline that:

- international conventions supersede relevant obligations under national law for any of the parties of the convention, and
- the IAEA has been selected as the focal international organization for the implementation of all these Conventions.

Standards: The IAEA has also been instrumental in the development of a formidable corpus of globally agreed international standards for radiation safety. The IAEA safety standards comprise more than 200 regulatory related publications. Many of these are directly applicable to decommissioning activities. They have been developed in co-operation with the Agency's Member States and with other international organisations, some of them with the NEA, and are issued in the IAEA Safety Standards Series.

The IAEA safety standards are substantiated by the findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) on the health effects of radiation exposure. Moreover, following a decision of the IAEA Member States, they are primarily based on recommendations of the International Commission on Radiological Protection (ICRP).

The standards are structured on three categories, namely:

- Safety Fundamentals - which set up the basic international policy in radiation safety, i.e., the basic objectives, concepts and principles to ensure radiation safety;

- Safety Requirements - which set up the 'shall' statements in the corpus of the standards, i.e., the basic requirements that must be satisfied; and

- Safety Guides - which set up the 'should' statements, i.e., recommendations - on the basis of international experience - relating to the fulfilment of the requirements; these would become mandatory in the absence of technically equivalent alternative solutions.

The IAEA safety standards cover safety requirements for nuclear installations, for other practices making use of ionising radiation and radioactive materials, for radioactive waste and specifically for the safe transport of radioactive material. In relation to decommissioning activities a most significant of the standards is the **International Basic Safety Standards** for Protection against Ionizing Radiation and for the Safety of Radiation Sources, which are also sponsored by FAO, ILO, NEA(OECD), PAHO and WHO, and were issued by the IAEA as Safety Series No. 115 (IAEA, Vienna, 1996). The IAEA has also developed a number of Safety Requirements and Safety Guides to assist countries in preparing for decommissioning activities. These are being used as a basis for their regulatory programmes.

Applications: Regarding the provisions for the application of its safety standards, the IAEA has an extensive ongoing programme. In relation to decommissioning, this programme includes activities for:

- providing direct safety related assistance in decommissioning to Member States;
- fostering the international exchange of safety related information on decommissioning;
- promoting education and training in safety aspects of decommissioning;
- co-ordinating research and development projects related to safe decommissioning; and, last but not least
- rendering a wide range of safety services, including peer reviews of decommissioning programmes to requesting Member States.

The Regulatory Aspects of Decommissioning

Now, after this introduction to the IAEA, let me turn to the specifics of the workshop itself, namely, the subject of the regulatory aspects of decommissioning.

The international standards presume that, in all States, legislation or laws provide the legal basis for the regulation of the peaceful uses of nuclear energy. Under these laws, a national authority is established as a regulatory body to control the safe use of nuclear power, nuclear material and ionizing radiation. For any facilities involving the use of radioactive materials, decommissioning is the final phase in the life of the facility.

It is the responsibility of the regulator to provide the requirements to ensure that the decommissioning is performed in a safe manner. To perform this duty, the regulators must change their thinking from that of regulating an operating facility to that of a cleanup or remediation. In some cases this can be very difficult. The regulator must combine many facets of safety and weave them into a coherent regulatory framework. This final activity may involve many different agencies, but must show to the general public that there is control, a defined path and a coherent programme.

Decommissioning may be used in various types of installations. They include installations of the nuclear fuel cycle, i.e., the so called nuclear facilities, installations where practices involving the use of radioactive materials have been operating, and even installations where a disproportionate amount of naturally occurring radionuclides are present. Decommissioning activities are also typical in the aftermath of a nuclear or radiological accident.

For nuclear facilities, in particular, decommissioning is becoming more and more important as the nuclear industry reaches maturity. The nuclear industry started over 50 years ago and many power plants and other nuclear facilities are reaching the end of their expected lifetimes. There are many reasons why these facilities have shut down and require decommissioning. These reasons range from changes in the political climate and economics to accidents which cause the facility to no longer operate. No matter what the reason, decommissioning provides new challenges which the operator and the regulator must face. Decommissioning is an important phase in the life cycle of a nuclear facility. It occurs at the end of the life of the facility and sometimes is forgotten until the time comes to shut the plant down and decide what to do. At this point it is too late to begin to dictate what the operator is to do. It can take as long or longer to decommission a facility as it did to commission it. There are more incidents of people getting injured or contaminated during decommissioning activities than during operation. The strain on resources is great.

With these general ideas, I could finish my opening remarks for this workshop. But, the IAEA will not be sincere with itself if we stop here. Because the more difficult regulatory problems of decommissioning today are not with the decommissioning phase itself. Rather, they are related with the radioactive residues that remain as a consequence of decommissioning activities. For that reason, I feel obliged to address this important aspect of decommissioning also. In particular, let me emphasize a number of specific topics which, on the one hand, are high on the international agenda today, and, on the other hand, are particularly important for safe decommissioning, and therefore of interest for this workshop. These topics are:

- the **regulation of the low-level radiation exposure** that may remain after decommissioning, taking into account the linear non-threshold (LNT) dose response relationship;
- the definition of the scope of the decommissioning regulations, including the concepts of exclusion and exemption; and
- the restoration of sites after decommissioning, i.e., the clean-up criteria.

Regulating low level radiation exposure after decommissioning: The Linear Non-Threshold (LNT) hypothesis

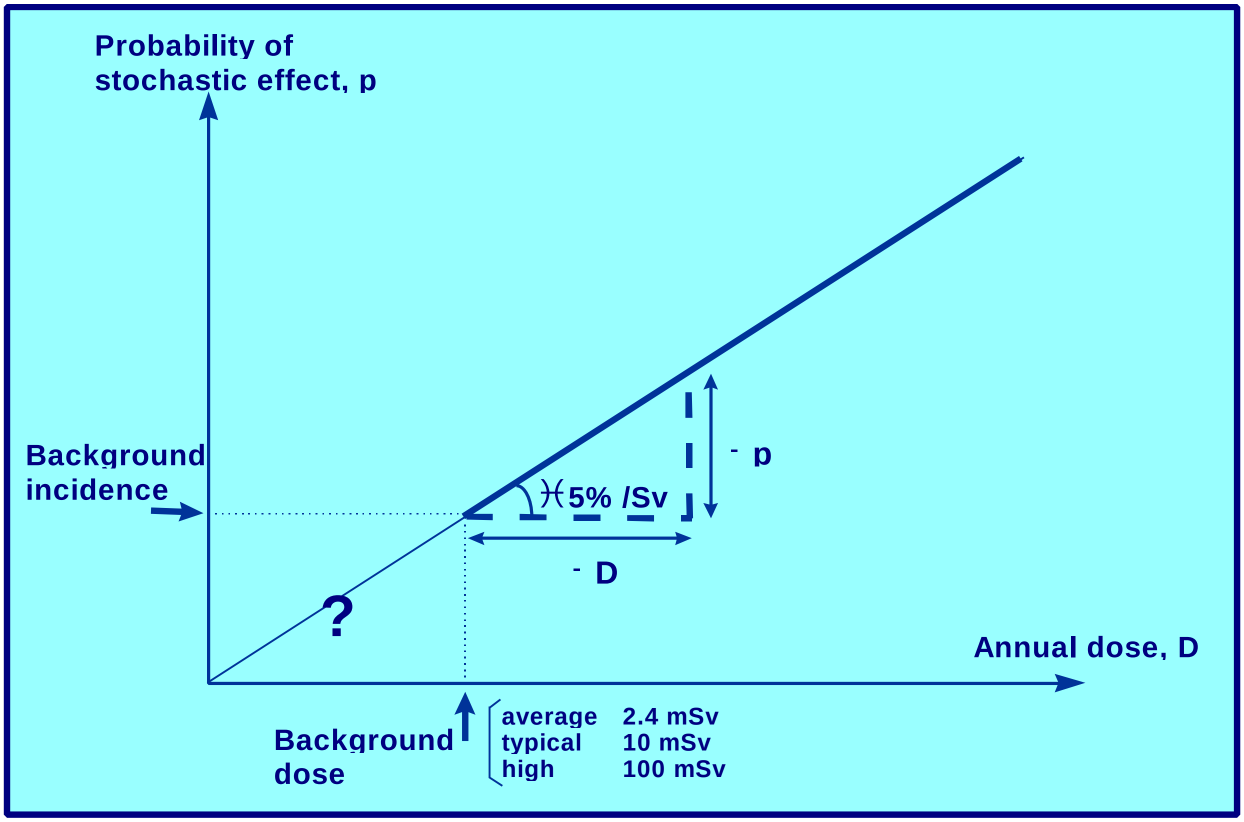
Any agreement on how to regulate the *low level radiation exposure* that are expected to occur after decommissioning requires a understanding on the expected health effects of this type of exposure. This has been a matter of recent controversy. The position on this issue of the IAEA and other international organizations is clearly addressed in the preamble of the International Basic Safety Standards, namely:

- health effects that can be clinically attributable to radiation in the exposed individual (the so-called *deterministic effects*) do not occur as a result of low level radiation exposure, as the dose threshold level above which these effects become manifest is much higher; and
- health effects that can be detected and attributed to radiation only through epidemiological studies of large exposed populations (so-called *stochastic effects*) are presumed to occur in direct proportion to the dose received, without a dose threshold.

In some forums, the international approach to stochastic health effects has been confusedly termed the *'linear non threshold'* (LNT) hypothesis.

It should be emphasized that the IAEA does not have a programme on its own on the controversial subject of the health effects of low level radiation exposure. Rather, as a member of the UN family, the IAEA relies on the policies of the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR regularly reports its findings to the highest UN body, the UN General Assembly. The so-called LNT is the UNSCEAR's policy on this matter.

The regulatory interpretation of the LNT: The LNT has been confusedly presented to regulators as a hypothesis requiring them to consider that at any dose, however small, a deleterious health effect should occur. However, the IAEA standards imply a much more subtle approach. The standards presume that - *above* the prevailing background level - an *increment in dose* will result in a *proportional increment in the probability of incurring a stochastic effect.* For regulatory purposes, therefore, the 'LNT' relationship recommended by the international standards is as presented in the figure.



The regulatory control of low level radiation: The controversy on LNT has focused on the biological effects of low doses of ionizing radiation; however, the bottom line issues in the debate are in fact how to regulate low-level radiation. The international standards presume that regulators should be able to regulate radiation sources properly with the current no-threshold linear dose response approach; i.e., with the approach that there is a linear dose-response, not necessarily linear to zero dose but linear above the relatively high background doses that all people unavoidably incur.

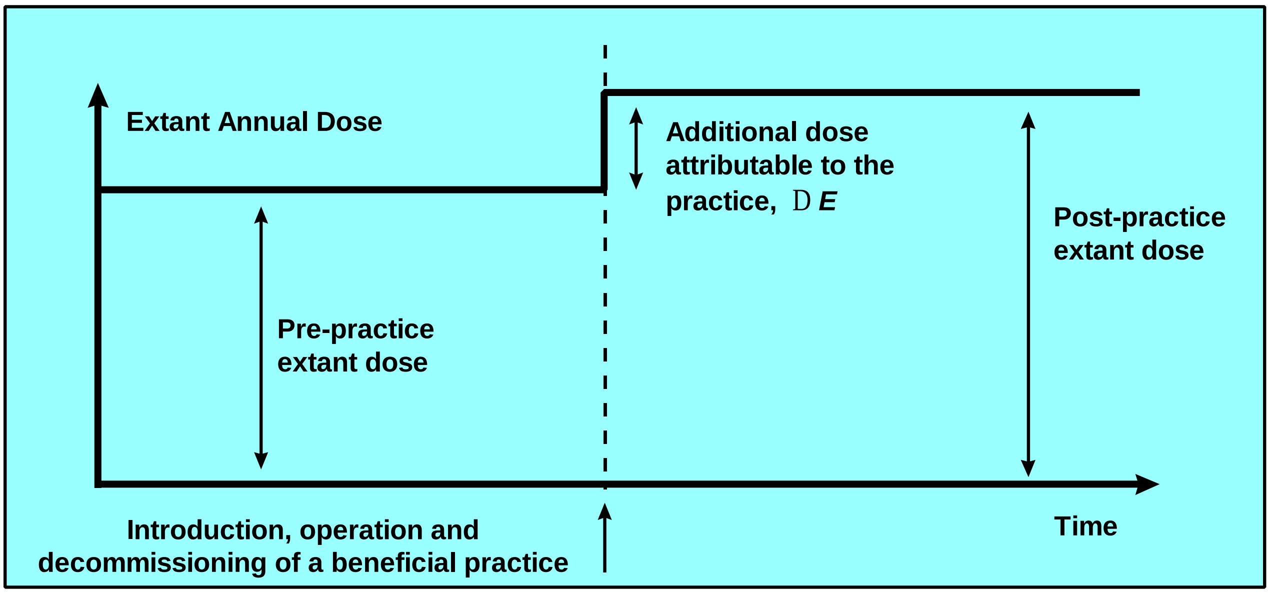
International standards divide radiation protection situations between:

- *prospective situations*, where protection can be planned in advance, i.e., a priori and prospectively, to control the *additional* radiation exposures (over the background exposure) expected to be caused by those situations - these are called '*practices'*; and

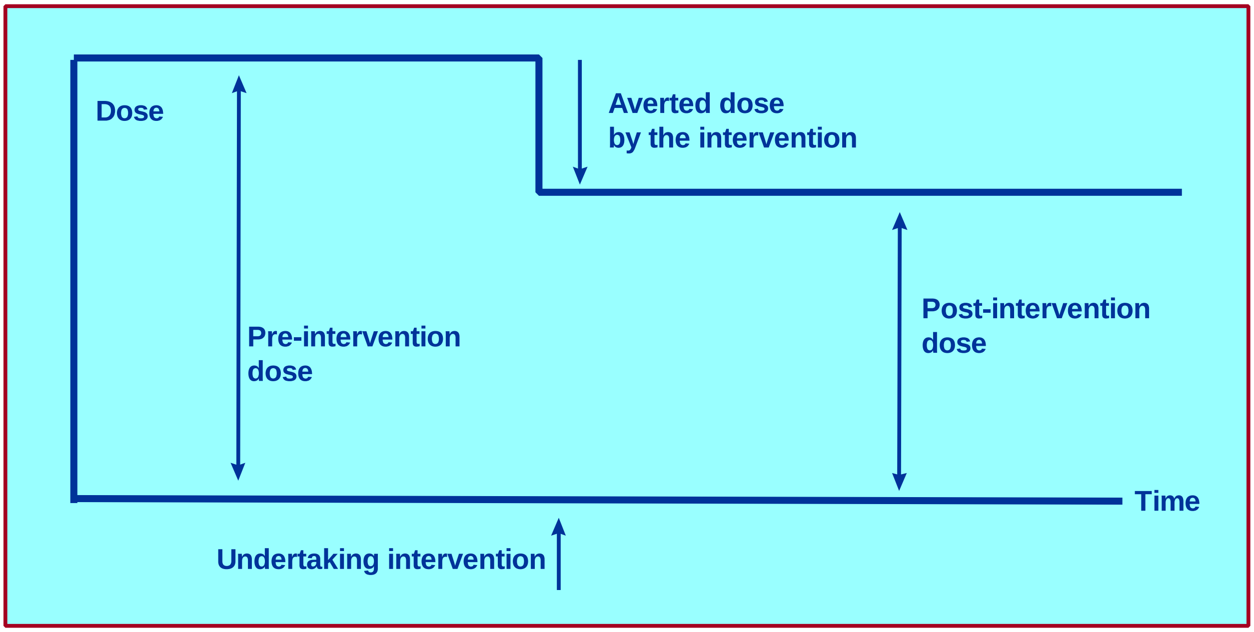
- *de facto situations*, where protection can be undertaken a posteriori, i.e., after the facts causing the exposure, by averting part of the *existing* exposures as much as possible under the prevailing circumstances — these are '*interventions*'.

According to the IAEA standards, decommissioning can be handled, from a regulatory point of view, as the final step of a practice, if it is done at the planning stage of the practice, that is to say, prospectively, in advance of the execution of the practice. This should be the case for the majority of the installations that are of concern of regulators today. But it could well be that the regulator is presented with a de facto situation of decommissioning for which no prospective planning has been made. In this case there will be no alternative than to regulate decommissioning as an intervention. The concepts of practice and intervention therefore are crucial for understanding the international approach to safe decommissioning. Let us explore them in more detail.

Practices involve situations where, given the decision to introduce a justified activity involving radiation exposure, i.e., an activity having positive marginal benefits, the IAEA standards require control prospectively of the *additional dose* that such a practice is expected to add to the *extant dose*. The standards control only the additional dose which is attributable to the practice in question rather than the total dose that an individual is receiving. Thus, the standards operate over the positive 'delta' dose expected from the practice; they do not deal with the (total) extant dose, neither with that existing before nor with that remaining after the implementation of the practice *(figure)*. This will be the situation for the usual decommissioning activity of a regulated practice.



However the regulatory authority could well be presented with the case of a *de facto* situation, i.e. an unregulated situation which originated in the distant past. In this situation what the standards require is to intervene if justified in order to reduce the extant doses. The objective in this case is to avert doses. Once again, the standards operate through a 'delta' dose; however a 'negative delta' in this case, which is termed the *'averted dose'*. For interventions the standards do not refer to the extant dose. They require: "to intervene if justifiable" and "to avert doses as much as reasonably achievable" *(figure)*.



In the case of interventions, therefore, since the issue is to reduce doses, the IAEA standards do not require the observance of dose limits or any other dose restriction. In the case of practices, an increase of doses is expected and therefore it is logical to prescribe limits to the increases; but why should the reduction in dose expected from interventions be restricted or limited? The objectives of the standards in this case are to have as high a reduction as reasonably achievable. Intervention requires: *to reduce doses as much as reasonably achievable without limitation*. It is logical for the regulatory authority to try to reduce these doses as much as reasonable within the principles of the system. Once dose reduction has occurred, the remaining doses - i.e., the total extant dose after intervention, the post- intervention dose, the residual dose, in other words - does not require further restrictions.

Defining the scope of radiation safety regulations: a clearance level for decommissioning?

An issue that is causing considerable discussion at the international level is the scope of radiation safety regulations; this is particularly important in the case of decommissioning. What is outside the regulations has been nominated with different terminology. It was initially termed *de minimis dose* (from the Latin expression *de minimis non curat lex*, or the law is not concerned with trivialities). The term caused great confusion. Then, the concept became termed *below regulatory concern*, or *BRC* for short. Again, the lack of precision in the language (and also in the concept itself) created confusion and ojection. Now, it seems, the term *clearance* appears to be favoured. Again, 'clear' is a term with many connotations in the English language and with no clear translation to other languages; clarity seems not to favour its usage.

The IAEA policy on the matter of regulatory scope is based on two fundamentals and distinct concepts, namely:

- ***exclusion*** of exposures from regulatory instruments, and,
- ***exemption,*** of particular radiation sources, from some regulatory requirements.

During this workshop, the leader of the waste safety activities of the Agency will address these concepts extensively. I will briefly refer to the general IAEA policy in this matter.

Exclusion: For the IAEA, an exposure is deemed to be *excluded* from regulatory instruments if its magnitude or likelihood is essentially *unamenable* to control through regulatory standards. The characteristics of an excluded exposure is not whether or not it is of 'concern', but rather that the exposure is simply unmanageable and uncontrollable through regulations. Exposure to cosmic rays and some other types of natural exposure are typical examples of cases for exclusion. Exclusion from regulatory instruments is not a peculiarity of radiation; it is common for many other pollutants, particularly of natural origin, which must be excluded from regulations because there is little or nothing that can reasonably be done to control them. The decommissioning of installations in areas of high natural background radiation is prone to be radiologically significant. However, these situations are deemed to be excluded from international standards.

Exemption: Again, for the IAEA, situations of radiation exposure that are not excluded from the regulations can nevertheless still be *exempted* from some of their requirements. The condition for exemption is that the expected radiation exposures should be trivial. There is an international agreement on the conditions for triviality. These are three, namely:

- the individual radiation risk attributable to the exempted source should be sufficiently low as to be of no regulatory concern;
- the collective radiological impact resulting from the exemption should be sufficiently low as not to warrant regulatory action under the prevailing social and economical circumstances; and**,**
- the exempted situation should be inherently safe, i.e., with no appreciable likelihood of scenarios that could lead a failure to meet the above criteria.

From these conditions, numerical exemption criteria and subsequently deduced exemption levels can be derived for different circumstances.

Exemption criteria for practices: In international safety standards, exemption criteria have been derived for practices, i.e., for the additional dose (to the one existing at the time of the introduction of the practice) attributable to and expected from the practice. The exemption criteria in this case are:

- the additional individual dose attributable to the exempted source should be of the order of 10 μSv (1 mrem) per year or less in a year; and,
- either the collective dose to be committed by one year of performance of the practice should not be more than about 1 man–sievert (100 person–rem) or exemption should be the optimum option.

Exemption levels for practices have been derived on the basis of the above criteria and are established in the international standards.

Exemption criteria for intervention: There are no international exemption criteria for interventions. Presumably, they should be established in terms of the extant annual dose or of any component of it. The International Commission on Radiological Protection (ICRP) has recommended the use of *intervention exemption levels* in order to avoid unnecessary restrictions in the international trade of commodities containing radioactive substances; and let me remind you that contaminated commodities can result from decommissioning activities. The intervention exemption levels should indicate a line of demarcation between freely permitted exports or imports and those subject to special decisions. According to ICRP, any restrictions applied to goods below the intervention levels should be regarded as artificial barriers to trade. It is regrettable that international agencies have not implemented this important recommendation yet.

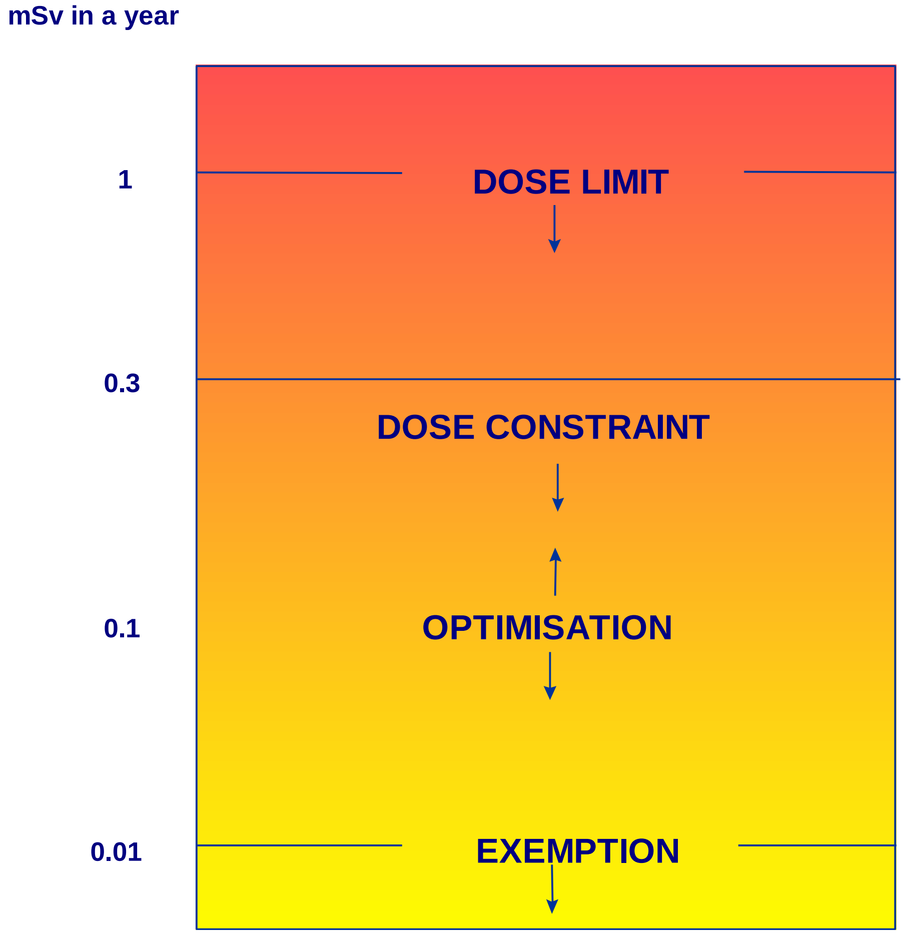
Clean up criteria following decommissioning

The absence of a clear international policy on the cleanup criteria following decommissioning has been a cause of great confusion and unnecessarily large expenditures. In spite of international recommendations on how to approach intervention, there has not been a unified approach on this issue among regulatory organizations. A basic question can be formulated as follows: Is this internationally recommended approach to intervention sufficient? It would appear that the answer is 'yes' from a logical point of view and from what a regulatory authority can actually do. But, looking at the reactions it has caused and at the problems that have occurred, it seems it is not enough for the members of the public and their representatives.

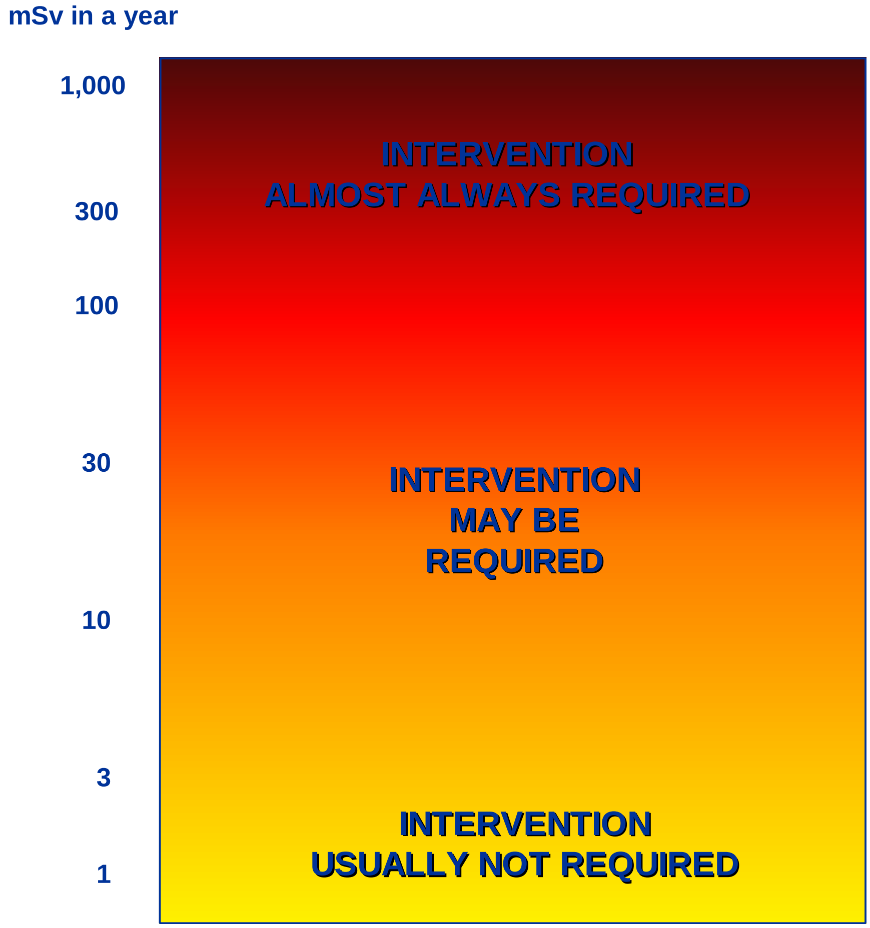
It seems that what might need to be recognized is that in addition to the appropriate control of 'positive deltas' of dose resulting from practices and management of 'negative deltas' of dose during interventions, people (and their representatives) may like to have an additional level of acceptability. They would like to have two clear recommendations: first, at what level of individual total dose, i.e. extant residual dose, should protective actions be undertaken under almost any circumstances; and at what level of dose can one say that the situation is basically safe for the individual.

Perhaps, without changing anything in the current international radiation protection system, it is possible to find additional references, which should be consistent with the system and make it possible to provide the level of acceptability that people are seeking. There is actually a tremendous amount of work being carried out in various international forums, including at the ICRP and the IAEA, as an attempt to find additional references aimed to resolve this problem. I will try to summarize what I think are the conclusions we are approaching from all the work being carried out.

The following *Figures* attempt to sum up the growing consensus to cleanup criteria. The first *Figure* summarizes the current system for practices, which restricts the dose which is attributable to the practices. It restricts the additional 'delta' doses with: a) a dose limit for the additional dose attributable to a pre-selected family of practices; b) dose constraints for any specific source within the practice; c) optimization of protection; and finally d) with exemption levels (in order not to overload the regulatory body with trivialities).



The second *Figure* shows the possible link with the extant annual dose. If the extant dose is above 100 mSv per year, there is no doubt that an intervention is required. If it is below 10 mSv per year intervention is normally not required. In the middle range, there undoubtedly is an area of concern, which requires a detailed assessment to decide whether or not to intervene.



Whether the international community will reach a final consensus on these criteria, I do not know. But - I submit - this is the line we should follow to solve a problem that remains in the shadows; namely: how to regulate low radiation doses in cases of environmental contamination with residues from decommissioning activities.

I would like to apologize for this long opening address. But because this important meeting is one of the first large international gatherings on the emerging issue of safe decommissioning, I think that it is appropriate to state clearly the IAEA's position on the subject, both from a functional perspective and also from the perspective of the technical criteria. I thank all of you for coming and hope you have a productive few days considering this complex subject. I also hope that you will have some time for enjoying the beauties of Rome.

WELCOME ADDRESS

Suzanne Frigren
Director, Nuclear Safety and Civil Protection, DG XI, European Commission

I would like to express the European Commission's appreciation that the initiative has been taken to organise a workshop on the Regulatory Aspects of Decommissioning. This item has taken on great importance for the European Union within the framework of ongoing and planned decommissioning activities in the Member States themselves and, now, also in view of the future enlargement of the Union with the accession of the candidate CEEC's.

Indeed, the very fact that the workshop has been organised jointly by the OECD/NEA, the IAEA and the EC is further evidence of the need felt by these organisations to collaborate in reaching harmonised views in this important and sensitive field as well as to work efficiently to make best use of our limited resources

Frequent contacts between our organisations already exist at management and technical levels and these contacts contribute to the identification of common objectives in the field of nuclear safety and radioactive waste management. By encouraging reciprocal participation in technical working groups and workshops, we are maintaining and further improving this co-operation.

You probably know that the European Commission itself has been involved in the research and development of i.a. decommissioning practices for more than twenty years, under the terms of the EURATOM Treaty. Several Commission services are involved in the preparation or implementation of policies in the nuclear safety field. These services are found within the Energy, Research and Development, Financial Services, External Relations and, of course, Environment Directorate-Generals.

The role of Directorate C of the Directorate-General for the Environment, Nuclear Safety and Civil Protection is i.a. to act as a watchdog at the European Union level in the Regulation and Policy areas concerning safety of nuclear installation and radioactive waste management.

Through the years we have built up a network of contacts with EU national experts and regulators and now, since a short while, we have had the opportunity of expanding our contacts with many nuclear experts and regulators from the EU applicant countries

The directorate is also responsible for the publication of EUR reports in these fields. These reports are widely available to the public through our publications office or through our internet site (http://www.europa.eu.int/comm/dg11/pubs/nuclear.htm.

I would like to thank our host, the ANPA, for so competently shouldering the responsibility of organising the workshop and in doing so allowing us this opportunity of coming to Rome.

I hope that this workshop will provide the opportunity for a fruitful exchange of views and information and that it will act as a modern "Forum" in the field of decommissioning policies. I wish you all every success.

SESSION 1

SETTING THE SCENE

INTRODUCTORY REMARKS

Jukka Laaksonen
STUK, Finland

On behalf of the organisation committee I would like to open this first session with some introductory remarks on the objectives and on the structure of this workshop.

The workshop is intended to provide a forum where representatives of all stakeholders, i.e. the regulators, the decommissioners and the organisations receiving and disposing of waste can exchange their views on regulatory issues that have to be addressed, in order to provide a smooth decommissioning process. Some of the issues have already been resolved in a satisfactory manner in some countries, and we want to share their experience. Other issues are still in need for further work. In making conclusions in the last session on Friday, we should suggest processes by which consensus can be reached in the future. So I ask everyone to give due regard both to the commendable practices and to the open issues that are brought out in the speeches you will hear, and be prepared to make constructive proposals during the closing panel.

The workshop is structured so that in this first session we want to give you an overview of the worldwide decommissioning situation, and tell what our sponsoring organisations are doing in the field.

For the second session we have invited representatives of three different stakeholders to speak about their experiences up to now and about their expectations for the future. I hope they will especially identify those issues that require international co-operation to be supported by our sponsor organisations.

After these two sessions of general nature, we shall move to specific questions. These are:

- management of materials from decommissioning,
- management of sites,
- financial aspects, and
- human factors.

Most of the time is devoted to materials management. The materials are of two types: radioactive waste and material that can be recirculated. As to the radioactive waste, we are not emphasising the methods for ultimate disposal but rather give a number of examples of alternative national strategies on how to organise the management of the waste before it is finally disposed of. The alternative strategies can be based on early versus delayed decommissioning, on centralised versus decentralised organisations doing the work, and on on-site versus off-site disposal of decommissioning waste. In order to give you a broad view on the alternatives, we have invited speakers from four countries to present their national strategies for management of radioactive waste from decommissioning.

A topic, which definitely requires good international consensus, is the exemption, clearance, and authorised release of decommissioning waste. We are going to start this topic with two papers on the progress made by the IAEA and the EU. Then we want to put the issue into a wider perspective by hearing about the regulation of naturally occurring radioactive materials. As you certainly know, there are waste piles of naturally occurring materials that on a risk basis significantly exceed the risk criterion, which is used for radioactive waste from nuclear industries. After that we have examples from four countries with wide experience from exemption and clearance of materials. We are going to hear both regulator and decommissioner viewpoints from those countries. And finally, the last two papers in the material session should be of great interest to us. These are presented by the representatives from the recycling industries, who will tell us what is their interest to recycle materials coming from nuclear industries, and under which terms they are prepared to do it.

Session number 4 is devoted to site aspects. We'll hear some very practical examples on how the work towards clearing nuclear sites has progressed, and also the regulator viewpoints on how to proceed from facility operation to final site release. This process certainly involves a number of safety criteria and licensing steps, and also active participation of the general public.

Session number 5 is dealing with the liability and financial aspects. Two big questions are facing us here: how to make credible cost estimates for the entire decommissioning process, and how to make sure that the money put aside for decommissioning is still there when it is needed. I hope the two papers of session 5 give us useful answers.

Session number 6 relates to the very early part of decommissioning, or rather the transfer from the operation stage to the decommissioning stage. One of the main questions is how to motivate the staff to maintain high safety until the end of the facility life. This is exactly the problem faced by our hosts in Italy right now. We have a privilege to hear first hand about their experiences. Another paper of the session will be a summary of the topical NEA workshop held earlier this week here in Rome.

BACKGROUND, HISTORY AND MOTIVATION

Ted Lazo
OECD Nuclear Energy Agency

As the world's fleet of nuclear reactors ages, increasing numbers of these plants will begin decommissioning operations. Because of the current and ultimate number of plants which will undergo decommissioning, there is great interest in the programmatic, technical and regulatory aspects of this work.

Since the stage of pilot programmes and demonstration projects in the late 1970's and early 1980's, decommissioning has significantly advanced technically. Currently, it is clear that decommissioning is a fully mature, industrial process. As of April 1998, there were 73 commercial nuclear power plants, in 10 countries, in some phase of decommissioning. These include 11 western-style PWRs, 14 BWRs, 11 PHWRs, 4 HTGRs, 3 HWGCRs, 3 FBR's, 2 GCRs, 14 Magnox Reactors, 1 SGHWR, 8 VVERs, and 2 RBMKs (IAEA 98).

With the increasing number of decommissioning projects underway, planned or foreseen, many countries are becoming more interested in the regulatory framework which is necessary to assure that decommissioning operations are seamless and well characterised. In a regulatory sense, decommissioning is relatively new. Although some countries have had comprehensive decommissioning regulations in place for many years, this is the exception rather than the rule.

For this reason, many countries within the NEA have over the past few years become increasingly interested in discussing these subjects. Within the NEA's standing technical committees, interest and projects have begun within the committees on Radioactive Waste Management (RWMC) and its Co-operative Programme on Decommissioning, Nuclear Regulatory Activities (CNRA), Radiation Protection and Public Health (CRPPH), Nuclear Development (NDC), and Safety of Nuclear Installations (CSNI). The International Atomic Energy Agency (IAEA) and the European Commission (EC) have also, for some time, had ongoing programmes in decommissioning.

Based on this broad interest, it was agreed that a joint workshop should be organised to discuss the regulatory aspects of decommissioning. The scope of the Workshop was to include the decommissioning of all nuclear installations, excluding mines, mills and mill tailings piles, as well as waste disposal facilities. It was noted, however, that many of the issues raised in this context are directly or partially applicable to the decommissioning of radioactivity contaminated facilities not explicitly included in these discussions.

Within this scope, the objective of the Workshop is to assist regulators, implementors and waste receiving organisations to appropriately identify those regulatory issues which are still in need of some resolution, and to begin working towards a mutual understanding of roles and needs, and towards the resolution of conflicts. More specifically, this Workshop is being held:

- to hold a focused dialogue among the organisations responsible for regulation of decommissioning activities, for operational decommissioning of nuclear installations, and for receiving and disposing of waste arising from the decommissioning process, in order to share viewpoints concerning the most significant regulatory aspects of decommissioning;

- to identify the points of international consensus regarding the regulation of decommissioning activities;
- to identify those issues where further discussion and work is needed in order to reach consensus among the various stakeholders; and
- to suggest processes by which consensus can be reached on the above issues.

Decommissioning Work within the NEA

In order to perform decommissioning work in the most efficient manner, in terms of worker safety, waste generation, desired end results, and cost effectiveness, the experience gained today must be effectively shared. For the past twelve years the NEA's Co-operative Programme in Decommissioning has served as a forum for the exchange of information in this very important area. The Co-operative Programme is briefly described here as context to the experience of the NEA in decommissioning activities.

In response to the growing interest in the decommissioning of nuclear facilities, the Nuclear Energy Agency of the OECD first began performing work in this area in 1978 a programme. For several years, activities in the area of decommissioning were somewhat limited, including the preparation of meetings and some survey-of-practice and state-of-the-art reports. These experiences led, however, to further interest, particularly on the part of decommissioning implementors, in a more substantial and formatted information and experience exchange programme. In response to this interest, the NEA initiated, in 1985, the International Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects. This concept of working together among a number of decommissioning projects exchanging information, experience and possibly personnel, and carrying out other forms of co-operation as appropriate, obtained strong support from all OECD countries having one or more important decommissioning projects either underway or in the planning process. Ten decommissioning projects from seven countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) were the first to join the programme.

The first five years of this programme (from 1985 until 1989) represented a watershed in the evolution of decommissioning as a mature technical discipline. In its own right, each of the participating projects made a significant contribution not only towards developing various decommissioning technologies, but also in demonstrating them in the field. During this period, six additional projects, including two from Belgium, joined the programme, bringing the total participation to 16 projects from 8 countries.

During the second five-year period (1990 until 1994) the primary objective was to contribute to the maturing of the decommissioning process towards full industrialisation, by facilitating the exchange of information and of related experience between participating projects. Based on the continued increase in participating organisations during this period, with an additional 13 projects joining the programme, some success in this objective was achieved. This period brought the total participation to 30 projects from 10 countries, including the first non-NEA member country.

The third five-year period, which will last from 1995 until 1999, the programme is focusing on taking the programme one step further from industrialisation, to begin looking at broader, generic issues, and to contribute to discussions of the various regulatory aspects of the decommissioning process. So far, an additional 5 projects have joined the Programme, bringing the total to 35 projects from 12 countries.

Programme Organisation

In order to assure the appropriate management and organisation of the Co-operative Programme, the Liaison Committee (LC), made up of project-management-level representatives of each project in the Programme, oversees the Programme's operations and administration, and sets Programme priorities, goals and objectives. The Technical Advisory Group (TAG), made up of technical representatives from the participating projects, reports to the LC and is the Programme's main forum for the exchange of technical information. Task Groups perform most of the Programme's in-depth technical studies assigned by the LC or proposed by the TAG and approved by the LC.

Thus far, it has been very important for the Programme that its members come from organisations which are in the process of decommissioning a facility, or who will in the relatively near future be decommissioning a facility. However for historical reasons, organisationally within the NEA's structure this programme depends upon the Radioactive Waste Management Committee (RWMC). The RWMC is made up of experts mostly focused on the disposal of high-level nuclear waste who are drawn from both national implementing organisations and national regulatory authorities. The Co-operative Programme will thus begin to interact more with the RWMC, particularly in terms of the regulatory aspects of decommissioning.

Project Characterisation and Programme Description

The 35 projects currently in the Programme include the decommissioning of 25 reactors, 7 reprocessing plants, 2 fuel material plants, and 1 isotope handling facility. A full list of those projects currently participating in the Co-operative Programme is provided in tabular form at the end of this paper.

As a result of the wide variation in the type of facility being decommissioned and in the environment under which the activity is undertaken, in order to assist in the comparison of information and experience the focus of the Programme has been in seven broad areas:

- assessment of activity inventories,
- cutting techniques,
- remote operation,
- decontamination,
- melting,
- radioactive waste management, and
- health and safety.

Detailed discussions of one or more of these topics, in the context of work being performed by one or more of the Programme's projects, are generally held during the semi-annual TAG meetings. Some of the more interesting and useful results of these discussions are detailed in two reports of the Co-operative Programme covering the first five years, and the first ten years of the programme respectively (see references).

In addition to this work, over the twelve years of the Co-operative Programme's existence, four task groups have, at various times, worked on in-depth studies of decontamination techniques, decommissioning costs, recycling and reuse of metals from decommissioning activities, and on the radiological characterisation of large volumes of various materials from decommissioning activities. Currently, the Task Groups on decontamination and on decommissioning costs are nearing the completion of their work, and will publish summary reports in late 1998 or early 1999. The Task Group on recycling and reuse published, in 1996 (see references), a document summarising its views pertaining to the development of radiological clearance levels for metals from decommissioning activities, and continues to participate in discussions of the establishment of clearance levels as international recommendations. The Task Group on radiological characterisation began work only recently, however still hopes to issue a summary report in 1999.

Future Directions of the Co-operative Programme

As described briefly above, with decommissioning having developed into a relatively mature and industrialised process. With this better understanding of the technical issues, the decommissioning process has moved from "case-by-case" R&D programmes toward being a much more standardised industrial process, taking specific site characteristics into account as necessary. This shift to more routine operations has allowed more time and effort to be consecrated to questions concerning more generically applicable issues, such as national and international regulations, guides and standards.

In this context, discussions have begun within the NEA concerning the regulatory aspects of Nuclear Installations decommissioning. In order to facilitate progress towards better mutual understanding of the rational behind and the practical implications of decommissioning regulations, dialogue between regulators and implementers is seen as being particularly valuable. Some important areas of interest are:

- The regulatory process of site "declassification" is of great interest to regulators and implementers alike. The phases of declassification of an operational facility will most likely involve some or all of the following: passage from operation to a cold-shutdown configuration, cold shutdown phase, passage from cold-shutdown to a safe storage phase, safe storage phase, dismantling phase, restricted and/or unrestricted site release. The regulatory process necessary for this declassification will most likely be stepwise, but will have larger or smaller steps depending upon the national regulatory context. The definition of this process will be of interest to all stakeholders, and should be discussed in an international and national context to help assure consensus, and understanding of national differences.

- As part of the declassification process, it is essential to demonstrate compliance with various regulatory requirements. For this to occur, clearly defined regulatory objectives are necessary. As part of this, it is essential to have defined clearance levels below which material can be either conditionally or unconditionally released from regulatory control. This question has two aspects. First, a level of individual public exposure, due to the release of slightly contaminate materials, below which regulatory controls need no longer be imposed, must be defined. Although no universally accepted level currently exists internationally, values of individual dose of from approximately 10 μSv/a to 250 μSv/a are currently being discussed in various countries and international organisations. The second step in the process is to use appropriate mathematical models to translate these annual dose values into clearance levels, in operational terms of specific activity (Bq/gm) and surface activity (Bq/cm^2). Work done already by the Liaison Committee's Task Group on Recycling and Reuse has presented one possible technique, that of global optimisation, for arriving at individual dose levels below which regulatory controls need no longer be imposed. This Task Group has also proposed a tiered system of release. As national and international standards are developed for individual exposure and for operational clearance levels, all stakeholders are interested in the decision-making process and in the resulting values. Here again, international and national discussions would be of benefit to the process of determining these values.

- Other aspects of the demonstration of compliance with national and international regulations are also of interest. For example, the technical aspects of release measurements will be discussed by a NEA Task Group. The regulatory aspects of compliance with clearance levels, and of regulatory certification for release, will be influenced by the technical aspects of the process, but, as with these other issues, will need to be discussed in a forum between regulators and implementers.

- Associated with the issues of clearance and release certification is that of public acceptance of the existence of "contaminated", although releasable, material in uncontrolled disposal sites and in the form of materials for recycling. Although this is not really a technical issue, it is important that the decision-making process which arrives at clearance levels includes an awareness of the necessity to achieve public acceptance, and includes members of the public in this process in some appropriate form.

- For those materials which can not, because of their contamination levels, be released for uncontrolled use, a national low-level waste disposal infrastructure must exist. This includes such things as a regulatory basis for waste disposal, the availability of licensed repositories, waste transportation issues, etc. Without such an infrastructure, decommissioning will not be possible, and thus this issue is clearly an important issue for implementers and regulators.

Conclusions

As the world's fleet of nuclear reactors ages, increasing numbers of these plants will begin decommissioning operations. In order to perform this work in the most efficient manner, in terms of worker safety, waste generation, desired end results, and cost effectiveness, the experience gained today must be effectively shared. For the past twelve years the NEA's Co-operative Programme in Decommissioning has served as a very useful forum for the exchange of information in this very important area. For the next five-year period the exchange of information and experience will continue, and additional emphasis will be put on ensuring promulgation of this valuable information and experience to a wider audience than the participating projects. It is also hoped that the continuing work of the Programme, with its vast practical experience, will be useful in the development of national and international standards and regulations in the area of decommissioning.

References

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STRATEGIES AND TRENDS FOR NUCLEAR REACTORS

Michele Laraia and **Zdenek Dlouhy**
International Atomic Energy Agency

Abstract

The current status in the area of decommissioning is well known. It is based on information about the number of shutdown nuclear facilities worldwide, of which some have undergone various stages of decommissioning and others are awaiting decision about their future fate.

More difficulties will arise when attempting to project future trends. Until recently, the estimates of nuclear facilities to be decommissioned in the future were based on information about their expected lifetime specified in the respective operational licence. In practice, the increasing competitiveness in the energy production may force the operators, on the one hand, to a premature shut down of their nuclear power plants, on the other hand, there is a trend to extend reactor lifetimes as far as possible, mainly for economic reasons.

With research reactors the situation is somewhat different. The current retirement rate of research reactors is rather due to the completion of research and experimental programmes or to safety considerations than to economical and political aspects. By now, for the above reasons, nearly one half of research reactors operated worldwide has been closed, whilst other have undergone upgrades and innovations resulting in life extension for new purposes.

In addition to this, it must be noted that the decision-making process involving shutdown of a reactor and its decommissioning is complex. There are timing, engineering, waste disposal, cost and lost generation capacity factors and the ultimate uptake of radiation dose to consider and, bearing on all of these, the overall decision of when to close a reactor and how to proceed with decommissioning may be heavily weighed by political and public acceptance dimensions. In the present paper these factors and dimensions are briefly reviewed with reference to the actual situation in the nuclear field.

The objective of this document is to provide information on the current trends as well as short and mid-term expectations in the area of decommissioning of nuclear reactors. Special consideration is given to various factors which may influence the decision-making process.

1. Introduction

Decommissioning is a topic of great interest to many IAEA Member States because a large number of nuclear facilities have reached or are approaching their operational lifetime and many more will have to be dealt with in the future. For these facilities, decommissioning is the final phase when they have completed their design objective, become obsolete or when they no longer fulfil current safety, technical or economic requirements.

The current status in the area of decommissioning is well known. It is based on information about the number of shutdown nuclear facilities worldwide, of which some have undergone various stages of decommissioning and others are awaiting decision about their future fate. More difficulties will arise when attempting to project future trends. Until recently, the estimates of nuclear facilities to be decommissioned in the future were based on information about their expected lifetime specified in the respective operational licence.

It should be noted that the decision-making process involving shutdown of a reactor and its decommissioning is complex. There are timing, engineering, waste disposal, cost and lost generation capacity factors and the ultimate uptake of radiation dose to consider and, bearing on all of these, the overall decision of when to close a reactor and how to proceed with decommissioning may be heavily weighed by political and public acceptance dimensions. In the present paper these factors and dimensions are briefly reviewed with reference to the actual situation in the nuclear field.

The objective of the present document is to provide information on the current trends as well as short and mid-term expectations in the area of decommissioning of nuclear reactors. Special consideration is given to various factors which may influence the decision-making process.

The document is dedicated to nuclear power plants and to research reactors for which sufficient reference data are available [1,2]. Whilst some considerations apply equally well to either nuclear power plants or research reactors, others will be different. For this reason it seems appropriate to deal with both types separately. As regards the time horizon to which the trends should aim, it seems that reasonable estimates of the situation on the decommissioning market should not exceed some 30-40 years in the future.

2. Major Factors Influencing the Closure of a Facility

There are several factors which play an important role in predicting future decommissioning needs. These can be grouped as follows:

1. Changes in safety philosophy
2. Changes in regulations
3. Extension of facilities useful life
4. Operational and decommissioning costs
5. Political and socio-economic aspects
6. Decommissioning strategies

In order to reach a conclusion whether a facility should be closed or operated further, all these aspects should be considered in a systematic way. The above factors can have either enhancing or hindering impacts on the retirement rate of nuclear facilities, as can be seen from more detailed discussions held in the subsequent text.

2.1 Changes in safety philosophy

Two major occurrences have substantially influenced the safety philosophy of nuclear facilities: the highly publicised accidents at Three Mile Island and Chernobyl. The nuclear industry began to feel pressure from both, the regulators and the general public, to enhance reactor performance, especially after the accident at Three Mile Island. With growing public concern about the safety of nuclear facilities and with increased anti-nuclear movement in most countries since Chernobyl, the regulatory climate has rapidly changed. These pressures resulted in strengthening drastically nuclear safety and environmental protection standards.

Based on the facility safety reviews, the major findings usually resulted in upgrading of safety related components, such as improved safety systems for prevention of accidents, facility equipment upgrades or, where appropriate, replacement of existing hardware with more resistant one. Improvements of organizational responsibilities, strengthening of radiation protection regulations, air monitoring, contamination control and application of the ALARA principle to optimization of exposures incurred by the personnel are more examples. In addition, radioactive waste management and disposal are important economic and environmental concerns.

2.2 Changes in regulations

The nuclear industry is highly regulated. The laws and regulations are often complex and overlapping, involving government ministries, state organizations and state-owned or private utilities, as well as the general public, through its regional governments and/or municipalities.

The laws and regulations typically provide licensing of various aspects of the nuclear industry, government oversight, setting of standards (both technical and environmental) and protection of human health from radiological (and other) hazards. For estimating future trends, the following regulatory activities are particularly important: (a) updating the nuclear safety and environmental protection standards; (b) regulation of closure and decommissioning operations; and (c) renewal of licences to continue operation of the facility.

a) Updating safety standards

In the beginning of the nuclear age, the lack of previous experience inevitably resulted in gaps in the regulation of safety-related issues. There were no laws directly governing nuclear power in any way. Over time, countries have commenced to establish simple rules which would regulate existing facilities and would provide guidance on how to design and operate the new ones. Common industrial standards served initially as a basis for regulation. With growing operational experience, R+D studies and numerous analyses of minor incidents, these standards were constantly upgraded to increasingly higher levels.

A break in the insight on safety related problems came with the Three Mile Island accident and led to establishment of more stringent safety standards. Some of the facilities were not capable to meet the new requirements and had to be shut down. In some cases the reasons were imperfect design, inadequate materials, or inappropriate site conditions. Excessive costs necessary for improvements were behind the decision about the premature closure of these facilities.

b) Regulation of closure and decommissioning

Within their legislative framework, all Member States with nuclear programmes have some regulations for closure and subsequent decommissioning of nuclear facilities. In general, the same or very similar framework used for licensing, commissioning and operating nuclear facilities is also applied to the shutdown and decommissioning and provides a continued but flexible safety regime until the decommissioned site is released for new purposes.

c) *Licence renewal*

The third important aspect influencing future trends in decommissioning is licence renewal. Here, the main role of the regulatory authority is to establish a reasonable process and such safety standards so that the licensees can make timely decision whether to seek licence renewal. This decision rests purely with the licensees. Based upon thorough technical studies, they must decide whether they are likely to satisfy the regulatory requirements and they must evaluate the costs of the venture. Successful licence renewal may then result in extension of lifetimes of facilities, otherwise candidates for decommissioning.

2.3 Extension of facilities useful life

On the basis of economic considerations and technical limitations, most countries with nuclear power programmes have defined time limits for useful service life of their commercial nuclear power plants. At present, these limits range between 20 and 40 years. However, consideration of the ageing mechanisms of reactors shows that the licensed lifetime is not the only suitable criterion for taking a decision as to whether a reactor should be shut down or not. Older plants in particular often have large reserves so that the safety targets can still be maintained by a simple improvement, even after the useful service life has expired. It is evident that such decision must also be considered from a financial point of view.

Research reactors represent a different problem; they fundamentally differ in their design, operation and utilization from nuclear power reactors. Older research reactors were designed, constructed and operated in compliance with standards valid in the country of origin at the time of construction. Engineering limits established for non-nuclear applications were frequently set with some conservatism for nuclear applications. As a result, structures, systems and components meeting common industrial practices were required to satisfy simple acceptance tests. With ageing of most of construction materials, strengthening of safety requirements and changes in reactors' utilization, many older research reactors had to be modified, upgraded or even completely refurbished.

Degradation of systems and components from ageing as well as relevant ageing mechanisms has been thoroughly studied and critical materials subjected to categorization, inspection and subsequent modification. The relevant projects covered nearly all of the main systems of the facility. Thus with time many of research reactors have been modified in some way, from replacement of individual components, through major changes in the reactor design, to a complete reconstruction including removal of the reactor tank and replacement of all major safety related systems and components. Most modification projects in 1970s and 1980s were mainly based on safety and ageing issues.

2.4 Operational and decommissioning costs

As mentioned earlier, at the end of the licence period the licensee can seek to renew the operating licence of the plant for another period, or can cease operations and begin the decommissioning process. Some licensees choose to cease power operation even before the licence period has been completed. The reason for this decision is usually financial; for example, the plant may require upgrades or repairs that are not economically justifiable or the licensee may find other sources of power that is less expensive than nuclear generation.

The high capital replacement costs for reactor facilities provides strong incentive to assure their continued operation. However, the first and most important operational requirement is that a reactor shall be able to meet its safety goals at any time, independent of age and other consideration. If these goals cannot be met in a viable and cost-effective fashion, the reactor must be shut down, regardless of its age.

In the case of research reactors, cost is also a factor which may limit the operation, but normally there are not such large expensive components like a power reactor pressure vessel limiting the lifetime of a research reactor on economic grounds.

2.5 Political and socio-economic aspect

A number of political and socio-economic aspects have to be considered prior to the decision on the future fate of a facility. Among them most important are: the country's political climate governed by the overall economic situation; the public attitude towards the nuclear programme; activities of anti-nuclear groups and movements; and sometimes also perception of country's nuclear programme by neighbouring states.

In some countries nuclear energy became a subject of deep political debates resulting eventually in referenda to stop construction of new power plants and/or to shutdown existing plants. Arguments defending the continued use of nuclear technology have included highlighting the overall costs of non-nuclear alternatives or the role which nuclear power can play in reducing emissions of greenhouse gases, as agreed in the Kyoto protocol.

Public attitude towards nuclear power is a critical factor for the future trends in nuclear energy. The Three Mile Island and Chernobyl accidents amplified the underlying negative feeling towards civilian nuclear power which was initially developed from military technology. The experts opinion that current nuclear power technologies pose minimal risks to the public has not been fully accepted in many advanced countries, particularly in those which have enough sources of alternative energy to slow down nuclear power development.

However, some other countries which do not have their own natural sources have either successfully developed nuclear power programmes or are planning to do so. This, and enhancing public understanding of nuclear power enabled to create a favourable political environment for example in France, in Eastern Europe or in Asia. The recent attention to the greenhouse effect is also giving a positive momentum to the nuclear power argument.

2.6 Decommissioning strategies

For future predictions of decommissioning trends, two typical strategies have to be considered. Some countries have adopted a strategy according to which dismantling and waste disposal should be carried out as soon as reasonably practicable after permanent shutdown. Other countries have adopted a strategy of deferred decommissioning, that is delaying complete dismantling for several decades until one hundred years, or more, following closure of the plant. This entails confidence that the required technology and waste disposal methods will become or remain available with passing time, that the eventual costs will not escalate or will be covered by accumulated funds, and that future governments will be able to cope with decommissioning in a way acceptable to the public. The deferred dismantling approach will inevitably shift a number of facilities awaiting dismantling into the far future.

In some countries, the choice of decommissioning options is strongly influenced by potential uncertainties in waste disposal costs and by concerns over the future availability of waste disposal sites. Although delayed decommissioning brings some disadvantages (shortage of personnel, site unavailability, continuing need for surveillance, higher future costs), delayed decommissioning is often used at multi-unit sites when one or more of the units shuts down while others continue to operate. In this case, the staff from the operating units assist in the maintenance and surveillance of the dormant units It should be noted that the selected (or available) decommissioning strategies have strong impact on the decision when to retire a facility permanently from service. It will be enough to consider the cash flow aspects of immediate vs. deferred dismantling strategies and the need to collect appropriate funds during reactor operation.

3. Nuclear Power Reactors

From a total of 523 nuclear power reactors constructed and operated worldwide, 80 have been shut down and 443 are still in operation. Their age ranges from less than one year in the case of newly constructed facilities up to 42 years in the case of the UK veteran station Calder Hall. The actual situation can be seen from Fig. 1. Altogether 63 nuclear power reactors still in operation (14%) are more than 30 years old, 143 reactors (32%) are more than 20 years old, and the rest - 237 reactors (54%) - are less than 20 years old (see Fig. 2). This bar chart highlights the growth of the nuclear industry in the 1970s and 1980s and subsequent decline. As regards the reactor type, the situation is shown on Fig. 3.

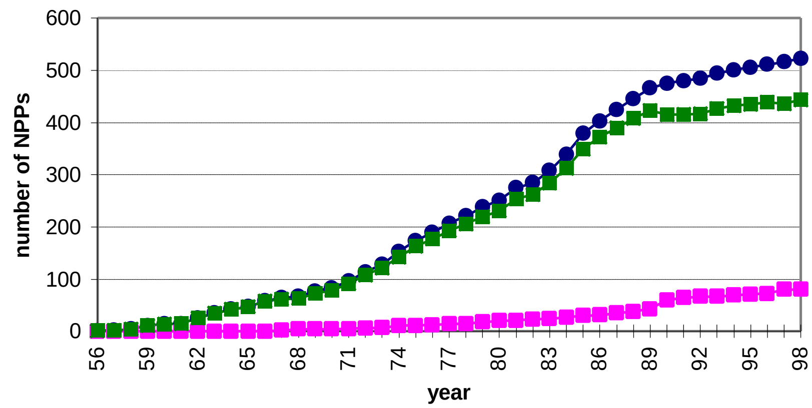

Figure 1. Number of nuclear power plants worldwide (top-total, middle-operational, bottom shutdown) [1]

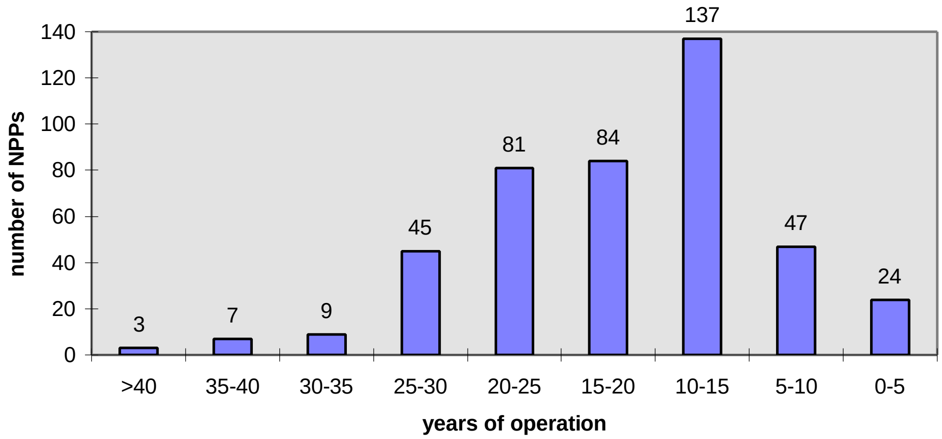

Figure 2. Age of operational nuclear power plants

Theoretically, operational lifetime of power reactors and hence, the needs for decommissioning, can be predicted from the reactor's type or from the operational licence issued by the respective regulatory authority. For example, reactors of the WWER or LWGR type had a design lifetime of 20-30 years; in another case, most BWRs and PWRs in the United States received a licence for 40 years of operation. On the assumption that the lifetime of nuclear power reactors would last over the whole designed or licensed periods, one can predict the commencement of decommissioning activities as shown in Fig. 4.

However, in practice the situation is different. As discussed in Section 2, various factors govern the real lifetime of power reactors. Practical impacts of these factors on power reactors are discussed in more detail in the following subsections.

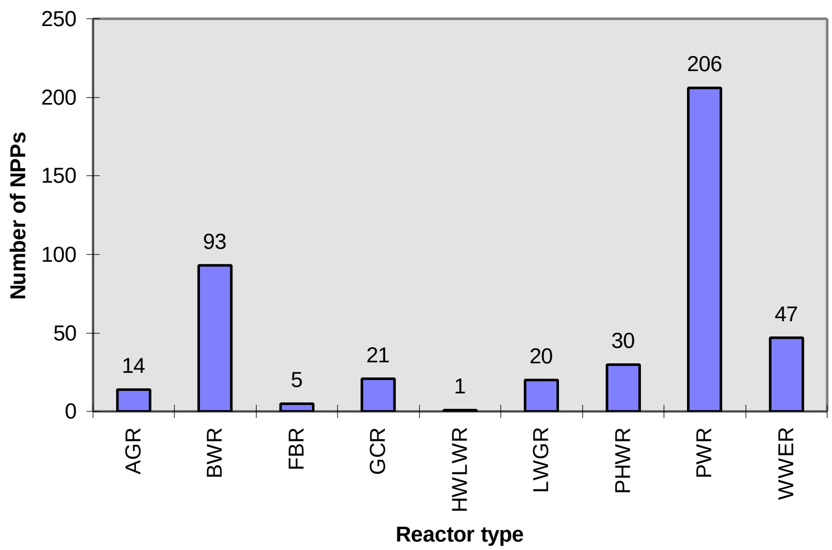

Figure 3. Number of operational NPPs according to the reactor type

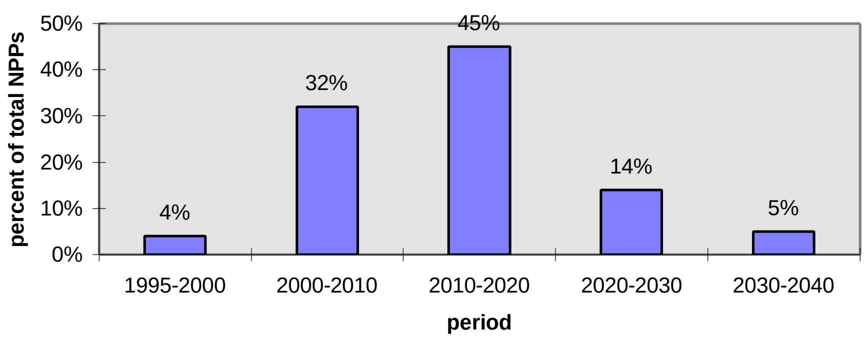

Figure 4. Predicted start of decommissioning activities of operational and shutdown NPPs

3.1 Changes in safety philosophy

In the past, nuclear safety was not seen as an overriding issue for the choice of nuclear reactors nor for their later increase in size. Above all, the dimensions of a nuclear accident were underestimated.

Only with the TMI accident and the introduction of the probabilistic safety analysis the scope of nuclear safety has considerable broadened, which has brought a number of safety provisions to cope with accident conditions of various types. Once identified, safety inadequacies required correction. Often, such safety upgrading turned out to be more expensive than the owner would be ready to pay for. As a result, approximately 60 power reactors, including several prototype reactors and those which have undergone an accident, had to be shutdown prematurely. One typical example is Fort St. Vrain HTGR which was shut down to replace an inoperable control rod. During this forced outage, stress cracking was noted in various places and thus resulted in a decision to permanently cease reactor operations [3].

Other US nuclear power plants also prematurely shut down exhibited deficiencies from the safety point of view: Indian Point-1 was permanently shut down because its emergency core cooling system did not meet current regulatory requirements. Humboldt Bay-3 was shut down due to seismic issues. Dresden-1 was closed to meet new federal regulations and to perform chemical decontamination of major piping systems. Yankee Rowe ceased operations because of concerns about reactor vessel integrity. For these reactors, continuing operation after upgrading to the required safety levels was estimated to be uneconomical.

Upgrading of older nuclear power plants to the modern safety standard, however, is a continuous process, as equipment in many facilities deteriorate by ageing. Recently, the four Pickering A CANDU reactors and the three Bruce A CANDUs were laid up as part of Ontario Hydro's nuclear recovery plan, which involves dedicating resources to upgrading its other 12 operating units to the current standards from the safety point of view [4].

The National Electricity Company in Bulgaria rejected concerns on the safety of Kozloduy's four older WWER reactors and the government said it has no intention of shutting down the station. In Armenia a project has been launched to increase safety and improve operations at the Armenia-2 nuclear power unit and support is also being given to the state safety regulator.

There are 19 WWER-1000s in operation, two in Bulgaria, seven in the Russian Federation and 12 in Ukraine. A further seven are under construction. Reviews have shown their design safety features are generally comparable to those designed at the same time in western countries. However, a number of operational deficiencies, including the quality and reliability of equipment have been identified and safety improvement programmes have been initiated [5].

3.2 Regulations and life extension

Currently, many laws/regulations related to nuclear power are in place, which are intended to protect all sectors of society, and enable NPP operators to close out in a safe manner the reactors and to start the decommissioning activities. Most countries engaged in an active nuclear programme already have detailed regulatory provisions and technical rules in the field of decommissioning. Nowadays, one of the issues being currently in the centre of major regulatory efforts is extension of facilities useful life.

Many utilities plan to extend the lifetime of their reactors from 20-30 years to 50-60 years. This is generally due to supposedly insurmountable difficulties in siting and constructing new NPPs. Other reasons include economics e.g. to make use of existing local infrastructures. Licensing procedures are necessary and, in some countries, these may be subject to a difficult, technical and political debate. One of the countries which have established a clear and reasonable regulatory process is the United States. Here a NPP licensee may apply to the Nuclear Regulatory Commission to renew its licence for up to 20 years. It is estimated that it would take a licensee between 3 to 5 years to prepare an application. The application would be subject to public hearings, which is a formal process. It is expected that the NRC staff will need between 3 and 5 years to complete a detailed technical review and for the hearing process to be completed [6]. Recently, two NPPs have applied for extension of their operating licence, namely the two-unit Calvert Cliffs NPP and the three-unit Oconee NPP [7].

A similar strategy has been recently pursued by the operators of Japan NPPs i.e. Fukushima 1, Mihama 1 and Tsuraya 1 and validated by the Ministry of International Trade and Industry (MITI). With this move, the service lives of these reactors would be extended to some 60 years [8].

Regulations in the United Kingdom do not contain special licence renewal provisions. They only require “to carry out a periodic and systematic review and assessment of safety cases” which should be performed at roughly 10-years intervals. Based on the standard licence, all the operating Magnox units have now been cleared for operation beyond 30 years and the two oldest, Chapelcross and Calder Hall, have been cleared for operation beyond 40 years [9].

In Finland, the authorities have issued an operating licence extension to the Olkiluoto NPP for additional 20 years and to the Loviisa NPP for 10 years. As a condition of the new licence, the operators have to submit a full safety analysis report to the regulator. Also other countries are seeking to prolong life of their nuclear facilities. This is especially true for operators of nuclear power plants of the WWER type in Eastern Europe who seek to extend their original design lifetime - 20-25 years - beyond this limit. The Russian utility Roseneroatom has already started a project aiming for life extension of its WWER-440 plants and it has been reported even in public that the objective is to operate until 2010 all those plants which according to their design lifetimes, were due to shut down between 2001 and 2004 [10]. There are no other practical alternatives in the Russian Federation for continuing operation of NPPs, given the current financial conditions of the country. The Swiss federal executive council has approved a 10-year extension of the operating licence for the Muehleberg BWR, and has given permission for a 15 percent increase in the rated output from the Leibstadt BWR from 1085 to 1200 Mwe [11]. Power uprating is now quite common in European and US reactors (Lasalle, Fermi 2) [12] and makes best sense in a strategy of continued operation and possibly life extension. To enhance the lifetime of operating plants in the United States, complete replacement of steam generators is ongoing or planned (McGuire, Farley, Kewaunee).

At the level of the individual plant, decisions about continued operation and life extension have to be made on a strictly commercial basis, taking into account all the safety and technical issues. The same attention must be paid to the increasingly competitive electricity market and continuing uncertainties about future decommissioning costs and waste disposal.

3.3 Decommissioning strategies

The choice between the two prevailing decommissioning options, immediate or deferred decommissioning, depends on a variety of factors, which have been discussed elsewhere (see, for example [13, 14]). Decommissioning costs, waste disposal problems and political aspects are presently considered as major factors governing the decommissioning strategies.

The alternative of leaving a plant in long-term safe storage may cause a specific waste management problem in the future. With future disposal facilities so uncertain, a number of utilities declare to be unprepared to take the risk. The prospect of not having a disposal facility available at any cost may greatly overshadow the economics involved in the long-term build-up of decommissioning funds. It seems that immediate decommissioning will prevail in some countries having limited waste disposal capacities in that recent decisions appear to be driven by the desire to take advantage of existing disposal facilities while the option is still available [15].

The decision to delay the start of dismantling may also depend on other aspects than those mentioned above. The French government, which has available sufficient funds and waste disposal facilities, decided that the Superph☺nix at Creys Malville will be closed, but dismantling will not start until 2005 [4]. Also other projects, e.g., for G2/G3 and EL4 should achieve in the near future a safe enclosure stage only.

To decommission its retired gas-cooled reactors at the Chinon nuclear power station, Electricite de France has chosen partial dismantling and has postponed final dismantling for 50 years. Although complete dismantling was technically possible, the utility preferred the delay, which will result in a significant reduction in residual radioactivity, thus reducing radiation doses during the eventual dismantling. Improved mechanical techniques are also expected to be available then, again reducing doses and also costs. As other reactors will continue to operate at the Chinon site, monitoring and surveillance do not add significantly to the cost.

In the United Kingdom, decommissioning has begun at the Berkeley Nuclear Power Station, which was closed for economic reasons in 1989, after 27 years of operation. Defuelling began in July 1989 and was completed in March 1992. The utility has proposed to the Government that 30 years' storage now take place, after which a "safestore" containment would be built around the residual buildings for a further storage period of 100 years.

Germany, on the other hand, has chosen direct dismantling over safe enclosure for the closed Greifswald nuclear power station in the former East Germany, where five reactors had been operating, one was nearing operation and two were under construction. Among various reasons for this strategy, the socio-economic aspect of maximizing use of in-house resources played a major role. In mid 1995 the site of the 100 Mwe Niederaichbach nuclear power plant in Bavaria was declared fit for unrestricted agricultural use. Following removal of all nuclear systems, the radiation shield and some activated materials, the remainder of the plant was below accepted limits for radioactivity and the state government approved final demolition and clearance of the site.

In Japan, where suitable nuclear sites are scarce, the official policy is that commercial power reactors should be dismantled and removed as soon as possible after shut down (usually within some 5-10 years) and the site should continue to be used for nuclear power plants. As a first case, the Japanese BWR at Tokai (JPDR) has been dismantled in 1996 and the site cleared for another nuclear use.

Various factors influenced the decision about decommissioning of some shutdown US nuclear power plants (see Fig. 5). While some plants have been or are being dismantled without putting the facility in a safe enclosure state (e.g. Trojan, Fort St.Vrain), the long safe enclosure periods for Dresden-1, San Onofre-1 or Indian Point-1 have origin in the utilities' considerations not to start dismantling unless other units located on site are also shut down.

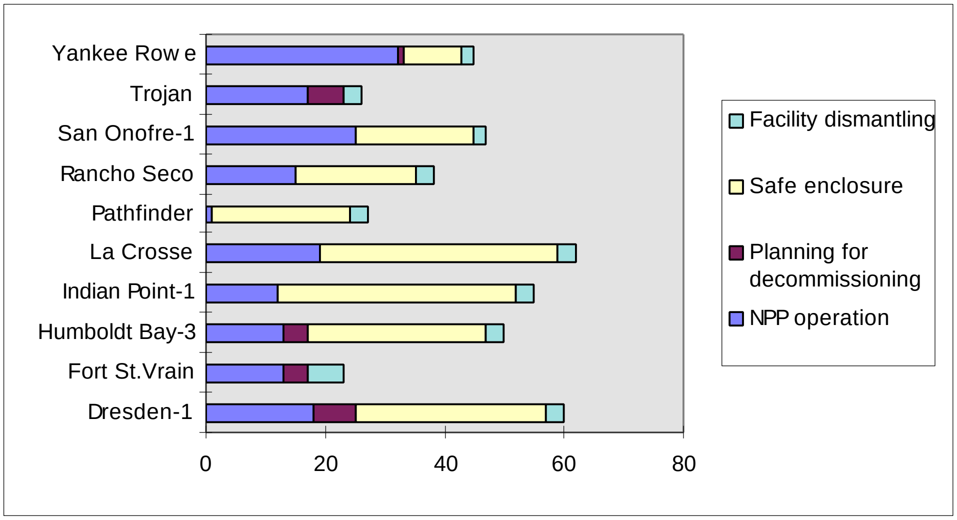

Figure 5. Differences in decommissioning strategies for some shutdown US NPPs

Independent from factors which are likely to prevail in the individual cases, it can be seen that the strategies eventually selected vary from country to country and even within one country. This is apparent from Table 1 showing differences between selected strategies for all 21 shutdown reactor units in the United States. Table 2 provides similar information on the actual situation in some European countries.

Table 1. Strategies selected in the US for shutdown nuclear power plants

Reactor unit	Type	Shutdown	Status
Indian Point 1	PWR	1974	SAFSTOR
Dresden 1	BWR	1978	SAFSTOR
Fermi 1	FBR	1972	SAFSTOR
GE VBWR	BWR	1963	SAFSTOR
Yankee Rowe	PWR	1991	DECON
CVTR	PTHW	1967	SAFSTOR
Big Rock Point	BWR	1997	DECON
Pathfinder	BWR	1967	DECON (Licence terminated)
Humboldt Bay 3	BWR	1976	SAFSTOR
Peach Bottom	HTGR	1974	SAFSTOR
San Onofre 1	PWR	1992	SAFSTOR
Haddam Neck	PWR	1996	decision pending
Fort St.Vrain	HTGR	1989	DECON (Licence terminated)
Zion 1	PWR	1998	decision pending
Zion2	PWR	1998	DECON
Main Yankee	PWR	1996	decision pending
Rancho Seco	PWR	1989	SAFSTOR
TMI 2	PWR	1979	SAFSTOR
Shoreham	BWR	1989	DECON (Licence terminated)
Trojan	PWR	1992	DECON
LaCrosse	BWR	1987	SAFSTOR

Table 2. Strategies selected in Europe for some shutdown nuclear power plants

Country	Reactor/Site	Type	Operation	Project	Aim
Belgium	BR-3 Mol	PWR	1962-1987	1989-2004	partial Stage 3
France	G2/G3 Marcoule	GCR	1958-1980	1982-1993	Stage 2 achieved
	EL4 Monts D'aree	HWGCR	1966-1985	1989-1999	Stage 2
Germany	KKN Niederaichbach	HWGCR	1972-1974		completed 1994
	MZFR Karlsruhe	PHWR	1965-1984	1984-2001	Stage 3
	HDR Grosswelzheim	BWR	1969-1971		Stage 3
	AVR Juelich	HTGR	1967-1988		Stage 3
	KWL Lingen	BWR	1968-1977	1985-1988	in dormancy
	Greifswald	WWER	1973-1990	1992-2000	ongoing (Stage 3)
Italy	Caorso	BWR	1978-1990	works ongoing toward Stage 2	
	Enrico Fermi	PWR	1964-1990	works ongoing toward Stage 2	
	Garigliano	BWR	1972-1979	works ongoing toward Stage 2	
	Latina	GCR	1972-1989	works ongoing toward Stage 2	
Slovakia	A1 Bohunice	HWGCR	1972-1979		Stage 1 achieved
Spain	Vandellos-1	GCR	1972-1989	1992-2000	ongoing (Stage 2)

3.4 Costs

The costs for decommissioning commercial nuclear power plants have shown dramatic change since the first estimates were performed in the late 1970's. In field experience, maturation of regulatory guidance, the need to store spent fuel on site, and low level radioactive waste disposal costs have had a profound effect on recently projected costs for decommissioning. The closure of regional disposal sites and the inability of states or regional compacts to develop new disposal sites have increased burial cost projections for radioactive waste by a factor of ten within the last decade.

One aspect which is causing concern over the continued operation of some nuclear power plants and which can result in their premature shutdown is deregulation of electric power markets in many industrial countries. In a deregulated market a nuclear facility is valued relative to alternative sources of electricity generation and customers are expected to shift to lower-cost suppliers as competition between electric utilities pushes down the market price of electricity. As a result, many utilities would have to cut high production costs or to shut down their nuclear power plants, thus leaving "stranded investments" in the form of uneconomic plant and equipment, the capital costs of which have not been fully paid off [16].

It has been generally conceded that some nuclear power plants can run at very low marginal costs. This is valid rather for older nuclear power plants with relatively lower capital costs than for plants constructed in the 1980s and 1990s. For example, a recently privatised UK nuclear utility plans to reap major benefits from extending the life of its 14 AGRs which were designed for a life of 30 years, while their accounting lives were initially set at 20-25 years and later lengthened to 25-30 years, with increasing confidence in the technology [17].

A way to overcome the expected impacts of deregulation has been proposed by some US utilities. It involves restructuring of the electricity utility, in particular reorganization of the ownership of some older nuclear power plants. These can be sold to another operator and continue to produce electricity based on its competitive operational costs [18]. Relevant examples include the sale of Beaver Valley, Pilgrim and TMI-1 NPPs including transfer of licences and decommissioning funds [19] in the United States. But suggestions that up to half of the US reactor population might close early still persist [20].

It is apparent that deregulation and needs for better management has caused major reorganizations in some countries. A proposal for a single company to run all of the country's nuclear power plants was reported in the Russian Federation. In China, as part of a major governmental reorganization to modernise its commercial activities, the China National Nuclear Corporation is being disbanded and its parts evolved into new independent concerns. Similarly Brazil transferred the ownership of Angra 1 and 2 from a state-owned utility to a new project management organization [4]. In Argentina, a privatization process is underway, involving the operational NPPs of Atucha 1 and Embalse and the completion works of Atucha 2 NPP, and includes the creation of a decommissioning fund for all these facilities.

Unfavourable economic conditions may also influence plant operations in some countries, especially in Eastern Europe and in the former Soviet Union. A continued economic depression may result in consumers not paying for electricity used. Lack of financial resources may impair the plant operators to retain qualified staff, attract and train new staff, procure spare parts, perform maintenance and incorporate safety improvements. However, fully regulated energy markets in these countries allow to the state-owned utilities to continue operations.

3.5. Political aspects

Decreasing public confidence in safety of nuclear facilities and growing anti-nuclear movement in some countries started to affect adversely the nuclear industry already several years prior to the Chernobyl accident. In Austria, the nuclear power plant at Zwentendorf was shutdown after a referendum in November 1978. In 1985 the Danish government definitively decided for non-nuclear country after an opinion polls in which 80 percent voted against nuclear power. In Italy, in the aftermath of the Chernobyl accident, all nuclear reactors in operation were closed down after a referendum.

The Swedish referendum of 1980 led to the decision that the country's nuclear power reactors should be shut down by 2010. However the apparently simple decision of 1980 has been overtaken by events. The infant nuclear industry has developed into a major energy source and now generates about half of the country's electricity and since 1980 the annual consumption has almost doubled. The Swedish government has in the meantime accepted other national and international commitments which might seem at variance with a nuclear shutdown [21].

With the time ongoing, the situation at the political forum has changed only very little. In February 1998, the Swedish government ordered Barsebaek to shut down, which would imply enforcing shutdown for reasons other than safety. A complaint was filed with European authorities, saying that the decision violated competitive practice. A decision on continued operation or decommissioning of Barsebaek is still uncertain at this time.

The Swiss government had recently announced a decision in principle to limit the operating lifetimes of the country's existing nuclear power plants, but had preserved the option of future nuclear build.

Sometimes the safety related problems are closely linked with the political ones. The Lithuanian government declared that the Ignalina power plant would stay in operation as long as it remained safe and cost effective; whereas shutting down the station before 2004 is not warranted, it may be inferred from various sources that closure of the plant would be a condition for Lithuania to join the European Union [4].

4. Research Reactors

By the middle of 1998, altogether 477 research reactors have been constructed worldwide and, of these, 262 were in operation. In addition, 13 research reactors are under construction. In total, 215 research reactors were shut down. The actual situation in research reactors worldwide is shown in Fig. 6.

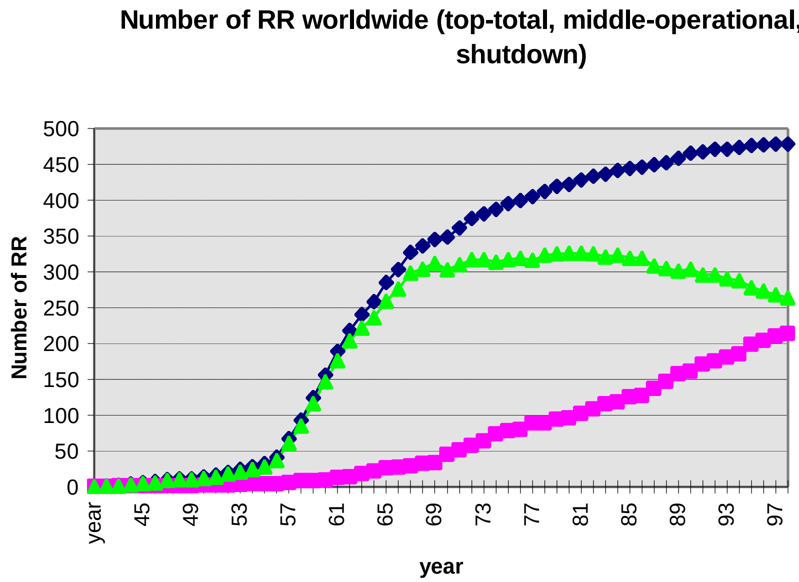

Figure 6. The actual situation in research reactors world-wide

As can be seen from Fig. 7, approximately 78 % of the reactors currently in operation around the world are over 20 years old, 59 % are over 30 years old, and 10% are over 40 years old.

In research reactors, the new safety regulations eventually led to imposing performance of safety analyses on all nuclear facilities of a given category, installation of self-monitoring reactor protection systems, and other changes in the research reactors hardware. In addition, significant upgrades in operator training and conduct of operations were required.

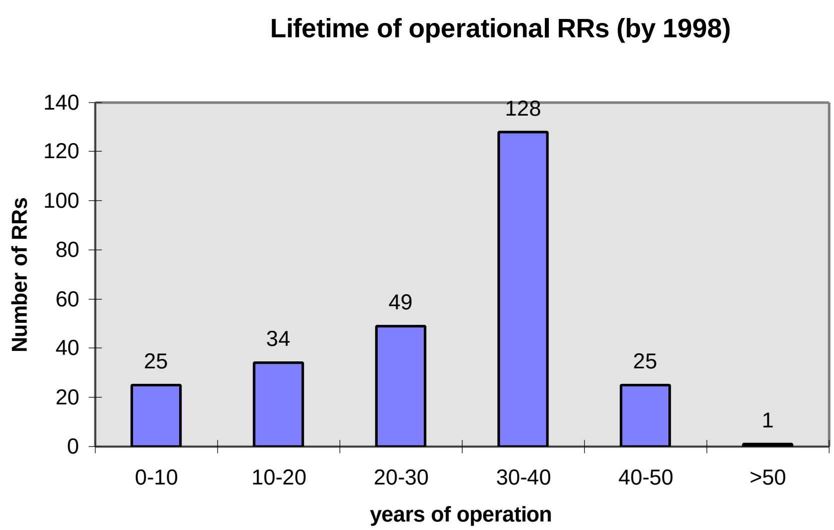

Figure 7. Mean age of the operational research reactors

These changes in the safety philosophy had, in general, a positive impact on the operational lifetime of research reactors. Based on periodical safety reviews, the operators could clearly demonstrate that the facility was operated in a safe manner and that there were no adverse impacts potentially resulting in decision to shutdown the facility from a safety reason. On the other hand, some prototype research reactors were shut down due to insufficient safety, as their upgrades occurred exceedingly expensive. Experience in the United States has shown that the operating costs may increase by a factor of three because of additional operators, safety analysis, and quality assurance groups [22].

Successful refurbishment of a research reactor in Belgium involved renewal of the whole internal matrix. The BR2 Materials Testing Reactor, acknowledged as one of the most effective of its type in the world, suffered from cracking of the beryllium channels. The entire refurbishment included many modifications and a series of inspections to satisfy the requirements for the whole 15-year extension period [23]. Successful large-scale refurbishment projects included the WWRs located in Budapest (Hungary) and Rez (Czech Republic) where the entire reactor tank was replaced.

The costs of operating research reactors can sometimes be a reason for reactor closure. Until recently, the UK operated four educational reactors and a commercial small-scale reactor producing radioactive tracer for the chemical industry. Relatively high operating costs, as well as the perceived costs of decommissioning and uncertainty about spent fuel management, have caused the operators to review their future very carefully. As a result, three reactors were shut down [24].

Many research reactors have been adapted to serve new purposes, from testing materials for nuclear power programmes and supporting nuclear physics experiments, to colouring gemstones, doping silicon and generating radionuclides. Research reactor applications may change substantially, which may cause significant changes in the facility itself. To increase the power density by reducing the core size, new reflectors (beryllium, heavy water) or a cold neutron source may be installed.

Numerous research reactors in the United States, originally supporting nuclear research and defence tasks, have fulfilled their mission and are faced now with the option of refurbishment and continued operation or closure and decommissioning. Although these reactors have been built with specific programmatic needs in mind, many of them are now available for use by other programmes. Two Oak Ridge research reactors can serve as typical examples of the decision-making process.

The Oak Ridge Research Reactor (ORR) and the High Flux Isotope Reactor (HFIR) were both temporarily shut down in 1987. In the case of the ORR, although it was over 30 year old, the costs for safety and environmental upgrades were not unreasonable. But the programmatic need was unsatisfactory and the final decision was to permanently shut down the facility. On the contrary, programmatic support for the HFIR - despite higher refurbishment costs - came from neutron scattering and radioisotope users; in contrast to the ORR, the HFIR was recommended for continued operation [22].

As another example, two German research reactors, FRG-1 and FRG-2 can be quoted. Both reactors were of the same type, operated by the same organization, however, the design of FRG-2 was limited to tests of power reactor components, such as pressure vessel steel, fuel, cladding materials, etc. The necessity for such tests has passed and so after 30 years of operation, the reactor was shutdown in 1995. The older 37-year old, FRG-1 was equipped with a cold neutron source and other measures to increase its use significantly; the operator believes that FRG-1 can be used up to the year 2010 (over 50 years of operation). This clearly demonstrates that if there are needs for future use of a reactor, the design can be adjusted and the potential effects of ageing solved to operate the reactor for a longer period of time [25].

Public acceptance aspects usually do not play a major role in the area of research reactor operations. In a vast majority, the reactors are located in nuclear research centres or in universities where they serve research and educational purposes. For non-proliferation reasons, political pressure is applied to research reactor operators currently using highly enriched uranium to reduce fuel enrichment to less than 20%.

5. Future Trends

Short assessments given in previous sections allow the drawing of the following conclusions:

Nuclear safety, costs and political aspects can affect negatively operating lifetimes of most power reactors. The nuclear power sector may be forced to shut down some units prematurely since competitive electricity prices may be too low to cover operating costs. Uncertainty over how individual plants will be able to reduce expenses will be of major concern in the next future. Some recently published prognoses estimate that approximately one half of power reactors operating in industrial Western countries may be shut down within the next decade because of deregulation and enhanced competition.

Opposite factors such as reactor lifetime extension trends, favourable electricity market and energy needs, as well as attempts to decrease greenhouse gases may result in extension of operating lifetimes of some nuclear power reactors in industrialized countries, and most reactors operating in developing countries. However, economical crises, policy and public attitude shifts, and other factors could change the picture in one or the other direction.

From the total of 523 operating and shutdown nuclear power units throughout the world in 32 countries, 85 percent are located in 11 countries. An attempt to summarise future trends in these countries is presented in Table 3 (elaboration from [26]).

Table 3. Future decommissioning trends in some selected countries

Country	Operating units	Shutdown units	Brief characterization of future trends
Canada	16	9	Operating NPPs will retire after licence expiration, some of them may be closed prematurely for economic reasons, safe enclosure is likely to prevail
France	59	10	Operating NPPs will retire after licence expiration, deferred dismantling will prevail
Germany	20	16	Complete phase out for political reasons, immediate dismantling expected
India	10		Trends to life extension, strategy not yet decided
Japan	54	1	Operating NPPs will retire after licence expiration, immediate dismantling will prevail
Korea, Republic of	12		Operating NPPs will retire after licence expiration, immediate dismantling will prevail
Russian Federation	29	4	Trends to life extension, strategy not yet decided
Sweden	12	1	Complete phase out for political reasons, strategy not yet decided
Ukraine	16	1	Trends to life extension, strategy not yet decided
United Kingdom	35	10	Trends to life extension, decommissioning delayed for long periods of time
United States	107	19	Operating NPPs will retire after licence expiration, some of them may be closed prematurely for economic reasons, others will seek licence extension, immediate dismantling is likely to prevail

Historically, the event which substantially influenced the closure of nuclear power plants, was the Chernobyl accident in 1986. This can clearly be seen from Fig. 8. The competitive electricity market in concert with reactor ageing commenced to impact the reactor retirement rates by the end of 1990s, and this trend may continue throughout the whole next decade, with the maximum in the period 2005-2010. However, opposite trends e.g. life extension programmes may lead to a levelling off at a retirement rate of few shutdown NPPs a year for a longer time, say, a few decades.

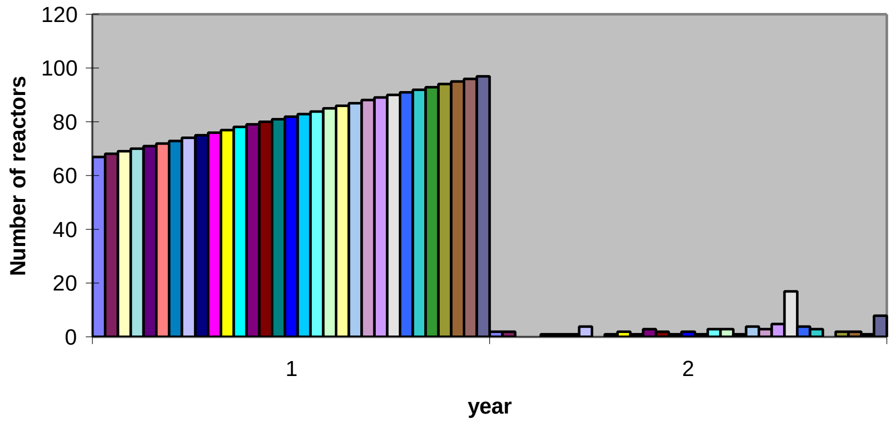

Fig. 8. Number of shutdown nuclear power reactors

It should also be borne in mind that the decommissioning process with its all phases (prolonged planning, strategic decision-making, safe enclosure, unavailability of waste disposal sites, etc.) can sometimes last for several decades, if not for one hundred years, or more. For these reasons it is difficult to predict the exact situation, since uncertainties are extremely high.

As regards research reactors from Fig. 9 it can be seen that the average lifetime of all shutdown facilities increased from 5 years in the 1960s (the so-called infant mortality of prototype facilities) until present 30 years. It is not unreasonable to expect that, in the future, the mean operating lifetime will achieve 35 or 40 years. In the case of 40 years' lifetime, the decommissioning needs will culminate in the first decade of the next century. Even for research reactors, extensive refurbishment and life extension programmes could significantly postpone this anticipated peek.

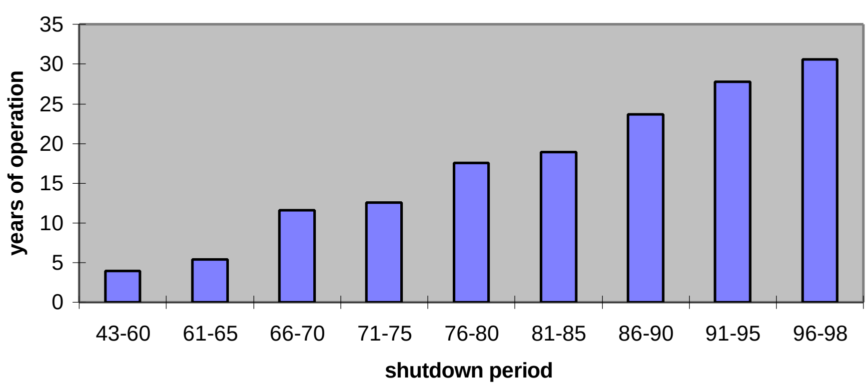

Figure 9. Increase of the operational period of shutdown research reactor with time

6. Conclusions

The increasing competitiveness in energy production may force the operators, on the one hand, to a premature shut down of their nuclear power plants, however, on the other hand, there is a trend to extend reactor lifetimes as far as possible, also for economic reasons. With research reactors the situation is somewhat different. The current retirement rate of research reactors is rather due to the completion of research and experimental programmes or to safety considerations than to economical and political aspects. By now, for the above reasons, nearly one half of research reactors operated worldwide has been closed, whilst other have undergone upgrades and innovations resulting in life extension for new purposes.

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DECOMMISSIONING POLICIES IN EUROPE AND THE EC PROGRAMMES

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1. Introduction

In 1997, Directorate-General XI[1] of the European Commission financed a study on the analysis of the existing situation regarding the decommissioning principles and policies in the Member States. The results of this study were officially published by the Commission services and were used as a basis for developing future thoughts and opinions on the subject[2]. At the end of 1997, following contacts with officials of the Candidate Countries, we were able to extend the Commission's knowledge of the situation in those States. In early 1998, Terms of Reference were prepared in collaboration with the members of the Commission's Advisory Committee on Programme Management (ACPM) with the aim of preparing a Commission Communication on the subject.

A first step was to prepare a situation report and define best practice guidelines in the field. This report was prepared under the auspices of DG XI/C2 with the active participation of eight guest experts coming from seven European Union "nuclear countries". The working group was composed of nuclear experts from regulatory bodies, radioactive waste management agencies and industrialists. We published the final report of this working group in the EUR series[3] and it is also available on request by e-mail.

2. General Background and Existing EC Directives

Decommissioning is the final phase in the life cycle of a nuclear installation and is to be considered part of a general strategy of environmental restoration after the final suspension of the industrial activities. At present, over 110 nuclear facilities∗ within the Union are at various stages in the decommissioning process and it is forecast that at least a further 160 facilities will need to be decommissioned over the next 20 years (with the present 15 Member States). Enlargement of the Union would contribute to a rapid increase in the number of nuclear facilities to be decommissioned (at least 50

1 Directorate-General XI: Environment, Nuclear Safety and Civil Protection. Directorate C, unit C2- Nuclear Safety, Regulation and Radioactive Waste Management.

2 A review of the situation of decommissioning of nuclear installations in Europe. EUR 17.622 (1997)

3 Nuclear Safety and the Environment. Decommissioning of nuclear installations in the European Union, supporting document for the preparation of an EC Communication on the subject of decommissioning nuclear installations in the EU. EUR 18.860 (1999)

∗ For the purpose of this presentation we consider that nuclear power plants, fuel cycle facilities, particle accelerators and nuclear research installations are included under the term "nuclear facility".

facilities). Since 1979, the European Commission's DG XII has conducted four successive five-year research and development programmes on the decommissioning of nuclear installations performed under cost-sharing contracts with organisations from the European Union. The main objective of these programmes was, and is, to establish a scientific and technological basis for the safe, socially acceptable and economically affordable decommissioning of obsolete nuclear installations. After almost 20 years of EU research and development activities on decommissioning, with the technology having reached industrial maturity, the time is ripe to review the related environmental and regulatory issues.

At the level of the European Union, four Council Directives have clear direct links with decommissioning activities.

The general guiding principles for "the protection of the health of workers and the general public against the dangers arising from ionising radiation" are established in Article 2b of the Euratom Treaty of 1957, leading to Chapter 3, and in particular Articles 30, 31, 32 and 37 thereof, and call for the establishment of Basic Safety Standards. These general guiding principles were originally formulated by the European Commission in 1959 and are regularly updated. The last version was published in Council Directive 96/29/EURATOM of 13 May 1996[4].

Another important document from the European Commission on radiation protection for the nuclear industry workers, applicable during decommissioning activities is "Council Directive 90/641[5] on the operational protection of outside workers". This Directive is of primary importance for the radiological protection of thousands of outside workers who will be involved in decommissioning activities at the European level.

The specific requirements related to these Directives will be outlined by my colleague A.Janssens during session 3B of this Workshop.

Directive 85/337/EEC[6], amended by Directive 97/11/EC7 of 3 March 1997, on the assessment of the effect of certain public and private projects on the environment, in annex 1, describes the projects subject to the Directive. It includes the dismantling and decommissioning operations of nuclear power reactors.

Directive 96/92/EC[8] of 19 December 1996, concerning common rules for the internal market in electricity, opens up, the European electricity market, for the first time, to competition, not only at the

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4 Council Directive 96/29 EURATOM of 13 May 96 "laying down basic safety standards for the protection of the health of the workers and the general public against the danger arising from ionising radiation" OJ-L159 of 29 June 1996

5 EURATOM 90/641, Council Directive of 4 December 1990 on the operational protection of outside workers exposed to the risk of ionising radiation during their activities in controlled areas.(OJ L-349 of 13/12/90 page 21)

6 Council Directive 85/337/EEC of 27 June 85. Official Journal N° L 174/40 of 5/7/85

7 Council Directive 97/11/EC of 3 March 97. Official Journal N° L 73/5 of 14/3/97

8 OJ L-027 of 30/01/97, pp20-29

production level, but also at the supply level. The directive requires vertically integrated electricity companies to separate their accounts for production, transmission and distribution. The obligation for transparency in the accounts means that a clear overview has to be given regarding the decommissioning financial provisions and the estimated final costs as well as their influence on the final selling price of electricity.

3. The Terms of Reference for the Expert Working Group

There are a large number of criteria to be considered in establishing a Community opinion on the decommissioning of nuclear facilities. Various regulatory, technical, financial and organisational aspects are closely intertwined in preparing a guiding framework. An analysis of the regulatory and organisational items relevant to decommissioning should be made in the form of an inventory of potential future EC and Member States actions. The guidelines will recommend some policies for the decommissioning of nuclear facilities, and will identify the relevant common base for the legislative aspects and will help Member States to gain experience from others.

The following list summarises some of the major elements which could potentially form the framework of the communication.

3.1 Policy aspects

3.1.1 The group of experts should identify the specific aspects of the health standards protecting the public and the workers under the Directives and recommendations of the Euratom Treaty in the field of decommissioning. This involves examination of the radiation protection aspects such as dosimetry, contamination control and the ALARA (ALARP) principle.

3.1.2 The group of experts should identify the responsibilities connected with decommissioning and waste management.

3.1.3 The group of experts should identify management policies for material resulting from decommissioning operations. This analysis will be performed in a context of the development of common practices of management and classification of radioactive waste.

3.1.4 The group of experts, in the context of the minimisation of waste generated, will examine the rules in force on the criteria for the release of materials. The EURATOM basic safety standards and recommendations will be considered.

3.1.5 The group of experts should examine potential ways of implementing the rules on the environmental impact assessment in national regulations. It will take into account Council Directive 97/11/EC of 3rd March 1997 amending Directive 85/337/EEC.

3.2 Financial aspects

3.2.1 The group of experts should consider the possible financing plans for the implementation of decommissioning operations. The fiscal aspects, the concepts of financial provisions and the management of funds will be examined.

3.2.2 The group of experts should analyse international co-operation in the field of decommissioning and consider its possible reinforcement. The synergies developed on a European Union scale could allow decommissioning costs to be reduced.

3.3 Technical aspects

3.3.1 The group of experts will recommend that a technical approach to decommissioning be established, based on the concept of the time required appropriate for the implementation of the various stages of decommissioning, on the current development of technical and scientific knowledge gained from the European Communities research and development programmes (3rd to the 5th framework programme of Directorate-General XII), and based on the social conditions, the nuclear energy perspective and the repository situation of each country.

3.3.2 The group of experts will examine and recommend possibilities to ensure that the quantities of waste produced during decommissioning operations are minimised. To this end, processes connected with recycling and/or re-use of materials should be explored. They should consider whether the environmental and energy-related impact of recycling is beneficial. Recent progress in the fields of decontamination and the segregation of isotopes will contribute to the analysis of this objective. The majority of radioactive waste volumes resulting from decommissioning operations have a very low level of activity.

3.3.3 The Group of Experts should consider the specific case of very low-level radioactive waste. Options for storage and final disposal will be examined within the possibilities available at national and Community levels.

Based on existing national experience in the field of decommissioning, the preparation of a Commission communication for decommissioning will have to integrate numerous economic, health-related and legislative parameters. This integration will be possible in the perspective of sustainable industrial development also incorporating a respect for the environment. To this end, consultation of the various European socio-economic actors involved will be necessary in order to define more efficiently the terms governing a Commission recommendation.

4. Summaries of the Expert Main Findings

The items listed in this chapter are taken from the complete report 3 published by the EC during spring 1999. This report reflects the opinion of the team of guest experts and does not necessarily reflect the views of the European Commission services.

4.1 Radiation Protection and Industrial Safety

4.1.1 The Group of experts indicated that the conventional safety issues that can be encountered during decommissioning work should also be considered, in addition to the nuclear and radiation risks

4.1.2 The dose limits imposed by the EURATOM BSS for the workers and the public protection are sufficient and are applicable even if the nuclear facility has changed status and/or has entered in a decommissioning phase.

4.1.3 The total yearly exposure will vary according to the stages of decommissioning and to the ALARA principle. If not at the beginning, the dose received by each individual will gradually decrease due to the removal of the radiation sources and to the decontamination of the plant.

4.1.4 The experts were of the opinion that International dosimetry tracking, although each Member State has put in place national dose recording systems, is deficient. Decommissioning projects may involve international private companies sending their workers to different decommissioning sites around Europe and it will be important to record properly the worker's total doses from each different country. Currently, the transfer of exposure data relies on the worker's willingness to communicate their exact dosimetry information to the next employer or authority. Therefore, based on EC Directive5 90/641, improvements in international dose tracking are useful.

4.2 General Responsibilities Related to Decommissioning

4.2.1 The Group of Experts recognises that the legal framework for decommissioning is different in each Member States, and should be treated as such: " harmonisation" of decommissioning practices need not necessarily be the objective.

4.2.2 On the other hand, each Member State must ensure that the risks involved in decommissioning are completely covered by the national regulatory framework put in place for this important task. The Experts stressed the importance oft the responsibilities and the participants being clearly identified by law in each country, without imposing a uniform guideline throughout the Member States.

4.2.3 In the case of the transfer of responsibilities, e.g. to future generations, the Member States must verify that this transfer is feasible and that not only the responsibilities are transferred, but also the knowledge and means to achieve them: eg. Technical knowledge and financial.

4.2.4 Each Member State must ensure that the decommissioning of each of its nuclear facilities be completed to the final stage determined by their Authorities

4.2.5 There is a particular responsibility for waste management: the Member States must determine clearly who is responsible for waste repositories and ensure that these responsibilities are fully covered in the long term

4.3 Decommissioning Material Management Policy

4.3.1 The Group of Experts was of the opinion that, when viable, the option of "recycle-reuse" is preferable to the option of "disposal-replacement".

4.3.2 The abolition of the borders within the EU makes the harmonisation of material management criteria highly desirable. To achieve this, co-operation between international organisations (IAEA, OECD-NEA, and EC) is desirable.

4.3.3 Worldwide criteria harmonisation will also protect the EU against unexpected importation of scrap of international origins. This harmonisation will let material released in one Member State be accepted freely in another through transboundary shipments.

4.3.4 It is important to keep open different pathways for the management of the material from decommissioning activities. The report depicts two different approaches for the management of these materials (OECD versus EC). These different approaches must be evaluated on a case-by-case basis depending on the national situation and the economics of the waste disposal prices that are different in each Member State and influence the national decision on material management. Following the expert's opinion, conditional clearance should remain an open possibility.

4.3.5 Economics also guide the selection of different specific processes, like material sorting, which in some cases is very expensive but in other cases is the best approach for sound material management similar to what is done in the conventional industry.

4.3.6 Material from decommissioning must be defined: some material originating from the non-controlled area is not expected to be contaminated and never came into the regulatory system. For the material coming from the controlled area segregation is necessary. One way of segregating the material is by zoning (used in France); clearance can be done by measurements and strict controls based on criteria, or on a case-by-case basis. It must be remembered that difficulties have been encountered in the acceptance of cleared material by scrap dealers or commercial smelters who refuse this kind of raw material for their production (public perception problem).

4.3.7 Decommissioners should also take into account the management of hazardous material: asbestos, PCB, …which may also be radioactive.

4.4 Release Criteria

4.4.1 The Group of Experts recommended that the concepts of exemption, conditional, and unconditional clearance be maintained. Although a disparity may be perceived between the values, they need to be maintained if we want to address the number of issues that decommissioning activities raise. The numbers of various concepts or criteria create confusion; therefore, one needs to find the correct language to put them across.

4.4.2 The Group of Experts was of the advice that industrial concrete is more and more recycled in the construction industry instead of disposed of in industrial dumps. If we want to pursue a similar process in the nuclear decommissioning industry, on-going work on release criteria for contaminated concrete should be pursued.

4.4.3 The Group of Experts raised the question of clearance levels and detection limits. The detectors, that to an ever-increasing extent are used by scrap dealers, are of sufficient sensitivity to detect radiation below clearance levels. This issue should be considered when developing a strategy of information to the public and to industrialists not familiar with health physics and radiation control.

4.4.4 The Group of Experts stressed the importance of co-operation and clarification on release principles and release criteria with other international organisations. It was felt it would be of great interest to pursue the work of an international working group with IAEA, OECD-NEA in order to reach a consensus on these issues.

4.5 Environmental Impact Assessment

4.5.1 The Group of Experts indicated that the Directive 97/11/EC[7] came out only in March 1997 and should be transposed into national legislation in March 1999. It seems too early to identify the approaches and the differences between the Member States to and on this matter.

4.5.2 The Group of Experts insisted on the importance, in the future, of a proper feedback from the Member States on the Environmental Impact Assessments that they put into place.

4.6 Financing Plans

4.6.1 The decommissioning and waste management costs should be included in the price of the kWh (internalisation of costs) with the exception of historical liabilities associated, for example, with national research or defence facilities.

4.6.2 Provided that financial provisions have been built up throughout the operating life of a nuclear facility, the costs per produced kWh should be relatively low and should not significantly influence electricity charges or lead to unfair competition between producers. If the appropriate financial provisions have not been built up over time, there is a potential risk that producers could choose to embrace the cheapest decommissioning strategy rather than make a balanced judgement based on all the relevant factors, e.g. safety and environmental issues.

4.6.3 This decommissioning financial provision obligation could handicap the nuclear electricity generators compared to fossil fuel generators. A fairer approach could be to integrate into fossil fuel electricity prices the cost of the greenhouse effects (e.g. a CO^2 tax).

4.6.4 The steps to be taken in determining financing requirements include identifying the decommissioning strategy to be applied and preparing detailed cost estimates that include appropriate risk margins. Advice is being prepared as part of the “Incosit”[9] initiative that should be a basis for decommissioning cost estimates (see paper 5.1 by L.Teuckens).

4.6.5 The best practice is to have full funding available at the time of the final shutdown of the facility. The benefit of this approach is to ensure that money is available when decommissioning

9 INCOSIT: Definition of INternationally standardised decommissioning COst ITems. EC DG XII contract FI14D-CT96-0009 with Belgoprocess and in co-operation with IAEA and OECD/NEA.

occurs and, should any decommissioning activities be deferred to a later date, financial burdens will not be imposed on future generations.

4.6.6 The funding of decommissioning nuclear installations in the EU should be based on the idea of:-

- Identifying the full amount of the funds required, including the waste management and final disposal costs;
- making the fund secure and controlled by the competent authorities;
- making sure that the appropriate amount of money is available when needed;
- dedicating the fund to decommissioning, and nothing else.

4.7 International Co-operation

4.7.1 The experts stressed the importance of the exchange of information on decommissioning within the European Community and recommended that the EC extend its initiatives on this subject.

4.7.2 The experts also expressed their strong recommendation that the EC continues its co-operation with the Member States by sponsoring projects and developments on decommissioning subjects.

4.7.3 The experts recommended that the training of engineers and technicians be developed by exchanges of staff and experts between countries inside and outside the EU. This would also be beneficial to the nuclear industry in preparation for the future enlargement of the EU.

4.7.4 The experts were of the advice that international co-operation should exist in the development of information strategies for the public.

4.7.5 The experts recognised the potential technical and financial benefits of international co-operation on waste disposal and waste transfer between countries. Although there are merits in sharing highly expensive waste or fuel repositories (e.g. why impose on a small nuclear waste producing state the high costs of its own deep repository for a few cubic metres of spent fuel or waste while a neighbouring state does the same for its own use), or swapping wastes between countries to optimise treatment and disposal, it was recognised that it may not be politically acceptable to all national governments.

4.8 Technical Approach to Decommissioning

4.8.1 The experts were of the opinion that the EC should publicise more widely the results of its 20 years of R&D activities on decommissioning. This publication should address the practical industrial aspects of decommissioning showing the industrial maturity that has been reached and the technical problems that have been solved. It should also identify new areas for further work and research.

4.8.2 There is not one decommissioning strategy, but a number of alternatives depending of the particular situation of each site. The choice between immediate and deferred dismantling is based on various factors: the existence or not of waste disposal sites, the social aspects and local employment, the need to clear sites for further nuclear or industrial activities, the technical solutions available at the time of the shutdown, the type of reactors or facility, the level and nature of the contamination, the decay optimisation, etc. The situation can vary depending on the social aspects, the use of specialist subcontractors, the existence or not of decommissioning funds…

4.8.3 Technical solutions exist for the majority of the projects involving decommissioning of nuclear installations, but the EC should identify the supplementary approaches from the conventional industry that could be directly applicable or transferred to decommissioning activities.

4.8.4 More investigation should be made on deferred decommissioning techniques and long term building integrity.

4.8.5 It is important to work on the best decommissioning techniques allowing the decommissioning costs and the wastes produced to be reduced to a minimum.

4.8.6 Within the framework of the enlargement of the EU to the eastern countries, it will become more important to study the WWER decommissioning cases. With the exception of Lithuania, the nuclear reactors in the other Central and Eastern countries are mostly of this type and their number warrants a serious investigation into existing documentation, applicable and available dismantling techniques and the need for further R&D programmes. The experts suggested the creation by the EC of a Centre of Excellence where technical exchanges between Eastern and Western specialists could take place, plant status and decommissioning programmes evaluated, and practical training on real decommissioning cases performed.

4.9 Minimisation of Wastes

4.9.1 The experts agreed with the suggestion for additional technological development programmes on:-

- non-metallic material recycling and environmental impact;
- control and measurement techniques of difficult-to-access surfaces;
- improvement of decontamination methods;
- improvement of volume reduction techniques.

4.9.2 The experts also made the following recommendations:

- Limiting the concentration of impurities in material, at the design stage of the plant, for example rare earths in concrete will reduce the production of Europium by neutron activation and limit the amount of waste generated by the dismantling of the plant.
- Examples of actions that could be taken during the operation of the plant to limit the spread of radioactivity are: primary water chemistry control which, in the case of the

BWR's, can be illustrated by the controlled addition of zinc. The permanent control of the cleanliness of the plant.

- At decommissioning time, the choice of adequate decommissioning techniques can be instrumental in the minimisation of wastes.
- Another decommissioning strategy for waste minimisation is to let the activity of the material decay. However, this technique is not always effective since, for example, the slow diffusion of tritium through the material could lead to larger quantities of waste.
- Additional R&D programmes on waste minimisation should be carefully proposed, taking account of the research projects being carried out or completed by the EC, DG XII.

4.10 Very Low Level Waste

4.10.1 The Experts highlighted the differences between Very Low Level Wastes and Very Low Level Material, i.e. that which remains radioactive after all attempts have been made to declassify, clear, recycle.

4.10.2 The Very Low Level Wastes is not a formally existing category of wastes except in France, where a specific VLLW site is planned.

4.10.3 The VLLW's are of such a low activity that it is not desirable, for financial reasons, to dispose of them in LLW repositories.

4.10.4 The Experts suggested avoiding the disposal of the large volumes of VLLW in LLW sites. Alternatives are specific disposal in VLLW sites or conditional release of these materials (not wastes) and controlled recycling as input for the production of new metal, or for the construction of roads.

4.11 Public Acceptance

4.11.1 Concerning the legacy to future generations, the experts were of the opinion that, although it is true that each generation must take care of their problems in order not to transfer unresolved issues to the future, decommissioning activities can be postponed to the next generation for particular reasons (technical, decay, overall cost of the cleanup) if the financial and technical means to solve the problems are transferred as well.

4.11.2 The responsibility for transferring any legacy to future generations lies not only with the national or private electricity producers or nuclear facility users, but also with the public who have received the benefits from the product (welfare, price stability).

4.11.3 It would be advantageous in terms of public information to produce an EC CD-ROM describing the decommissioning programmes within the EU, the results of the R&D projects, the principles of decommissioning strategies and alternatives. It should also be advertised on Internet.

4.11.4 The experts expressed the opinion that any decommissioning actions are per se positive environmental activities that are aimed at solving issues and reducing the risk from industrial activities to the population.

4.11.5 Recognising the difficulties in explaining complex messages to the general public, professional public affairs advice should be taken in developing the means and details of how to convey appropriate messages and information to the public on decommissioning.

5. European Commission Conclusions

This expert report is considered as a valuable input to the Commission's work in the area. The Commission will carefully examine the expert's recommendations and will, in particular, assess to what extent they can be included in its future communication on the subject.

5.1 The European Commission Communication on Decommissioning

It will address the issues that include the share of responsibilities connected with decommissioning; the management policy of the materials and waste; radiation protection; the impact on the environment; public perception; the technical approach and the financial aspects. After a first review of the actual situation, it seems that the responsibilities involved in the decommissioning of nuclear facilities and the management of their wastes are environmental, technical, social and financial. In some Member States it is not clearly defined who will bear these responsibilities for the decommissioning of the nuclear installations to the final stage. Until now decommissioning projects have often been regulated on a case-by-case basis and a build-up of experience is necessary in this field.

The development of common views within the EU on the decommissioning of nuclear facilities could result in a better protection of the population and of the environment, and in a more standardised technological practice lead to, inter alia, a reduction in the generation of waste. Well established decommissioning practices in the Member States and the development of specific decommissioning policies could render regulatory decisions easier, more efficient, transparent and more readily acceptable by the public.

5.2 The European Commission opinion on the financial aspects of Decommissioning

In the Commission's second report to the Council and the European Parliament on harmonisation requirements[10] concerning common rules for the internal market in electricity, the issue of decommissioning or dismantling of nuclear power plants is included due to the specific effects relating to the different financing and accounting approaches. The report does not intend to question the different organisational and technical approaches towards decommissioning.

10. Second report to the Council and the European Parliament on harmonisation requirements. Directive 96/92/EC concerning common rules for the internal market in electricity. COM(1999) 164 Final. Brussels 16.04.99

5.2.1 *Extracts of the report:*

"The main costs of nuclear power generation include capital investment, fuel, ongoing generation and maintenance costs, plus, and this is the main difference to other types of generation, the costs for nuclear waste storage and future dismantling costs[11]. It is evident that the evaluation of these latter costs is rather complex. Depending on the valuation of these cost factors and the legal obligation to calculate provisions into the electricity prices, the resulting prices of nuclear sources have considerable bandwidth. Regarding liquidity, thus looking at generators from a cash flow perspective, the timing of the payments related to the costs is significantly different for nuclear electricity generation compared with other types of generation. A nuclear power generator has to make provisions for substantial future payments, namely the costs of nuclear waste storage and dismantling. With regard to its future financial obligations, the generator itself or a separate entity will seek to invest the cash surplus which is collected through provisions or other levies. Thus, nuclear generators can be seen as trustees for funds to cover future decommissioning costs. Since electricity generators have to compete with each other as of 19 February 1999, diverging regulatory approaches to the management of decommissioning funds may cause substantial market distortions."

"The electricity directive 96/92/EC opens for the first time competition in the European electricity market, not only at the production level, but also at the supply level. The need for transparency in the electricity-producing companies' accounts foresees a clear need for a full integration of the end of life decommissioning costs."

"Different situations exist among the Member States for the financing of decommissioning, e.g. simple provision in the accounts of the electricity companies allowing reinvestment of the collected funds for other than decommissioning purposes, segregation of collected funds outside the sphere of the company, or a complete State organisation and management of decommissioning by separate specialised, mostly publicly owned companies. Moreover, the amount of yearly funding required, the requirements as to when and how decommissioning has to be accomplished and the applied calculation methods and discount rates differ substantially between Member States. This situation questions the principles quoted above and could lead to distortion and discrimination between the new competing nuclear electricity producers from different Member States. Decommissioning costs are clearly seen as part of the electricity production costs. They may not be cross-subsidised from the transmission activity nor be directly subsidised via state aid to the extent that they are incompatible with the EU Treaty."

"Provided that financial provisions have been built up throughout the operating life of a nuclear facility, the costs per kWh should be relatively low and should not significantly influence electricity charges or lead to unfair competition between producers."

"The steps to be taken in determining financing requirements include identifying the decommissioning strategy to be applied and preparing detailed costs estimates that include

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11. The chapter focuses on decommissioning costs because of the diverging accounting and financing methods. Costs associated with waste storage related to the current operation of the plant are in that sense similar to pollution generated by other forms of power generation.

appropriate risk margins. Sound decommissioning financing will also increase the public acceptance of the potential legacy to the future generations. The benefit of this approach is to ensure that money is available when immediate decommissioning occurs, and that financial burdens and risks are not imposed on future generations should any decommissioning activities be deferred to a later date."

"If appropriate financial provisions have not been built up over time, there is a potential risk that producers could choose to elect the cheapest decommissioning strategy rather than make a balanced judgement on all the relevant factors, e.g. safety and environmental issues."

5.2.2 EC suggested approach:

- that the Member States should apply transparency of the financing plans and of its calculation method, that the required full amount of the fund/provision be identified, including the complete decommissioning process, the waste management and final disposal costs;
- that these full decommissioning costs be included in the selling price of the kWh (internalisation of costs) with the potential exception of historical nuclear liabilities associated, for example, with national research or defence facilities for which clear specific financial arrangements should be taken at national levels;
-
- that the fund/provision be secured and controlled by the mandated national authorities;
- that the fund/provision be dedicated to decommissioning purposes, and nothing else; and
- that the full funding be available at the foreseen time (fixed in licence) of the final shutdown of the facility.

"It has to be emphasised that most of these principles can be derived either from the unbundling requirements of the electricity directive or from the competition rules of the EC Treaty. Nevertheless, due to the specific aspects of decommissioning and the importance for the level playing field in the European electricity market, a harmonised approach could be beneficial."

5.3 The European Commission Opinion on the Environmental Impact Assessment

Council Directive 97/11/EC[7] of 3 March 1997 on the Environmental Impact Assessment, annex 1, describes the projects subject to the Directive. It includes dismantling and decommissioning operations for nuclear power reactors. However, while the general requirements are set out in the Directive, the detailed requirements could vary from state to state. Formally, the Directives set out the broad principles of the environmental assessment system to be put in place by the Member States. At first sight, the existing decommissioning plans, in most of the countries inside and outside the EU, focus only on radiological impact assessments rather than the wider Environmental Impact Assessment (EIA) covered by the Directives.

The final destination of a nuclear installation being part of a global environmental restoration strategy it is an important matter for the public. The general public is concerned over what will happen to the waste and over potentially extended time-scales for decommissioning. In addition, there is concern about leaving our wastes to future generations. Even if the existing regulations and practices used during decommissioning protect workers and the general public, the public still needs to be informed on the measures taken. Decommissioning operations and the related strategy decisions should be done with transparency, involve the public and be open to their concerns.

SESSION 2

THE CURRENT SITUATION

KEYNOTE ADDRESS

U.S. REGULATORY EXPERIENCE AND PERSPECTIVE IN DECOMMISSIONING

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Introduction

The United States of America (hereafter U.S.) relies on multiple regulatory agencies to control nuclear waste generated by the decommissioning and decontamination of nuclear fuel cycle facilities and other contaminated sites and operations. The U.S. Environmental Protection Agency (hereafter USEPA) is charged with the development of generally applicable standards for radiation in the environment, the U.S. Nuclear Regulatory Commission (hereafter USNRC) regulates licensing and decommissioning operations involving commercial and non-U.S. Department of Energy (hereafter USDOE) facilities, and USDOE manages the clean-up of USDOE facilities. Under the provisions of the Atomic Energy Act of 1954 [AEA, 1954], as amended, Section 274, USNRC can relinquish authority for the regulation of by-product, source, and some special nuclear material to individual States. These States are referred to as Agreement States.[1] However, all commercial nuclear reactors are regulated by the USNRC, since Agreement States do not have authority to regulate nuclear reactors. Although this may seem to be an unwieldy arrangement at first, it does provide a system of checks and balances in the application of health and safety principles to the use of nuclear materials.

The USNRC is implementing a risk-informed, performance-based strategy in regulating licensed nuclear activities [NRC, 1999]. Stated succinctly, a risk-informed, performance-based regulation is an approach in which risk insights, engineering analysis, and judgment including the principle of defense-in-depth and the incorporation of safety margins, and performance history are used to: (1) focus attention on the most important activities; (2) establish objective criteria for evaluating performance; (3) develop measurable or calculable parameters for monitoring system and licensee performance; (4) provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes; and (5) focus on the results as the primary basis for regulatory decision-making.

The Commission does not endorse a risk-based approach, because regulatory decision-making is then solely based on the numerical results of a risk assessment. Such heavy reliance on risk assessment results is currently not practicable for reactors, because of uncertainties in probabilistic risk assessment such as completeness (risk-based decisions rely solely on the numerical results of a risk assessment, thereby ignoring applicable qualitative information) [NRC, 1999].

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1 The designation of "Agreement States" refers to the individual States that have requested the responsibility for regulation of most radioactive materials. The USNRC makes a determination that the individual State, requesting such status, has the resources and expertise to regulate certain specific commercial uses of nuclear materials.

Risk-informed decommissioning guidance is currently being developed and will allow cost-effective analysis regarding implementing safety objectives, focusing licensee efforts, and achieving greater efficiency in the use of resources for facility safety.

Several International Atomic Energy Agency (hereafter IAEA) Member States, including the U.S., regulate decommissioning operations in two broad categories of facilities. The first category is the larger facilities in the nuclear fuel cycle (e.g., nuclear power plants, uranium conversion facilities, and fuel fabrication facilities), which consist of a few hundred licensees. The second category is materials licensees (medical, industrial, and contaminated soils) of which there are tens of thousands. As one would expect, the decommissioning licensing approach taken for reactors is different than that for other types of facilities.

It is necessary to establish international consensus on achievable decommissioning criteria, so that the criteria are not so restrictive that they constitute a disincentive to partial or stepwise clean-up. This must be a balanced approach considering release of former facilities and sites, which are decommissioned, primarily to achieve adequate health and safety protection goals, without compromising the societal benefits of the safe use of nuclear energy and materials.

U.S. Experience in Decommissioning- Infrastructure developed within the last decade.

USNRC initiated its efforts in setting decommissioning standards in 1988, with the promulgation of regulations requiring licensees to set aside sufficient funds to cover the costs to decommission facilities at the end of use [NRC, 1988]. These regulations also stipulated that licensees were to submit decommissioning plans describing the planned decommissioning activities. From 1993 through 1997, USNRC's regulations were modified to address important issues (e.g., licensees were required to set up a financial assurance mechanism for ensuring the necessary funding for decommissioning would be available). Decommissioning procedures for nuclear power reactors were codified in 1996 [NRC, 1996], and the regulation stipulating radiological criteria for license termination was finalized in 1997 [NRC, 1997].

Timeliness for Decommissioning

An example of an issue not addressed in the 1988 rule concerned the timing in which licensees should begin and complete decommissioning their facilities. Some USNRC licensees were delaying decommissioning their facilities, which was resulting in situations where USNRC had to issue orders to establish schedules for timely completion of decommissioning. Delaying decommissioning could cause problems if a licensee were to encounter financial difficulties, resulting in insufficient funds for clean-up, or if staff familiar with the facility become unavailable over time, or if problems developed associated with continued containment of radioactive materials. To alleviate this situation, USNRC set a time period of up to 2 years for a facility to remain idle, at which point a decommissioning plan would need to be submitted [10 CFR 30.36].

Radiological Criteria

In 1997, USNRC addressed another issue that was not fully addressed in the 1988 regulations. USNRC established radiological criteria to support license termination decisions. One provision of the criteria was that a site may be released for unrestricted use, and the license terminated, if the dose to the average member of a critical group does not exceed 0.25 milliSieverts (mSv) per year or, equivalently, 25 millirem (mrem) per year, with a provision that the dose also be as low as is reasonably achievable (ALARA). The 0.25 mSv per year limit was adopted because it was considered to be a reasonable fraction of the public dose limit which is 1 mSv (100 mrem) per year. An additional provision was that a licensee could terminate its license by releasing a site for *restricted* use if it could be demonstrated that: (1) it was not ALARA to reduce radioactivity to levels permitting unrestricted use of the site; (2) legally enforceable institutional controls were in place to assure that the dose did not exceed 0.25 mSv (25 mrem) per year with the restrictions in place; (3) the dose did not exceed 1 mSv (100 mrem) per year if the restrictions failed; and (4) the local community had been allowed to give input regarding the restrictions.

Other Considerations in Decommissioning Safety

One of the modifications to USNRC's regulations was the provision for licensees to set up a system for ensuring that records necessary for decommissioning, such as records of accidental releases or spills, would be available at the time of decommissioning. Although this topic does not appear to be quantitative, it is still very intertwined with the maintenance of safety. If knowledgeable personnel from the operational period are no longer available, the proper records can help focus decommissioning on areas and equipment that may have been involved in past incidents.

Finally, the U.S. has had to deal with the multi-faceted aspects of radioactive waste management, in general, and decommissioning, specifically. Although USNRC functions primarily in the control of impacts from commercial use of nuclear energy and materials, the issues of toxic, nonradioactive components, or mixed waste, have challenged the U.S. regulatory community.

Other issues that are also common to other Member States – such as the protection of the environment [e.g., the Precautionary Principle] beyond levels established for human safety – have been routinely raised in the process of license termination. As is true of other Member States, there are several mandates and considerations that the U.S. needs to address in the licensing decision to decommission a facility, site, or practice. These include:

- The National Environmental Policy Act of 1969, as amended [NEPA, 1969].
- Quality Assurance/Quality Control
- Export/Import of Contaminated Materials (Recycle/Reuse)
- Cost Optimization
- Overlapping Jurisdictions (with USDOE and USEPA)

The U.S. will continue to pursue an equitable strategy to encourage proper decommissioning within the legal and societal expectations of its regulatory infrastructure. It should not be surprising to observe that the infrastructure is a complex and burdensome one, but one which values the open forum of public and external opinion in a process of consensus- building resolution.

Areas of Progress and Cooperation- Lessons Learned

Sites Decommissioned

USNRC terminates about 300 licenses each year. Most of these decommissioning activities involve simple and routine cases dealing with sealed sources, gauge users, and licensees that can decommission using simple remediation methods applicable to normal operations. There are, however, 19 nuclear power plants, 9 research reactors, 6 test reactors, and about 40 non-routine materials licensee facilities undergoing decommissioning under USNRC oversight.

In 1990, USNRC established the Site Decommissioning Management Plan (SDMP) to focus staff resources on a series of difficult, non-routine materials decommissioning cases. The difficult cases involved licensees having large quantities of contaminated soils and other materials, ground-water contamination; previously terminated licenses where additional contamination had been identified; or inadequate financial assurance mechanisms. Since 1990, 24 of the SDMP sites have been removed from the SDMP list; 36 sites currently remain. One of the primary difficulties identified in the remediation of these cases has been inadequate site characterization data. This has complicated the planning for site clean-up. Consequently, remediation efforts were incomplete, requiring the licensee to prolong the process of clean-up activities. Such inadequate characterization resulted in inefficient use of licensee funds and long delays in completing decommissioning. Based on USNRC's experiences, a thorough and comprehensive initial characterization of the extent and nature of site contamination is absolutely essential to an efficient decommissioning process.

Table 1 provides a list of some of the completed facility and materials site decommissioning activities. Appendix 1 contains the complete, current list of facilities and sites that have either been or are being decommissioned, and their current status. This appendix includes non-routine materials licensee facility remediation completed under the SDMP.

During the decommissioning of two nuclear power reactors (Fort St. Vrain and Shoreham), the licensees used commercially available remediation methods. One of the most important comments from the Fort St. Vrain and Shoreham experiences was the fact that the final surveys, used to demonstrate compliance with the decommissioning criteria, were excessively expensive

However, USNRC recently published new final survey guidance in conjunction with the new license termination rule promulgated in 1997. The new survey guidance, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) was developed in cooperation with USNRC, USEPA, USDOE, and the U.S. Department of Defense [NUREG-1575]. The new survey protocol is a comprehensive guide to planning, conducting, evaluating, and documenting radiological surveys, using statistical analyses to demonstrate compliance with the decommissioning standards. Our Federal agencies anticipate that the MARSSIM guidance should reduce licensee costs for nuclear power plant and other materials site final surveys.

Table 1.
Nuclear Facility Decommissioning Status

Nuclear Power Plant	Type	Status
Pathfinder	66 Mwe experimental BWR	Decommissioning complete in 1992 except for minor contamination in turbine and condenser now used with gas-fired boiler
Fort St. Vrain	330 Mwe HTGR	Decommissioning complete in 1997
Shoreham	849 Mwe BWR	Decommissioning complete in 1995
Cintichem	5 MWt research reactor	Decommissioning complete; site released in 1998
SDMP Site	History	Status
Anne Arundel County/Curtis Bay; Anne Arundel County, Maryland	Thorium nitrate storage	Decommissioned and removed from the SDMP list in 1997
Babcock & Wilcox; Apollo, Pennsylvania	Fuel fabrication	Decommissioned and removed from the SDMP list in 1997
Budd Company; Philadelphia, Pennsylvania	Hot cell operations	Decommissioned and removed from the SDMP list in 1993
Cabot Corporation; Boyertown, Pennsylvania	Metal extraction from thorium-containing ores and slags	Decommissioned and removed from the SDMP list in 1998
Old Vic; Cleveland, Ohio	Research and electronic component production	Decommissioned and removed from the SDMP list in 1993
Pratt & Whitney; Middletown, Connecticut	Nuclear engine research	Decommissioned and removed from the SDMP list in 1995
RTI, Inc.; Rockaway, New Jersey	Hot cell	Decommissioned and removed from the SDMP list in 1997
Schott Glass Technologies; Duryea, Pennsylvania	Thoriated glass production	Decommissioned and removed from the SDMP list in 1998
UNC Recovery Systems; Wood River Junction, Rhode Island	Fuel research	Decommissioned and removed from the SDMP list in 1995

U.S. Government Agency Cooperative Efforts

USNRC has cooperated with the USEPA and other Federal agencies in the development of dose conversion factors for risk assessments (e.g., Federal Guidance Reports No. 11 and No. 12) [EPA, 1988; EPA, 1993]. USNRC is also working with the USEPA and other Federal agencies to prepare a "Multi-Agency Radiation Laboratory Protocols" (MARLAP) manual. MARLAP will provide an up-to-date set of approved radionuclide laboratory analysis procedures for licensee activities.

Decommissioning Guidance

USNRC is also developing a series of licensing guidance documents, including standard review plans, to help licensees prepare various decommissioning submittals. Moreover, the standard review plans provide the regulators with uniform criteria and guidance for reviewing licensee submittals relating to decommissioning. The status of the principal guidance documents for decommissioning is shown on Table 2.

Issues That Need To Be Addressed InThe Decommissioning Arena

Differences in Radiological Management Targets and Guidelines

The national and international radiation standards are harmonious with respect to the primary public dose limit. Thus, it is generally acceptable that the limit for the public dose should not exceed 1.0 mSv (100 mrem) per year Total Effective Dose Equivalent (TEDE) above natural background levels. USNRC's public dose limit in 10 CFR 20.1301 and USDOE's primary standard public dose limit from all sources (except background, medical, and radon sources) of 1.0 mSv (100 mrem) per year reflect general agreement. Furthermore, national and international agencies also agree, in general, on the concept of using a "source upper bound" limit where exposures to *any single source* or practice are allotted a lower dose value than the primary public dose limit.

For most cases, regulatory agencies in the U.S. adopted a "source upper bound" limit which is lower than the primary public dose limit for radiological management of a single source for clean-up, decommissioning, or license termination. However, in managing the risk associated with the clean-up or decommissioning, the dose criteria differ among these agencies. For example, USNRC has adopted an unrestricted-use, radiological criterion for license termination, of 0.25 mSv (25 mrem) per year from any single source to an average member of the critical group from all pathways, including contributions from ground water (10 CFR 20.1402) [NRC, 1997]. In addition, USNRC requires that residual radioactivity be reduced to levels that are ALARA; in effect, this is equivalent to the "optimization principle" in the international context. USEPA, however, is currently setting preliminary remediation goals (PRGs) for radionuclides in the 10-6 to 10-4 lifetime-incidence risk[2] range and is limiting annual doses for PRGs and CERCLA[3] clean-ups to 0.15 mSv (15 mrem) per year.

An additional complication to uniform risk management has been the USEPA's proviso of an additional, separate requirement for ground-water protection. This additional requirement is frequently cited to be 0.04 mSv (4 mrem) per year, but the USEPA's approach of establishing maximum contaminant levels (MCLs) in drinking water imposes consideration of the individual radionuclide(s) involved. Because the MCLs are radionuclide-specific, individual MCLs may impose dose limits ranging from 10-4 mSv (0.01 mrem) per year to as much as 1 - 2 mSv (100 - 200 mrem) per year.

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2 It should be noted that the USNRC has adopted a mortality risk approach. When the USEPA incidence risk is corrected to reflect mortality, USNRC and USEPA numbers are compatible (USNRC uses 3.8X10-4 versus USEPA's risk equivalent to premature mortality of 3x10-4, which is indistinguishable from the 1X10-4 often seen in USEPA documentation).

3 Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

Table 2. Decommissioning Guidance[4]

Guidance Document	Status
USNRC Regulatory Guide (DG-1067), "Decommissioning of Nuclear Power Reactors"	Draft guide issued for comment in June 1997; final guide scheduled for issuance in April 1999
USNRC Regulatory Guide (DG-1071), "Standard Format and Content for Post-Shutdown Decommissioning Activities Report"	Draft guide issued for comment in December 1997; final guide scheduled for issuance in April 1999
USNRC Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors"	Final guide issued in January 1999
USNRC Regulatory Guide (DG-1069), "Fire Protection Program for Permanently Shutdown and Decommissioning Nuclear Power Plants"	Draft guide issued in July 1998; final guide scheduled for issuance in August 1999
USNRC Regulatory Guide (DG-4006), "Demonstrating Compliance with Radiological Criteria for License Termination"	Draft guide issued in August 1998; final guide scheduled for issuance in 2000
USNRC Regulatory Guide, "Cost Estimates Required by 10 CFR 50.82"	Draft scheduled for issuance in 2000
"USNRC Standard Review Plan for Decommissioning Nuclear Power Reactors"	Draft scheduled for issuance in July 1999
"USNRC Standard Review Plan for License Termination Plans"	Draft issued for comment in December 1998
USNRC Standard Review Plan for Cost Estimates Required by 10 CFR 50.82	Draft scheduled for issuance in 2000
USNRC Standard Review Plan for Decommissioning Materials Licenses	Scheduled for issuance in 2000

USDOE's basic requirement for protection of the public is to control activities to limit public doses from all sources and pathways to 1 mSv (100 mrem) per year. USDOE employs a dose constraint of 0.30 mSv (30 mrem) per year from USDOE-generated sources and applies the ALARA process to ensure that combined sources do not result in exposures that will cause public doses to exceed 1.0 mSv (100 mrem) per year. For release of property containing residual radioactivity, USDOE requires authorized limits for release of property be below 0.25 mSv (25 mrem) in addition to ALARA [DOE, 1993].

Although there is little practical difference between 0.15, 0.25 and 0.30 mSv (15, 25, and 30 mrem) per year, from the radiological health and safety stand point, these differences are troublesome for practical implementation and demonstration within the context of a uniform decommissioning national standard. This is most evident in consideration of the cost associated with implementation of each

4 Single copies of printed Regulatory Guides may be obtained free of charge by writing the Reproduction and Distribution Services Section, USNRC, Washington, DC 20555-0001, USA, or by fax at (301) 415-2289.

compliance limit in light of the relative benefit gained. Therefore, a policy issue that needs to be addressed in the decommissioning arena is the risk/dose harmonization to establish a consistent and comparable national/international radiation criterion for clean-up and decommissioning under unrestricted release conditions.

Approaches to Assessment of Risk/Dose Impacts for Compliance with the Decommissioning Criteria

U.S. Federal agencies have adopted generic approaches for assessment and quantification of dose and risk. USNRC employs the concept of the "average member of the critical group," which is a relatively small and homogeneous group of the population expected to potentially receive the largest radiation dose. Such critical groups are defined on the basis of the residual radioactivity, source location and the associated potential exposure scenarios of the critical group via transport through the geosphere and biosphere environmental media (e.g., residential-farmer scenario).

The next step in estimation of the dose and risk is to analyze potential exposure pathways for the critical group, which involves the consideration of different pathways (e.g., internal dose from ingestion of plants grown in contaminated soil and irrigated with contaminated water). Appendix 2 is a chart that displays the typical pathways associated with four scenarios (e.g., residential, building renovation, building occupation, and drinking water) commonly used in dose impact analysis. As can be seen from that chart, the interactions and interconnections between the numerous factors influencing the final dose can be complex and problematic.

After estimating the radionuclide burden through ingestion, inhalation, and direct exposure, dose conversion factors are used to convert the rate of radionuclide intake/exposure by the critical group member to the dose or risk associated with each pathway [EPA, 1988; EPA, 1993]. Finally, the TEDE of the critical group member is derived from all corresponding exposure pathways. In this regard, the U.S. differs from many other Member States that have adopted the International Commission for Radiological Protection, Publication 60 concept of the effective dose [ICRP, 1990].

Uncertainties in the current dose and risk models and the input parameters could result in unreliable dose results compared with the low risk/dose criteria adopted by regulatory bodies. For example, in demonstrating compliance with either USEPA (0.15 mSv or 15 mrem per year) or USNRC (0.25 mSv or 25 mrem per year) unrestricted use criteria, the differences in the doses derived, because of model and parameter uncertainties, could far exceed the 0.10 mSv (10 mrem) per year difference between the two criteria. However, the cost differences associated with the implementation of these two limits could be significant. Therefore, there is a need for further coordination and harmony on the issue of selection and verification of dose and risk models and the input parameters. In addition, there is also a need to promote and maintain international forums to discuss uncertainties in derivation of dose/risk values and propagation of such uncertainties.

Screening Analysis for Compliance with Decommissioning Criteria

A specific issue, basic to any regulatory infrastructure, is the determination of compliance. In the decommissioning arena, a stubborn problem is that associated with clean-ups involving naturally occurring radionuclides. As was discussed earlier, mathematical models for detailed assessment of the critical group dose impacts from potential releases of residual radioactivity are becoming rather sophisticated and complex. National and international agencies recognized that sophisticated and complex models use a great deal of site-specific input data and may not be sufficiently robust to use under diverse site and environmental conditions (e.g., representing a wide spectrum of physical and environmental conditions).

Therefore, conservative screening approaches corresponding to simple models were developed.

USNRC, in evaluating the tools available for screening, is examining the following:

- Conservatism in the screening analysis
- Generic default parameters for screening analysis
- Verification and testing of screening models
- Approaches for refined screening analysis to minimize undue conservatism
- Development of probabilistic tools to accurately reflect uncertainty in the screening analysis
- Development of cautious, but reasonable, critical group characteristics and exposure pathways for screening analysis
- Methods and tools for measuring low levels of residual radioactivity
- Methods for estimation of background

However, in some instances, such as in the case of alpha emitters, estimated exposures resulting from screening can be rather low, and as such, cannot be measured within the fluctuation range of natural background. An example of this can be seen in Table 3, which shows surface contamination levels for common alpha emitters in disintegrations per minute per 100 square centimeters (dpm/100 cm^2) equivalent to 0.25 mSv (25 mrem) per year using USNRC's screening and default input parameters [NUREG/CR-5512, Vol. 2].

Considering these low values, the issue of detectability versus compliance is an obvious obstacle in implementation of decommissioning standards and criteria. Furthermore, the issue of distinguishing residual activity from natural background cannot be underestimated.

Clearance, Recycle, and Reuse

Establishing an acceptable and enforceable consensus for the release of low-activity contaminated materials (metals, rubble, etc.) has been a significant part of the IAEA and the U.S. regulatory focus. USNRC, USEPA, USDOE, individual States in the U.S., and other organizations, such as the U.S. Customs Service, are cooperating in an effort to arrive at release criteria, which are protective of health and safety, yet provide flexibility within the spectrum of recycling and reuse of materials posing little or no hazard to the general public. Previous attempts to establish dose limits for unrestricted release of materials associated with – but not necessarily contaminated by – nuclear facilities and operations have met with failure. Using an enhanced public participatory process takes advantage of the public's perspectives in promulgating such a regulation and USNRC is currently pursuing such an approach in support of a rulemaking effort for clearance of radioactively contaminated materials.

Table 3. Screening Values under Consideration for Common Alpha Emitters[5]

Radionuclide	Symbol	Screening Levels for Unrestricted Release		Action Plan Values[6]	
		dpm/100 cm^2	Bq/cm^2	dpm/100 cm^2	Bq/cm^2
actinium-227	^{227}Ac	1.8	0.0003	100	0.0167
thorium-228	228Th	41	0.0069	100	0.016
thorium-232	^{232}Th	7.3	0.0012	1000	0.167
protactinium-231	^{231}Pa	8.6	0.0014	100	0.0167
uranium-235	^{235}U	97	0.0162	5000	0.835
uranium-238	^{238}U	100	0.0167	5000	0.835
plutonium-239	^{239}Pu	28	0.0047	---	---
americium-241	^{241}Am	58	0.0097	---	---

It is clear that the international community has been quite active in this area also. The European Commission, the Nuclear Energy Agency, and the IAEA have published reports on the subject of recycle, reuse, and clearance. It now remains for all of us to seek convergence, because the illicit trafficking in contaminated materials, especially metals, presents transboundary concerns similar to other problems associated with loss of control of radioactive material. On the other hand, if the global scientific community can come to terms with setting an acceptable, safe limit, which actually does remove some of the regulatory burdens of disposition of low-concentration materials, then the problem eases, becoming one of proper detectability and monitoring. If we should fail, we may result in having criteria associated with such trivial levels of potential exposure that would be meaningless in terms of realistic reuse and recycling of radioactively contaminated materials.

Institutional Control

USNRC's regulation for decommissioning also allows for license termination under restricted conditions when further reductions in residual radioactivity necessary to release the site for unrestricted use: (1) would result in net public or environmental harm; or (2) were not being made because the residual levels are ALARA. Under conditions of restricted release, legally enforceable institutional controls are required to ensure that the restriction(s) remain in effect after regulatory control is released. Institutional controls may be based on property rights or on a government's sovereign or police powers. Institutional controls based on property rights involve a party that owns rights which restrict the use of, or access to, the property. Among the more common examples of government institutional controls are zoning, well-

5 These screening values are not official and serve only to indicate the difficulty in setting clean-up values for alpha contamination. USNRC staff is currently revising this table.

6 Action Plan Values are given in USNRC Regulatory Guide 1.86 and are not explicitly dose based [NRC, 1974].

water use restrictions and building permit requirements. Physical controls (e.g., fences, markers, earthen covers, monitoring, and maintenance) can only be used to meet institutional control requirements when they are used in combination with an instrument that permits legal enforcement of the physical control, and financial assurance that the control will continue. Issues that need to be addressed when establishing institutional controls include:

- *Need for durable controls*. An important consideration in determining the acceptability of an institutional control is that it be sufficiently durable to provide an appropriate level of protection for the amount of radioactivity remaining at the site.
- *Duration of controls*. The restrictions should remain in place until unrestricted release conditions can be met. The conditions that end the restriction should be clearly stated, and the procedures for canceling or amending the restriction should be readily available.
- *Funds for enforcement of controls*. Adequate funds should be set aside for the inspection and maintenance of physical controls. If funds are required for long durations, the appropriate rate of return for determining the present worth of annual costs can become an issue.
- *Financial assurance*. Licensees should provide financial assurance sufficient to enable an independent third party to assume and carry out responsibilities for any necessary control and maintenance of the site, if the site landowner is unwilling or unable to perform such activities. Financial assurance arrangements should include oversight of the party by a government entity or the courts. Acceptable financial assurance mechanisms include:
    - Funds placed into an account segregated from the licensee's assets and outside the licensee's administrative control;
    - A surety method, insurance, or other guarantee method; or
    - A statement of intent by Federal, State, or local government licensees, or an arrangement deemed acceptable by a government entity, when the government entity assumes custody or ownership of the site.
- *Public advice*. Diverse community concerns and interests can be useful in developing effective institutional controls, and this information should be considered and incorporated as appropriate in the licensee's decommissioning plan

Summary and Observations

Many of the aforementioned considerations and issues apply equally to all areas of radioactive waste safety management. This is a function of the interdependency of the multi-faceted nature of waste safety. However, there are a few issues that are especially relevant to, and significant for, decommissioning and clean-up. Briefly, it is clear that the international scientific community needs to consider, among other issues:

- Uniformity and consistency of cleanup criteria and their application
- Validation, or confidence-building, of dose models and their associated uncertainties
- Resolution of key technical shortcomings in determining compliance with criteria (e.g., alpha contamination); this is an implementation issue, as well.

- The sharing of lessons learned from past experiences can help clarify consistently problematic issues, as well as help bring about a pragmatic strategy for dealing with clean-ups in a safe and expedient manner. Such a strategy includes:

  - thorough and comprehensive initial characterization of the site;
  - early consideration of decommissioning in the early stages of design; and
  - public involvement in the decision-making process.

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APPENDIX 1

Table 1.
Nuclear Power Plant Decommissioning Status

Nuclear Power Plant	Type	Status
Pathfinder	66 Mwe experimental BWR	Decommissioning complete in 1992 except for minor contamination in turbine and condenser now used with gas-fired boiler
Fort St. Vrain	330 Mwe HTGR	Decommissioning complete in 1997
Shoreham	849 Mwe BWR	Decommissioning complete in 1995
Big Rock Point	67 Mwe BWR	Dismantlement underway
Connecticut Yankee	590 Mwe PWR	Dismantlement underway
Dresden Unit 1	200 Mwe BWR	SAFSTOR
Fermi Unit 1	200 MWt LMR	SAFSTOR
Humboldt Bay	63 Mwe BWR	Limited dismantlement underway
Indian Point Unit 1	257 Mwe PWR	SAFSTOR
Lacrosse	50 Mwe BWR	Limited dismantlement underway
Maine Yankee	860 Mwe PWR	Dismantlement underway
Millstone Unit 1	660 Mwe BWR	SAFSTOR
Peach Bottom Unit 1	115 Mwe HTGR	SAFSTOR
Rancho Seco	913 Mwe PWR	Limited dismantlement underway
San Onofre Unit 1	436 Mwe PWR	SAFSTOR
Saxton	28 MWt PWR	Dismantlement underway
Three Mile Island Unit 2	792 Mwe PWR	SAFSTOR
Trojan	1095 Mwe PWR	Dismantlement underway
Vallecitos	50 Mwe BWR	SAFSTOR
Yankee Rowe	167 Mwe PWR	Dismantlement underway
Zion Units 1 and 2	1040 Mwe PWRs	SAFSTOR
Cintichem	5 MWt Research Reactor	Decommissioning complete; site released in 1998

Table 2.
Site Decommissioning Management Plan Sites

SDMP Site	History	Status
Advanced Medical Systems; Cleveland, Ohio	Sealed source manufacturing	Licensee cannot meet financial assurance requirements
Aluminum Company of America; Cleveland, Ohio	Magnesium-thorium alloy research	Decommissioned and removed from the SDMP list in 1996
Allied Signal Aerospace; Teterboro, New Jersey	Thorium research	Decommissioned and removed from the SDMP list in 1992
Amax, Inc., Wood County, West Virginia	Rare earth recovery operations	Transferred to the USDOE and removed from the SDMP list in 1994
Anne Arundel County/Curtis Bay; Anne Arundel County, Maryland	Thorium nitrate storage	Decommissioning complete and removed from the SDMP list in 1997
AAR Manufacturing; Livonia, Michigan	Thorium alloy product manufacturing	Remediation underway
Army Aberdeen Proving Ground; Aberdeen, Maryland	Depleted uranium ammunition testing	Reviewed ground-water survey plan and removed from the SDMP list in 1997
Babcock & Wilcox; Apollo, Pennsylvania	Fuel fabrication	Decommissioned and removed from the SDMP list in 1997
Babcock & Wilcox; Parks Township	Fuel fabrication	Site remediation underway
Babcock & Wilcox; Parks Township	Shallow Land Disposal Area	Licensee developing decommissioning plan
BP Chemicals; Lima, Ohio	Depleted uranium catalyst production and use	Remediation underway
Budd Company; Philadelphia, Pennsylvania	Hot cell operations	Decommissioned and removed from the SDMP list in 1993
Cabot Corporation; Boyertown, Pennsylvania	Metal extraction from thorium-containing ores and slags	Decommissioned and removed from the SDMP list in 1998
Cabot Corporation; Reading, Pennsylvania	Metal extraction from thorium-containing ores and slags	Decommissioning plan under review
Cabot Corporation; Revere, Pennsylvania	Metal extraction from thorium-containing ores and slags	Decommissioning plan under review
Chemetron Corporation – Harvard Avenue; Cuyahoga Heights, Ohio	Depleted uranium catalyst production	Decommissioning complete
Chemetron Corporation - Bert Avenue; Newburgh Heights, Ohio	Depleted uranium contamination in unregulated disposal site	Decommissioning complete

Table 2. Cont.
Site Decommissioning Management Plan Sites

SDMP Site	History	Status
Chevron Corporation; Pawling, New York	Fuel research	Decommissioned and removed from the SDMP list in 1994
Clevite Corporation; Cleveland, Ohio	Uranium metal research and fuel fabrication	Decommissioned and removed from the SDMP list in 1998
Dow Chemical Company; Midland, Michigan	Magnesium-thorium alloy production	Remediation underway
Elkem Metals; Marietta, Ohio	Metal extraction from thorium-containing slags	Final survey report under review
Engelhard Corporation; Plainville, Massachusetts	Fuel fabrication	Transferred to the State and removed from the SDMP list in 1997
Fansteel; Muskogee, Oklahoma	Metal extraction from thorium-containing ores and slags	Decommissioning plan under review
Fromme; Detroit, Michigan	Thorium alloy product manufacturing	Decommissioned and removed from the SDMP list in 1996
Hartley & Hartley Landfill-SCA; Bay County, Michigan	Magnesium-thorium alloy slag disposal	Waiting decommissioning plan
Hartley & Hartley Landfill-MDNR; Bay County, Michigan	Magnesium-thorium alloy slag disposal	Waiting decommissioning plan
Heritage Minerals; Lakehurst, New Jersey	Metal extraction from thorium-containing ores	Decommissioning plan under review
Jefferson Proving Ground; Jefferson, Indiana	Depleted uranium munitions testing	Waiting decommissioning plan
Horizons; Cleveland, Ohio	Uranium and thorium metal refining	Remediation underway
Kaiser Aluminum; Tulsa, Oklahoma	Metal extraction from thorium-containing ores and slags	Waiting decommissioning plan
Kerr-McGee, Cimarron; Crescent, Oklahoma	Fuel fabrication	Remediation underway
Kerr-McGee, Cushing; Cushing, Oklahoma	Uranium and thorium research	Decommissioning plan under review
Kerr-McGee; West Chicago, Illinois	Thorium production	Site transferred to State; removed from the SDMP list in 1990
Lake City Army Ammunition Plant; Independence, Missouri	Depleted uranium ammunition production	Remediation underway
Magnesium-Electron; Flemington, New Jersey	Metal extraction from thorium-containing ores	No licensable material and removed from the SDMP list in 1995

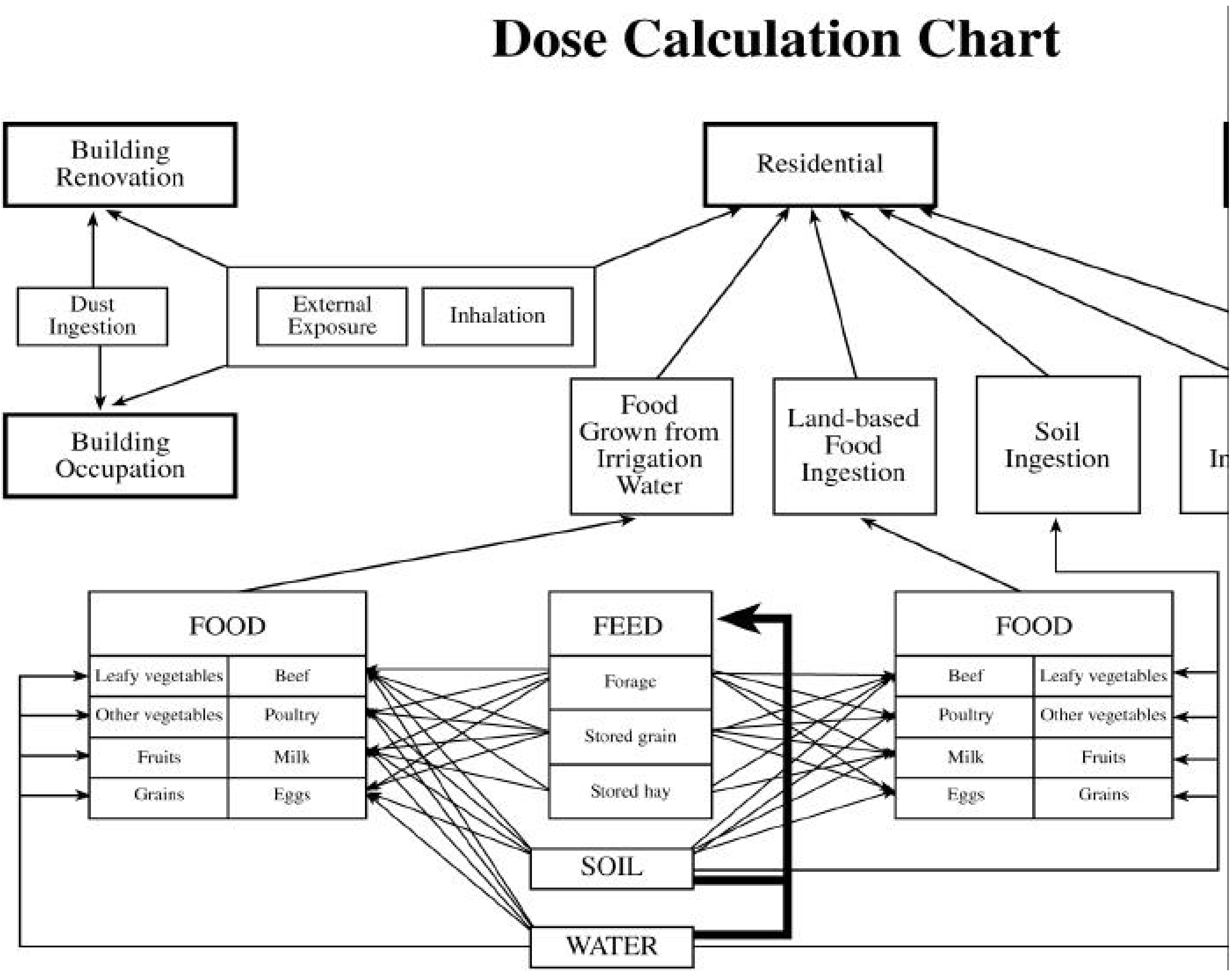
Table 2. Cont.
Site Decommissioning Management Plan Sites

SDMP Site	History	Status
Mallinckrodt; St. Louis, Missouri	Fuel fabrication	Site operations in standby; removed from the SDMP list in 1992
Minnesota Mining and Manufacturing; Kerrick County, Minnesota	Uranium and thorium research	Decommissioning plan under review
Molycorp; Washington, Pennsylvania	Metal extraction from thorium-containing ores	Decommissioning plan to be submitted
Molycorp; York, Pennsylvania	Metal extraction from thorium-containing ores	Decommissioning plan under review
Northeast Ohio Regional Sewer District; Cleveland, Ohio	Possesses Co-60 contaminated sewer sludge	Remediation plan under review
Nuclear Metals; Concord, Massachusetts	Depleted uranium ammunition production	Transferred to the State and removed from the SDMP list in 1997
Old Vic; Cleveland, Ohio	Research and electronic component production	Decommissioned and removed from the SDMP list in 1993
Permagrain Products; Media, Pennsylvania	Hot cell	Remediation underway
Pesses; Pulaski, Pennsylvania	Thorium metals reclaiming	Remediation underway
Pratt & Whitney; Middletown, Connecticut	Nuclear engine research	Decommissioned and removed from the SDMP list in 1995
RMI Titanium; Ashtabula, Ohio	Uranium metal extrusion	Remediation underway
RTI, Inc.; Rockaway, New Jersey	Hot cell	Decommissioned and removed from the SDMP list in 1997
Safety Light; Bloomsburg, Pennsylvania	Self-illuminating watch and sign production; various uses of multiple nuclides	Decommissioning plan under review
Schott Glass Technologies; Duryea, Pennsylvania	Thoriated glass production	Decommissioned and removed from the SDMP list in 1998
Sequoyah Fuels; Gore, Oklahoma	Uranium conversion	Decommissioning plan under review
Shieldalloy-Cambridge; Cambridge, Ohio	Metal extraction from thorium-containing ores and slags	Waiting decommissioning plan
Shieldalloy-Newfield; Newfield, New Jersey	Metal extraction from thorium-containing ores and slags	Waiting decommissioning plan

Table 2. Cont.
Site Decommissioning Management Plan Sites

SDMP Site	History	Status
Texas Instruments; Attleboro, Massachusetts	Fuel fabrication	Decommissioned and removed from the SDMP list in 1997
UNC Recovery Systems; Wood River Junction, Rhode Island	Fuel research	Decommissioned and removed from the SDMP list in 1995
Watertown GSA; Watertown, Massachusetts	Contamination from uranium metal research	Decommissioning plan under review
Watertown Arsenal Mall; Watertown, Massachusetts	Contamination from uranium metal research	Decommissioning plan under review
West Lake Landfill; Bridgeton, Missouri	Unregulated disposal site	Deferred to USEPA and removed from the SDMP list in 1995
Westinghouse Waltz Mill; Madison, Pennsylvania	Contamination from test reactor	Decommissioning plan under review
Whittaker; Greenville, Pennsylvania	Metal extraction from thorium-containing ores and slags	Waiting decommissioning plan
Wyman-Gordon; Grafton, Massachusetts	Magnesium-thorium alloy production	Transferred to the State and removed from SDMP list in 1997

APPENDIX 2


Dose Calculation Chart
Building Renovation
Residential
Dust Ingestion
External Exposure
Inhalation
Building Occupation
Food Grown from Irrigation Water
Land-based Food Ingestion
Soil Ingestion
FOOD
Leafy vegetables
Beef
Other vegetables
Poultry
Fruits
Milk
Grains
Eggs
FEED
Forage
Stored grain
Stored hay
FOOD
Beef
Leafy vegetables
Poultry
Other vegetables
Milk
Fruits
Eggs
Grains
SOIL
WATER

OPERATIONAL DECOMMISSIONING EXPERIENCE AND PERSPECTIVE

Jim Jones
AEA Technology plc, Nuclear Engineering

Presented by Shankar Menon

1. Introduction

1.1 In response to the growing interest in the decommissioning of nuclear facilities the Nuclear Energy Agency of the OECD set up in 1985, for an initial period of five years, the International Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning.

1.2 The Programme has proved to be very successful and is now into its third five year period. The basic scope has remained unchanged regarding the exchange of scientific and technical information except that now there are 35 projects from 13 countries participating. However, in this third five-year programme some changes were agreed to assist in maximising its effectiveness. It was considered necessary to more effectively disseminate to a wider audience the experiences and lessons learnt within the Programme, and to be able to influence the decision-makers who set the national and international regulatory regimes and standards under which decommissioning projects are undertaken.

1.3 Where topics could justify further and more detailed study special Task Groups were set up with reports issued and published. The topics considered and their results to date reported are:-

- Decommissioning Costs
- Decontamination required for Decommissioning
- Recycling and re-use of materials arising from Decommissioning.

(It is this latter study and its findings and conclusions that I wish to consider in more detail (Ref 1).

1.4 It was concluded that, after treatment, significant quantities of waste generated from decommissioning could be recycled and re-used. Indeed, recycle and re-use options provide a cost-effective solution to the management of waste arisings. The most significant impediment to the use of recycle and re-use is the absence of consistent release standards within the nuclear, and indeed the non-nuclear, industry. Organisations such as the IAEA and EC have proposed recommended criteria with the object of agreeing to an internationally accepted set of release levels.

2. Current Policies

2.1 The management of the large volumes of contaminated materials arising from the decommissioning of nuclear facilities represents one of the most substantial cost items of such projects. Consequently the minimisation of the volumes that have to be disposed of as radioactive waste is a high priority objective for those responsible for decommissioning. The recycling of such material without radiological restrictions is seen as a significant means of achieving this aim. Moreover, recycling has beneficial advantages such as the conservation of natural resources and protecting the environment. However, the absence of consistent and internationally accepted criteria to regulate the release of recyclable materials has a major impact on the utilisation of recycling and re-use as material management practices.

2.2 Over the last 20 years, despite the absence of consistent international release criteria, some 400,000 t of material from various decommissioning projects has been released on a case by case basis. The concept of clearance does imply complete removal from regulatory control, whereas in practice various options are considered and implemented. Melting of metals is one case in point where metal is transported to melting facilities and melted into ingots. Then when the appropriate criteria are met, the ingots are released for unconditional re-use. Where this was not possible then the ingots were released for re-use in other nuclear related applications or stored to permit the radioactive elements to decay to permissible release levels.

2.3 Release criteria varied on a country by country basis, as can be seen in Tables 1 and 2, with some variations being significant. In addition to this national policies and regulations required different measurement requirements to demonstrate that material met the required release standard. Thus there are different requirements for the selection of instrumentation, frequency of measurement, sampling protocols, documenting practices and quality assurance.

2.4 The various regulatory regimes have a common objective with that being the protection of human health and safety. Notable differences do exist in both release criteria and in their application with potential for confusion and significantly restricting the utilisation of recycling and re-use as material management practices. Indeed within many countries release regimes are considered on a project by project basis. Thus the re-use of released materials is almost insurmountable between countries, or indeed between projects within a country.

2.5 Surely a common objective must be for the international community to establish a common base from which to establish clearance standards for the release of materials whilst achieving the ultimate goal in the protection of human health and safety.

3. International Scene

3.1 The IAEA published TECDOC 855 in 1996 proposing nuclide specific clearance, ie release levels for solid materials. It was issued on an interim basis for comment, with the intent of re-issuing following the comments made and in the light of the experience gained in its application.

3.2 In 1998 EC published Radiation Protection 89 - Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations. This gave two options:-

- direct release based only on surface contamination
- melting at a commercial foundry followed by recycle and re-use. Mass specific and surface specific levels are provided.

3.3 The current recommendations of the IAEA and EC are aimed solely at minimising radiological risks. No other risks have been considered. The OECD/NEA Task Group considered both radiological and non-radiological detriments as well as considering social, economic and environmental issues. This is seen to be fully in harmony with the ICRP concept that the justification of a practice should take into account the total detriment and not only the radiation detriment. It was found in comparing the "total risks" of recycling with the disposal/replacement of the disposed metals, that the non-radiological risks are much larger than the radiological and the non-radiological risks associated with the replacement of material are much higher than those associated with recycling. In addition there are the benefits of recycling such as the conservation of natural resources and protection of the environment.

3.4 It is encouraging to see that the concept of "total risk" approach is gaining support from regulators. In the foreword to the EC document "Radiation Protection 89" it is stated that:-

> "From a larger perspective it is reasonable to assume that recycling has a net positive impact on the health of workers and population compared to disposal as radioactive or ordinary waste and compared to the impact of metal ore mining to ensure replacement of spent metals. This net benefit should significantly outweigh the minor radiation detriment associated with the recycling of scrap with very low levels of radioactive contamination".

3.5 Radiation protection and the management of radioactive material have hitherto been concerned mainly with artificial nuclides arising within the nuclear fuel cycle. In the last few years there has been an increasing awareness of naturally occurring radioactive material (NORM) and the enhancement of its concentrations in various non-nuclear industry processes. This technologically enhanced NORM is of the same activity levels as low level waste and is very similar to the candidate material for exemption and clearance in the nuclear industry but occurs in quantities that are huge in comparison.

3.6 Both in the United States and in Europe the radiological regulation of such NORM is underway. The EC came out with a new Directive in May 1996 with revised basic safety standards (BSS) for the radiation protection of both workers and the general public (Ref 2). The Directive covers radioactivity in both nuclear and non-nuclear industries and will have to be ratified by Member States within 4 years.

3.7 In the EC, BSS industries are divided into "practices" (where radionuclides are, or have been, processed in view of their fissile or fertile properties) and "work activities" (where the presence of radioactivity is incidental). Broadly speaking "practices" refer to the nuclear industries, while "work activities" to the non-nuclear ones such as oil and gas or phosphate industries where naturally occurring radioactivity is incidental but technologically enhanced.

3.8 The table of exemption values in the new EC-BSS covers only practices. The exemption values for work activities are not explicitly given. It is not clear from the text whether the same or different criteria would be considered for exemption/clearance in the nuclear and non-nuclear industries.

3.9 In the United States a draft set of regulations for technologically enhanced NORM (TENORM) were issued in 1997 by the Conference of Radiation Control Program Directors (CRCPD). The CRCPD is an organisation primarily consisting of directors and technical staff from State, Local and Federal Regulatory Agencies to address NORM related health and safety issues. Several States have regulations already in place to meet their specific needs. There is, however, no uniformity in these regulations. One of the main aims of CRCPD is to work towards uniformity in regulations governing radiation.

3.10 The current international recommendations for the "exemption" of radioactive material from being regulated and the "clearance/release" levels of such materials already regulated are both based on the criteria laid down by the IAEA Safety Series No. 89 (Ref 3) regarding individual doses (10µSv/year) and collective doses (1 person-Sv/year). Typically exemption levels are a factor 10 higher than clearance values. The explanation for this is that "exemption" is intended to be applied to moderate quantities of material (say 1 - 10te) which are very similar in radioactive characteristics to NORM while "clearance" concerns large quantities. If radioactivity is to be regulated in a consistent manner it will not be practically feasible to relate release levels to quantities when the comparatively huge volumes of NORM material are brought under regulation. So the resolution of the NORM issue is not only of high interest to the non-nuclear industries concerned, but also of the highest interest to those undertaking nuclear decommissioning or site remediation where projects are characterised by the large volumes of very low level materials arising.

4. Health, Environmental and Socio-Economic Impacts

4.1 In their considerations the OECD/NEA Task Group defined the recycle or re-use of materials resulting from decommissioning as a practice. Further, it was assumed that the justification of a practice should encompass far more than simply the detriment attributable to risks from radiation. Thus in examining the justification for the release of radioactive materials from regulatory control for the purposes of recycling or re-use, they considered not only the risks from radiation but also from major non-radiological socio-economic, environmental and health effects. A "tiered" system for release criteria was developed as the basis for comparison with those attributable to disposal and subsequent replacement of radioactive scrap metal.

4.2 The alternative to releasing radioactive scrap metal for recycling is disposal as low-level waste in unrestricted landfills and low-level waste disposal facilities. This would require the cutting and packaging of the radioactive scrap metal for transportation and disposal. This may also involve decontamination to reduce workers exposures and possibly melting to reduce volume. As disposal would withdraw radioactive scrap metal from the world's stock of metal, the materials would have to be replaced by metal newly produced from ore. The processes required for such replacement include mining, ore enrichment or refining, metal smelting, casting and fabrication, together with the production of energy to accomplish these activities. Inherent in these activities are significant health, environmental and socio-economic impacts that must be considered as part of any comprehensive justification of recycling, given that disposal and replacement is currently the principal alternative for the disposition of metal scrap.

4.3 It is proposed that four tiers would comprise the system, with each incorporating options in accordance with specified release criteria and type of end use. Tiers A, B and C pertain to public/industrial releases from the regulatory environment, whereas Tier D involves recycling within the nuclear industry. As envisaged the "Tiered" system is shown in Fig 1 and would address a wide range of restricted and unrestricted uses.

4.4 Tier A-1 has surface activity levels and A-2 volumetric activity levels that apply to objects that are released in their original form (eg office furniture, tools or structural steelwork). Tiers B and C pertain to scrap with fixed surface or volumetric activity that would be decontaminated and then melted in a controlled (licensed) facility. Ingots would then be released for recycling under Tier B-1 (re-melted at a commercial melter) or Tier B-2 (milled without dilution). Melting serves as a decontamination measure for some radionuclides and would also facilitate measurement of the activity in the metal. Tier B has volumetric activity levels that are appropriate for a wide range of metal products in unrestricted uses. Slag from the commercial melting is assumed to be used in the paving of roads or car parks.

4.5 Tier C releases requires restricted distribution of finished metal products from a controlled melting and milling facility to prescribed initial uses that involve minimal public exposure. The main advantage of Tier C recycling is the ability to use metals that are contaminated with relatively short-lived radionuclides while controlling health risks.

Human Health Risks

4.6 There are potential health risks to workers and the general public associated with both recycle/re-use and the disposal/replacement alternatives for radioactive scrap metal management. These alternatives involve health risks from exposures to radiation and toxic elements as well as from industrial and transport accidents. Health risk estimates are summarised in Table 3 (Ref 1.4).

4.7 For both alternatives the physical risk to workers from workplace accidents and to the public from transport accidents are greater in magnitude than the risks from radioactive materials or chemicals.

4.8 Recycling scrap metals that meet the derived activity levels for Tier A, B or C would result in a lifetime cancer fatality risk for an individual or a member of the general public of less than 10^{-7} to 10^{-6} from annual exposure.

4.9 Risks to commercial metal workers would be of similar magnitude and could be reduced to even lower levels by employing protective measures. The total population risk level would be less than 10^{-2} to 10^{-1} cancer fatalities from an annual recycling practice of 50,000t. For the disposal/replacement alternative some miners would be exposed to naturally occurring radioactivity that could exceed the regulatory dose limit for nuclear workers. Such dose levels are more likely for non-ferrous metals than iron mining.

4.10 The non-radiological health risks are greater overall than the radiological risks for either alternative. The highest health risk levels are those for fatalities or disabling industries from workplace accidents. For the recycling alternative these risks apply to decontamination activities including controlled melting and commercial smelting. Overall, these risks are at least twice as high for the disposal and replacement option because it involves iron mining, coal mining, coke production and blast furnace operation in addition to steel smelting.

4.11 Transportation accident fatality risks are of the order 10^{-3} for each km that 50,000t of radioactive scrap metal or replacement materials are transported. Thus transport requirements and therefore accident risks are likely to be several times higher for disposal/replacement.

4.12 With regard to chemical exposures risks to commercial metal workers and the public from melting radioactive scrap metal would be less than those generated by smelting metal from ore. For the portion of scrap metal that comprises the relatively large quantity of suspect but probably non-radioactive scrap, both the radiological and non-radiological risks to the public and metal workers would be lower for recycling than for replacement, because most of the radionuclides and contaminants that naturally occur in ore would have been removed in the original smelting of the radioactive scrap metal.

4.13 In summary, the recycle option involves controlled risks borne by radiation workers and small increase in risks to commercial metal workers and the public, whereas the disposal and replacement option involves controlled risks to radiation workers and substantial increase in relatively uncontrolled risks to miners and the public. Health risks for the disposal/replacement alternative are at least twice the level for radioactive scrap melting.

Environmental Risks

4.14 Adverse environmental impacts are much higher for replacement/disposal alternatives. Although recycling and re-use alternatives will impact on the environment by using relatively small amounts of low-level waste disposal capacity replacement/disposal presents more severe adverse impacts to the environment from land use, disruption and damage that results from mining and related processes. The production of 1t of steel requires more than 2t of iron ore and 0.5t of coke, together with energy requirements.

4.15 There are other adverse conditions from the replacement option such as leaching of heavy metals from soils, mining wastes, increased sedimentation in streams and rivers, emissions of toxic chemicals from mining operations, waste piles, coke production and increased energy requirements. Environmental impacts are summarised in Table 4.

4.16 Recycling/re-use and disposal/replacement each present different socio-economic impacts. The issues seen to be of most concern for the public acceptability of the recycling/re-use option is the availability of low-level waste disposal facilities. Public acceptance of the practise of recycling metals with traces of radioactivity may be problematical because of the stigma associated with the nuclear industry in most industrialised countries.

4.17 Ultimately public perceptions of the acceptability of both radioactive scrap metal management alternatives will significantly influence the implementation of either alternative. Consequently additional information on the relative risks of both management alternatives could be a determining factor in the formation of public opinion and in the decision making process.

5. Conclusions Reached by the OECD/NEA Task Group

5.1 Substantial quantities ($3 \times 10^{+7}$t) of scrap metals (predominantly steel) are likely to be generated in the near future from decommissioning and dismantling nuclear facilities. Without release standards these potentially valuable metals cannot be systematically recovered for the re-use or recycle practices. A significant portion of this metal is only slightly, or not at all, contaminated with radioactivity.

5.2 A comparison of the relative merits of disposal and replacement versus recycle and re-use practices shows that recycle and re-use produces lower human health risks and environmental impacts by more than a factor of two. Moreover, disposal and replacement alternatives for radioactive scrap metal management may involve imposition of greater health and environmental impacts in less developed countries through mining and processing operations.

5.3 The IAEA and EC proposals offer a meaningful approach to the evolution of consistent international clearance standards for the management of waste arising from the decommissioning of nuclear installations. However, the following comments are made:-

The IAEA proposal is intended to provide de minimis release criteria. The issue here is that, if considered alone, this may hinder or preclude recycle technologies.

- Although a risk based approach for setting radioactive scrap metal releases is generally accepted, varying degrees of conservatism have been incorporated in different analyses. As a result, derived release levels have ranged over several orders of magnitude. These differences emphasise the need for a consistent set of international standards, especially for materials possessing varying commodity values and with between-country trade implications. In addition to the radiological risks, as indicated in the ICRP 60 recommendations, other types of health and environmental risks should be considered in developing release levels.

- In the recycling of radioactive scrap metal, non-radiological health, environmental and socio-economic risks associated with the replacement of the materials not only negate, but surpass, recycling.

- Whilst the Task Group concentrated on metal recycling and re-use, with the forthcoming decommissioning of commercial nuclear stations there will be large quantities of concrete that will need to be processed.

6 References

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6.3 International Atomic Energy Agency, 1988, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control, IAEA Safety Series No. 89, Vienna, Austria.

6.4 Nieves, L A et al, 1995, Evaluation of Radioactive Scrap Metal Recycling. ANL/EAD/TM-50, Argonne National Laboratory, Argonne, Illinois.

7 Acknowledgements

7.1 I wish to thank the OECD/NEA Co-operative Programme on Decommissioning Liaison Committee for permission to give this Paper.

7.2 Perhaps more importantly, I wish to recognise the hard work undertaken by the Task Group on the Recycling and Re-use of Scrap Metals.

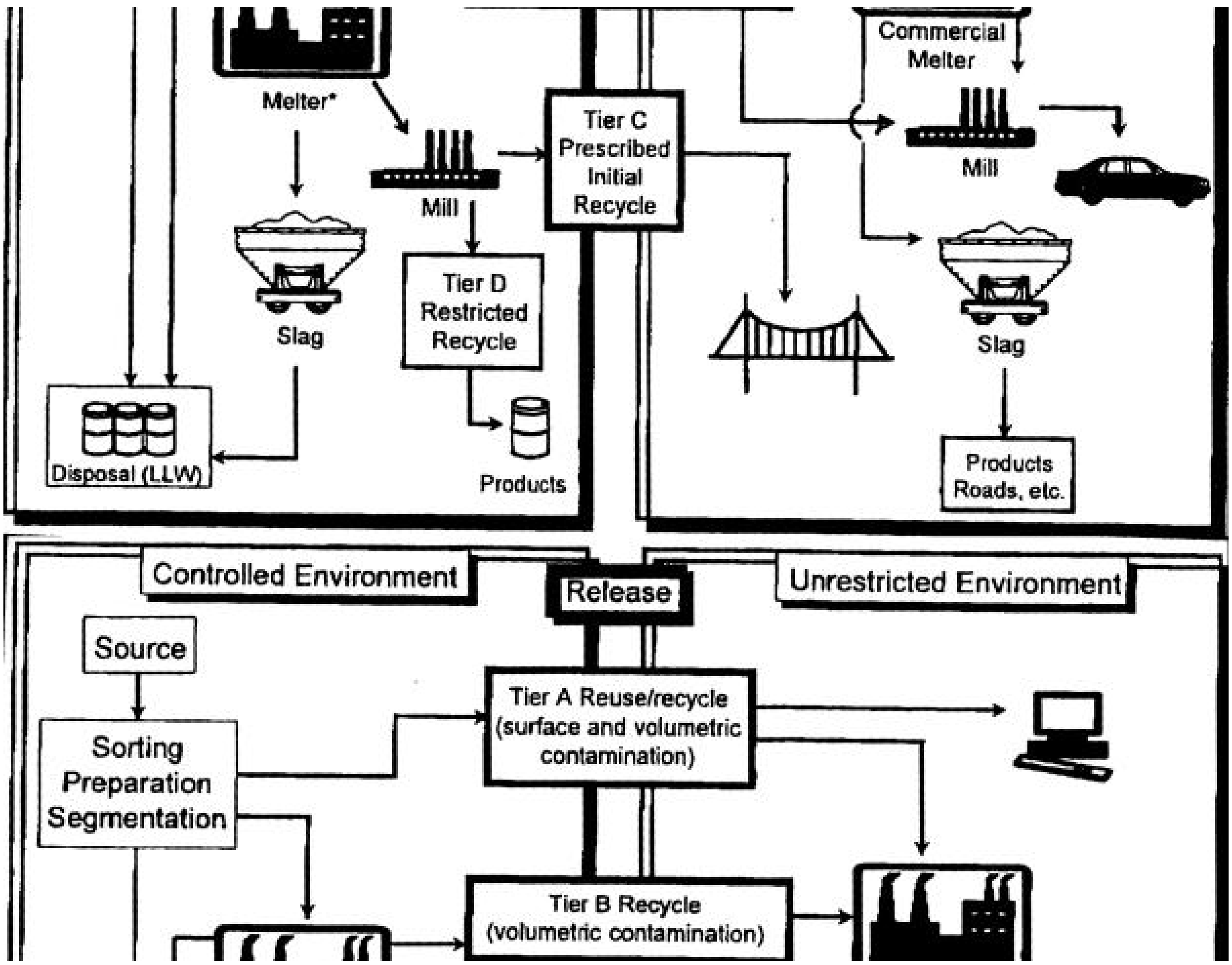

Figure 1. Conceptual Illustration of Tier Release System

Table 1
Surface Contamination Limits for Beta/Gamma Emitters

Contamination limit	Country	Additional Information
0.37 Bq/cm^2	Germany	Over 100 cm^2 for fixed and removable contamination and for each single item
0.40 Bq/cm^2	Finland	Removable surface contamination over 0.1m^2 for accessible surfaces
0.40 Bq/cm^2	Belgium	Mean value for removable surface contamination over 300 cm^2, for beta-gamma emitters and alpha emitters with low radiotoxicity
0.83 Bq/cm^2	USA	Surface contamination above background over no more than 1 m^2, with a maximum of 2.5 Bq/cm^2 above background if the contaminated area does not exceed 100 cm^2
4.00 Bq/cm^2	Sweden	Mean value for removable surface contamination over 100 cm^2, with a maximum of 40 Bq/cm^2 if the contaminated area does not exceed 10 cm^2

Table 2
Specific Activity Limits Regardless of Type of Emission

Contamination limit	Country	Additional Information
0.10 Bq/g	Germany	–
0.10 Bq/g	Sweden	Over and above the content of natural activity that occurs in corresponding goods outside the nuclear installation (primarily for limiting the activity in materials that, having been melted down, can be re-used in new products
0.40 Bq/g	Great Britain	Total activity for solids, other than closed sources, that are substantially insoluble in water
0.40 Bq/ml	Great Britain	Total activity for organic liquids that are radioactive solely because of the presence, either separately or simultaneously, of Carbon 14 and Tritium
1.00 Bq/g	Germany	Re-use of metal in a general melting facility
N/A	USA	The United States has not developed a volumetric release standard

Table 3
Summary of Health Risks from the Radioactive Scrap Metal Management Alternatives

Impact Categories	Recycle/Re-use	Dispose and Replace
*Radiological risk**	• 10^{-7} to 10^{-6} fatal cancer risk to metal workers and public • 10-2 to 10-1 population risk per year of practice	• Potential elevated cancer risk to miners
Non-radiological risks		
• Accidents (workplace)	• About 7 fatalities or serious injuries to workers	• About 14 fatalities or serious injuries to workers
• Accidents (transportation)	• 10-2 fatality risk to workers and public	• 10-2 fatality risk to workers and public
• Chemical exposure from smelting**	• 10-3 fatal cancer risk to workers: 10-4 to public	• 10-3 fatal cancer risk to workers: 10-4 to public
• Chemical exposure from coke production	• None	• 1 fatal cancer risk to workers: 10 - 2 to public

* Risk estimates represent maximum individual lifetime risk associated with a 50,000t throughput, operated so that individual dose does not exceed 10 µSv/a.

** Maximum individual lifetime risk of cancer fatality in the United States resulting from one year of exposure at the maximum permissible concentration.

Table 4
Health Risk Estimates for Radioactive Scrap Metal (Steel) Management Alternatives

Activity	Group Affected	Risk Type	Health risk estimate from one year of activity*
Activities common to both alternatives			
Radioactive scrap metal transportation**	• Public • Truck Drivers	• Accident/fatalities • Radiation/cancer • Radiation/cancer	• 5×10^{-3} (collective) • Negligible • 1×10^{-5}
Radioactive scrap metal disposal (low-level waste)	• Nuclear workers • Public	• Radiation/cancer • Radiation/cancer	• 10^{-3} (regulatory limit)*** • 5×10^{-5} (regulatory limit)***
Recycling activities			
Radioactive scrap metal decontamination and preparation	• Nuclear workers	• Radiation/cancer • Chemical/cancer	• 10^{-3}(regulatory limit)*** • 10^{-3}(regulatory limit)***
Controlled melting	• Nuclear workers • Public	• Radiation/cancer • Chemical/cancer • Radiation/cancer • Chemical/cancer	• 10^{-3} (regulatory limit)*** • 10^{-3}(regulatory limit)*** • Unquantified • Unquantified
Ingot transportation**	• Truck drivers • Public	• Radiation/cancer • Accident/fatalities • Radiation/cancer	• 1×10^{-5} • 5×10^{-3}(collective) • Negligible
Commercial smelting	• Smelter workers • Public	• Radiation/cancer • Chemical/cancer • Accident/fatalities and injuries • Radiation/cancer • Chemical/cancer	• 10^{-7}- 10^{-6} *** • 10-3 (regulatory limit)*** • 8×10^{0} • 3×10^{-8} *** • 2×10^{-4}
Metal end use	• Public	• Radiation/cancer	• $10^{-7} \times 10^{-6}$ ***
Disposal and replacement activities			
Iron ore mining and enrichment	• Miners • Public	• Radiation/cancer • Chemical/cancer • Accident/fatalities • Chemical/cancer	• 5×10^{-5}- 1×10^{-2} • 10^{-3} (regulatory limit)*** • 1×10^{-2} • Unquantified
Ore transportation	• Public	• Accident/fatalities	• 1×10^{-3} - 4×10^{-2} (collective)****

Table 4 (contd)
Health Risk Estimates for Radioactive Scrap Metal (Steel) Management Alternatives

Activity	Group Affected	Risk Type	Health risk estimate from one year of activity*
Coking coal production	• Miners • Oven workers • Public	• Accident/fatalities • Chemical/cancer • Chemical/cancer	• 2×10^{-3} - 3×10^{-2} • 1×10^{-2}- 6×10^{0} • 1×10^{-3} - 7×10^{-2}
Coke transportation	• Public	• Accident/fatalities	• 1×10^{-3}- 4×10^{-2} (collective)****
Pig iron production (blast furnace)	• Workers • Public	• Radiation/cancer • Chemical/cancer • Accident/fatalities and injuries • Radiation/cancer • Chemical/cancer	• Unquantified • 10^{-3} (regulatory limit)*** • 7×10^{0} • Unquantified • 2×10^{0}
Steel smelting (basic oxygen process)	• Smelter workers • Public	• Radiation/cancer • Chemical/cancer • Accident/fatalities and injuries • Radiation/cancer • Chemical/cancer	• Unquantified • 10^{-3} (regulatory limit)*** • 8×10^{0} • Unquantified • 2×10^{0}

* Assumes 50,000 t of radioactive scrap metal or replacement steel. All risks are for the most exposed individuals unless designated as collective.
** Assumes 100 km per round trip and 20t per shipment.
*** Maximum individual lifetime risk of cancer fatality resulting from one year of exposure at the maximum permissible concentration in the United States.
**** Rail transport has the lowest rate and truck transport the highest.

EXPERIENCE AND PERSPECTIVE ON THE HANDLING OF WASTES FROM DECOMMISSIONING

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Presented by Jurgen Krone

Abstract

Safe disposal of radioactive waste and spent nuclear fuel is considered to be a major challenge for the present generation independent from current and future scenarios of nuclear power use in different countries.

According to the Joint Convention of September 27th, 1997 on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management contracting parties committed themselves "to take the appropriate steps to aim to avoid imposing undue burdens on future generations". Due to the enormous complexity and to extremely long implementation periods of up to some decades of years radioactive waste disposal projects require mature concepts developed well in advance and continuous effort in order to comply with the taken commitment.

Extensive research and project implementation efforts have been in place for several years in all leading industrial nations. In Europe, repository experience for low and intermediate level waste exists in several countries. Further decisions regarding site selection, site confirmation and licensing as well as construction of repositories, especially for high-level waste and spent fuel, are still pending in many countries.

In spite of differences between national concepts and status of national programmes many parallels and common issues can be identified. Some of these topics already are the subject of an active multinational co-operation and technical information exchange throughout the world. In this context strategies for the management and disposal of wastes from decommissioning are expected to become an aspect of major interest in near future.

At present some less then 500 civilian nuclear reactors are in operation world-wide. Most of them will complete their service lifetime and shall be decommissioned in the next decades. In addition, as a consequence of the end of the Cold War, a serious number of obsolete nuclear research and production facilities used before for military purposes are left as well as several hundreds of military reactors. Particular difficult problems raised already up today in the North-west and Pacific regions of Russia, where about 170 laid up nuclear powered submarines are waiting for decommissioning, most of them with fuelled reactors aboard. The Chernobyl Shelter Implementation Plan (SIP) is considered as another major challenging decommissioning and waste disposal effort requiring close and efficient international co-operation and support.

Even in most of the leading industrial countries a few nuclear installations were decommissioned over the last years practical decommissioning experience and experience with waste disposal from decommissioning is relatively limited. Thus, different views exist concerning the most appropriate technical approach and particular concerning the related waste management strategy.

In principal requirements to the management of decommissioning waste comply with overall requirements applicable to operational waste. Nevertheless some specifics of decommissioning waste management and disposal shall be highlighted. Besides some technical aspects (e.g. relatively large dimensions, relatively high level of induced activity, some design specific waste material properties etc.) scheduling of different decommissioning steps has the major impact on the selection of the appropriate waste management strategy. Large variations are possible between two extremes: long-term safe enclosure of obsolete nuclear installations or near term complete removal.

Economical, technical and last not least safety advantages and disadvantages of different options are still under discussion. Independently decommissioning planning shall involve a detailed planning of waste management and disposal options at an early stage in order to identify possible bottlenecks and in order to ensure the availability of adequate operational storage, treatment and disposal facilities in time.

Considering the lessons learned from the extremely slow progress of radioactive waste disposal projects world-wide a pretty simple but important conclusion can be made:

An appropriate solution of the decommissioning tasks already raised and objectively arising over the next decades requires an acceleration of common efforts in regard to the development and implementation of waste disposal facilities. This is our responsibility and obligation to our children and grandchildren.

SESSION 3A

MANAGEMENT OF RADIOACTIVE WASTE FROM DECOMMISSIONING

THE MANAGEMENT OF MATERIALS AND WASTE FROM DECOMMISSIONING IN BELGIUM

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1. Introduction

In Belgium, decommissioning programmes have been in progress since 1989. These programmes started with R&D and small pilot projects on dismantling and decontamination techniques with the aim to define and to develop suitable techniques, as well as to provide information on their performances and costs. Later on, techniques were improved in order to optimise working conditions, performances and costs, and to decontaminate decommissioning materials for clearance, avoiding them to have to follow the costly radioactive waste routes. Today, D&D operations are performed under industrial conditions against acceptable costs. Nevertheless, waste management at a reasonable cost, especially for very low-level waste, needs to be further worked on with regard to strategies and implementation.

Requirements and recommendations from international organisations constitute the basis for regulations and strategies. Thus, ongoing decommissioning planning forms part of the practice since 1991, and efforts are continuously being made to improve technologies for waste volume reduction by means of e.g. dry abrasive and chemical decontamination of metallic components or shaving of concrete structures. In this way, high percentages of material arising from decommissioning can be recycled on the non-nuclear field.

The remaining radioactive waste is taken over by ONDRAF-NIRAS in the same way as the other types of waste coming from any sources in the country, and is processed, conditioned and stored by its subsidiary BELGOPROCESS while awaiting final solutions for disposal. The lack of a disposal site is not really an obstacle for the progress of the ongoing decommissioning projects.

2. Regulations, guides and standards

The Belgian regulation related to radiation protection, licensing and other requirements for construction, operation and decommissioning is laid down in the Royal Decree of 28.2.1963 and its later amendments. It makes no major difference between operation or post-operation activities and surveillance, owing to the fact that the objectives are similar in both cases: the protection of the workers, the population and the environment. Nevertheless, this regulation doesn't address specific requirements for decommissioning licensing as is done for construction and operation. It requires of the licensee to provide an adequate destination for all material arising from post-operational activities, and especially for such material with a radiation level "higher than the natural background". The interpretation of this requirement remains until now the responsibility of the Head of the Health Physics department and the Regulatory Body. However, different regulatory developments are likely to occur in the near future, and in particular, the completion of the requirements regarding clearance criteria and licence application for decommissioning. Furthermore, the responsibilities of the Regulatory Body are until now spread over two ministerial departments, but they will soon be located at the newly created “Federal Agency for Nuclear Control”, FANC-AFCN.

In 1991, the legislator assigned by law certain responsibilities in the field of decommissioning to the “National Agency for Radioactive Waste Management and enriched Fissile Materials”, ONDRAF-NIRAS. Among others, this agency has to collect information related to the decommissioning programmes of nuclear installations within the country, to approve those programmes, and to execute programmes at the demand or in the case of failure of an operator. Thus, initial, ongoing and final decommissioning planning following the IAEA-Safety Requirements and Guides in the field of decommissioning {2}, {3}, {4}, {5}, is now common practice.

Strategies for decommissioning and site restoration activities, as well as for the management of the resulting radioactive waste, are essentially guided by the principles of the Safety Fundamentals of the IAEA {1}. As those activities are associated rather with “practice” than “interventions”, optimisation of radiation exposures as well as dose limitation (ALARA) are required. The burden on future generations is limited as much as possible by adequate decommissioning planning, including the provision for the financing of activities in the future. This is also why the legislator furthermore assigned by law to ONDRAF-NIRAS in 1997, the elaboration of an inventory of all nuclear installations and all sites containing radioactive substances within the country, including the verification of the existence of sufficient financial provisions for the execution of decommissioning and restoration programmes. The burden on the future generations is also reduced by the recycling of materials as much as is economically possible, rather than leaving future generations with radioactive waste which needs to be disposed of. Furthermore, recycling preserves raw material sources, and follows tendencies for waste management in general, i.e. other than radioactive waste, essentially for ecological reasons.

Finally, Belgian experts collaborate within international groups to define recommendations and strategies in the field of decommissioning and other related matters. For instance, they are actively involved in the definition of internationally acceptable clearance criteria, and it is likely that the legislator will introduce these criteria into the Belgian legislation once a consensus is reached. The importance of an international consensus in this field, especially for small countries having large commercial exchanges with other countries, must be mentioned. In fact, the probability that material remains in the country where it has been released, is very low

3. The evolution of decommissioning programmes and technologies

The execution of extensive decommissioning activities started in 1989 with the preparatory work for the former EUROCHEMIC reprocessing plant. It was jointly operated by a consortium of 13 European countries, but after its final shutdown, only Belgium remained responsible for the execution of the decommissioning programme and the largest part of its financing. The Belgian government concluded a convention for the decommissioning and cleanup of the site with ONDRAF-NIRAS, which subcontracted the execution of the work to its subsidiary BELGOPROCESS. They started out with the complete decommissioning till green field of 2 small storage buildings, a pilot programme with the aim of defining techniques suitable to be used for dismantling of contaminated process equipment, and the decontamination of building structures. The programme also had to provide performances on suitable techniques under semi-industrial conditions, as well as unit costs of the techniques.

Later on, techniques for dismantling and decontamination were optimised with the objective to facilitate work for the operators working in protective clothing under severe conditions in α-contaminated cells, as well as to improve performances under real industrial conditions. To do so, a semi-industrial dry abrasive decontamination facility for thorough decontamination of dismantled metallic parts was developed and implemented on the BELGOPROCESS site. This facility is now in operation since the middle of 96, and the results of the decontamination of about 350 tons of metallic parts, followed by clearance, are more than satisfactory. Furthermore, shaving technologies were developed for the semi-automatic decontamination of thin layers of concrete on building structures with the generation of low amounts of radioactive waste.

The progress of the decommissioning programme for the 106 hot cells of the EUROCHEMIC main reprocessing building at the end of 1998, can be summarised as follows:

30 cells were completely finished and measured,
11 cells were empty, and the decontamination of the infrastructure was in progress,
40 cells were under dismantling of the process and other equipment,
25 cells remained on standby.

The decommissioning programmes also started in 1989 on the BR3 site with the in-situ decontamination of the primary loop and an R&D programme to define suitable techniques for the underwater dismantling of highly activated reactor internals. As for the EUROCHEMIC decommissioning programme, the Belgian government decided to conclude another convention with ONDRAF-NIRAS for the overall management of the whole of the decommissioning and restoration programmes on both sites in MOL and DESSEL. The carrying out of the activities has been subcontracted to the CEN°SCK. Several cutting techniques were compared on the thermal shield dismantling, and the most suitable techniques were selected for the cutting of the other reactor internals. Preparatory work and preliminary cold tests are currently under way for the next step of the programme: the dismantling of the reactor vessel.

In parallel, R&D work has been performed at the CEN°SCK BR3 site for the thorough decontamination of metallic parts using chemical Ce+ techniques. This installation is now starting to work on a semi-industrial scale. Data on performances and costs under such conditions are not yet available.

Furthermore, several buildings where physical, chemical and biological nuclear R&D was performed in the past, were decontaminated and released from nuclear surveillance in 1995-96 at the CEN°SCK site in Mol. They are now used for conventional technological research by a Flemish institute.

Finally, in 1991, the Belgian government also assigned the cleanup of the historical waste and the decommissioning of the redundant facilities on the former waste management site of the CEN°SCK, by a convention to ONDRAF-NIRAS. This site became the property of the Agency which subcontracted the execution of the work to its subsidiary BELGOPROCESS. The work started in 1991 with the cleanup of the mostly unknown waste, which first had to be recovered from inadequate storage grounds or pits, processed, conditioned and stored in an appropriate manner awaiting the final solution for disposal. The decommissioning of some redundant process and storage facilities began in 1998 on an industrial scale, and some facilities have now reached a green field status.

4. The principle of radioactive waste management, including decommissioning waste

Radioactive waste arising from decommissioning is taken over by ONDRAF-NIRAS in the same way as all types of waste coming from other sources in the country, and is processed, conditioned and stored by its subsidiary BELGOPROCESS while awaiting final solutions for disposal. The lack of a disposal site is not really a hurdle for carrying out decommissioning programmes thanks to the availability of processing and storage facilities for waste. Nevertheless, costs for radioactive waste management are rather high in Belgium, compared to some other countries in Europe and elsewhere. There are several reasons for this:

- Belgium is a small country, but with a broad nuclear programme in the past and even in the present. For instance, the first PWR reactor in Europe of the Westinghouse type was built and operated in Mol, the EUROCHEMIC reprocessing plant was built and operated in Dessel, etc. These programmes, associated with a large R&D programme at the CEN°SCK research centre, as well as the collaboration with BELGONUCLEAIRE for the development of fast breeder and MOX fuel, generated historical waste with a broad range of radiological and chemical (toxic) components. The amounts for each type of this waste are rather small compared to those in larger countries.
- The public and political tendency within each country to solve its own waste management problem, led the small countries to run numerous oversized, and thus expensive, waste processing, conditioning and storage facilities. In fact, the safety requirements imposed on such facilities are nearly the same as for large facilities which are able to process or to store large amounts of waste. Furthermore, up to now, there is no political acceptance for the processing of foreign materials and waste in our country, even with the guarantee that the radioactive inventory will be returned to the country of origin. This means that overcapacity exists in our country which is an important factor in the unit cost of waste management.
- Finally, the same burden weighing on each country having to provide for its own disposal of radioactive waste, even if the amounts of waste are negligible compared to those in larger nuclear countries, imposes upon them R&D and, in the end, the implementation of adequate solutions. In this way, Belgium is largely involved in studies and development for near surface disposal facilities as well as for deep geological disposal sites. The costs for R&D and for the implementation and operation of the future disposal sites are now charged at the price of generated waste.

The high radioactive waste management costs are an excellent incentive for the nuclear industry, but also for non-nuclear activities such as medical applications, universities and chemical industries, to minimise waste generation during the whole operating process. As decommissioning is also a waste generating process, the operators of those programmes are also aware of the positive influence on the total costs of volume reduction techniques, including decontamination and recycling. All the efforts to reduce the generation of radioactive waste is thus the main reason why the unit costs for radioactive waste management have been continuously increasing in Belgium over the last ten years.

ONDRAF-NIRAS is actively involved at the moment in a selection process for a near surface disposal site for short-lived, non-α-bearing waste. It adopts an open and transparent approach towards the political decision-makers and the public in general. Nevertheless, a local referendum in the only area where interest had been manifested for the potential disposal site, and which was organised by the local politicians in favour for the implementation of the site, turned out to be a disaster: 93% of the voters were against the site. The project was no longer defensible for this site. The studies are continuing, based on a new approach involving a local partnership between people living or working in the area, and those concerned by the project. The final objective is to define within a common agreement between all involved parties, not only the technical aspects of the project, but also the economic, social and other cultural compensations for the area and the people accepting the project.

5. The material and waste streams during decommissioning

5.1 The principle of clearance

The principle of material management, i.e. decontamination and recycling of material as much as is economically justifiable, is based on, and requires a free release system from radiological control. The legal framework makes, up to now, reference to the natural background, and the interpretation of this reference level is the responsibility of the authorised site management in agreement with and controlled by the regulator. In practice, general procedures for clearance have been elaborated for each site involved in such activities, but the final release of a lot of material is decided on a case by case basis. As said earlier, the Belgian legislator is waiting for internationally agreed clearance criteria.

5.2 The principle of material management

Principle 7 of the IAEA Safety Fundamentals {1}, i.e. "the generation of radioactive waste shall be kept to the minimum practicable" constitutes the basis for the material management of decommissioning programmes, mainly, but not only, for the above mentioned expensive radioactive waste management costs. The material management pathways are essentially the following:

- Re-utilisation if possible, e.g. shielding blocks,
- Recycling within the nuclear field. Nevertheless, possible applications are limited within Belgium owing to the political moratorium on the construction of new nuclear plants,
- Thorough decontamination, followed by unrestricted release and recycling within the non-nuclear field,
- Radioactive waste circuit.

The evaluation in 1996 of the whole of the decommissioning programmes related to the nuclear liabilities for which ONDRAF/NIRAS signed a series of conventions with the Belgian state and the utilities, provided the following figures for the material maagement pathways:

Joint NEA / IAEA / EC Workshop
on The Regulatory Aspects of Decommissioning
Rome, Italy, 19 – 21 May, 1999

ERRATA: These figures of the proceedings replace those on page 115.

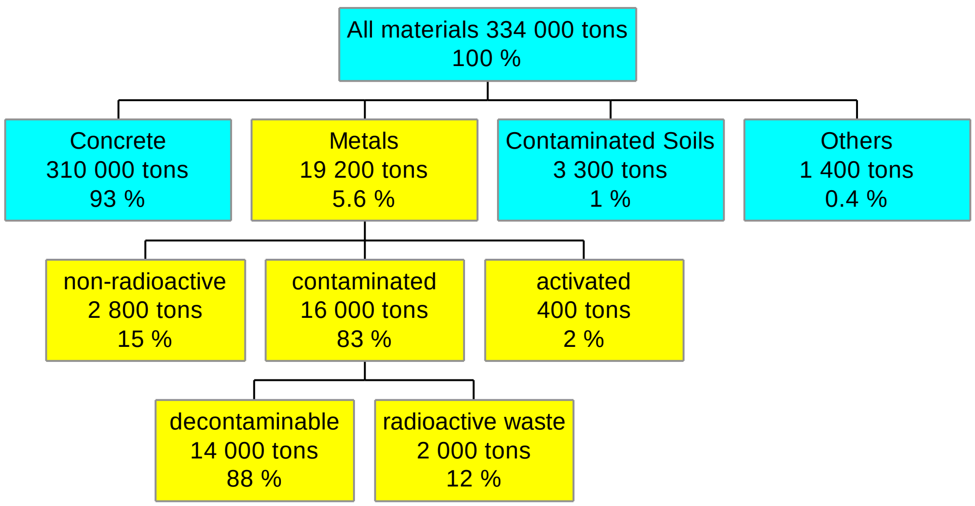

Fig. 1

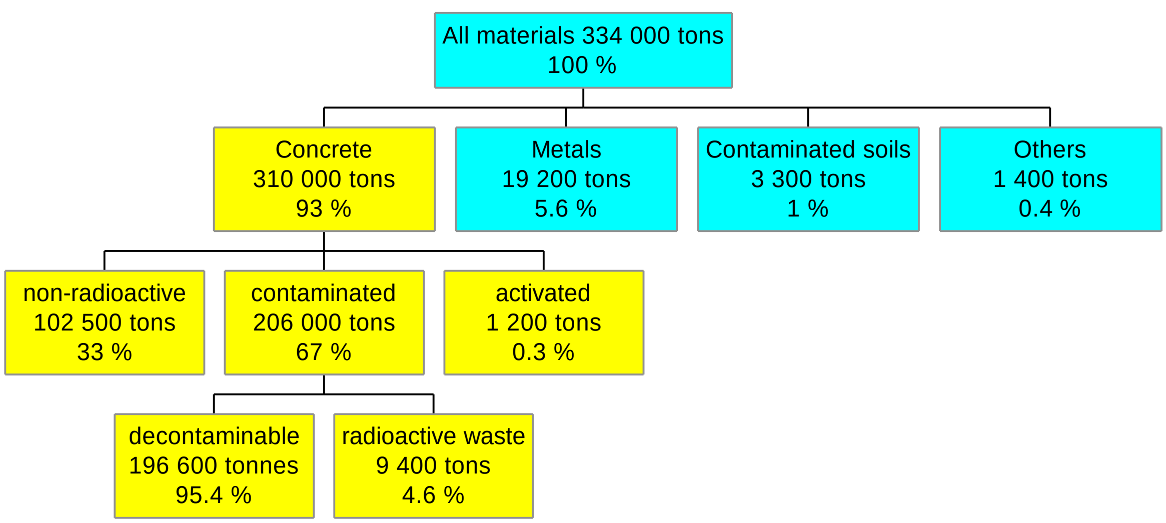

Fig. 2

For metallic components (fig. 1):

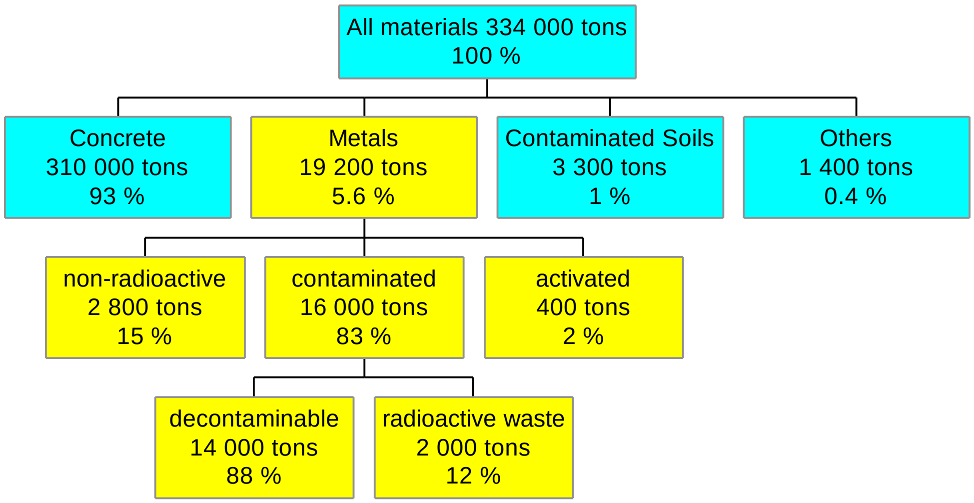

Fig. 1

The non-radioactive and the decontaminable parts are free releasable and amount to about 88% of the total metallic masses. The remaining 12% constitute radioactive waste which needs to be treated as such.

For concrete infrastructures (fig. 2):

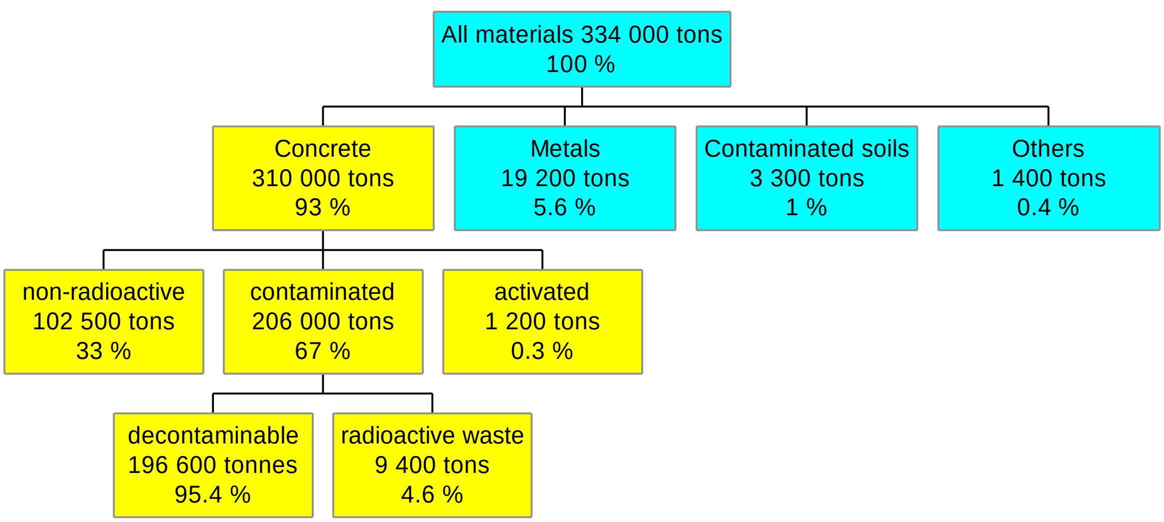

Fig. 2

The free releasable part of the infrastructure within the controlled area of the 3 evaluated nuclear sites amounts to about 96% of the whole mass. Less than 5% is estimated as radioactive waste.

6. The practical experience with material and waste management

6.1 The EUROCHEMIC reprocessing plant

The evolution of the cumulated dismantled metallic masses within the main processing building since the beginning of the programme in 1989 is shown in fig. 3. The increased production rate since 1992 is due to a rise in the workforce, but also to the results of the development and the improvement of techniques and working conditions.

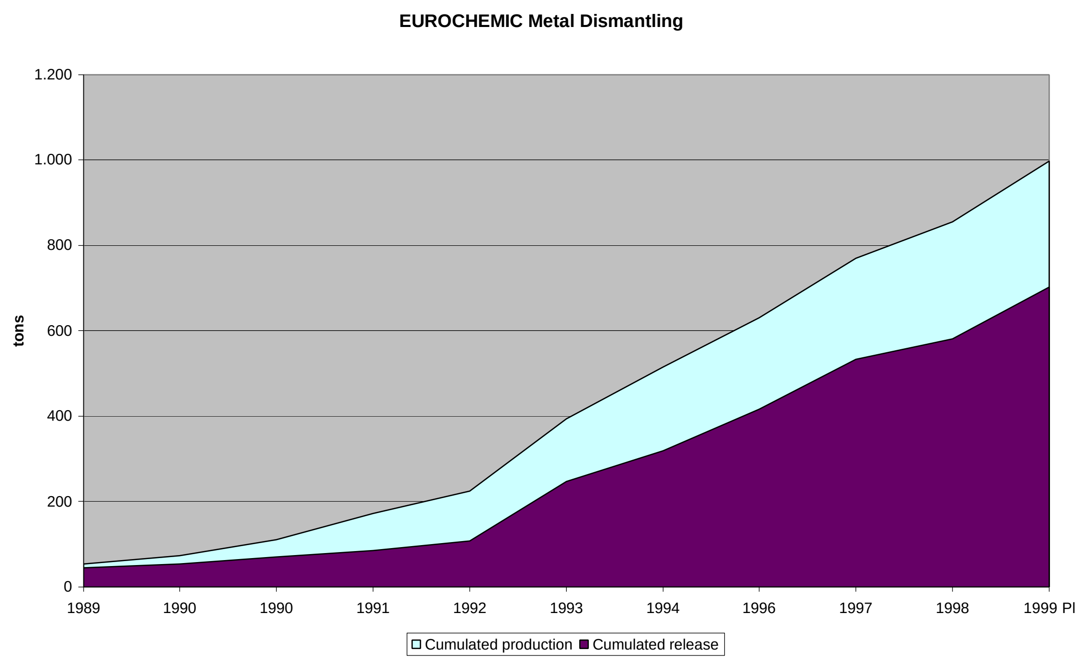

Fig. 3

The evolution of the free released part of the dismantled metal masses is shown in fig. 4. The high rate of released material in 1989 is due to the removal of non-contaminated masses from the processing area. The dismantling of process components from the U and Pu main cells explains the relatively low rate in 1998.

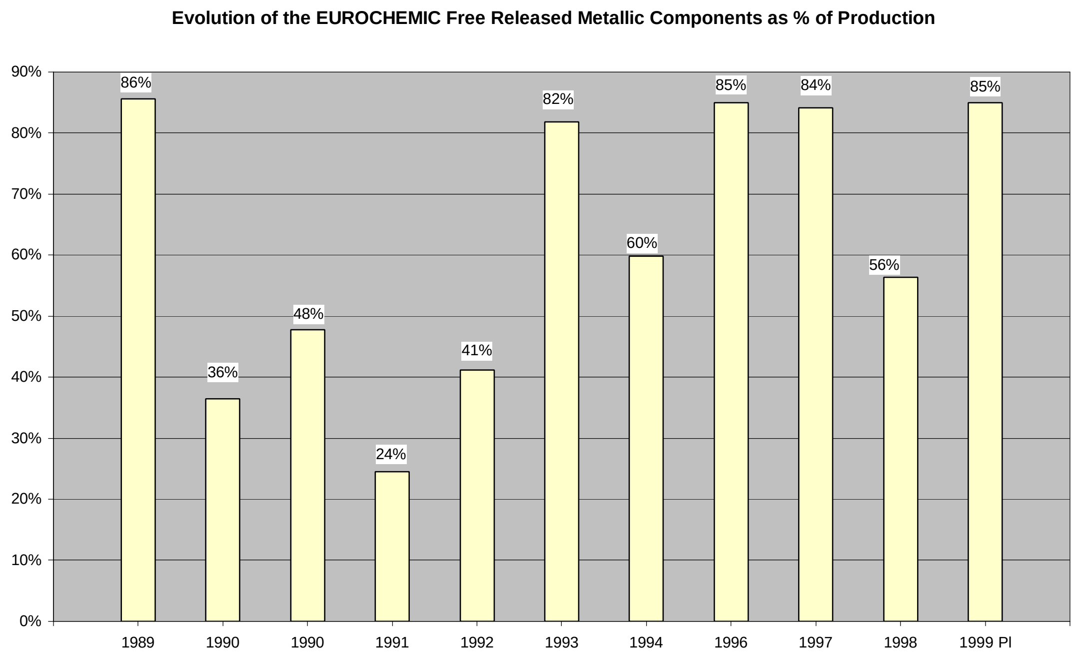

Fig. 4

The high decontamination rates for metallic components are obtained thanks to the use of an industrial dry abrasive decontamination unit operated by BELGOPROCESS. Since the start-up of the facility in 1996, a total amount of 345 tons of metal has been decontaminated to free release limits. 43% of this quantity was released after two times 100% surface measurement, 56% was sent to a foundry where the whole amount was released after melting. Only 1% of the decontaminated masses remained as radioactive waste.

6.2 The former CEN°SCK waste processing and storage site

The recovery and cleanup of the stored waste on this site is in progress since 1989. Some special waste still needs to be recovered in the future. Nevertheless, the decommissioning of some obsolete facilities started in 1998 on an industrial scale. The production and release rates during the year 1998 are shown in the following table 1.

1998	Dismantled masses (tons)	Free released parts (%)
Metallic components	55	99.7
Concrete structures	535	98.4
Other materials	22	84.8

Table 1.

These largely exceed the expected release rates of 88% for metals and 96% for concrete structures (chapter 5.2.), and there is no reason, at present, to doubt that in the future the average values would change at this site.

6.3 The BR3 decommissioning programme

The decommissioning programme started in 1989 with the in-situ decontamination of the primary loop. During the following four or five years, the dismantling of the thermal shield and other reactor internals generated mostly high- and medium-level waste. A cleanup programme during the year 1997 generated a high amount of material which was free released for 95.7% of the global masses. The dismantling and cleanup activities during the year 1998 generated another 90% of free released material.

The results of the dismantling and cleanup activities since the beginning of the decommissioning programme are summarised in the following fig. 5. No concrete structures have been dismantled or decontaminated up to now. The molten metallic parts were recycled within the nuclear field.

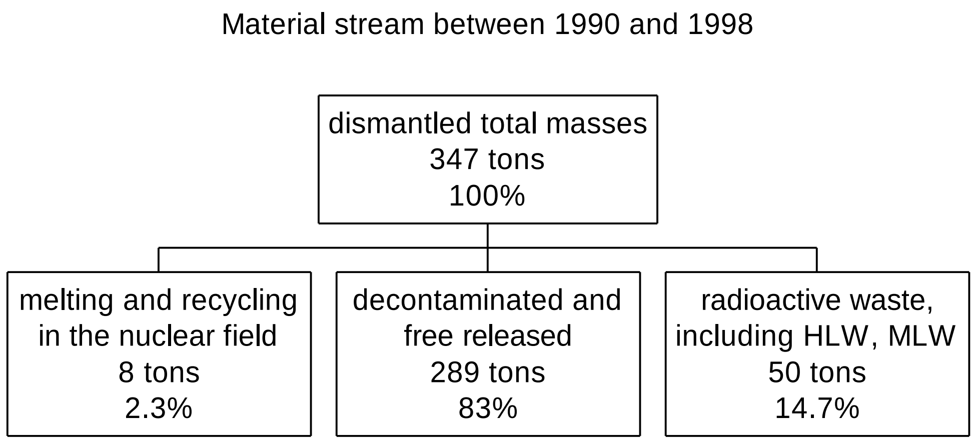

Fig. 5

Furthermore, R&D were performed at the BR3 site on aggressive chemical decontamination using Ce+ as decontamination agent. A semi-industrial decontamination unit is being implemented based on the results of this work, and the operation of this facility is planned to start now. The aim of this facility is to provide an additional capacity for the decontamination and recycling pathway for metallic materials.

6.4 Various other cleanup activities on the CEN°SCK site

Since the creation of the nuclear liability fund related to the decommissioning and restoration of the Nuclear Research Centre CEN°SCK in 1991, already mentioned before, a cleanup programme has been carried out at the other research reactor facilities BR1 and BR2 which are still in operation today, as well as at various laboratories on the site. Some facilities, where physical, chemical and biological research was performed in the past, were completely decommissioned and re-used for conventional research by a Flemish institute.

The balance of the material stream related to those activities is shown in fig. 6 below.

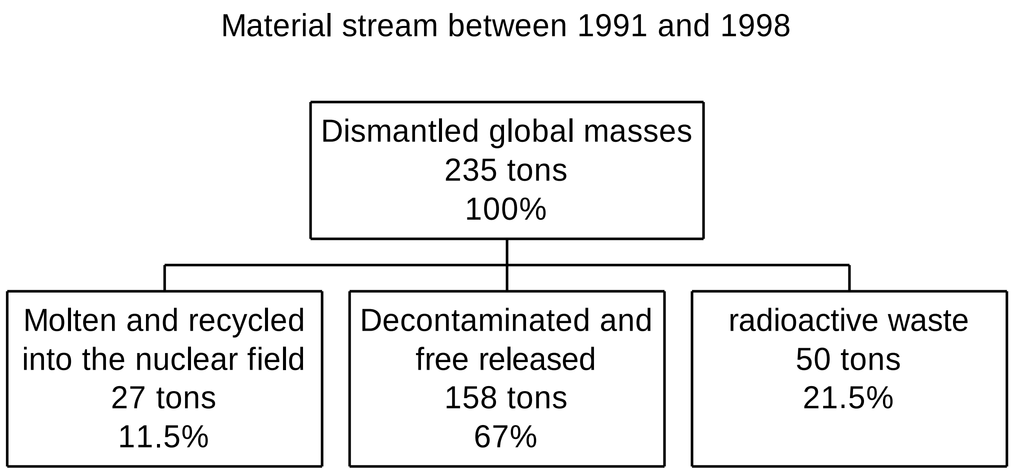

Fig. 6

7. General conclusions

Some points regarding decommissioning and related material and waste management need further investigations and resolutions concerning regulatory aspects and international consensus. Such resolutions would largely facilitate the decommissioning and site restoration work. The most important subjects seem to be:

- clearance criteria accepted by nuclear and non-nuclear industry and at international level,
- transboundary implementation of solutions for waste management, especially in collaboration within the European Union,
- strategies for an economic management of very low-level waste in association with solutions for NORM and TENORM materials.

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THE DECOMMISSIONING OF NUCLEAR FACILITIES IN FRANCE: RADIOACTIVE WASTE MANAGEMENT

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1. Introduction

59 nuclear power reactors are in operation in France today, generating about 80% of the country's electricity. The vast nuclear program initiated in the '70s materialized in a large number of nuclear installations: France had 131 basic civilian nuclear installations (BNI) on 31 December 1997. Added to these are a number of nuclear installations involved in nuclear weapons manufacture.

32 installations have already been shut down, some decommissioned at different levels. Only around 2020 will the pressurized water reactors currently in operation be progressively shut down, and the first of them, the Fessenheim reactors, may be scheduled for shutdown after 2015, after about 40 years of service.

These shutdowns will generate miscellaneous waste, for which suitable management systems must be available. After a brief review of the regulatory framework of nuclear facility decommissioning, as set by the government, this document describes the long-term waste management systems, operational or under development. Certain specific aspects of decommissioning waste management are then presented.

2. Responsibilities in the decommissioning of nuclear installations

As a rule, the operators of the nuclear installations are responsible for their decommissioning. Operations are conducted according to a regulatory framework (see Section 3) defined by the government, and particularly by the Nuclear Installation Safety Directorate (DSIN), which sets the guidelines for nuclear safety.

The operators propose the technical arrangements for meeting these objectives with due justification. They are approved by the DSIN, which then checks their proper implementation, by inspections, relying on the Regional Directorates for Industry, Research and the Environment (DRIRE).

The National Radioactive Waste Management Agency (ANDRA) is in charge of long-term radioactive waste management. Its missions were defined by the law of 30 December 1991:

- participate in research on long-term management and the definition of the radioactive waste;
- management of the long-term disposal facilities;
- design, install and construct new disposal facilities;
- draw up conditioning specifications for disposal;
- compile an inventory of radioactive waste present in France.

ANDRA takes charge of the radioactive waste in a contractualized framework with the waste generators. The safety objectives of the disposal facilities, both for operation and for the long term, lead ANDRA to draw up rules for acceptance of the waste at these facilities via technical specifications, and to confirm compliance by the waste generators.

3. Regulatory framework of decommissioning

The decree governing the operation of nuclear installations was enacted in 1963. It was specifically amended in 1990 to define a framework for their shutdown and decommissioning. It stipulates that the phases of final suspension of operations, and final shutdown and decommissioning, must take place according to procedures subject to DSIN approval:

"If, for any reason whatsoever, the operator plans the final shutdown of the installation, he informs the Director of the Safety of Nuclear Installations accordingly and sends him:

- a document justifying the status selected for the installation after its final shutdown and setting out the steps of its subsequent decommissioning;
- a safety report applicable to the final shutdown operations and the measures to guarantee the safety of the installation;
- general rules of surveillance and maintenance to be observed to preserve a satisfactory level of safety;
- an update of the internal emergency plan of the installation concerned."

Final shutdown and decommissioning are the subject of specific decrees and may be hence submitted to a public inquiry procedure. Note that these operations can also lead to transform the basic nuclear installations for new storage applications or; sometimes, change them in installations classified for environmental conservation.

As of 31 December 1997, 21 research and power reactors, 11 plants and laboratories, had already initiated or completed this process. 13 of them were no longer on the list of the BNI after their partial or total decommissioning.

4. Long term radioactive waste management systems available and under study

4.1 Classification of waste in France

Specific systems for radioactive waste management have been installed and are under study, appropriate to the activity and the half-life of the radioelements present. Near-surface and subsurface disposal facilities can accommodate very low, low and medium-level, short-lived waste. The presence of long-lived elements is only admissible if their activity is sufficiently low. The management systems available or under study can thus be classed as follows:

	Short half-life (half-life of main radioelements < 30 years)	Long half-life
Very low level	under study near-surface disposal	
Low level	near-surface disposal Aube facility	under study (subsurface) * radium-bearing waste * carbon 14
Intermediate level	near-surface disposal Aube facility	under study law of 30 December 1991
High level	under study law of 30 December 1991	under study law of 30 December 1991

4.2 High-level waste long-lived waste: the law of 30 December 1991

The law of 30 December 1991 set a 15-year limit for research on this waste. When the deadline arrives, it stipulates that the procedures of its long-term management will be the subject of a parliamentary debate. It sets three research directions:

- separation and transmutation of long-lived radioelements;
- reversible or irreversible disposal in deep geological formations;
- long-term near-surface storage.

The French Atomic Energy Commission (CEA) is in charge of the first and third research directions, while ANDRA investigates the feasibility of disposal in deep geological formations.

These researches are evaluated by a National Evaluation Commission, and will be addressed in a report submitted to the government in 2006.

On 9 December 1998, the government authorized ANDRA to build an underground laboratory in a clay formation on the Bure site in the Meuse département, and asked ANDRA to identify a second site for the installation of a laboratory in a granite formation.

4.3 Low- and intermediate-level short-lived waste

Since 1969, this waste has been accommodated in a near-surface disposal facility. The Manche facility was operated from 1969 to 1994 and will shortly enter its institutional control phase after having received its cap. The Aube facility started operations in 1992.

Safety is based on a three-barrier concept: the conditioning in the waste package, the disposal structure, and the host environment. The third takes over if the first two barriers fail. Long-term safety is guaranteed by stringent management of the activity of the packages (acceptance thresholds), the activity of the structures and the radiological inventory of the facility, particularly concerning long-lived radioelements. For example, the acceptance limits for the packages are 50 Mbq/g for cobalt 60 and

330 000 bq/g for cesium 137. They are lower for longer-lived radioelements, particularly for alpha emitters, for which the limit is 3700 bq/g.

When the structures are loaded, the packages are protected from the weather by a mobile framework. The structures are then closed and covered by a watertight material. A final cap including a layer of clay or artificial sealant is then installed after operations are terminated, in anticipation of the site's institutional control period, expected to last no more than 300 years.

Besides the disposal installations, the Aube facility also features conditioning installations:

- 1000 ton press for compacting technological waste;
- a facility for grouting 5 and 10 m³ metal caissons, specifically intended for large waste.

Waste is either delivered for treatment to the installations of the Aube facility, or conditioned at the waste generators. In 1999, Socodei commissioned a waste incinerator and a metal fusion installation at Codolet near Marcoule. These installations will significantly reduce the volume of waste to be disposed of.

Thus the Aube facility, initially licensed to accommodate one million m³ of waste packages, should, at the present delivery rate of 12 000 m³ per year, be able to accommodate all the low- and medium-level waste produced in France for another 60 years.

4.4 VLL disposal facility

Very low-level waste corresponds to an activity class stretching from natural radioactivity to 100 bq/g. Controlled and specific management of this waste is a precautionary measure to guarantee traceability, with an acceptable cost.

The safety of the disposal facility designed by ANDRA is based on containment by two barriers: a sealant material, on which the waste is deposited, plus the waterproof roofing materials and the host formation. Thus the waste, which must be solid, and inert or inerted, will not require preconditioning before acceptance. However, the type of waste will be the subject of specifications (non dispersibility, absence of liquids). As for the Aube facility, the waste is sheltered from rainwater. After operations are terminated, this facility could be institutionally controlled for 30 years.

The government has organized a national consensus on this project. This will shortly materialize in the construction of a facility with a capacity of 750 000 tons of waste, covering requirements up to about 2030.

5 Decommissioning waste forecasting

Decommissioning operations have already been conducted on certain installations. Thus from its commissioning in January 1992 to the end of 1998, the Aube facility has received 9000 packages attributed to these operations, representing a volume of 9500 m³ for a total of nearly 210 000 packages received and 95 000 m³.

For research reactors and laboratories, the decommissioning strategy is to reach decommissioning level 3 (total and unconditional release of the site) promptly whenever possible. For power reactors, Electricité de France, the national electrical utility, has adopted a strategy of passage to level 2 (partial or conditional release of the site with reduced monitoring of a containment zone and environmental surveillance) as soon as possible after final shutdown of the installation, followed by a hiatus of 50 years before the transition to level 3. This hiatus allows the short-lived elements to decay, thereby reducing the exposure of the operating personnel in comparison with immediate decommissioning.

The quantities of waste that will be generated by French power reactors operating today have been estimated (five GCRs and 58 PWRs). The table below gives the raw figures, not including any further conditioning.

Waste type	**NON RADIOACTIVE**			**VLL**			**ILL**		
Approximate tonnage	TLC	Metal	Rubble	TLC	Metal	Rubble	TLC	Metal	Rubble
Operation 1994-2038	6400	12000	i 0	20000	500	5500	600	12000	i 0
Decommissioning Level 2	11000	47000	2.5 10^6	26000	380000	120000	2700	47000	13000
Decommissioning Level 3	1400	50000	7.5 10^6	15000	410000	300000	1300	60000	30000
TOTAL	**i 10 000 000 t**			**i 1 500 000 t**			**i 200 000 t**		

TLC: Technological waste, combustible liquids, thermal insulation and electrical cables.

Added to these quantities is some waste inadmissible in a near-surface facility, primarily consisting of metallic vessel internals. They are accounted for in decommissioning level 3.

6 Some aspects of decommissioning waste management

6.1 Acceptance principles

The waste acceptance rules at the different disposal facilities make no distinction between the operations which generate the waste. Hence decommissioning waste follows the same process as all the other waste categories, for example, operating waste.

Thus to demonstrate the acceptability of the waste packages intended for the Aube facility, the producer must submit a file describing the origin of the waste, and its conditioning method. He must demonstrate that the conditioning meets the acceptance requirements. He justifies the method for evaluating the activity of the waste and presents the quality assurance arrangements set up to guarantee the conformity of the packages produced.

The radiological characterization of decommissioning waste could raise specific problems. The spectrometry which may be associated with an active or passive neutron count is used on certain construction sites. Yet the handling of large parts is not always compatible with the available measurement techniques. Thus the knowledge of the methods by which a decommissioned part has been contaminated or activated must be exploited in order to identify the typical activity spectra per zone of the installation, to enable a compilation of the list of radionucleides potentially present and to design the simplest and most appropriate measurement method. On large packages, the definition of a transfer function could thus provide a link between a dose rate and the radiological properties of the waste.

Evaluating the activity is also conditioned by the technical limits of the measuring instruments, of which the detection threshold is often similar to the waste orientation threshold. The presence of short-lived emitters can also complicate the detection of long-lived radionucleides by the background noise they create.

6.2 Adapting disposal facilities to decommissioning waste

The ideal decommissioning packages for waste sent to the Aube facility are 200 liter drums and 5 and 10 m³ metal caissons. The former are used for the treatment of compressible or incinerable waste, in the Aube facility and at Socodei respectively. The latter are ideal for large parts. Caissons fitted with a pre-concreted internal sheath can also accommodate irradiating waste. This is conditioned in the grouting facility of the Aube facility.

Yet these standardized packages will not suffice to receive all the decommissioned equipment. Some very large parts will have to be cut and chopped, an operation that could expose the workers to ionizing radiation. This makes it necessary to adapt the handling equipment in the disposal facilities, and possibly even the structures, to receive bulky waste.

Although it does not strictly correspond to a decommissioning operation, the disposal project for vessel heads of pressurized water reactors offers one example of the adaptation of the disposal facilities to bulky decommissioning waste. The heads will be transported as such in special containers and placed in specialized structures. Weighing about 100 tons, these packages will be conditioned by grout injection in the structures themselves. This operation could accordingly foreshadow the handling of objects such as steam generators, components of reactor primary circuits, etc.

6.3 Preparation of a major decommissioning project: the case of Marcoule

The first French reprocessing plant, UP1, was commissioned at Marcoule in 1958. After having reprocessed nearly 20 000 tons of fuels from GCR reactors and research reactors, operations were suspended in late 1997. In 1998, the plant initiated its first final shutdown phase. This shutdown lasted three years and was succeeded by decommissioning, and retrieval and conditioning operations of wastes temporarily stored on site, expected to end around 2030. All these operations are performed by the operator of the site, COGEMA, and are supervised, technically and financially, by a structure, CODEM, representing “ customers ” of the plant: CEA, EDF and COGEMA.

In accordance with the rules in force, a waste management plan has been drawn up. This plan was presented to ANDRA in 1998. This joint planning arrangement between the decommissioning operator and the future waste manager had several objectives:

- present the conditioning and radiological characterization methods adopted and confirm that they meet the acceptance requirements on the facility;
- provide a first assessment of the radiological content of the packages delivered and confirm the compatibility of the anticipated activity with the capacity of the facility, particularly concerning alpha emitters;
- draw up the advance program for examining acceptance files for disposal;
- check the consistency of the waste package disposal program with the handling possibilities at the facility.

The final shutdown of the UP1 plant in Marcoule and its decommissioning will culminate in the examination of several package acceptance files for the Aube facility. These packages will represent a volume of about 45 000 m^3 to be received over a 20-year period. The waste will be conditioned at Marcoule, primarily in steel fibre reinforced concrete caissons or metal drums.

In light of the planned schedule for decisions on long-lived waste management, storage facilities have been built at Marcoule. They will accommodate packages which fail to meet the acceptance criteria of the Aube facility.

7 Conclusions

The decommissioning of the nuclear installations operated in France takes place in a regulatory framework which has been supplemented to account for the specificity of these operations. The operators of the installations will be responsible, under the supervision of the authorities, represented by the DSIN (Nuclear Installation Safety Directorate).

ANDRA, which is responsible for long-term radioactive waste management, now has a system at the Aube facility for accommodating low- and medium-level short-lived waste. A disposal facility will be created in the coming years, to be dedicated to very low-level waste. This in fact accounts for most of the volume of the waste produced by decommissioning operations. Research on management methods for long-lived waste is conducted within the framework of the law of 30 December 1991. This law calls for a parliamentary debate to take place after 2006. Yet the waste concerned represents a very small proportion of total decommissioning waste and, according to the strategy currently adopted for nuclear reactors, will only significantly appear in the second half of the 21st century.

The preparation of the decommissioning operations demands close cooperation between the operators and the waste manager. It is aimed to adjust the conditioning and storage facilities to the specificities of the waste produced, to identify the ideal methods of treatment, and to dimension the disposal needs accordingly. This joint project, which also aims to reduce the exposure of all the operators involved to ionizing radiation, also includes the designers of the installations. On this subject and by way of example, the use of low cobalt alloys in the primary circuits still significantly reduced and will reduce in the future the activity of the waste and the level of radiation in the planned reactors, both for operating waste and for decommissioning waste.

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DECOMMISSIONING PLANS IN FINLAND

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1. General

There are two major nuclear sites in Finland: the Loviisa NPP with two 488 MW_e PWR units and the Olkiluoto NPP with two 840 MW_e BWR units. The nuclear power plants have been in operation for about 20 years and are planned to be operated at least another two decades. Thus no major decommissioning projects are underway or foreseen in near future.

The principal legislation regulating nuclear activities in Finland is the Nuclear Energy Act and Decree of 1988. They define the responsibilities and the principles for financing decommissioning projects. The licensing procedures for decommissioning are not yet defined in detail.

The licensees are responsible for the implementation of decommissioning. In the event that the licensee is incapable doing so, the state has the secondary responsibility. In this case, the costs are covered by assets collected in the Nuclear Waste Management Fund and by securities provided by the licensees.

The Government is the licensing authority for nuclear facilities. The Ministry of Trade and Industry approves the decommissioning plans and the Radiation and Nuclear Safety Authority (STUK) is responsible for the regulation of safety. The safety related regulations are issued by the Government (general rules) and STUK (detailed rules). Currently, there are no regulations specific to decommissioning, but the regulations concerning clearance from regulatory control of nuclear waste are applicable to decommissioning, too.

2. Decommissioning plans

According to a governmental policy decision of 1983, the licensees are obliged to update their decommissioning plans every five years. These plans aim at ensuring that decommissioning can be appropriately performed when needed and that the estimates for decommissioning costs are realistic. The latest updates of the decommissioning plans [1,2] were published at the end of 1998 and will be reviewed by the authorities during this year.

The decommissioning plan for the Loviisa NPP is based on immediate dismantling, in less than 10 years from the shutdown of the reactors, excluding facilities needed for spent fuel storage. The plan for the Olkiluoto NPP envisages a 30 years safe storage period prior to dismantling the reactors. These strategies are justified by the likely future use of the sites for e.g. energy production. At the Loviisa site, replacement of the existing facilities with new ones may be needed while at Olkiluoto, nearby sites can be used for locating new plants.

The Finnish decommissioning plans cover dismantling of only structures and components that exceed the clearance constraints; thus the “green field” option is not required on the basis of our regulatory policy.

Some key figures of the Loviisa and Olkiluoto decommissioning plans are listed below.

	Decommissioning plan for the Loviisa NPP	Decommissioning plan for the Olkiluoto NPP
Duration of decommissioning phase (years)	8	36
Need of labour (man years)	2 800	1560
Occupational collective dose (manSv)	9,2	6
Waste to be disposed (m^3)	15 000	28 000
Estimated cost (Meuro)	190	160

A special feature of the Loviisa decommissioning plan is that large components, i.e. the pressure vessels and steam generators would be removed intact, without cutting them in pieces. Before dismantling, the whole primary circuit would be decontaminated. A decontamination performed at the Loviisa 2 unit in 1994 showed that contamination level of the primary circuit components could be easily reduced by a factor of 100 or more.

In the latest decommissioning report of the Olkiluoto NPP, a similar dismantling option is discussed. The overall conclusion is that removal of pressure vessels as such seems very attractive in comparison with its segmentation.

3. Radioactive waste management

3.1 Clearance from regulatory control

It has been estimated that from decommissioning of the Loviisa and Olkiluoto NPPs, the quantities of metal scrap to be cleared amount to 5000 and 8000 tonnes respectively [3]. In addition, several tens of thousands cubic metres of “clearable” concrete would arise, if all structures at the controlled areas were dismantled.

In our country, only waste from the repair and maintenance of the NPPs, including a few major plant modifications, has been cleared from regulatory control so far. These waste quantities, typically some tens of tonnes of metal scrap and trash waste annually, are modest in comparison with those arising from dismantling of the NPPs.

The clearance principles are defined in STUK’s Guide YVL 8.2 [4]. It specifies the radiation dose and activity constraints and provides guidance for the determination of the waste activities and other clearance procedures. The radiation protection principles are the same as recommended in IAEA’s Safety Guide [5]. STUK’s Guide defines two clearance options: unconditional and conditional.

The following activity constraints are applicable to unconditional clearance:

- The total activity concentration, averaged over a maximum amount of 1000 kg of waste, shall not exceed 1 kBq/kg of beta/gamma activity or 100 Bq/kg of alpha activity. In addition, no single item or waste package weighing less than 100 kg may contain more than 100 kBq of beta/gamma activity or 10 kBq of alpha activity.

- The contamination of non-fixed radioactive substances on accessible surfaces, averaged over a maximum area of 0.1 m2, shall not exceed 4 kBq/m2 of beta/gamma activity or 400 Bq/m2 of alpha activity.

For conditional clearance, activity constraints based on a case-by-case approval by the STUK are applied which, however, shall remain below those included in the Nuclear Energy Decree, viz:

- The average activity concentration in the waste shall be less than 10 kBq/kg.
- The total activity of cleared waste received by a transferee in one year shall be less than 1 GBq and the alpha activity less than 10 MBq.

Our present clearance practices work fairly well, though monitoring of waste for clearance is a demanding task from both the implementor and regulator point of view. Consequently, more efficient monitoring methods should be developed for the decommissioning phase when the waste quantities to be cleared will be tenfold higher than currently.

3.2 Disposal of decommissioning waste

Both utilities envisage on-site disposal of dismantling waste. The existing repositories for operational low and intermediate level waste, located in the crystalline bedrock at the NPP sites, would be enlarged to accommodate the waste from decommissioning as well.

On-site disposal of decommissioning waste involves significant benefits in comparison with off-site disposal. Conditioning and packaging of waste for disposal becomes easier, because the waste packages need not meet the transport requirements concerning e.g. external dose rate and surface contamination. Then it is even possible to remove and dispose of large components as such, without cutting them in pieces. Considerable cost savings and some reduction in occupational doses can be achieved in this way.

The schemes of the disposal facilities are illustrated in Figures 1. And 2. The repository at the Loviisa site would consist of two disposal compartments, located at the depth of about 100 m. Low level waste, packed in drums and concrete containers, would be placed in a large rock cavern. The pressure vessels with core internals would be put into concrete silos in two large deposition holes. The rock cavern above them is intended for disposal of steam generators and other decontaminated large components. The spaces in the emplacement rooms would be backfilled with concrete grout, mixture of crushed rock or bentonite and with crushed rock depending on the type and activity level of waste.

The repository at the Olkiluoto site would consist of three new silos, with a height of about 30 m and bottom of about 100m depth. Two of the silos are for low level waste and one for intermediate level waste. The former are shotcreted bedrock silos while the latter has also an internal concrete silo. The waste packages would be put into large concrete boxes and then lowered into the silos. Concrete grout is used as backfill.

There is also an optional plan to dispose the intact pressure vessels with most of the core internals into a bedrock shaft (diameter 8 m and depth 110 m). In that case, only two silos would be needed for the rest of decommissioning waste.

The decommissioning waste disposal plans include fairly comprehensive safety assessments [6,7]. Due to the similarity of the design and the system of barriers, the same methodologies as in the respective assessments for the repositories in operation were applied.

The long-lived activity in decommissioning waste is about two orders of magnitude higher than that of the operational low and intermediate level waste. However, the radiotoxicities of dominating nuclides (calculated in ALIing-values) in decommissioning wastes, such as Ni-63, are low in comparison with those of the dominating nuclides in operational waste. In addition, most of the activity in decommissioning waste is incorporated in massive metal components which corrode very slowly in the alkaline conditions that prevail in the repository. Consequently, the assessments indicate that the same safety level as for disposal of operational waste can be achieved. The highest individual doses remain well below the constraint of 0,1 mSv/a and the cumulative collective dose over 10 000 years is not more than about 1 manSv.

In STUK's earlier review of the decommissioning plans, it was concluded that the planned disposal concept and site are likely to provide safe disposal of decommissioning waste. It is expected that the ongoing review will not arrive in a divergent conclusion.

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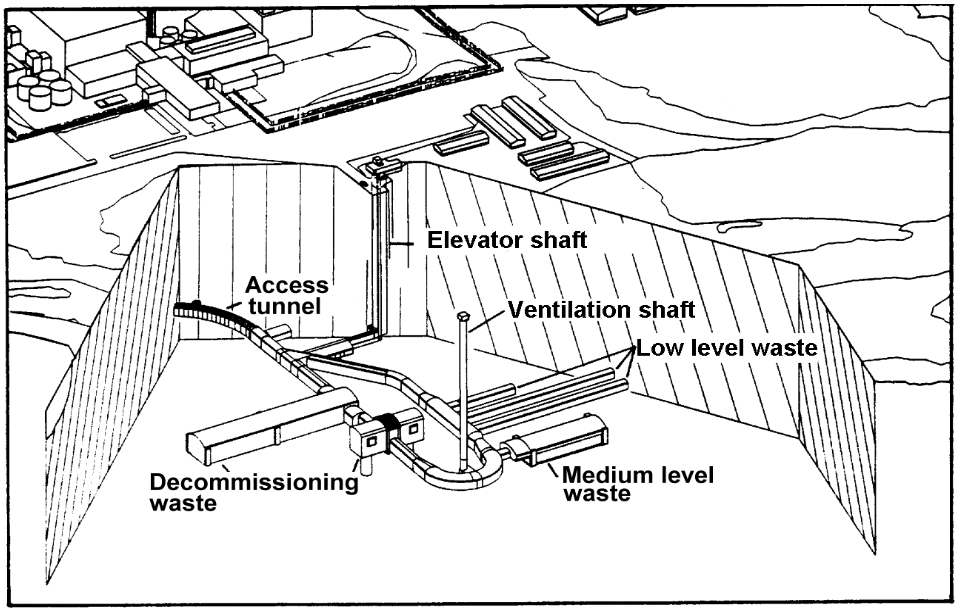

Fig. 1. Repository for decommissioning waste from Loviisa NPP

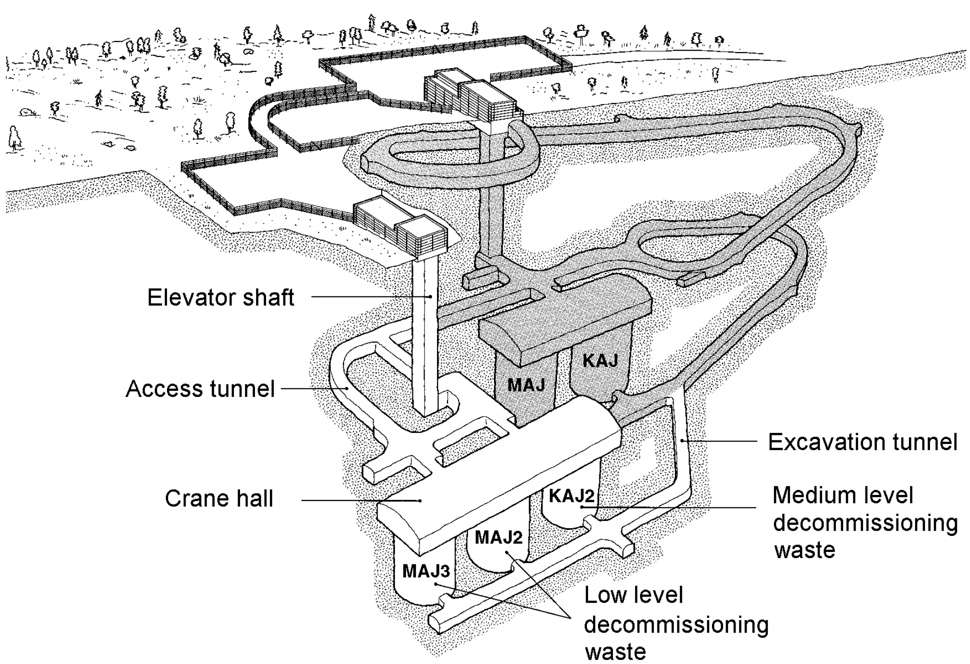

Fig 2. Repository for decommissioning waste from Olkiluoto NPP NPP

EXPERIENCE AND CURRENT DISCUSSION ON MANAGEMENT OF MATERIALS FROM DECOMMISSIONING IN JAPAN

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Abstract

Japan has some experiences of the nuclear facility decommissioning. The Japan Atomic Energy Research Institute conducted the Japan Power Demonstration Reactor decommissioning program. The program completed successfully and it showed that nuclear power plants can be dismantled safely. The radioactive waste was classified depending on materials and radioactivity levels applying the criterion published by the Nuclear Safety Commission (NSC) to distinguish types of waste into non-radioactive and radioactive. The Tokai Power Station of the Japan Atomic Power Company was retired from service in March 1998 and will be dismantled in the near future. The Atomic Energy Commission and the NSC are examining the strategies and regulatory rules of radioactive waste management including the clearance levels, respectively. Nuclear power plants will be dismantled smoothly and economically after the regulatory rules of waste management are completed.

Introduction

The Japanese basic policy on decommissioning nuclear power plants is that they should be dismantled and removed as soon as possible after their shutdown [1]. Based on this policy, the Japan Atomic Energy Research Institute (JAERI) conducted the Japan Power Demonstration Reactor (JPDR, 90MW(th), BWR) decommissioning program from 1981 through 1996, which consisted of development of decommissioning technologies and actual dismantling of the facility. The program completed successfully and it showed that nuclear power plants can be dismantled safely.

The Tokai Power Station (166 MW(e), GCR) of the Japan Atomic Power Company, which is the first commercial nuclear power plant in Japan, was retired from service in March 1998. The plant will be dismantled in the near future according to the Japanese basic policy on decommissioning nuclear power plants. To implement the dismantling smoothly and economically, it is necessary to complete the regulatory rules of radioactive waste management including the clearance levels. The Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC) are examining the strategies and regulatory rules of radioactive waste disposal, respectively.

The experiences of waste management gained from the JPDR decommissioning program and the current discussion on waste management by AEC and NSC are described in this paper.

1. Experiences of Waste Management during the JPDR Decommissioning Program

The JAERI has experiences of the dismantling of research reactors (JRR-1, 2, 3, JPDR), the nuclear ship “Mutu” and a reprocessing test facility (JRTF). Since the dismantling of JPDR is the main fruit by JAERI's decommissioning activities, the experiences of waste management gained through the program are described below.

When the JPDR was dismantled, the clearance levels were unavailable in Japan. The criterion published by the NSC to distinguish types of waste into non-radioactive and radioactive was available [2] and it was applied to the dismantling of JPDR. The JPDR dismantling generated 24,440 tons of waste including 3,770 tons of radioactive waste, which consisted of 1,189 tons of metal, 2,143 tons of concrete and 438 tons of secondary waste. The radioactive waste was classified depending on materials and radioactivity levels as shown in Table 1. Fig. 1 shows the total quantities of classified radioactive waste.

Table 1. Classification ofthe JPDR decommissioning waste

Type of waste Classification	Activated metal and concrete Surface contaminated concrete	Surface contaminated metal Secondary waste
Level I	> 4 kBq/g	> 400 kBq/cm^2
Level II	4 k - 40 Bq/g	400 kBq/cm^2
Level III	40 - 0.4 Bq/g	4 k - 40 Bq/cm^2
Level IV	< 0.4 Bq/g	< 40 Bq/cm^2

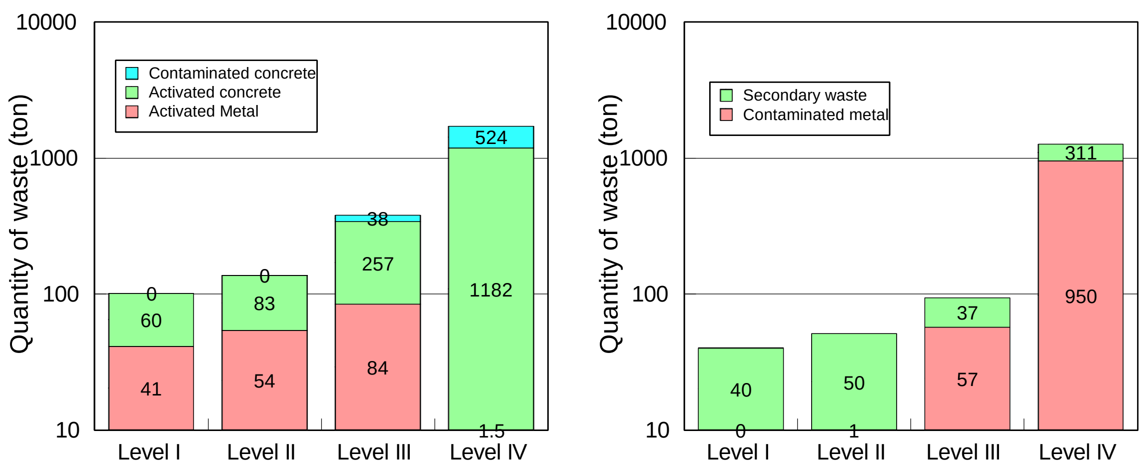

Fig. 1 Total quantities of classified radioactive waste

Highly activated components such as core internals and a part of reactor pressure vessel were contained in shielded containers made of spherical iron. The other activated or contaminated components such as pumps, pipes and concrete were contained in steel containers (200-liter drums, 1-m3 and 3-m3 containers). Very low-level (VLL) radioactive concrete rubble was packed into a polyethylene and polyester sack called a flexible container to handle waste safely and to prevent dust generation. The flexible container consists of three sacks, i.e. inner, middle and outer sack and has external dimensions of about 1 m in diameter and height, and a capacity of about 0.8 m3.

All radioactive metal waste and a part of radioactive concrete waste were stored in interim storage facilities in JAERI. VLL concrete waste was used for the demonstration test to ensure the safety of simple earthen trench disposal [3]. About 6,900 tons of non-radioactive concrete rubble out of 18,000 tons were crushed and used to backfill the sites of demolished buildings. The rest will be used for construction materials such as roadbed material. Non-radioactive metal was sold for recycling.

The site of disposal test is about 2 km north of JPDR and is along the Pacific Ocean. The distance between the test site and the sea is about 200 m. The disposal pit has external dimensions of approximately 16 m in width, 45 m in length and 3.5 m in depth. It is divided into six cells by walls, and is equipped with a sliding roof to prevent rainwater permeation during the emplacement of waste into it. Approximately 1,700 tons of VLL concrete waste, whose total radioactivity was about 230 MBq, was disposed of. The emplacement started in Nov. 1995. The packed wastes were placed in the pit in piles of three levels. The emplacement of waste finished in March 1996, and final cover soil was placed and grass was planted on the surface in June 1996. The thickness of the final cover is about 2.5 m to reduce the impact of human intrusion into the pit after closure. The disposal facilities will be controlled for around 30 years. In that period, maintenance of the disposal facilities, environmental monitoring, and land use control will be performed. Fig. 2 shows the schematic representative view of the disposal pit.

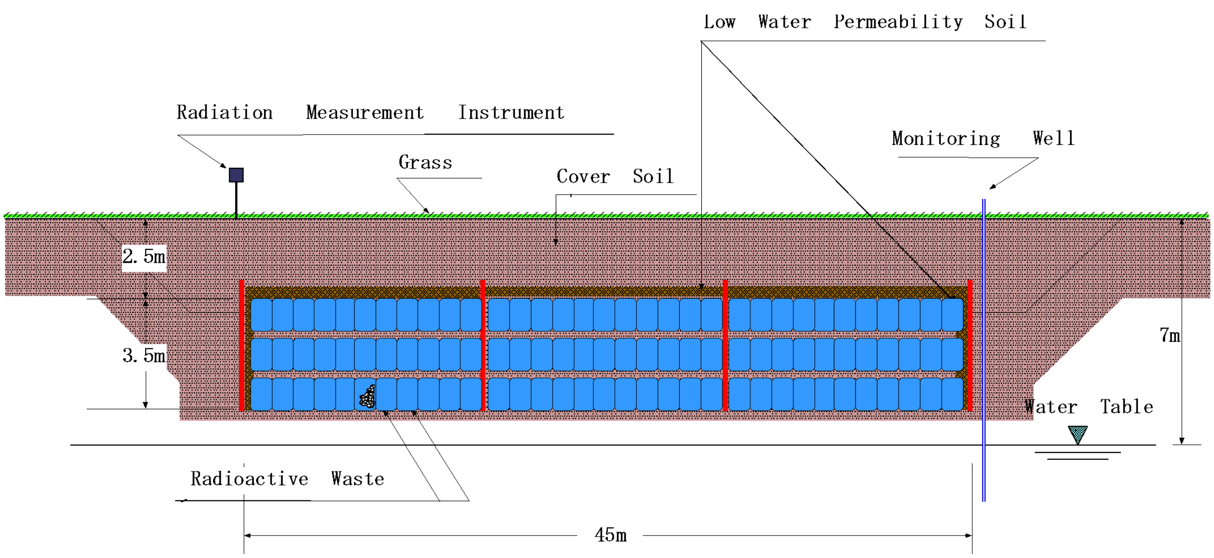

Fig. 2. Cross-section view of the waste disposal pit

2. Current Discussion on Waste Management by AEC and NSC

The AEC proposes that low-level solid radioactive waste (LLW) should be disposed of in near surface disposal facilities on the responsibilities of waste generators [1]. According to this strategy, the NSC published the safety requirements for near surface disposal [4] and the upper bound concentration limits for several types of LLW arising from reactors, which are permitted to be disposed of in near surface disposal facilities [2, 5].

The Science and Technology Agency (STA) stipulated the upper bound concentration limits as the government ordinance based on the examination by NSC as shown in Table 2. The STA also prescribed the technical standards and technical details to ensure the safety of near surface disposal.

At the present time, however, the regulatory rules for disposal do not cover all types of LLW as shown in Table 2. The AEC and the NSC examine the strategies, safety requirements and upper bound concentration limits to complete the regulatory rules.

Table 2. Current status of regulation of waste management in Japan

<table>
<tr><th colspan="3" rowspan="2">Type of Waste</th><th colspan="3">Situations of Establishment</th></tr>
<tr><th>Concentration Upperbounds (Government Ordinance)</th><th>Technical Standards (Prime Minister's Order)</th><th>Technical Details (STA Nortification)</th></tr>
<tr><td rowspan="7">LLW</td><td>Low-Level Radioactive Waste (LLW) with High Concentrations of â .and â -emiters</td><td>Core internals, spent control rods, etc.</td><td colspan="3">Unestablished</td></tr>
<tr><td rowspan="4">LLW
Solidification into Packages
*) Those difficult to solidify are to be disposed of into concrete vault after sealing the openings.</td><td>Solidified liquids</td><td>Established('87.3.27)</td><td>Established('88.1.13)</td><td>Established('88.1.13)</td></tr>
<tr><td>Dry active waste</td><td rowspan="4">Established('92.9.11)</td><td rowspan="4">Established('93.2.26)</td><td rowspan="2">Established('94.9.8)</td></tr>
<tr><td>Concrete waste</td></tr>
<tr><td>Large metal waste</td><td>Unestablished</td></tr>
<tr><td rowspan="2">Very Low-Level Radioactive Waste
üNo needs for solidificationüj
üOpen trench disposal and backfilüj</td><td>Concrete waste</td><td></td></tr>
<tr><td>Metal waste etc.</td><td colspan="3">Unestablished</td></tr>
<tr><td colspan="2">Wastes below Clearance Levels
(This waste class includes the waste not regareded as radioactive)</td><td>Concrete waste
Metal waste etc.</td><td colspan="3">Unestablished
Criterion to distinguish types of waste into radioactive and non-radioactive which was proposed in the report admitted by Nuclear Safety Commission (June 1992).</td></tr>
</table>

2.1 Disposal Concept for High b and gray Emitters

The LLW from nuclear reactors, except high β and γ-ray emitters such as core internals, can be disposed of in near surface disposal facilities in Japan. The AEC, therefore, examined the strategies of disposal and proposes that the waste can be disposed of at a depth of 50 – 100 m below the earth surface [6]. The AEC also proposes to take the following measures for the safety disposal:

- The selection of disposal site should be carried out considering the presence of natural resources and the capability to delay the migration of radionuclides released from a repository.
- The waste should be conditioned in containers and placed in engineered barriers such as concrete vaults.
- The leakage of radionuclides from the repository and the migration of radionuclides via groundwater should be monitored for appropriate duration.
- The use of land above the repository should be controlled for a few hundreds years.

The NSC is examining safety requirements and upper bound concentration limits of high β and γ-ray emitters based on the disposal strategies proposed by AEC.

2.2 Establishment of Clearance Levels

The NSC published the report for the clearance levels in March 1999 after inquiring the public opinion [7]. The NSC derived the clearance levels for concrete and metal arising from the operation and dismantling of nuclear reactors. Seventy-three exposure pathways related to disposal and recycle/reuse were calculated with realistic parameter values of Japanese natural and social conditions. The clearance levels of 20 radionuclides were derived from an individual dose of 10 µSv/y. The derived clearance levels are shown in Table 3. The derived clearance levels of most radionuclides (e.g. γ-ray emitters such as 60Co and α-ray emitters such as 239Pu) are nearly same as those shown in IAEA-TECDOC-855 [8]. However, the clearance levels of some β-ray emitters such as 99Tc and 129I are smaller than those shown in IAEA-TECDOC-855.

Table 3. Comparison with clearance levels derived by NSC and IAEA

Radionuclide	Derived clearance levels (Bq/g)	IAEA-TECDOC-855 (Bq/g)	
		Ranges	Single
H-3	200	1000 – 10000	3000
C-14	5	100 – 1000	300
Cl-36	2	100 – 1000	300
Ca-41	80	N.A.*2	
Mn-54	1	0.1 – 1	0.3
Fe-55	3000*1	100 – 1000	300
Co-60	0.4	0.1 – 1	0.3
Ni-59	600	N.A.*2	
Ni-63	2000	1000 – 10000	3000
Zn-65	1	0.1 – 1	0.3
Sr-90	1	1 - 10	3
Nb-94	0.2	0.1 – 1	0.3
Tc-99	0.3	100 – 1000	300
I-129	0.7	10 – 100	30
Cs-134	0.5	0.1 – 1	0.3
Cs-137	1	0.1 – 1	0.3
Eu-152	0.4	0.1 – 1	0.3
Eu-154	0.4	N.A.*2	
Pu-239	0.2	0.1 – 1	0.3
Am-241	0.2	0.1 – 1	0.3

Note:
*1: The unit of clearance level for Fe-55 is Bq/cm^2 because the limiting pathway is reuse of surface contaminated equipment.
*2: Clearance levels for these radionuclides are not available in TECDOC-855.

The NSC continues to discuss the clearance levels for solid materials arising from nuclear facilities except for reactors and the application of radionuclides to hospital, research facilities. And then Japanese government will make the regulatory rules of clearance based on these results in 2001.

3. Conclusions

Japan has some experiences of managing waste arising from the decommissioning of nuclear facilities. The present regulatory rules are not determined in detail for all types of materials arising from decommissioning of nuclear facilities. Almost the generated wastes from the decommissioning are stored on the site. The AEC and the NSC examine vigorously the strategies and regulatory rules for waste management including clearance. Nuclear power plants will be dismantled smoothly and economically after the regulatory rules of waste management are completed in Japan.

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SESSION 3B

EXEMPTION, CLEARANCE AND AUTHORISED RELEASE

INTERNATIONAL GUIDANCE ON THE REMOVAL OF REGULATORY CONTROLS FROM MATERIALS CONTAINING RADIONUCLIDES

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1. Introduction

The International Basic Safety Standards (BSS) [1] establish requirements for protection against the risks associated with exposure to ionizing radiation. Radiation occurs everywhere in the environment and radiation which cannot be attributed to current human activities is known as background radiation. Human activities that add radiation exposure to that which people normally incur due to background radiation, or that increase the likelihood of their incurring exposure, are termed ‘practices’ in the BSS. Human activities that seek to reduce the existing radiation exposure, or the existing likelihood of incurring exposure, which is not part of a controlled practice, are termed ‘interventions’. The BSS provide the basis for a regulatory system for the control of radiation: one part of the system applies to practices, another to interventions.

One purpose of a regulatory system is to ensure appropriate implementation of protection requirements. Some practices require a greater degree of regulatory control than others in order to achieve an appropriate level of protection, that is to keep the increase in exposure within acceptable bounds. Some situations of existing radiation exposure require more extensive intervention action than others in order to reduce doses to an acceptable level. Regulatory effort should be tailored to the circumstances by focusing on areas where real benefits can be obtained.

The full regulatory system does not need to be applied to practices that give rise to radiological risks that are not of regulatory concern. Similarly, it is clearly not efficient or desirable for the scope of regulations to cover situations of existing exposure where it would be impracticable to reduce doses. There are two regulatory concepts and related procedures for deciding when the requirements of the Standards need not be applied: ‘exclusion‘ and ‘exemption’. These terms are concerned with leaving things outside the requirements of regulations; that is, with not bringing them under regulatory control. A further term – ‘clearance’ – is closely related to exemption and is concerned with releasing things from regulatory control. These and other related concepts such as authorized recycle, reuse, discharge and disposal are illustrated in Figure 1.

At the IAEA Specialists Meeting [2] held in 1997, attention was drawn to the confusion which is resulting from the variety of different terms being used internationally and nationally to describe these and related concepts. Since then, IAEA working groups have made proposals for a consistent terminology in this area and these are presented in the paper.

Currently, work is going on to revise the basic international guidance document on “Principles for the Exemption of Radiation Sources and Practices from Regulatory Control” which was cosponsored by the IAEA and NEA and issued in 1988 [3]. In this revision process the concepts which define the scope of radiation protection regulations are being examined and elaborated. Many of the issues discussed in this paper are still under consideration in the revision process.

2. Intervention and Exclusion

Actions intended to reduce or avert exposure, or the likelihood of exposure, to sources that are not part of a practice or which are out of control as a consequence of an accident are termed interventions. However, some exposures to radiation are part of the natural human environment and it is not practicable to reduce them. Examples include exposures from cosmic radiation at the earth's surface and exposures from potassium-40 in the body. Exposures of this kind are regarded as unavoidable and, most importantly, it is usually not practicable to control them through regulation. The deliberate omission by a Regulatory Authority of a particular category of exposures (including potential exposures) from regulatory control on the grounds that they are not considered amenable to control through regulation is termed exclusion in the BSS. Such exposures are termed excluded exposures.

People may receive exposures from several different sources, both natural and manmade. The regulatory system may need to be applied differently to each component of exposure. If the exposure is being caused by a certain human activity in such a way that it adds to the exposure that would otherwise have been received, it should be dealt with as arising from a practice. That is, regulatory controls should be applied to the practice that causes it. Note that inhabiting the natural environment is not considered a practice, so that, for example, moving from a region of low natural background radiation to a higher background area is not a practice.

If the exposure is not treated as arising from a practice, it may be excluded from regulatory requirements or dealt with by intervention. This is the case, for example, when the exposure already exists and cannot be attributed to an identifiable practice. The key to determining whether a component of exposure may be excluded is whether or not it is amenable to control. If there are no reasonably practical means of reducing it, it may be excluded from the regulatory system. The borderline between what may be regarded as amenable to control and what is not is not clear-cut. There will be cases in which it may be physically possible to reduce exposures, but cause unreasonable costs.

When radiation exposures in situations which are generally excluded rise to unacceptable levels, perhaps as a result of enhanced natural radionuclide concentrations at a particular location, then intervention may be appropriate. Action levels for intervention in the case of radon exposure are specified in the BSS.

3. Practices and Exemption

3.1 Exemption based on triviality of dose

Some practices cause greater exposures than others. Clearly, there is some point towards the lower end of the spectrum of doses caused by practices below which it makes no sense to apply regulatory requirements. The cost of regulation would exceed any benefit from a marginal reduction in doses. The point at which practices, or sources within practices, could be left outside the regulatory requirements, through 'exemption' corresponds to a level of radiation risk that is considered trivial.

Practices or sources within practices may be exempted from the requirements of the BSS with the exception of the requirement for 'Justification', provided the Regulatory Authority is satisfied that the practices or sources meet the principles and criteria for exemption specified in the BSS. Maintaining the requirement for 'Justification' is important; exemption should not be used to allow unwarranted or frivolous use of radionuclides. Furthermore, the fact that an exempt source or practice still has to be justified means that it is within regulatory purview. The exemption is from the procedural aspects of regulatory control.

The general principles for exemption provided by the BSS and based on the guidance of reference [3] are:

a) the radiation risks to individuals caused by the exempted practice or source be sufficiently low as to be of no regulatory concern;

b) the collective radiological impact of the exempted practice or source be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and

c) the exempted practices and sources be inherently safe with no appreciable likelihood of scenarios that could lead to a failure to meet the criteria in (a) and (b).

Taking the concept of trivial risk into account, the BSS further state that:

'A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations:

a) the effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of 10 microSv or less in a year; and

b) either the collective effective dose committed by one year of performance of the practice is no more than about 1 man.Sv or an assessment for the optimization of protection shows that exemption is the optimum option'.

The BSS includes in its Schedule 1, levels of activity and activity concentration such that sources at or below such levels - or practices using only such sources - can be granted exemption. These levels are termed exemption levels and are derived using the criteria described above.

3.2 Exemption based on optimization

In certain circumstances, other considerations could be taken into account in deciding whether to exempt a practice or source within a practice, such as whether any reasonable control procedures can achieve a significant improvement in radiation protection [4]. The fact that a practice fails to meet the criteria based on triviality of risk does not necessarily mean that all aspects of the regulatory system should be imposed. The Regulatory Authority may be satisfied that the general principles for exemption are satisfied and that exemption, or some measure of exemption, is the optimum regulatory option. The degree of imposition of regulatory requirements should be linked to the anticipated benefits in radiological protection terms. Thus, in cases where the Regulatory Authority is confident that radiation protection is optimized, including compliance with any relevant dose constraints, and that specific regulatory requirements would not achieve any improvement in protection, and that there is little likelihood that these circumstances could change, it could grant exemption from those requirements of the BSS.

4. Practices and Clearance

Sources, including substances, materials and objects, within notified or authorized practices may be released from further requirements of the BSS, subject to complying with clearance levels approved by the Regulatory Authority. A clearance level is a level of activity or activity concentration such that materials at or below such levels can be granted clearance. The clearance concept is different from the exemption concept, since the materials subject to clearance are already under regulatory control until the Regulatory Authority clears them. It is the responsibility of the Regulatory Authority to establish requirements for clearance and to verify compliance with the requirements.

Cleared sources and materials have no further regulatory controls applying to them; they are outside the regulatory system. Thus, the doses or risks associated with the subsequent use or disposal of the materials should be 'sufficiently low to be of no regulatory concern' which, in this context, should be taken to mean that they should be trivial. It follows that clearance levels should take account of the exemption criteria specified in the BSS.

In establishing requirements for clearance, the Regulatory Authority should not only take account of the exemption criteria specified in the Standards but also of the exemption levels specified in Schedule 1 of the BSS or as described by the Regulatory Authority on the basis of the criteria specified in Schedule 1. This latter requirement is intended to avoid situations where material is released from regulatory requirements at one point only to re-enter at another due to exemption levels being exceeded. The IAEA and CEC have proposed generic clearance levels [3, 5, 6].

5. Other Mechanisms for Release of Materials Containing Radionuclides

When dealing with release of radioactive materials, clearance is just one of the possibilities. Material may be discharged into the environment, within a management system which includes the concept of authorized release, or the material may be dealt with through the process of authorization for further use or recycling, or where no further use is foreseen, authorization for disposal. In these cases, the risk is not necessarily trivial, whereas the concept of clearance applies when the risk is trivial.

Radioactive wastes in liquid or gaseous form may be released to the environment through authorized discharge. While direct control over the discharged material is lost, the process of release to the environment is kept under regulatory control. Control is carried out at the point of discharge and surveillance may be performed in the environment depending upon the assessed level of risk. Under the terms of the authorization, conditions may be imposed on the form of the material, the rate at which it may be released, the ambient meteorological and environmental conditions required for discharge, and so on. For example, it may be possible to release liquid material to sewage or local waterways under controlled conditions of concentration and release rate; environmental monitoring can confirm that any possible radiological consequences continue to be acceptably small.

Regulatory control of materials intended for re-use or recycling, but which do not meet the criteria for clearance, may be relinquished when such use is authorized by the Regulatory Authority and when the authorized use has been verified. That is, control of material is retained until it has been established that it has been used for the purpose for which the authorization was given. For example, it may be acceptable to use overburden from a uranium mine as construction material for road foundations. The road builder would be required to give an undertaking that the material would be used only for the approved purpose, and could, in principle, be subject to regulatory control until the road has been constructed and the authorized use verified. It is implicit in the concept of authorized use that, in making a decision, the Regulatory Authority will take into account the likelihood and implications of other uses being made on the material in the future. An example of authorized recycling might be the release for sale, on decommissioning, of cleaned and re-usable components of a uranium mill to another industrial application, such as a non-uranium mineral extraction plant.

Authorized discharge and authorized use require the optimization of protection, subject to dose and risk constraints. They also require *a priori* assessment of the scenarios of exposure. They allow the *a posteriori* verification of these assessments.

The relationships between clearance, authorized discharge, authorized use and retention of regulatory control are illustrated in Figure 2.

6. Release of Sites and Buildings

Radioactive residues on land and buildings can be caused in several ways. They may be left behind following the decontamination and subsequent reclamation of sites that were used for practices. They can also be caused by the accumulation of residues due to the normal discharge of radioactive effluents from practices into the environment. Some sites and buildings are affected by residues because the requirements of the BSS for practices were not followed or, in the case of some historic sites, because such requirements were not in force at the time when the practice was terminated. They can also be the result of accidents, which caused the release of radioactive materials to the environment.

At the end of a practice involving the use of radioactive materials which has been subject to the requirements of regulatory control it is desirable to return the sites and buildings which were a part of the practice to a normal and unregulated state. If the site and buildings of a former practice can be shown to satisfy the annual dose constraint for all its future plausible uses the site may be released for unrestricted use. This is termed authorized release.

It is noted that the radiological considerations relevant to the situation described in the previous paragraph are different from those concerning the release of materials through clearance. In the case of the release of sites and buildings, the range possible future uses of the site and buildings and therefore the maximum possible radiation doses to people living and working there, is limited and can be fairly accurately predicted. The materials released from regulatory control means that they could be subsequently modified and used for a wide variety of purposes. Furthermore they could be transported beyond national boundaries where different regulatory regimes exist. For these reasons, their unrestricted release or clearance must be rigorously controlled by requiring that they be released in amounts that can only give rise to trivial risks.

In cases where, for radiological protection reasons, it is not feasible to release sites for unrestricted use, the site may still be released but only for restricted use. The restrictions on the use of the site, for example, a prescription of the types of use to which it may and may not be put, should be such that they provide reasonable assurance that the annual dose constraint will be satisfied.

Restricted use will usually involve some form of ongoing institutional control, for example, by the maintenance of a record of the status of the site in a land use registry and through periodic radiological monitoring at the site.

7. Application to Naturally Occurring Radioactive Materials

Exposures arising from "unmodified concentrations of radionuclides in most raw materials" can be excluded from the requirements of the BSS [1]. The interpretation of this requires further consideration. It presumably implies that exposures such as those received at home due to radon gas or due to external radiation from terrestrial sources can be excluded provided that the action levels for intervention mentioned in Section 2 are not exceeded.

Where such materials are being used as part of a practice which results in an increase in exposure to workers and, possibly, to the public, then arguably, they should be subject to the regulatory requirements governing practices. This is more clearly the case when the concentrations of naturally occurring radionuclides are enhanced by processing. Thus, it would seem that mining, processing and working with minerals containing naturally occurring radionuclides should be considered as practices. In principle, the concept of exemption is relevant in these situations but the activity concentrations of naturally occurring radionuclides corresponding to the trivial dose levels defined earlier (in Section 3) are usually too small a fraction of the activity concentration typically found in such practices to be of very much help.

Other regulatory alternatives are:

- to establish exemption levels based on other than trivial dose levels - but the rationale for this is not apparent.
- to allow exemption based on optimization considerations as outlined in Section 3.
- to regulate the practice, recognizing that there are different possible levels of regulatory action ranging from "light" regulation, involving only notification of the regulatory authority, to full regulation, where the practice is licensed with formal conditions being applied to control radiation risks.

Recommendations on the most appropriate regulatory policies for dealing with industries using materials containing naturally occurring radionuclides are one of the products expected from the ongoing discussions of international working groups.

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Figure 1 **Options for radiation source control**

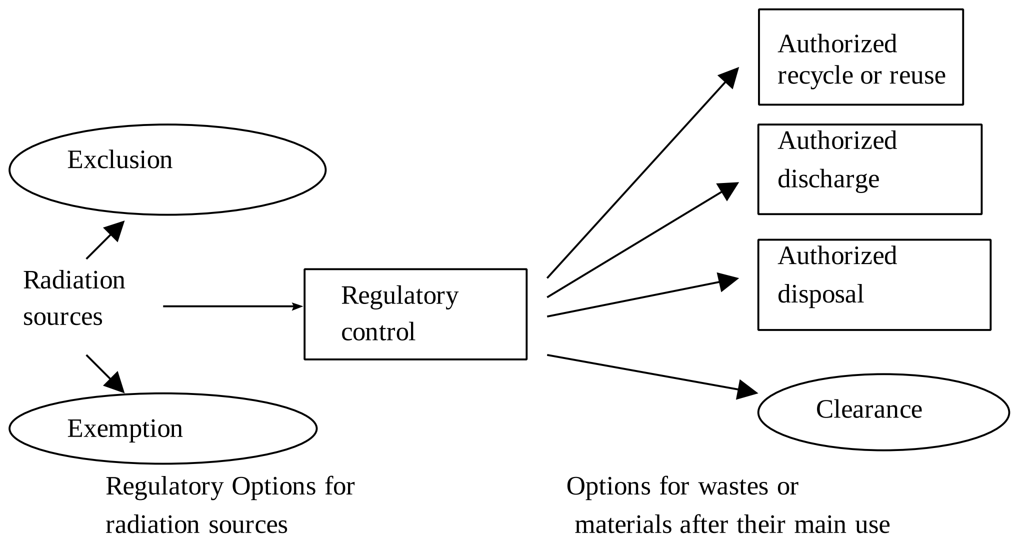
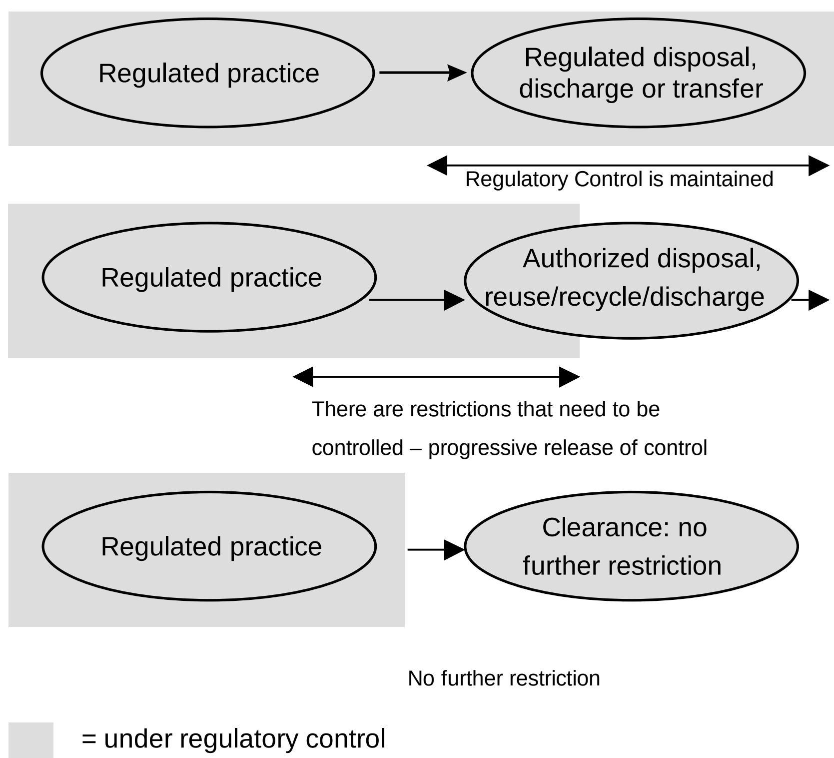


Figure 2 **Regulatory processes for dealing with relinquishment or transfer of regulatory responsibilities for radioactive materials.**



CONCEPTS OF EXEMPTION AND CLEARANCE IN THE EU BASIC SAFETY STANDARDS

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1. Introduction

The concepts of exemption and clearance have been introduced in the new Basic Safety Standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (Council Directive 96/29/EURATOM, adopted on 13 May 1996). In this way the new Basic Safety Standards provide a complete framework for the administrative requirements enabling an appropriate regulatory control of practices, commensurate to their radiological impact. Key features in this framework are the closely related concepts of exemption, clearance and exclusion. These concepts pertain to different ways of avoiding regulatory resources to be wasted to such practices for which there would be no or nothing but a trivial benefit. This paper focuses on the concepts of exemption and clearance, but in the context of exposure to natural radiation sources they will be discussed in relation to the concept of exclusion as well.

2. EU - Basic Safety Standards

2.1.1 Scope

The scope of the Basic Safety Standards is in principle not very different from the earlier Standards, but the wording has been structured so as to allow for the distinction introduced by ICRP (Publication 60) between practices and intervention situations. The concepts of *exemption* and *clearance* pertain to the regulatory control of practices. Materials contaminated as a result of past practices which for any reason have not been subject to regulatory control (e.g. military applications) or which have terminated as a result of an accident are subject to the basic requirements for *intervention.*

The Directive further introduces a third category: *work activities* involving the presence of natural radiation sources. In the ICRP recommendations such exposures are either regarded as an intervention situation (e.g. radon in dwellings) or as practices. The Directive considers this new area of radiation protection in its own right (see Chapter 4).

It is also within the context of natural radiation sources that the concept of exclusion is introduced: certain categories of exposure to natural radiation sources are not amenable to control: they have been excluded from the scope of the Directive and need not be accounted for in the total exposure for compliance with dose limits. Within a scheme for regulatory control of work activities decided upon by national authorities there may also be room for excluding (or not including) part of the exposure to natural radiation sources from the total exposure.

1 This paper reflects the views of the author and is not binding to the European Commission; reference is made to guidance from the Article 31 Group of Experts, part of which has not yet been formally approved by the Experts.

It will be discussed in further detail in chapter 4 in which way the BSS introduced regulatory control of work activities and to what extent also the explicit derogation from regulatory requirements (exemption or clearance) may be applied to work activities.

2.1.2 Administrative requirements for practices

2.1.2.1 Reporting and Prior Authorisation

The Directive requires Member States to establish a schedule for regulatory control of practices by competent authorities. All practices shall be reported by the undertaking, unless they are exempted from this requirement (Art. 3). Certain categories of practices are subject to prior authorisation by the competent authorities (Art. 4). The disposal, recycling or reuse of materials containing radioactive substances is explicitly subject to prior authorisation (Art. 5).

2.1.2.2 Exemption

No reporting need be required for practices involving radioactive substances at levels of activity or activity concentrations below nuclide specific *exemption values* listed in Annex 1 of the Directive. No reporting is required for apparatus satisfying certain criteria, inter alia for disposal. While there is a legal obligation to fulfil the specified conditions, the exemption of apparatus containing radioactive sources implies that their disposal is not subject to prior authorisation. Inversely, materials released to the environment (effluents, metal scrap, …) can give rise to contamination at activity concentrations above the exemption values. Provided this results from authorised waste disposal, recycling or reuse (Article 3.2.f) there is no need to report e.g. the holding or processing of such materials. Thus any inconsistencies between exemption values and clearance levels would not give rise to ambiguous or incoherent administrative requirements. Nevertheless one would in general expect clearance levels to be lower than or equal to exemption values.

Derivation of exemption values

The exemption values2 have been calculated for those radionuclides for which a possible use could reasonably be imagined and the likely physical form of the source or matrix could be established. The scenarios introduced to calculate annual individual exposure from exempted sources took into account normal use, misuse and disposal of the sources. In case of misuse the radiological criteria can be read either as a potential exposure of 10 µSv (1 mSv with a probability of exposure less than 1% per year), or as a "worst case" dose of 1mSv under very conservative assumptions. In addition to the dose criterion for effective dose a limiting equivalent dose to skin of 50 mSv has been introduced.

The scenarios considered only moderate amounts of material in case of exempt concentration values. They were not derived in view of the disposal of large amounts of waste material from nuclear industry nor of bulk materials in process industries with enhanced levels of naturally occurring

[2] Principles and Methods for establishing concentrations and quantities (exemption values) below which reporting is not required in the European Directive, Radiation Protection N° 65, 1993

radionuclides. Typical domestic or industrial applications are smoke detectors, surface density gauges, leak testers, tracers in biochemical research, etc.

Annex 1 of the Directive gives, in addition to the list of exemption values, the basic criteria for exemption. This allows Member States to define in exceptional circumstances specific exemption values different from the generic values. One can conceive situations where certain exposure pathways (e.g. ingestion) are more important than was considered in the generic approach. There may also be a need for lower specific exemption values pertaining to large amounts of materials, specific to a type of practice.

2.1.2.3 Prior Authorisation

Prior authorisation is required for a number of categories of practices, in particular for the entire nuclear fuel cycle. In general authorisation or permission is granted by the competent authority on individual application (Art. 1). The very general wording of some of the categories would include practices of minor importance (e.g. dental X-ray sets) for which it might be preferable to grant general authorisation subject to conditions laid down in national legislation rather than upon individual application. Thus in Article 4.3 of the Directive, exemption from prior authorisation also applies to cases where "a limited risk of exposure does not necessitate the examination of individual cases…".

Exemption from reporting does not imply exemption from prior authorisation in case of deliberate direct or indirect administration of radioactive substances to persons (Art. 4.1.bd). Exemption from reporting within the nuclear fuel cycle is in practice not applicable. Exemption values may apply to the production of consumer products3 to the extent they would not be exceeded in the course of the fabrication process. It is worth noting however that this does not extend to applications which are explicitly forbidden on grounds of insufficient justification (e.g. in toys, see Art. 6.5).

2.1.2.4 Disposal, recycling and reuse

The definition of *disposal* refers both to the emplacement of (solid) wastes in a disposal site, and dispersion in the environment in a more general sense (see also Article 37 of the EURATOM Treaty). Article 5 of the Directive states that disposal (in whatever form) is subject to prior authorisation. The recycling or reuse of materials is also subject to authorisation. Competent authorities may, however, establish *clearance levels* below which the disposal, recycling or reuse of materials is released from the requirements of the Directive. While clearance levels may very well be defined generically, the application of clearance levels is an individual decision of the competent authorities on the basis of a case-by-case evaluation of the practice which gives rise to the contaminated or activated material. The undertaking can *judge* whether clearance levels apply to any of their waste streams and submit an application to the authorities, but it is for the authorities to *decide*. This is the fundamental difference between exemption values and clearance levels. The receiver/holder of radioactive substances must be in a position to *decide* unambiguously whether he should notify his practice to the authorities by looking into

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[3] Directive 96/29/EURATOM does not define consumer *goods*; in the IA-BSS consumer *products* are defined to include devices such as a smoke detector, luminous dial or ion generating tube that contains a small amount of radioactive substance. This definition does not restric the concept to goods for private use only.

the exemption rules. In case of possible clearance, the practice is already reported and subject to regulatory control.

2.1.2.5 *Exemption and Clearance Criteria*

Article 5.2 specifies that clearance levels should be established while taking into account the basic criteria for exemption spelled out in Annex 1. These are essentially the same as in the IA-BSS (taken over from Safety Series 89, 1988). The basic criteria are presumed to be fulfilled without further consideration if the effective dose to be incurred by any individual member of the public is of the order of 10 µSv (or less) in a year and the collective dose committed during one year is no more than about 1 man Sv.

Satisfying the above criteria implies exemption without further consideration. It is nevertheless in principle permitted to release materials not complying with these numerical criteria. With regard to collective dose clearance is also possible if an assessment of optimisation of protection shows that exemption (clearance) is the optimum option (e.g. in case of a high administrative burden for a small benefit of maintaining regulatory control). The basic criteria allow to extend the criterion in terms of individual dose to levels higher than 10 µSv. Note that the original guidance (Safety Series 89) considered doses of a few tens of µSv to be trivial, rounding down to 10 µSv was merely convenient, also with regard to possible exposure from more than one exempted source.

The non-numerical basic criteria may allow even greater flexibility for the release of materials from regulatory control, as long as the radiological consequences are acceptable. This however would normally require a thorough case-specific examination.

3. Recycling of materials from the dismanthg of nuclear installations

Article 5.2 not only refers to the basic criteria used in Annex 1 but also requires national competent authorities to take into account, when establishing clearance levels, technical guidance provided by the European Atomic Energy Community. So far guidance for the dismantling of nuclear installations has been provided by the Article 31 Group of Experts under the EURATOM Treaty. Guidance on the recycling or reuse of metals has been published4, guidance on buildings and building rubble is in preparation.

The guidance pertains to the general recycling of materials (metals and building rubble) or their unrestricted reuse (metal tools, buildings). It is noted that other options exist, such as recycling within nuclear industry (e.g. in waste containers) or under continued regulatory control in view of specific non-nuclear applications. Building rubble from nuclear installations could also be used e.g. for backfilling of underground mines. Such options can be considered in accordance with national regulations and after a specific radiological impact study. Options involving this type of disposal or recycling are, however, not dealt with in the recommendation of the Article 31 Experts.

4 Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations, Radiation Protection N° 89, 1998

The term *clearance* is thus reserved for release of material which does not require further regulatory control to ensure the actual destination of the material. *Specific clearance levels* are introduced for specific *conditions* which can be verified *prior to release*.

The fact that guidance on clearance levels is made available to Member States does not constitute an obligation to use the clearance option. National authorities may wish to keep some form of regulatory control or traceability after release. It is nevertheless considered good practice to recycle all suitable materials rather than dispose of them, in order to save energy and raw materials (see foreword to Radiation Protection N° 89).

3.1 Traceability

In addition to the option to release materials below general clearance levels specific levels for specific management options may be defined.

The essential feature of this option is not to trace the material wherever it goes but to clear it for a particular use or destination without further follow-up. Thus the concept of specific clearance levels applies to a release from the regulatory regime where only the first step of the cleared material is controlled in order to ensure that it follows the prescribed scenario. The regulatory control does not extend beyond this because the need for further control would contradict the concept of clearance (= release from regulatory requirements). The traceability is thus limited to this first step e. g. disposing of material at a landfill, mixing fly ash into concrete under certain conditions or preparing, the material in such a way that only a specific use is possible (e.g. cutting metal items in pieces so that they can only be recycled as scrap and not be reused).

Specific clearance pathways should be approved by the regulatory authorities before being carrying out. The procedure should include a clear description both of the technical constraints and of the means to ensure traceability.

In particular, it should be strictly forbidden to carry out *deliberate* dilution in order to meet the clearance criteria. Such an operation should be considered as a fraudulent action. This is a sensitive problem. Authorities should implement appropriate means of regulatory control to master it. On the other hand, in a number of cases dilution with approval of the authorities may have benefits when considering objectively the various alternatives for the management of residual radioactive materials.

For materials or residues above the general clearance levels, there are four alternatives:

- the material may be stored in specialised, dedicated centres; this applies especially to waste disposal;

- it may be decontaminated until reaching the general or specific clearance levels; this applies especially to recyclable materials;

- it may enter specific, controlled processes or pathways for which a demonstration through scenarii of exposure has proven that the dosimetric impact is acceptable from the health point of view even for residual radioactivity above the general clearance levels; traceability through control at the point of release is required for release below specific clearance levels;

- traceability can in principle be extended to the final destination e.g. for recycling metals in non-nuclear domains (railway tracks, …). In such cases it is important that the receiver (railway company, …) can keep control of the material so as to ensure that at secondary recycling there is no problem. In general, it will be very difficult to demonstrate protracted traceability.

The considerations above are focused on radiation protection. In the case of very low level radioactive materials, it is obvious that health aspects other than radiation may be prominent, like chemical toxicity (industrial waste) or infectious risk (medical waste). Management of the materials should comply with the specific, relevant regulations. Chemical or infectious risk may indeed be well above the radiological risk.

3.2 Community guidance on specific clearance

3.2.1 Methodology

While referring to the guidance offered in Safety Series 89, ICRP points to the difficulty that exemption (or clearance) is a source-related issue while the triviality of dose is related to an individual (ICRP-publication 60, par. 288). The activity content of the metals should thus be related to an individual dose by constructing a set of exposure scenarios.

In the case of *metals* the scenarios took into account the entire sequence of scrap processing, starting with transport and handling of the scrap metal up to exposure from consumer goods made of recycled metal. The different steps in the metal processing have been considered in the greatest possible detail. The exposed population consists essentially of workers employed in the scrapyard, smelter or refinery, or manufacturing industry. Workers are exposed to external radiation essentially from the scrap heap, to inhalation of resuspended dust upon handling and cutting of the scrap or of the fumes in the foundry. Secondary ingestion through hand contamination is allowed for as well as external beta ray exposure of the skin. Workers are also exposed as a result of the disposal of slags and dust on landfill. These by-products can be enriched in their radioactivity content as a result of element-specific distribution among fumes, slags and metal. Members of the public may be exposed to external radiation from gamma-emitting radionuclides that are retained in the final product. Slags and dust may also be recycled leading to public exposure e.g. by resuspension.

In the case of *buildings* the exposure scenarios relate to the reuse of the building for non-nuclear industrial or other occupation. In the case of building rubble, in addition to disposal on a landfill, many recycling options are available. Generally the rubble must first be processed (including crushing) and then sorted according to grain sizes depending on the later use. The material can be used in civil engineering for road construction or as an additive for manufacturing of new concrete. Rubble can also be used in foundations, to backfill holes or in recultivation and landscaping projects for which the rubble does not necessarily need to be processed.

3.2.2 *Dose Calculations*

The entire sequence of calculations proceeds along the following lines:

- choice of scenarios
- pathways of exposure
- choice of parameters
- calculation of individual doses per unit activity concentration (per unit surface concentration for direct reuse)
- identification of the limiting scenario and pathway
- reciprocal individual doses yield activity concentrations corresponding to 10 µSv, rounded to a power of ten.

The rounding[5] to powers of ten is consistent with the approach followed for the exemption levels. It implies that in reality the individual doses are not exactly 10 µSv but can in theory be up to 33 µSv. The rounding factors were examined so as not to be too large for the most important radionuclides. For a few radionuclides it was judged inappropriate to round down to 0.1 Bq/g, the doses corresponding to 1 Bq/g being judged acceptable.

In nearly all practical cases more than one radionuclide is involved. To determine if a mixture of radionuclides is below the clearance level a simple summation formula can be used:

$$\sum_{i=1}^{n} \frac{c_i}{c_{Li}} < 1.0$$

where

c_I	is the level of activity of radionuclide *I* in the structure,
c_{Li}	is the clearance level of radionuclide *I*,
n	is the number of radionuclides in the mixture.

It is worth noting that the sum-rule is conservative since the pathways of exposure or the reference group of exposed individuals is not necessarily the same. In many cases it will be useful to identify a measurable indicator nuclide within the spectrum and apply correspondingly a sum-index as defined above to the clearance level for that nuclide.

Collective doses have been estimated both on the basis of individual doses and the number of people exposed and on the basis of generic exposure scenarios assuming widespread dispersion still correlated with human occupation. In case of metals, multiple recycling was allowed for. For some radionuclides the collective dose at the clearance level is close to 1 man Sv, but for a realistic radionuclide distribution the overall impact is well below this criterion. Moreover it is considered that, in the light of

5 If the calculated value lies between 3 10X and 3 10X+1, the rounded value is 10X+1.

the benefit of recycling both in economic and ecological terms over landfill disposal, there is no doubt as to whether recycling is a sound option.

Thus in practice only the individual dose criteria (10 µSv effective dose, in a few cases 50 mSv skin dose) are of importance for the establishment of the clearance levels.

3.2.3 Application

It is the responsibility of the competent authorities to lay down the conditions in which clearance levels can be used. The authorisation of dismantling operations will pertain to the entire sequence of operations, from the characterisation and segregation of the material up to the amounts that can be cleared at certain levels. The Article 31 Experts have in particular recommended the following:

For metals:

Mass and surface specific clearance levels have been defined for recycling. The total activity is averaged over a few 100 kg (100 cm2) and the surface and mass criteria apply together, surface activity including fixed and non-fixed activity.

Release for direct reuse requires a conservative assessment of surface contamination in case of non-accessible surfaces. Allowance shall be made for alpha-beta activity under paint or rust. Clearance levels for reuse are in general lower than for recycling, thus reusable parts must be cut in pieces before recycling clearance levels can be applied. No mass specific activities for reuse are given. Activated materials can be accounted as if it were surface activity.

For buildings and building rubble:

Three main situations are considered:

- clearance of buildings for any purpose (reuse or demolition);
- clearance of buildings for demolition only;
- clearance of building rubble.

Clearance Criteria for the Reuse or Demolition of Buildings

The recommended clearance levels pertain to the total activity in the structure per unit surface area. After clearance the building can be used for non-nuclear purposes or demolished.

The surface specific clearance levels apply to the total activity on the surface to be measured divided by its area. The total activity is the sum of the fixed and non-fixed activity on the surface plus the activity which has penetrated into the bulk. The surface area over which averaging is allowed should in general not exceed 1 m^2.

Clearance of Buildings for Demolition Only

Buildings at a decommissioned nuclear site will often be demolished and the resulting rubble either recycled or conventionally disposed of. Either the standing structure of the buildings to be demolished can be cleared or the building rubble resulting from the demolition can be cleared using mass specific clearance criteria. Clearing the standing structure ensures that high level surface contamination is not mixed with the uncontaminated interior of the building structure. The clearance levels are expressed as total activity in the structure per unit surface area in the same way as above but in general at higher levels.

Clearance Criteria for Building Rubble

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

The mass over which averaging is allowed should in general not exceed 1 Mg.

The mass specific clearance levels are valid for any quantity of rubble, typically on the order of one nuclear power plant. For quantities of rubble not exceeding about 100 Mg/a from one site the authorities may want to relax the clearance levels. For such quantities mass specific clearance levels could be up to a factor 10 higher.

4. Naturally occurring radionuclides

4.1 Provisions on natural radiation sources in the Basic Safety Standards

With regard to natural radiation sources within the scope of the Directive a distinction is made between:

1. Utilisation of natural radionuclides which are or have been processed in view of their radioactive, fissile or fertile properties. Such cases are considered *practices* and all the provisions of the Directive on practices apply.

2. *Work activities* where the presence of natural radiation sources leads to a significant increase in the exposure of workers or members of the public. The Directive applies to these work activities in accordance with Title VII.

The Directive does not apply to exposure to radon in dwellings or to natural levels of radiation, i.e. to radionuclides contained in the human body, to cosmic radiation prevailing at ground level or to above ground exposure to radionuclides present in the earth's crust. For the sake of clarity it is preferable to use the concept of exclusion only for exposures which are unamenable[6] to control.

[6] IAEA gives consideration to the extension of the concept of *exclusion* to include not only exposures which are essentially unamenable to control but also types of practices (work activities) for which the regulatory authority considers that controls are not justified by the possible reduction of exposure.

The provisions on work activities involving exposures to natural radiation sources are given in Title VII of the Directive. Articles 40 and 41 establish a stepwise system in which the Member States are required 1) to identify, by means of surveys or by any other appropriate means, work activities which may be of concern, 2) to set up appropriate means for monitoring exposure in the identified work activities and as necessary 3) to apply all or part of the system of radiological protection for practices or interventions, as prescribed elsewhere in the Directive. "All or part" is underlined because in principle it allows to skip certain requirements (e.g. the requirement of reporting and correspondingly exemption values.

Some generally utilised raw materials contain elevated levels of natural radionuclides. Raw phosphates and zircon sands are good examples. Such materials are not generally regarded as radioactive but in some circumstances operations with them may cause significant exposure to the workers or the members of the public. Surveys will thus pertain to the characteristics of industries processing materials with (enhanced levels of) naturally occurring radionuclides (NORM).

The approach of Title VII is rather general offering flexibility for the Member States to take into account national circumstances. It would, however, be advantageous if Member States would adopt similar approaches in identifying the relevant work activities, in taking corrective measures and in applying the system of radiological protection in occupational and in public exposure. The Group of Experts referred to in the Article 31 of the Euratom Treaty has provided technical guidance[7] on the implementation of Title VII (not only for NORM but also for radon in workplaces and for aircrew).

4.2 Industries processing NORM

The significant pathways may be external gamma radiation, inhalation of dust or sometimes radon if important masses of materials containing radionuclides of the uranium series are handled indoors. Radionuclides may concentrate significantly in some process phases, also within industries where the raw materials contain only small amounts of natural radionuclides. Examples of such cases are precipitation of radium in pipes in oil and gas industry or volatilisation of 210Po and 210Pb in some thermal processes and accumulation of these nuclides into stack filters. Cleaning operations may cause significant exposure to the workers and the disposal of the generated waste (including liquid and airborne effluents) may also lead to significant exposure of members of the public. Residues of some industries may also contain enhanced levels of radionuclides. Disposal or reuse of such materials may be significant especially with regard to public exposure. Certain work activities generate large amounts of slurries which are discharged in a river or in the sea. Dust or volatile particles are discharged through the stack. Regulatory authorities may decide whether such effluents need to be controlled and monitored and apply appropriate dose constraints for exposure of members of the public. Residues may be recycled e.g. in building materials (fly-ash in cement, …) and thus be cause of exposure, which however needs to be put in the overall context of exposure from building materials. Scales deposited on steel pipes are a possible source of exposure upon recycling of the metal.

[7] Recommendations for the implementation of Title VII of the European Basic Safety Standards Directive concerning significant increase of exposure due to natural radiation sources (Radiation Protection 88, 1977), guidance on Reference Levels to be published as RP 95, technical support document as RP 107

4.3 Implementation of a system of protection

Depending on the nature of the work activity and the monitoring results it shall be required, as necessary, to apply all or part of the system of radiological protection for interventions or for practices. In this chapter an overview is given of available guidance[8] from the Article 31 Group of Experts in order to put the concepts of exemption and clearance in perspective to the overall scheme of regulatory control.

Action Levels and Reference Levels

Radon

It is assumed on the basis of the conventional dose conversion factor proposed by ICRP (Publication 65), and for standard exposure conditions, that 100 Bq/m3 at a work place causes an annual effective dose of about 0.6 mSv. It is recommended that, within the European Union, the Action Level for places of work should be set in the range 500-1000 Bq m-3 time-averaged radon gas concentration, equivalent to an effective dose range of 3 to 6 mSv. Occupational exposures to radon above the Action Level will be subject to regulatory control, and exposure from radon should be included in the overall exposure (from work with NORM materials or with artificial nuclides) e.g. for compliance with the dose limits.

Naturally occurring radionuclides

Control of Exposure of Workers

The important routes of exposure of workers from the processes involving naturally occurring radionuclides are normally external gammas and inhalation of dust. The appropriate control measures may include limitation of exposure time, special arrangements for the storage of bulk material and dust control.

Normal common-sense precautions should be taken to avoid all unnecessary exposures to radiation. Beyond this, assessments should be made to estimate the doses to workers from such natural radionuclides. If the doses are less than 1 mSv per year then no special precautions are required. If annual doses exceed 1 mSv then the normal scheme for controlling exposures can usually be applied. If doses exceed 6 mSv then it may, in rare cases, be appropriate to define a controlled area.

If doses exceed 1 mSv in normal conditions but are less than 6 mSv it would be appropriate to consider, for example, whether doses could effectively be reduced and whether there is a possibility that doses increase either over time or as the result of an accident. If doses are low and cannot effectively be reduced and if there is no realistic potential for accidents then few radiation protection measures are likely to be required beyond whatever is necessary to ensure that doses do not increase.

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[8] Extracted from Radiation Protection 88.

Control of Exposure of the Public

The practical protection of members of the public can be dealt with as in Title VIII or part of it. Article 47 stipulates that the undertaking responsible for a practice shall achieve and maintain an optimal level of protection for the environment and the population.

The general understanding is that the *enhanced* exposure from work activities should comply with the dose limits for members of the public. There is however presently no consensus among Member States as to the appropriate *dose constraint* for natural sources.

Reference Levels of Activity Concentrations

The Commission launched a study on the "Establishment of reference levels for regulatory control of workplaces where materials are processed which contain enhanced levels of naturally occurring radionuclides". *Reference levels* allow the identification of those industries for which workers exposure should require regulatory control. They are specified in terms of activity concentrations. The exposure scenarios are based on a review of relevant industries within the EU and consider both prudently realistic and unlikely situations.

This study was limited to the exposure of workers. The exposure of members of the public and the corresponding control of radioactive effluents and management of radioactive waste cannot easily be dealt with merely on the basis of activity concentrations.

4.4 Exemption and clearance

The schedule of administrative requirements of reporting and prior authorisation, part of Title III, may in certain cases be found useful. The exemption values referred to in Article 3 of the Basic Safety Standards are applicable to naturally occurring radionuclides only to the extent that the sources would have been processed in view of their radioactive, fissile or fertile properties.

The main distinction between the regulatory control of work activities and of practices is that the former normally operate under specific, non-nuclear, licences and are identified by the authorities on the basis of surveys where appropriate on the basis of reference levels, while for the latter it is the responsibility of the undertaking to notify the holding of a radioactive sources and the planned practice to the authorities. Hence there should be no need for *exemption values* for naturally occurring radionuclides as part of a work activity. In some cases where residues with enhanced levels of radioactivity need to be disposed of or where they can be recycled, there may be a need for *clearance levels*, applicable to work activities under regulatory control.

In general it is considered more appropriate to define right away the full range of specific regulatory control measures, including the release of residues. Clearance levels are in any way not applicable to work activities which have not (yet) been identified. Where clearance levels are applied the released material could enter another potential work activity. If the latter is subject to exemption values, these should logically not differ from the clearance levels. Thus for work activities the concepts of exemption and clearance seem to merge and where appropriate the same levels should be introduced.

The definition of exemption values and clearance levels cannot proceed on the basis of the trivial risk criteria established in Annex I of the Basic Safety Standards. Individual exposures will in general be much higher than 10 µSv and collective doses can be very important. The authorities may nevertheless judge that the general criteria for exemption are satisfied. This can be sustained because work activities intrinsically cannot give rise to extremely high exposures. Even elevated concentrations of natural radioactivity are low by comparison to most artificial sources (potential exposures are correspondingly low). In addition, while for practices it is not considered good practice to mix or dilute contaminated materials, for naturally occurring radionuclides one can argue that dilution is nothing more than re-establishing the original natural concentration of the ore. There are thus many arguments for exemption-clearance dose criteria for naturally occurring radionuclides to be at a higher level than for practices. A dose criterion of 300 µSv is often considered but there is currently no firm guidance to that effect.

The more relaxed regulatory approach for work activities has been said to be incoherent with the strict control of practices. This apparent incoherence arises merely from the fact that the socio-political constraints require the release from regulatory control of artificial sources to yield nothing but negligible exposures. Releases under regulatory control at higher levels are in principle possible but this would be at the expense of a considerable cost of ensuring long-term traceability and reassurance by environmental monitoring.

5. Exemption values for the trade ofmetal scrap

5.1 Import of metal scrap

The EU recommendations on clearance levels for metal scrap did not consider the question of scrap imported into the EU from outside sources.

Under the BSS, the import of scrap metal[9] is a practice subject to the requirement of reporting, unless this practice is exempted. The exemption values (Annex 1) are currently the only basis for exemption. These are in general a factor 10 higher than the corresponding clearance levels. For moderate amounts of imported scrap processed by the same foundry there is no radiological problem, but industry would not understand being subject to more severe restrictions for scrap arising from the dismantling of European nuclear installations.

Member States may require reporting of import of metal scrap or establish as foreseen in Art.3.2b "in exceptional circumstances, different (exemption) values authorised by the competent authorities".

The clearance levels have been calculated on the assumption that 10,000 tonnes is the maximum amount of scrap to be recycled in one year. For the sake of simplicity it is recommended to make the same assumptions on the amount of material imported as for the clearance of metals and to presume that European and imported metal are not processed in the same foundry. Thus the *specific exemption values* for import of metal scrap should be identical to the recommended clearance levels. The assumption on the amounts of imported contaminated metal scrap needs to be kept under review however.

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9 Since scrap metal is not waste material it is debatable whether Directive 92/3/Euratom or 93/1493/Euratom applies

Upon receipt of metal for recycling it will often not be possible to establish whether the origin of the material is a work activity rather than e.g. uranium mining (even though one can in principle discriminate between natural and enriched uranium). Thus for naturally occurring radionuclides the specific exemption values ought to be set equal to the clearance levels for work activities.

5.2 Gate monitoring

Specific exemption values for the import and trade of metal scrap within the EU are helpful in defining regulatory responsibilities. In practice, the control of radioactivity is carried out by gate monitoring (dose rate).

A conveyance of scrap metal at the clearance level (or specific exemption value) for gamma-emitting radionuclides would probably trigger the monitors installed for protecting the metal industry against inadvertent receipt of an orphan source (at the border or at the metal works). In reality it is unlikely that the whole conveyance is contaminated. At levels about a factor 10 lower (cf. The German SSK Recommendation) the alarm should not be triggered. It would not seem appropriate however to constrain clearance levels by the detection level of gate monitors. Inversely, one could recommend a lower limit of detection at a dose rate corresponding to a typical mix of gamma emitting radionuclides at, say, one tenth of the clearance levels.

In such cases where gate monitors are still triggered by cleared metals it is impossible for the undertaking to decide whether or not there is a hidden orphan source. Only if the conveyance is documented so as to identify its origin and content can the undertaking decide to take the metal. In general this presumes that there is a contractual relationship between the dismantler of a nuclear installation, scrap dealer and smelter.

Such contractual relationship may be required by the regulatory authority as part of the conditions to be fulfilled *before* clearance is granted. If the dismantler keeps documents on the destination of the material this allows the authorities to ensure traceability wherever this would be required.

In the same way as for artificial radionuclides, NORM-contaminated metal[10] triggers gate alarms. Documentary evidence of the origin of the material should allow such alarms to be resolved.

6. Impact of decommissioning on other Member States

The Euratom Treaty has established a specific procedure for the examination whether a plan for the disposal of radioactive waste is liable to affect another Member State. Under Article 37 of the Treaty Member States provide general data pertaining to such plans and the Commission gives an opinion (published in the Official Journal) within six months.

The concept of "disposal of radioactive waste" is not straightforward. It pertains to waste "in whatever form", and this is understood to include solid wastes in addition to airborne or liquid effluents. Also the concept of "liable to result in the radioactive contamination of the water, soil or airspace of

[10] It can be argued that since the radioactivity content of metals is in general very low this justifies a lower dose criterion than for other work activities. On the other hand upon recycling naturally occurring radionuclides will essentially be distributed to dusts and slags, not to the metal product.

another Member State" is difficult to translate in technical terms. In order to harmonise the implementation different Commission Recommendations have been issued over the years.

Recommendation 91/4/EURATOM, currently in force, is in need of revision for a variety of reasons, one of which is the application to the dismantling of nuclear installations. So far general data were required upon reaching stage III of dismantling as defined by IAEA. A new Recommendation is in course of adoption. It will require the dismantling of nuclear reactors and reprocessing plants to be submitted six months before any corresponding new authorisation for the disposal of radioactive waste is granted. The underlying idea is that new types of waste will be generated at some stage of dismantling and require a new authorisation.

Among the "new types of waste" are the contaminated materials to be released from the requirements of the Basic Safety Standards, for disposal, recycling or reuse. The general data request information on criteria for release, in particular clearance levels established by competent authorities and on envisaged types and amounts of released materials.

The examination of general data for dismantling operations will thus allow the Commission to judge whether e.g. the clearance for recycling in one Member State is liable to affect another Member State. Thus, should it occur that clearance criteria are applied inadequately, the Commission has a means to recommend a more appropriate approach.

7. Prospects

The new Basic Safety Standards need to be implemented by May 2000 in national legislation and regulatory practice. The European Commission can, to some extent, help with the practical interpretation of the Directive and facilitate a harmonised implementation without, however, altering the meaning of the requirements of the Standards, reducing the flexibility left to Member States, nor infringing by any means on the responsibility of Member States to ensure compliance with the Standards.

Community guidance has been produced for the application of the clearance concept for the reuse, recycling or disposal of materials arising from the dismantling of nuclear installations (metals, buildings and building rubble). It is at this stage not envisaged to produce similar guidance for the application of the concept to other installations (accelerator buildings, medical waste). Clearance for disposal has been looked into only for building rubble. Landfill disposal in general is considered to be a matter of national competence rather than an issue for the Community (even though transboundary movements of waste may need to be taken into consideration).

The clearance of metal scrap on the other hand has definitely a transboundary impact and harmonisation of the clearance levels would be highly desirable. This can be achieved within the current Directive only by voluntary co-operation between Member States. The Commission can take further regulatory initiatives, e.g. propose specific exemption values for the placing on the market of metal scrap. Monitoring at the borders of the EU may be encouraged. Minimum detectable dose rates for this purpose can be derived from the specific exemption values.

Member States may also find it useful to define general clearance levels for any possible application. Such a lower boundary to materials under regulatory control would again usefully be established at Community level. While, in the absence of further Community initiatives, it is up to Member States to introduce such general levels, this would not seem contrary to existing Community guidance provided any such levels are lower than, or equal to, all specific clearance levels and provided the conditions for application are complied with.

International harmonisation of clearance levels, in particular for general clearance, is an issue of great importance.

Within the EU, while setting clearance levels is a matter of national competent authorities, Community guidance needs to be taken into account. In addition, the examination of plans for the disposal of radioactive waste from dismantling operations will ensure a harmonised approach to the implementation of clearance criteria.

REGULATION OF NATURALLY OCCURRING RADIOACTIVE MATERIALS

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Abstract

There are numerous instances where the level of naturally occurring radioactive material (NORM) in commercial and industrial products has the potential to expose members of the general population to a significant fraction of the recommended annual radiation exposure limit. Additionally, there are waste piles, ponds, etc., of NORM that on a risk basis exceed that risk criterion which is used for decommissioning and remediation of radioactive material from the nuclear industry. The regulation of NORM varies from country to country and even between industries in the same country. In the United States regulations vary between individual states. The magnitude of the problem posed by NORM is presented along with dose and risk estimates by industry. Suggested exemption, exclusion and clearance criterion are presented.

MANAGEMENT OPTIONS FOR VERY-LOW-LEVEL WASTE FROM DECOMMISSIONING OF NUCLEAR INSTALLATIONS

Spanish Regulator's Viewpoint

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1. Introduction

The decommissioning of Nuclear Installations will produce various amounts of radioactive wastes with different activity levels. In many cases, these residues have a very low level of activity, as a result of which they may be disposed of, as normal wastes, using conventional methods, or be reused outside of the regulated sector.

Regulation on how to deal with such wastes will have to be enacted, including a threshold for unconditional release and the requirement that the way in which materials subject to authorised releases have been recycled or reused, and how very low level wastes have been disposed of, be traceable.

It is said that exemptions are established to avoid the application of excessive regulatory procedures to clearly justified practices, in order to save regulatory effort, but probably the relief of the burden on operators is more important. In any case, the logical objective of any risk management decision is the best allocation of limited resources in order to maximise social benefits and this is the context in which an exemption or clearance policy has to be analysed.

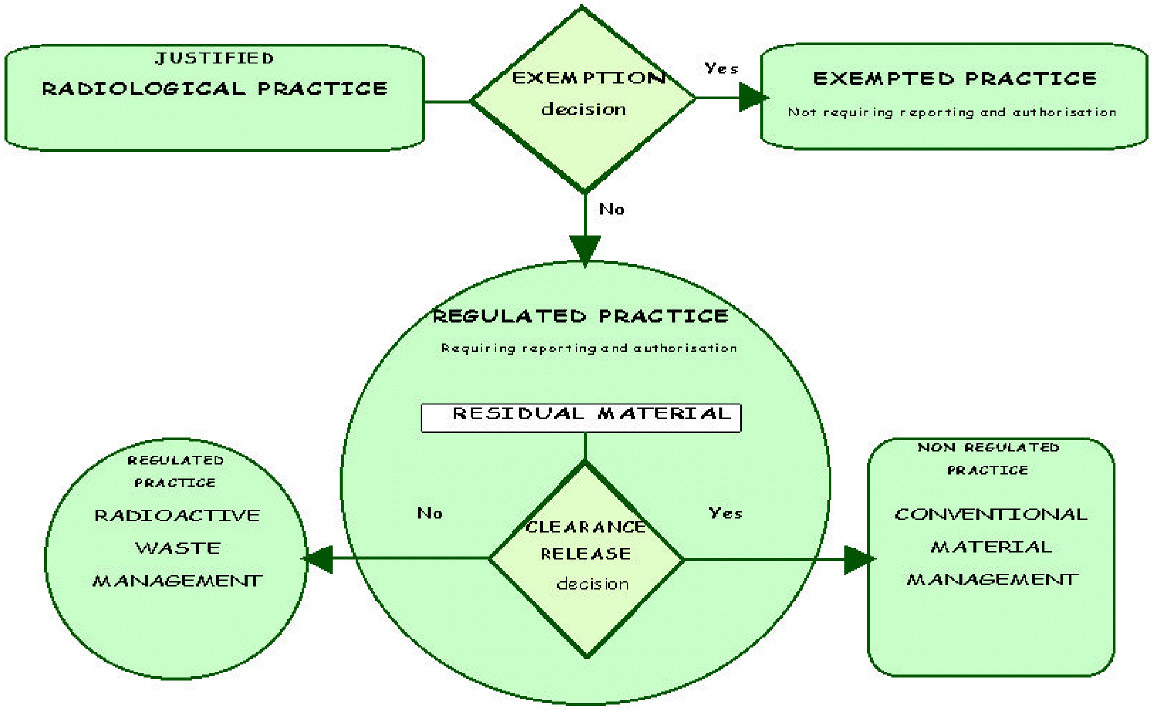
Authorisation for the release or clearance from regulatory control of these materials is the responsibility of the competent national authority and, in the case of Spain, is carried out by the Nuclear Safety Council on the basis of "ad hoc" case by case decisions.

The main aim of this paper is to present the management options for very low level waste materials being considered in the case of the Closure and Dismantling Plan Authorisation granted for the Vandellós 1 Nuclear Power Plant decommissioning project.

2. Waste Materials Candidates for Release

We refer to solid wastes with very low levels of activity or contamination, generated as part of a regulated practice, which are candidates for management in a conventional and non-regulated manner, differently from the established practice applied to the management of radioactive waste (fig 1).

Figure 1



Not only economic factors, but also reasons relating to the saving of resources, drive the search for these alternative management methods for such very low level contaminated materials.

The recycling and reuse of materials offer the potential to extend the life of valuable natural reserves, pollution can be reduced and recycling often results in a net energy saving. The economic benefit of recycling might also be considered in the case of recovering valuable material.

Of greater value are the potential savings to be achieved in the cost of conditioning, packaging, storage, transport and disposal of very large quantities of "nominally" active materials, considering the volume reduction of the waste streams to be disposed of in a regulated low level waste repository.

To make this full or partial release from regulatory control possible, it is necessary to establish conditions for these materials to be managed during their later reuse or final disposal.

The analysis required in order to assure the proper radiological protection of society may well be done in the context of the International Commission of Radiological Protection (ICRP) system of dose limitation, although, in practice, a simplified procedure based on the triviality of individual and collective risk is used.

3. Radiation Protection Analysis

A decision on the radiological justification principle derives from considerations that are much broader than those based on radiation protection alone. But if a new practice, with authorised solid waste release, is introduced in substitution for another previously justified, practice, as might be the case, the resource saving of relinquishing control of a particular residual material, in comparison with its management as radioactive waste, will need to be taken into account as an important part of the decision making process.,

It may be easily demonstrated that this new practice would be justified, as long as the net benefit of the replaced practice plus the saving in protection measures (including radioactive waste management of the material) is large enough to compensate for the cost of the supplementary radiological detriment, if the profits and costs of both practices are equal.

Any free release of solid material to the environment has to demonstrate that the radiological detriment it causes is as low as reasonably achievable. We find here, as a particular case of the optimisation process, the so-called “general protection principles for exemption”:

- Radiological risk to the individuals caused by the cleared material must be sufficiently low (as not to be of any further regulatory concern).

- The exempted sources must be inherently safe, with a very low likelihood of scenarios that might lead to failure to meet the criteria previously mentioned.

- The collective radiological impact of the clearance policy must be sufficiently low (as not to warrant regulatory control under the prevailing circumstances).

If the justification and optimisation of protection have been conducted effectively, the next step will simply be to corroborate that the individual-related dose limits for members of the public are being accomplished to prevent unacceptable individual detriment:

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

It is necessary to keep in mind that benefits and detriment are not equally distributed through society and that there is always the possibility of cumulative exposures due to several sources. For this reason, it is necessary to incorporate a restriction on the individual dose limit to be applied to the averaged individual dose to the critical group of the affected population.

These source-related dose constraints imposed to any authorised liquid or gaseous release of radioactive materials are in the range of 1/100 1/10 of the effective individual dose limit and may well be applied also to the release authorisation for solid materials.

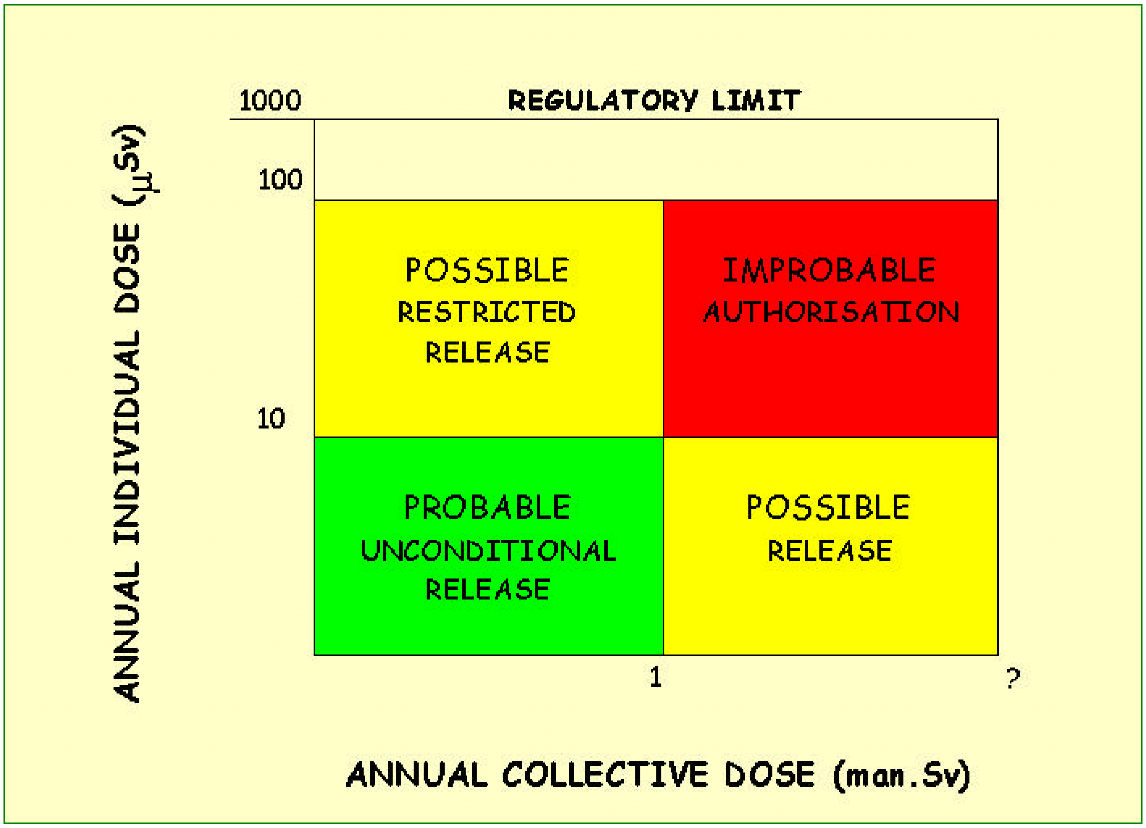
A simplified approach, based on the triviality of individual and collective risks is more often used for the exemption of practices and for the clearance of residual materials. A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations

- The effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of 10 μSv or less in a year.

- The collective effective dose committed by one year of performance of the practice is no more than about 1 man.Sv.

In summary, a competent authority may authorise the release of solid materials generated within a regulated facility, based on the ground of trivial risk methodology, if individual and collective doses are so low that they may be reasonably neglected in all feasible situations (fig 2).

Figure 2



It might also be possible, once some requirement for protection are established, to authorise the release if an optimisation analysis indicates that extra protective measures would not be warranted by any reduction in doses, and that the doses in the most probable scenario are well below the dose constraint imposed.

The trivial risk (small individual doses and small collective dose) either acts as a by pass of or limits the optimisation step in the system of dose limitation of the ICRP as a way of short-circuiting the full optimisation procedure. It really means that it is not worth going on with the radiological optimisation process if we compare it with the level of risk reached in the implicit optimisation of other habitual sources of risk in society.

4. The Situation in Spain

The existing regulations, which are in line with those established in the European Union (EU), indicate those cases in which certain sources and practices are exempted. Additionally, and within the framework of its habitual licensing and operational control activities in relation to certain installations, the Nuclear Safety Council (CSN) has paid specific attention to the release of certain quantities of radioactive materials, usually liquids containing very low levels of activity. This is the case in general for hospital facilities, especially those in which small quantities of short-lived radionuclides are handled.

A basic criterion applied by the CSN is the obligation of the licensee to provide documented evidence, in the evaluation of its management procedures, that some fraction of the so-called regulatory "Annual Incorporation Limits" have not been exceeded.

It should also be pointed out that, in very specific cases, the CSN has favourably viewed the conventional disposal of solid wastes generated by these facilities, when such wastes have had a specific activity of less than 74 Bq/g (2nCi/g), this being the value for exemption included in the old European and existing Spanish standards. In such cases, the licensee must provide documentary proof of the availability of suitable procedures and present his estimates of activity on the basis of the most restrictive radionuclides.

There is now a new legal definition for radioactive waste in Spain (Law 40/1994) in line with the most up-to-date international guidance:- "Radioactive waste is any waste product or residual material for which no further use is foreseen and which contains, or is contaminated with, radionuclides in concentrations or activity levels higher than clearance values, as defined by the Regulatory Authorities". But this legal definition has not been yet implemented.

Spain has no general regulatory policy on the clearance of solid materials, and to date the authorisations for releases have been included in the licence or authorisations granted to each individual holder to whom the clearance applies.

This is the case of the Dismantling and Closure Plan authorisation issued for Vandellós 1 NPP, where a framework of three basic possibilities for the application of clearance appears:

a) Use of derived unconditional generic levels, based on published international guidance.

b) Generic use of derived conditional, waste stream-specific clearance levels, based on "ad hoc" internationally published guidance.

c) Use of derived conditional, waste stream and management route-specific clearance levels, based on "ad hoc" specific studies.

5. The Decommissioning of Vandellos 1 NPP

In August 1990, because of a fire which occurred in the main turbine-generator set in October 1989, the Spanish Ministry of Industry ordered the definitive shutdown of the Vandellós 1 NPP, a natural uranium-graphite gas cooled reactor.

ENRESA, the responsible operator during the dismantling period, submitted the Decommissioning and Closure Plan to the Safety Authorities with the following immediate objectives:

- Dismantling of the nuclear power plant to IAEA level 2 in 5 years, releasing 80 % of the site and maintaining the remaining 20 % as a restricted area with a new building for the reactor box.

- Waiting period of 30 years prior to initiating complete dismantling to level 3, thus releasing the whole site.

The Ministry of Industry granted the title transfer and authorisation to ENRESA in February 1998. Dismantling works in active areas started just a month ago.

The residual materials produced by the dismantling activities of Vandellós 1 NPP are categorised in three different categories:

a) Radioactive waste materials with a level of contamination such that any decontamination is impracticable and that must be conditioned in order to meet the waste acceptance criteria of "El Cabril", the final disposal repository where the waste will be disposed of.
b) Non-contaminated materials coming from non-radiological zones, previously established in an initial radiological survey, materials coming from radiological zones with contamination levels below the unconditional clearance levels may also be placed in this category.
c) Materials coming from radiological zones with very low levels of contamination and that are candidates for management in some non-radiological regulated route, according to the established clearance levels.

6 Clearance Levels

A framework consisting of three basic possibilities for the application of clearance appears in the Dismantling and Closure Plan Authorisation granted for Vandellós 1 NPP: unconditional clearance, generic conditional clearance and specific conditional clearance (fig 3)

Figure 3

CLASSIFICATION	MANAGEMENT
Radioactive Waste	Radioactive Waste Management
N 3	SPECIFIC CONDITIONAL CLEARANCE
Specific Material or Waste Stream (To be proposed)	Specific Management Route (To be proposed)
N 2	GENERIC CONDITIONAL CLEARANCE
Defined Material or Waste Stream	Defined Management Route
N 1	UNCONDITIONAL CLEARANCE
No Contaminated Material	Conventional Management

6.1 Unconditional Clearance Levels

A first set of unconditional clearance levels expressed in terms of gross activity concentration and surface contamination has been issued for the free release of material.

- Total β/γ 0,2 Bq/g
- Total α 0,1 Bq/g
- Surface contamination total β/γ 0,4 Bq/cm^2
- Surface contamination total α 0,1 Bq/cm^2
- Surface contamination weak β/γ 4 Bq/cm^2

It should be pointed out that these figures are not supported by any specific radiological study but are issued in order to avoid inconsistencies with other generic licensing documents, such as transport regulations or radiological protection manuals in different facilities within the country.

A second set of radionuclide specific clearance levels taken from the IAEA TecDoc 855, may also be used for the unconditional clearance of solid materials (table 1)

Table 1

Range of activity (Bq/g)	Radionuclides					Representative single value (Bq/g)
0,1						
	Na-22	Ag-11m	Ra-226	U-235	Cm-224	0,3
	Na-24	Sb-124	Ra-228	U-238		
	Mn-54	Cs-134	Th-228	Np-237		
	Co-60	Cs-137	Th-230	Pu-239		
	Zn-65	Eu-152	Th-232	Pu-240		
	Nb-94	Pb-210	U-234	Am-241		
1						
	Co-58	Sr-90	In-111	Ir-192	Po-210	3
	Fe-59	Ru-106	I-131	Au-198		
10						
	Cr-51	Tc-99m	I-125	I-129	Tl-210	30
	Co-57	I-123	Tc-99	Ce-144	Pu-241	
100						
	C-14	Cl-36	Sr-89	Cd-109		300
	P-32	Fe-55	Y-90			
1.000						
	H-3	S-35	Ca-45	Ni-63	Pm-147	3.000
10.000						

Compliance with these clearance levels will provide a high degree of assurance that the individual dose criterion of 10 μSv per year will not be exceeded, irrespective of the user or application of material after its release.

6.2 Conditional Clearance Levels

The aforementioned authorisation allows the licensee to propose the clearance of residual materials to be managed in some conventional way. The CSN might consider the proposal and other different conditional clearance levels might be issued if the final destination of the residual materials can be assured and an "ad hoc" assessment can demonstrate that the radiological protection of the population is guaranteed.

In these cases, the possible release authorisation is constrained twice. Firstly because the fate of the material being considered in the clearance is known, so that only a limited number of reasonable possible exposures routes have to be considered in deriving the clearance levels.

Secondly, because the CSN imposes source-related dose constraints based on the triviality of doses, for the most exposed individual of the proposed practice and for the collective dose committed per year of the proposed practice.

- Individual dose $\cong$ 10 μSv/yr
- Collective dose $\leq$ 1 man x Sv

Individual dose limits are also taken into consideration in the assessment review. The CSN imposes the annual limit for the skin dose, averaged over any 1 cm^2 area, and the individual effective dose for public exposure for potential doses due to events having low probability in the proposed practice.

- Skin dose $\leq$ 50 mSv/yr
- Dose due to events having low probability < 1 mSv/yr

As part of the licensing procedure, ENRESA submitted a plan for the conventional management of the metallic scrap produced during the decommissioning program. The study was realised in support of a proposal of clearance levels applicable to this material.

It is necessary to realise that once regulatory control is removed, it cannot be guaranteed that economically valuable materials will remain within the country in which regulatory control is lifted.

The CSN, considering that the licensee's proposal did not have any geographical constraint, and in order to avoid the necessity of any further radiological controls, decided to adhere, as far as possible, to the international consensus available at the time of issue.

The current authorisation states the acceptability, as generic conditional clearance levels for metallic scrap, of the figures defined in the draft document "Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations (Nov. 1994)" drawn up by the EURATOM Article 31 Expert Group (tables 2 and 3.

Table 2

(N_2) GENERIC CLEARANCE LEVELS FOR RECYCLING OF METALLIC SCRAP

RADIONUCLIDE	CLEARANCE LEVEL	
	SPECIFIC ACTIVITY Bq/g	SURFACE CONTAMINATION Bq/cm^2
H-3	1.000	100.000
C-14	100	1.000
Mn-54	1	10
Fe-55	10.000	10.000
Co-60	1	10
Ni-59	10.000	10.000
Ni-63	10.000	1.00
Zn-65	1	100
Sr-90	10	1
Nb-94	1	10
Tc-99	100	1.000
Ru-106	1	10
Ag-108m	1	10
Ag-110m	1	10
Sb-125	10	100
Cs-134	0,1	10
Cs-137	1	100
Pm-147	1.000	1.000
Sm-151	10.000	1.000
Eu-152	1	10
Eu-154	1	10
U-234	1	0,10
U-235	1	0,10
U-238	1	0,10
Np-237	1	0,10
Pu-238	1	0,10
Pu-239	1	0,10
Pu-240	1	0,10
Pu-241	10	1
Am-241	1	0,10
Cm-244	1	0,10

These clearance levels appear in the authorisation defined as (N 2) generic conditional clearance levels. The conditions imposed refer only to the management route chosen and to the properties of the material itself before clearing. No radiological conditions are considered after the act of clearing the material. All potentially reusable metallic parts must comply with the most restrictive set of clearance levels for direct reuse of metallic equipment and components (table 3); unless recycling by melting in a foundry is reasonably assured.

The European Commission's final "Radiation Protection 89" document, published last year with the recommended criteria for the recycling of metals from the dismantling of nuclear installations, considerably increases the number of radionuclides considered, but the new recommended levels do not differ significantly from those adopted by the CSN.

Table 3

(N_2) CLEARANCE LEVELS FOR THE DIRECT REUSE OF METALLIC EQUIPMENT AND COMPONENTS

RADIONUCLIDE	CLEARANCE LEVEL FOR DIRECT REUSE
	SURFACE CONTAMINATION Bq/cm^2
H-3	10.000
C-14	1.000
Mn-54	10
Fe-55	1.000
Co-60	1
Ni-59	10.000
Ni-63	1.000
Zn-65	10
Sr-90	10
Nb-94	1
Tc-99	1.000
Ru-106	10
Ag-108m	1
Ag-110m	1
Sb-125	10
Cs-134	1
Cs-137	10
Pm-147	1.000
Sm-151	1.000
Eu-152	1
Eu-154	1
U-234	0,10
U-235	0,10
U-238	0,10
Np-237	0,10
Pu-238	0,10
Pu-239	0,10
Pu-240	0,10
Pu-241	10
Am-241	0,10
Cm-244	0,10

As part of the licensing procedure ENRESA submitted another study supporting its proposal for exemption of the rubble produced during the dismantling of the facility. Two different types of management modes were considered for the concrete debris: disposal to a tip and recycling or reuse of the buildings.

Attempting once more to reach the desirable consensus, and based on a previous analysis of published reports and recommendations, the CSN considered to be applicable the clearance levels taken from the IAEA Safety Series SS-111-P-1.1 "Application of Exemption Principles to the Recycle and Reuse of Materials from Nuclear Facilities - 1992" (table 4).

Table 4

(N_2) GENERIC CLEARANCE LEVELS FOR CONCRETE DEBRIS AND BUILDINGS

RADIONUCLIDE	CLEARANCE LEVELS		
	RECYCLED CONCRETE Bq/g	REUSE OF BUILDINGS	
		OCCUPATION Bq/cm^2	REHABILITATION Bq/cm^2
Cl-36	20.000		
Ca-41	200.000		
Mn-54	1	0,4	4
Fe-55	200.000	0,9	900
Co-60	0,3	0,1	1
Ni-63	100.000	3.000	20.000
Zn-65	2	0,6	6
Sr-90	300	10	70
Nb-94	0,5	0,02	2
Tc-99	50.000	1.000	9.000
Cs-137	1	0,4	4
Eu-152	1	0,4	4
U-238	3	1	1
Pu-239	0,9	0,2	0.3
Pu-241	50	10	20
Am-241	0,9	0,2	0,3

The activity concentration levels are for the recycling of concrete as aggregate for further concrete constructions.

Two different reuse scenarios are considered. The most restrictive, occupational ones should be applied together with the activity concentration clearance levels, to those buildings which might be demolished in the future.

6.3 Verification of Clearance Levels

Once clearance levels are established, another very important responsibility of the regulatory authority is to assure that the authorised clearance levels will be properly implemented. A very strict control programme is requested to support and verify compliance with the aforementioned criteria prior to the release of any residual materials from the Vandellós 1 NPP premises.

On the basis of a documented preliminary radiological survey, it is decided whether the material is potentially clearable and the measuring efforts for its clearance are determined. Some key aspects to be analysed in this preliminary characterisation of the candidate material for clearance are:

- Radionuclide spectrum and key nuclides
- Scaling factors to be used to determine activity of very difficult to measure radionuclides
- Activity distribution and location of potential "hot spots"

The goal of keeping doses in the range of a few μSv per year implies that the dose rates to be detected are a small fraction of natural background, as a result of which it is necessary to operate at a very low limit of detectability. Aspects such as the measurement equipment to be used, the calibration procedures and the influence of the background must be specifically reviewed.

A well-documented decision process with a quality control program is very important from the regulatory point of view. Materials cannot be deliberately diluted in order to meet the clearance levels, and in order to assure the management route of the cleared material it is also possible to consider requiring contractual arrangements with the first recipient.

7 Final Considerations

Exemption criteria or clearance levels have been used one way or another by all regulatory agencies concerned with some particular risk management. This is the case also for radiological risk, for which, exemption and clearance policies are fully available options derived from a strict and responsible application of the existing radiation protection system. The matter is now well Under Regulatory Concern, and it is precisely for this reason that regulators might consider the risks implied to be too small to justify the use of extra resources for their control, so as to allow other more beneficial allocations for them.

It is clear that there is a need to define derived, practically applicable, criteria for clearance at international level. More than just values, what is needed is a clear and well defined technical and administrative framework to guide the responsible management of residual materials having very low level radionuclide contents, by using clearance. In this respect it is strongly recommended that whatever effort may be necessary be made to establish a consistent but pragmatic approach for exemption and clearance. Many positive goals would be achieved by using the same derived values, at least for the unconditional application of clearance.

A basic component of any responsible policy on clearance is the guarantee that the cleared materials comply with the defined criteria. In this sense, measurements of radioactivity content and characterisation of materials are, and will continue to be, a key issue.

It should be recognised that public acceptance may be a critical constraint in the implementation of a general clearance policy, and should be an important consideration in any proposed approach. It may be helpful to describe the clearance policy as a consequence of a resources optimisation analysis, considering that the risks implied by this policy have too low a priority to be further regulated, rather that presenting those risks as having an acceptable low level.

THE SPANISH DECOMMISSIONER VIEWPOINT

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1. Introduction

Decommissioning is generally understood to be the set of administrative and technical actions taken at the end of the useful lifetime of a regulated facility to retire it from service, and ultimately remove it from regulatory control, in a manner which provides adequate protection for both workers and public, minimizes impact on the environment and involves manageable costs. These actions involve dismantling and removing radioactive materials, wastes, components and structures to the extent necessary.

Two of the most essential aspects when defining and carrying out nuclear facility dismantling projects are the radiological protection of both the people and the environment, and the adequate management of the various materials generated. In keeping with current world trends, aspects such as the minimization of waste production and recycling emerge as necessary components of such projects.

Within the Regulatory framework existing in this field, there are two key concepts to optimization of the process along the lines of the trends indicated above; these are: 1) clearance, and 2) authorized release, recycling or reuse (from hereon "authorized release") for management of the materials generated during the process.

When developing and applying these two concepts in practice, there are three different aspects that should be taken into account in a differentiated manner, since they entail problems that require different approaches and frameworks for a solution:

- The basic radiological protection criteria to be used
- The derivation of values of practical use for application.
- Actual application and the verification and control methods to be put into practice.

This paper proposes to debate the aforementioned issues from the standpoint of the Organization responsible for the dismantling of nuclear power plants in Spain, and responsible also for radioactive waste management in the country.

The paper first briefly discusses the current situation at world level, as regards application of the concepts of "clearance" and "authorized release", and then goes on to deal with the way in which these are being applied in the specific case of decommissioning of the Spanish Vandellós 1 plant.

It should be pointed out that in this dismantling project the regulatory framework applied has been the one in force in the country governing generic nuclear activities, since no specific framework was available. In addition, the environmental standards applied have been in line with the corresponding European Union Directives in force.

Likewise, and in the interest of clarity, it should be remembered that the basic structure of the different agents intervening in this type of processes is as follows (Figure 1.1.):

Ministry of Industry and Energy
Ministry of the Environment
Nuclear Safety Council
European Commission (Art. 37 of the Euratom Treaty)
Local Authorities
HIFRENSA (former operator of the plant)
ENRESA (company responsible for dismantling)

2. International Framework

The concepts of "exemption", "clearance" and "authorized release" are part of the radiological protection system used practically at world level, and are the direct result of the application of its three basic principles: justification, optimization and limitation. Their rational application allows the available resources to be used in a more optimal fashion and might presumably have a positive impact in the medium term on public perception of radiological risk.

There is a very general consensus as regards the basic radiological protection criteria to be used in order for the management of radioactive materials outside the Regulatory system to be acceptable. This consensus is established around two different concepts (figure 2.1) which were the basis of the publication by the IAEA, jointly with NEA/OECD, of the document "Safety Series 89" in 1988.

Those two concepts have been further developed and clarified in publication ICRP 60 (par. 287) which says: "There are two grounds for exempting a source or an environmental situation from regulatory control. One is that the source gives rise to small individual doses and small collective doses in both normal and accident conditions. The other is that no reasonable control procedures can achieve significant reductions in individual and collective doses".

In brief, management of radioactive materials outside of the Regulatory control system is feasible if:

a) Either, the radiological impact can be considered "trivial", or
b) The Regulatory control would not produce significant additional benefits

On the basis of these two concepts and in order to progress in their application, there have been various developments in recent years at international level (and others at national level), the most relevant documents drawn up being as follows:

IAEA Basic Safety Standards (IAEA Safety Series 115, Vienna, 1995)
European Council Directive 96/29.

The aforementioned documents may be said to adequately reflect the level of consensus currently existing. Both develop the concept of "exemption" to the practical level of application, with certain aspects still requiring some additional clarification, as is the case of natural radionuclides.

As regards the concept of "clearance", however, both documents simply define the basic radiological protection criteria to be used, without establishing derived values or defining additional guidelines for practical application.

Since their publication, and even before in certain cases, numerous projects, studies, initiatives, etc. have been undertaken at international level to attempt to define - with the highest possible degree of consensus - ways of carrying out this practical application, defining directly usable derived levels for this purpose. In parallel to the above, various countries have undertaken their own individual initiatives and studies, with a view both to solving their own specific problems and to contributing to international efforts.

Without mentioning the undoubtedly interesting, but very numerous, national studies performed, let us go on to indicate some of the most relevant results of the international efforts made to date in this area.

- IAEA Safety Series Nº 111-P-1.1.- Application of exemption principles to the recycle and reuse of materials for nuclear facilities (Vienna, 1992).
- IAEA-TECDOC-855.- Clearance levels for radionuclides in solid materials. Application of exemption principles. (Vienna, 1996).
- IAEA-TECDOC-1000.- Clearance of materials resulting from the use of radionuclides in medicine, industry and research. (Vienna, 1998).
- Radiation Protection 89.- Recommended Radiological Protection Criteria for the Recycling of metals from the dismantling of Nuclear Installations. (Luxembourg, 1998).
- Radiation Protection 101.- Basis for the definition of surface contamination clearance levels for the recycling or reuse of metals arising from the dismantling of Nuclear Installations (Luxembourg, 1998).
- Recommended Radiological Protection criteria for the clearance of building and building rubble arising from the dismantling of nuclear installations.- (Draft 6, Brussels, March 1999)
- Nuclear Decommissioning. Recycling and Reuse of scrap metals (NEA/OCDE, 1996).

Unfortunately, from the comparative analysis of these international results - and even more so if the analysis of other national studies are brought into the equation - it may be deduced that the necessary degree of consensus has not yet been reached. There are differences of a conceptual and methodological nature, and even differences relating to terminology, which need to be analyzed and resolved in the near future. If this were not the case, it would be extremely difficult to achieve the necessary degree of public acceptance. As a result of which decision-making by the Regulatory Authority would be made more difficult, the projects for nuclear installation decommissioning would become more complex and costly, and the international market for certain products (e.g., metallic scrap) would be affected

In the search for the desirable, and probably necessary, degree of consensus, the recent approval by the IAEA of the revision of its recommendations for transport: "Regulations for the safe transport of radioactive materials, 1996 Edition. IAEA ST N.1", is considered to be particularly relevant. In this case, the decision was taken to accept, other than in certain specific cases, the derived values already defined for "exemption" at international level, with regard to both total and specific activity. This was done for reasons of coherence and public understanding, despite the fact that the values in question were not strictly suitable for certain specific transport exposure scenarios. Complementary to the above, values were defined for the event of surface contamination and for the transport of natural radionuclides.

Mention should also be made, in reference to the more recent past, of the developments under way within the framework of the IAEA's RADWASS program. This organization is planning the preparation of two documents in its "Safety Standards" series, at the "Safety Guide" level, which will be oriented respectively towards the following:

- Definition of the criteria to be adhered to in applying the concept of "deregulation", from a broad viewpoint and ensuring that all the situations currently imaginable are contemplated. (as revision of the IAEA-SS-89)
- Definition of the methodology and procedures to be used in practice for application of "clearance" contemplating aspects such as recording, measurement, control of compliance, etc.

Part of this effort is dedicated also to updating the contents of IAEA-TECDOC-855, using the most recent results available from national and international studies. However, despite their importance, the aim is not only to define derived values: the two aforementioned documents will foreseeably define not only the criteria and the derived values for application, but also the guarantee mechanisms to be established in order to ensure responsible use by the different actors involved.

Additionally, the European Commission is promoting parallel actions, as derived from the Directive 96/29, trying to develop practical guidance for the Member States to incorporate and apply harmonically such Directive as part of their national regulations. Aspects like clarification of the concept of "exclusion", practical guidance to apply "clearance" for various situations and how NORM's should be treated, are part of these actions.

The following ideas are presented as suggestions for the international efforts currently on-going to achieve the desired level of consensus, from the viewpoint of an organization responsible for decommissioning projects:

Exemption, clearance and authorized release are reasonable options deriving from strict and responsible application of the existing radiation protection systems. They should be so presented and so understood by Society.

The system to be established should be comprehensive, as currently oriented, and cover both the criteria and the values derived for application, as well as the mechanisms for control, recording and verification to be adhered to.

Adequate and differentiated consideration should be given to "practices" and "interventions", and there should be specific treatment of "natural radionuclides", differentiating those cases in which the presence of such radionuclides is incidental to the process or industry in which they appear.

Possible differentiated application of the two existing basic criteria for protection (Fig. 2.2):

- *Triviality of dose* – on which "unconditional clearance" (or just clearance) would be based, similarly to what is applied in the case of exemption.

- *The regulatory control does not provide any significant additional advantage* – on which would be based "authorized release", "conditional clearance" (if this name is to be maintained) and treatment of natural radioactivity outside its use for its radioactive properties.

It would be desirable to reach an international agreement regarding the definition of derived values for the application of "unconditional clearance" and that these were of general use and valid for international trade. It would be ideal if they were consistent with those already agreed on for "exemption" and for "transport" at international level (or directly related to them).

A degree of discretion should be maintained, such that values different (higher) than those mentioned above might be established for "conditional clearance" or "authorized release", which would be defined on a case by case basis, depending on the material and the specific circumstances applicable. (and possibly at national level)

Complementary to the above, it would be advisable to progress in relation to practical aspects of application, such as verification and control systems offering a reasonable guarantee of the established criteria being met, in an industrial context. This is an area that has not yet received sufficient attention at international level, although it is recognized that several methods are available and might be used, such as: direct measurement; laboratory measurement on representative samples; use of properly derived scaling factors, or any other method as accepted by the Regulatory Authority.

Throughout this process, sight should not be lost of the primary objectives of radiological protection, which constitute the basis for responsible application of these concepts. These objectives have been the starting point for the definition of derived values of an increasing level of practical applicability: numerical dose values, derived concentration values and measurement techniques and methods. In defining these criteria, factors of conservatism have been incorporated; this should not be forgotten, since the only criterion that really needs to be adhered to is the primary one.

It is essential that the aforementioned consensus be obtained, and the way in which these concepts are applied in practice be brought into harmony, if the aim is to achieve credibility in the eyes of the public and, consequently, facilitate responsible use as a way of optimizing the system overall.

3. The Situation In Spain: The Decommissioning of Vandellos I NPP

The Spanish standards governing radiological protection encompass the contents of the applicable European Union (EU) Directives and take into account the guidelines developed by the IAEA. In both, criteria and practical guidelines for the application of "exemption" are defined, along with basic criteria for the application of "clearance" to materials arising from regulated practices.

For the application of "clearance", the Spanish Regulatory Authority is taking into account the most recent international developments, in defining derived values for application to various streams of materials, both unconditionally and conditionally, although they also accept "case by case" approaches in a way similar to what has recently become known as "authorized releases". In all cases there is a need for an express positive declaration by the Regulatory Authority.

This has been the basic framework considered by ENRESA in developing and undertaking the decommissioning of the Vandellós 1 Nuclear Power Plant. It has also been used in structuring the classification of materials, as described in figure 3.1. The following definitions are relevant for correct use in this project:

Non-radioactive materials

Those coming from areas of the facility not having radiological implications as a result of design and operating history. By extension, materials meeting the criteria for "unconditional clearance" are catalogued and managed as non-radioactive materials.

Radioactive materials

In principle, those arising from areas of the facility with radiological implications due to their design and operating history are classified as radioactive materials.

Cleared or authorized materials

Those radioactive materials which contain or are contaminated with levels of radioactivity equal to or lower than those defined by the Regulatory Authority.

Radioactive waste

Those waste products or residual materials for which no further use is foreseen and which contain or are contaminated with radionuclides in concentrations or activity levels higher than certain values, as defined by the Regulatory Authority.

It is a well known fact that there is a lack of homogeneity, and even some confusion, at international level as regards the establishment of derived values for practical application of the concept of clearance (see the previous point). For the specific case of the decommissioning of Vandellós I, the Regulatory Authority has adopted three (3) sets (or levels) of values (See table 3.1) applicable for "residual" and "recyclable or reusable" materials.

Level 1 (N-1) for unconditional clearance (Table 3.2)
For total activity content (a, ß and ?)
For specific isotopes

Level 2 (N-2) for conditional generic clearance applicable to specific waste streams: (metallic scrap or demolition debris). (A kind of authorized release) (Table 3.3.)
For specific isotopes

Level 3 (N-3) for conditional specific clearance applicable to specific waste materials. (A kind of authorized release)
Not defined but open to "case by case" study.

The materials management strategy shown in figure 3.2 was established on the basis of these values, and of the results obtained from the studies and activities carried out for the initial radiological characterization of the facility. These were also used latter for assessment of the total quantities of the different materials streams generated during the current phase of decommissioning, which are to be managed in accordance with previously established routes, as shown in figure 3.3.

The quantification referred to and the strategy described are reflected in the corresponding Working Plans to be undertaken during decommisisioning, with the basic objective of guaranteeing adequate accounting and technical-administrative control of all the materials produced and of the management methods applied to them.

In the specific case of the current phase of decommissioning of Vandellós 1 (equivalent to the so-called “level 2” in the IAEA nomenclature), two basic documents have been defined:

Control Plan for clearance candidate materials
Radioactive Waste Management Plan

For optimum application, a computer application (PECO) has been developed, this containing the basic data on the initial inventory of equipment, components and structures of the facility and its initial radiological characterization. The information generated throughout the process of applying these Plans will be progressively incorporated into this application, such that all the materials be fully “traceable”, from their initial location to their final destination. This application will subsequently link with the ENRESA Corporate System (SGR) as regards the management of radioactive wastes.

The overall objective pursued is that there be an exhaustive control and complete documentation of each and every one of the materials generated as a result of the decommissioning of a nuclear installation.

The Spanish situation described above is not without difficulties as regards application at industrial level to the Vandellós I decommissioning project. Certain of these difficulties are described below:

Firstly, the initial radiological characterization work cannot be exhaustive in scope nor as regards the type of radiological determinations performed. This problem makes it necessary to continue this task during the execution of the decommissioning activities, conditioning the rate at which the tasks involved in the process may be performed.

Secondly, it is necessary to perform directly, “in situ”, an initial discrimination of the materials being produced; distinguishing those which are considered “candidates for clearance” from those others which are to be managed “within the regulated system”. An essential factor in this respect is the efficiency attributed to the decontamination processes to be carried out. For this project, a value 10 times the value of N2 has been provisionally chosen, this requiring radiological measures to be taken directly “in situ”.

Thirdly, the need to control and trace all the materials generated makes it necessary to structure the work in a specific manner and to establish technical and administrative systems for supervision of the work, this being complicated to implement.

Fourthly, the very values defined by the Regulatory Authority for the application of “clearance” are really very low and are, in addition, to be applied assuming the simultaneous presence of various radionuclides, many of which are difficult to measure. This has made it necessary to define a series of "type spectra", depending on the origin of the materials, such that it be possible to apply correlation factors between the isotopes actually measured and those others present in each type of material. It also makes it necessary to group the materials produced depending on their origin.

In fifth place, the system for verification of the activity should be part of the industrial process of decommissioning and be automated to the extent possible, since any manual approach is discouraging as regards the consumption of resources. Great progress has been made in recent years in this respect, and there have now been positive experiences using industrial equipment of high sensitivity, efficiency and reliability. Nevertheless, this aspect requires special attention and effort in order for it to be accepted by the Regulatory Authority.

Finally, the lack of international consensus as regards general acceptance values for application of the concept of "clearance" to these materials might complicate the situation to a large extent, if any of these were to be reintroduced on the international market.

4. Conclusions

The concepts of "exemption", "clearance" and "authorized release" are part of the existing radiological protection system, and their application is both in keeping with the basic principles thereof and necessary and advisable for a number of reasons, not the least the public perception of the radiological risk.

The efforts made at national and international level over the last decade have made it possible to define and agree on a reasonably complete framework for application of the concept of "exemption". This is not yet the case for "clearance" and "authorized release", a fact which represents a problem, for example when addressing nuclear installation decommissioning projects.

Great effort is currently being made to solve this shortcoming by both individual countries and internationally, and the problems still pending a solution have now been identified. Nevertheless, progress is painfully slow, often for reasons which are difficult to understand and which have little relation with the origin of the concept based on pure radiological grounds.

International consensus is considered to be essential in this respect, as the only stable and long-lasting mechanism providing the entire process with credibility and facilitating its suitable development. This consensus is understood as being possible in the basic terms that gave rise to the concept of "exemption", as a way of optimizing Regulatory activity.

In the specific case of Spain, the decision taken by the Regulatory Authority is making it possible to undertake the decommissioning of Vandellós I with a reasonable level of optimization and using an industrial approach. The question of the measurement and control systems is still to be agreed on in detail.

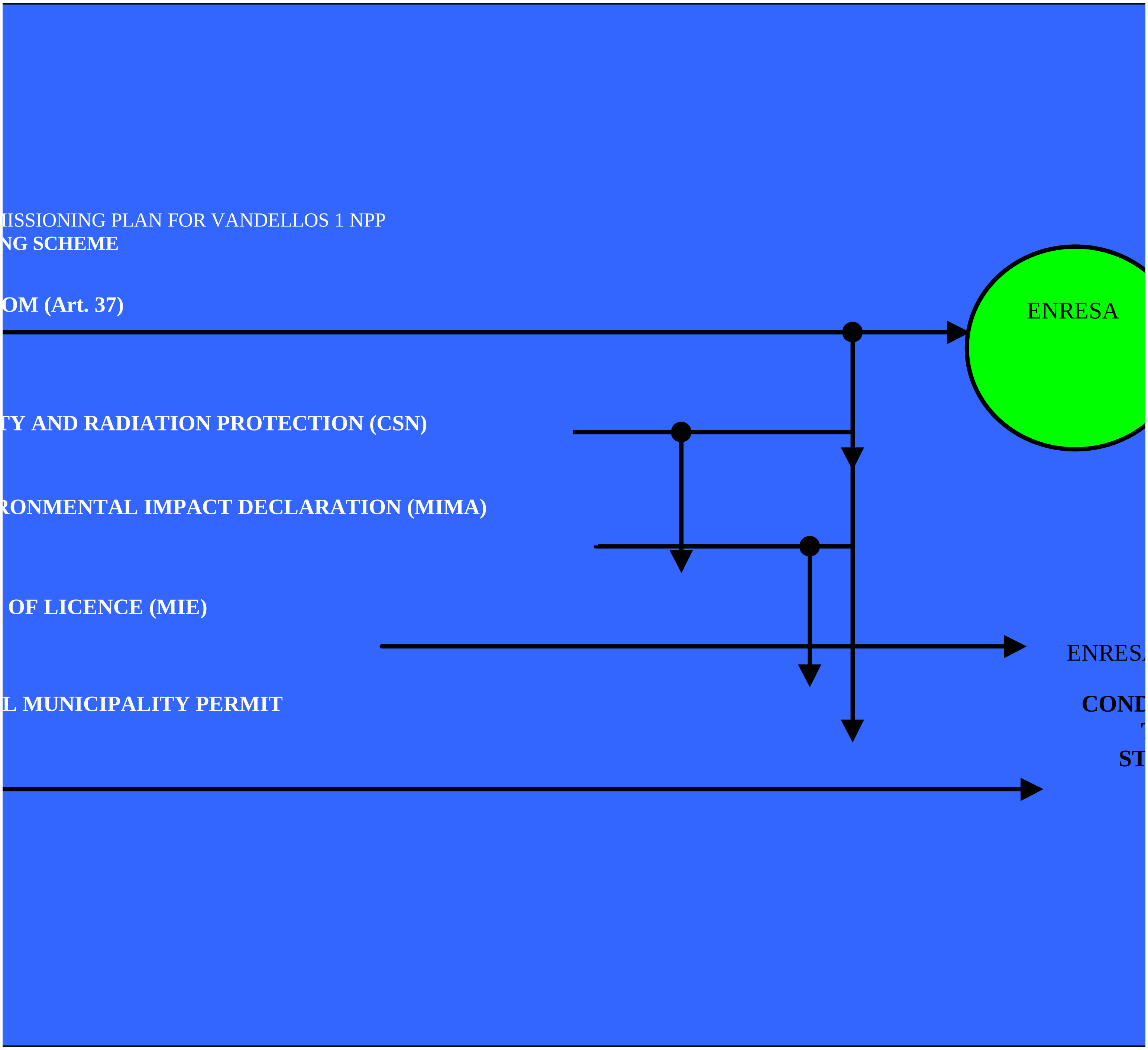
MISSIONING PLAN FOR VANDELLOS 1 NPP
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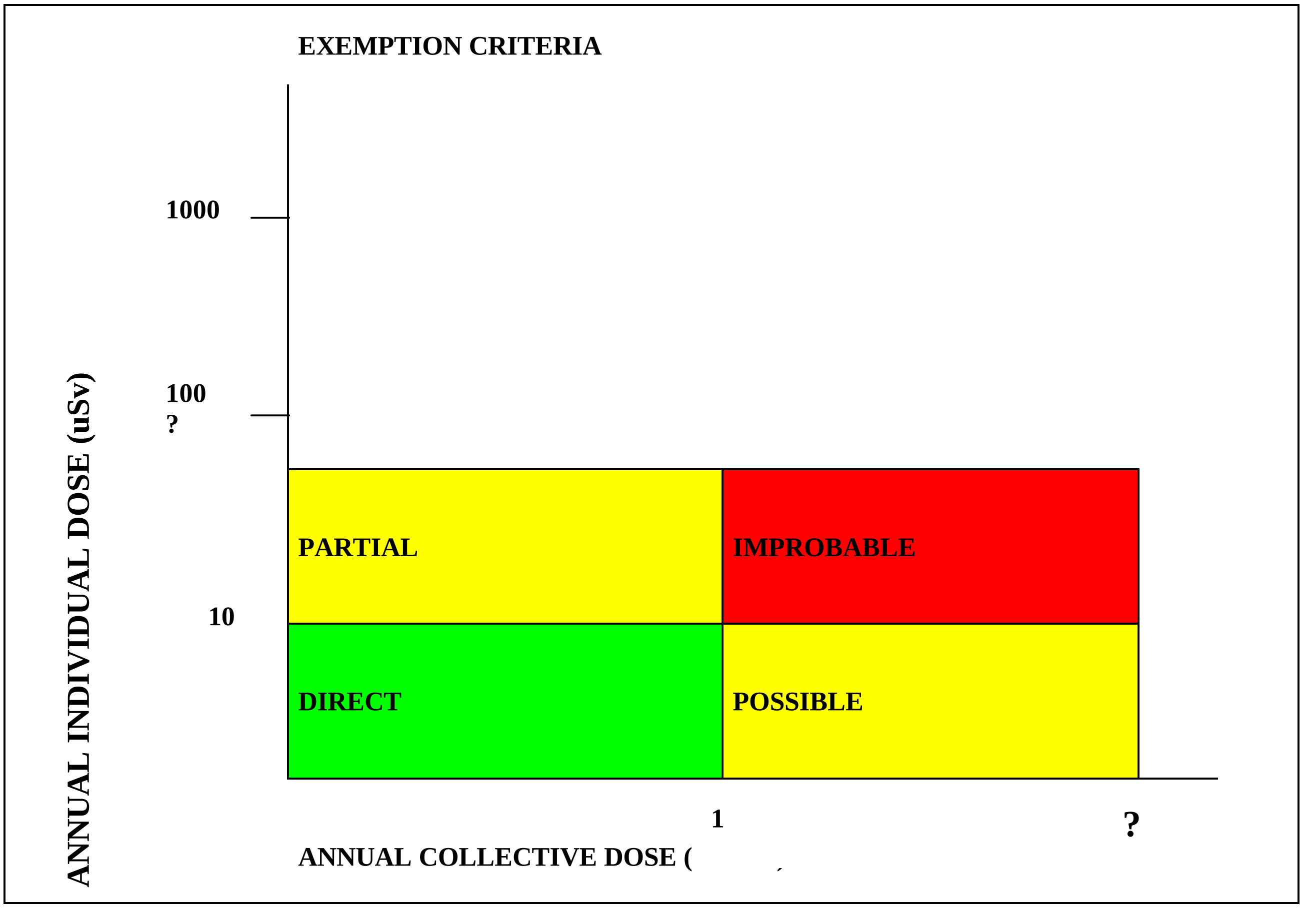
Figure 2.1.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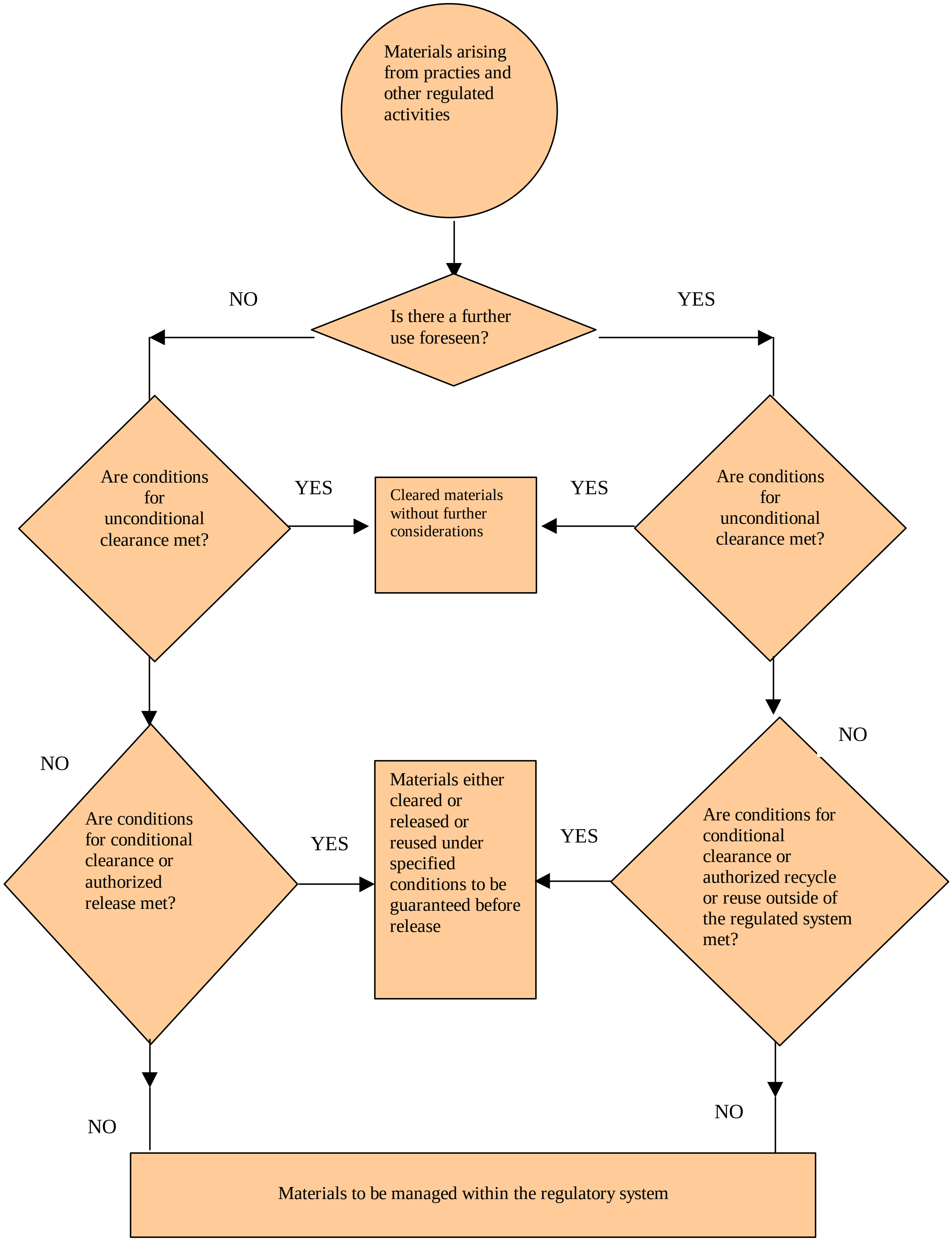


Figure 2.2. **Decision Scheme for the Management of Radioactive Materials Arising from Practices and Other Regulated Activities**

Classification and Management Scheme of Material Arising in the Decommissioning of Vandellos 1 NPP, According to their Radioactivity Content

Table 3.1.

	LEVEL	**CLASSIFICATIONS OF MATERIALS**	**MANAGEMENT OF MATERIALS**
		Radioactive waste or recycle materials	Recycled within the regulated system or managed as radioactive waste
N-3	Conditional and specific clearance	Cleared or authorised materials for specific purposes and uses	Management as defined “case by case”
N-2	Conditional and generic clearance	Cleared or authorised for specific streams and final destination	Management by streams according to their final destination
N-1	Unconditional clearance and non-radioactive	Non-radioactive	Conventional management routes

Table 3.2.

Unconditional Clearance Levels For Material Arising In The Decommissioning Of Vandellos I NPP

A.- TOTAL ACTIVITY CONTENT

Activity Concentration

Total ß/? 0,2 Bq/g
Total a 0,04 Bq/g (0,1

Surface Contamination

Total ß/? 0,4 Bq/cm^2
Total weak ß,? 4 Bq/cm^2
Total a 0,04 Bq/cm^2 (0,1)

B.- SPECIFIC ISOTOPES (GROUPED)

RANGE OF ACTIVITY Bq/gr	TYPE OF RADIONUCLIDE					REPRESENTATIVE SINGLE VALUE
0,1 - 1	Na-22 Na-24 Mn-54 Co-60 Zn-65	Nb-94 Ag-110m Sb-124 Cs-134 Cs-137	Eu-152 Pb-210 Ra-226 Ra-228 Th-228	Th-230 Th-232 U-234 U-235 U-238	Np-237 Pu.239 Pu-240 Am-241 Cm-244	0,3
1 - 10	Co-58 Fe-59	Sr-90 Ru-106	In-111 I-131	Ir-192 Au-198	Po-210	3
10 - 100	Cr-51 Co-57	Tc-99m I-123	I-125 Tc-99	I-129 Ce-144	Tl-210 Pu-241	30
100 - 1000	C-14 P-32	Cl-36 Fe-55	Sr-89 Y-90	Cd-109		300
1000 - 10000	H-3	S-35	Ca-45	Ni-63	Pm-147	3000

Table 3.3 (1/3)

Derived Clearance Levels for Recycling of Metallic Scraps.

RADIONUCLIDE	CLEARANCE LEVEL	
	SPECIFIC ACTIVITY (Bq/g)	SURFACE CONTAMINATION (Bq/cm^2)
H-3	1000	100.000
C-14	100	1000
Mn-54	1	10
Fe-55	10.000	10.000
Co.60	1	10
Ni-59	10.000	10.000
Ni-63	10.000	1000
Zn-65	1	100
Sr-90	10	1
Nb-94	1	10
Tc-99	100	1000
Ru-106	1	10
Ag-108m	1	10
Ag-110m	1	10
Sb-125	10	100
Cs-134	0,1	10
Cs-137	1	100
Pm-147	1000	1000
Sm-151	10.000	1000
Eu-152	1	10
Eu-154	1	10
U-234	1	0.10
U-235	1	0.10
U-238	1	0.10
Np-237	1	0.10
Pu-238	1	0.10
Pu-239	1	0.10
Pu-240	1	0.10
Pu-241	10	1
Am-241	1	0.10
Cm-244	1	0.10

Table 3.3 (2/3)

Clearance Levels for the Direct Reuse of Metallic Equipment and Components

RADIONUCLIDE	CLEARANCE LEVELS FOR DIRECT REUSE
	SURFACE CONTAMINATION (Bq/cm^2)
H-3	10000
C-14	1000
Mn-54	10
Fe-55	1000
Co.60	1
Ni-59	10000
Ni-63	1000
Zn-65	10
Sr-90	10
Nb-94	1
Tc-99	1000
Ru-106	10
Ag-108m	1
Ag-110m	1
Sb-125	10
Cs-134	1
Cs-137	10
Pm-147	1000
Sm-151	1000
Eu-152	1
Eu-154	1
U-234	0.10
U-235	0.10
U-238	0,10
Np-237	0,10
Pu-238	0,10
Pu-239	0,10
Pu-240	0,10
Pu-241	10
Am-241	0,10
Cm-244	0,10

Table 3.3 (3/3)

Clearance Levels for Concrete Debris

	CLEARANCE LEVELS (Bq/g)		
RADIONUCLIDE	RECYCLED CONCRETE	REUSE OF BUILDINGS	
		OCCUPATION	REHABILITATION
Cl-36	2.10^{4}		
Ca-41	2.10^{5}		
Mn-54	1.10^{0}	4.10^{-1}	4.10^{0}
Fe-55	2.10^{5}	9.10^{-1}	9.10^{2}
C0-60	3.10^{-1}	1.10^{-1}	1.10^{0}
Ni-63	1.10^{5}	3.10^{3}	2.10^{4}
Zn-65	2.10^{0}	6.10^{-1}	6.10^{0}
Sr-90	3.10^{2}	1.10^{1}	7.10^{1}
Nb-94	5.10^{-1}	2.10^{-2}	2.10^{0}
Tc-99	5.10^{4}	1.10^{3}	9.10^{3}
Cs-137	1.10^{0}	4.10^{-1}	4.10^{0}
Eu-152	1.10^{0}	4.10^{-1}	4.10^{0}
U-238	3.10^{0}	1.10^{0}	1.10^{0}
Pu-239	$9,10^{-1}$	2.10^{-1}	3.10^{-1}
Pu-241	5.10^{1}	1.10^{1}	2.10^{1}
Am-241	9.10^{-1}	2.10^{-1}	3.10^{-1}

Figure 3.1.

Classification of Materials Arising in the Decommissioning of Vandellós 1 NPP

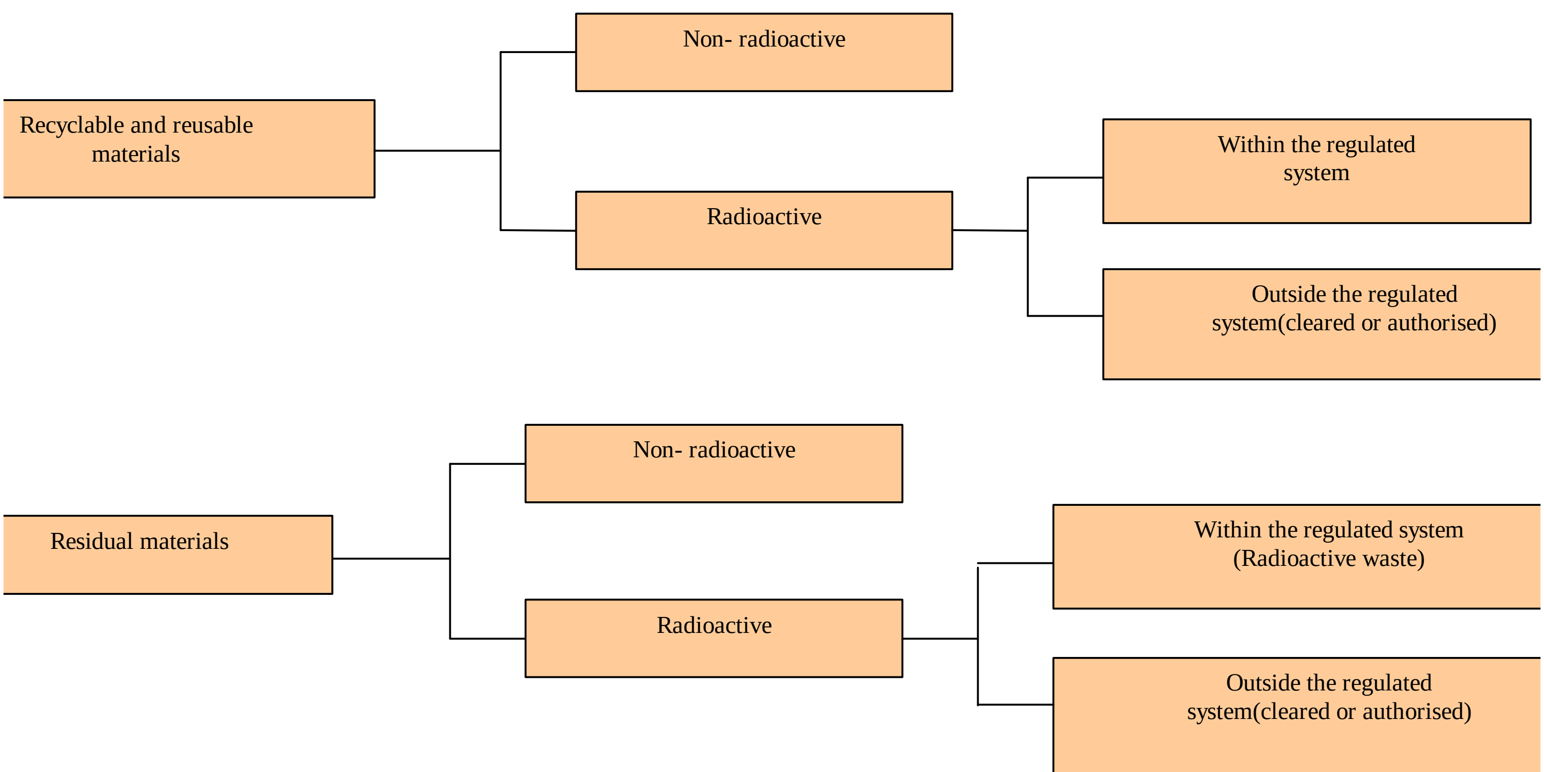


FIGURE 3.2. MATERIALS MANAGEMENT STRATEGY

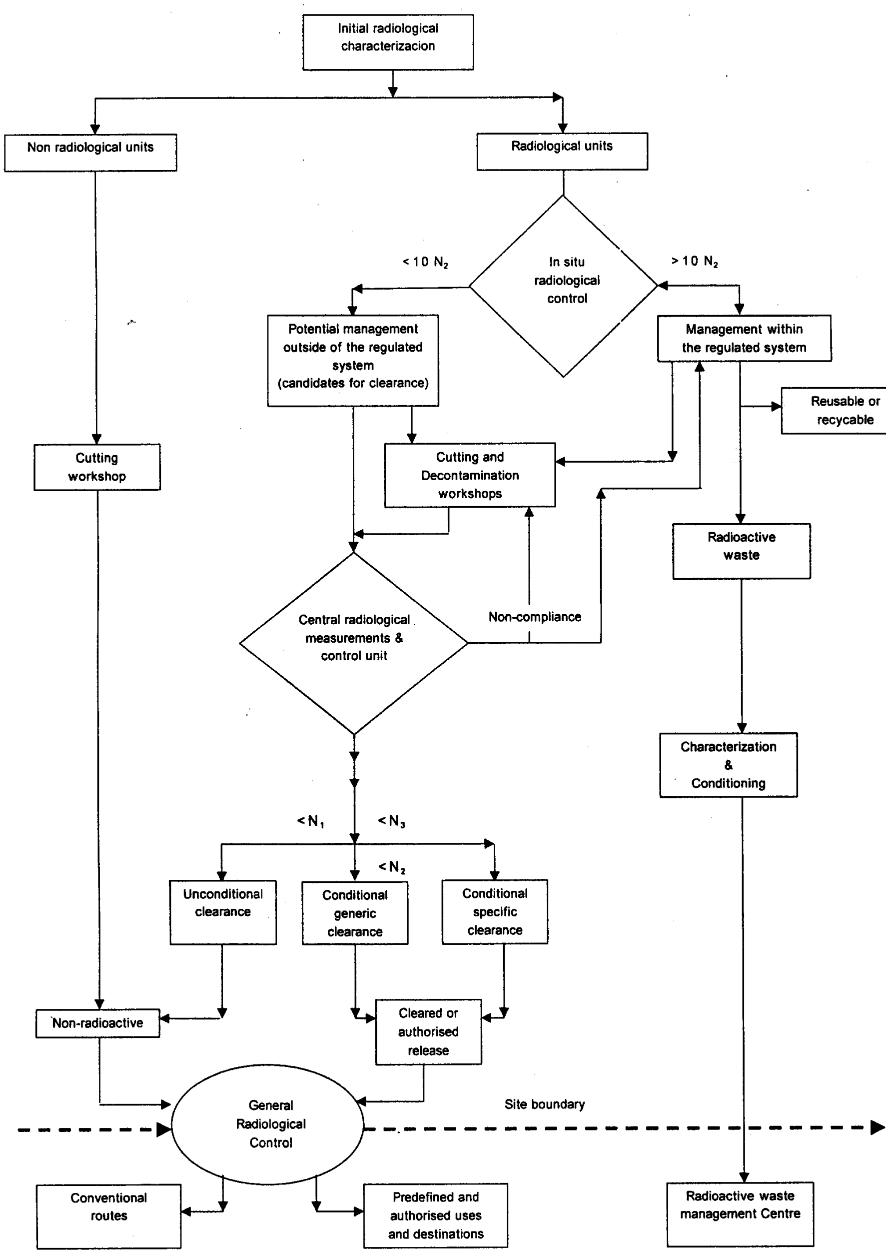
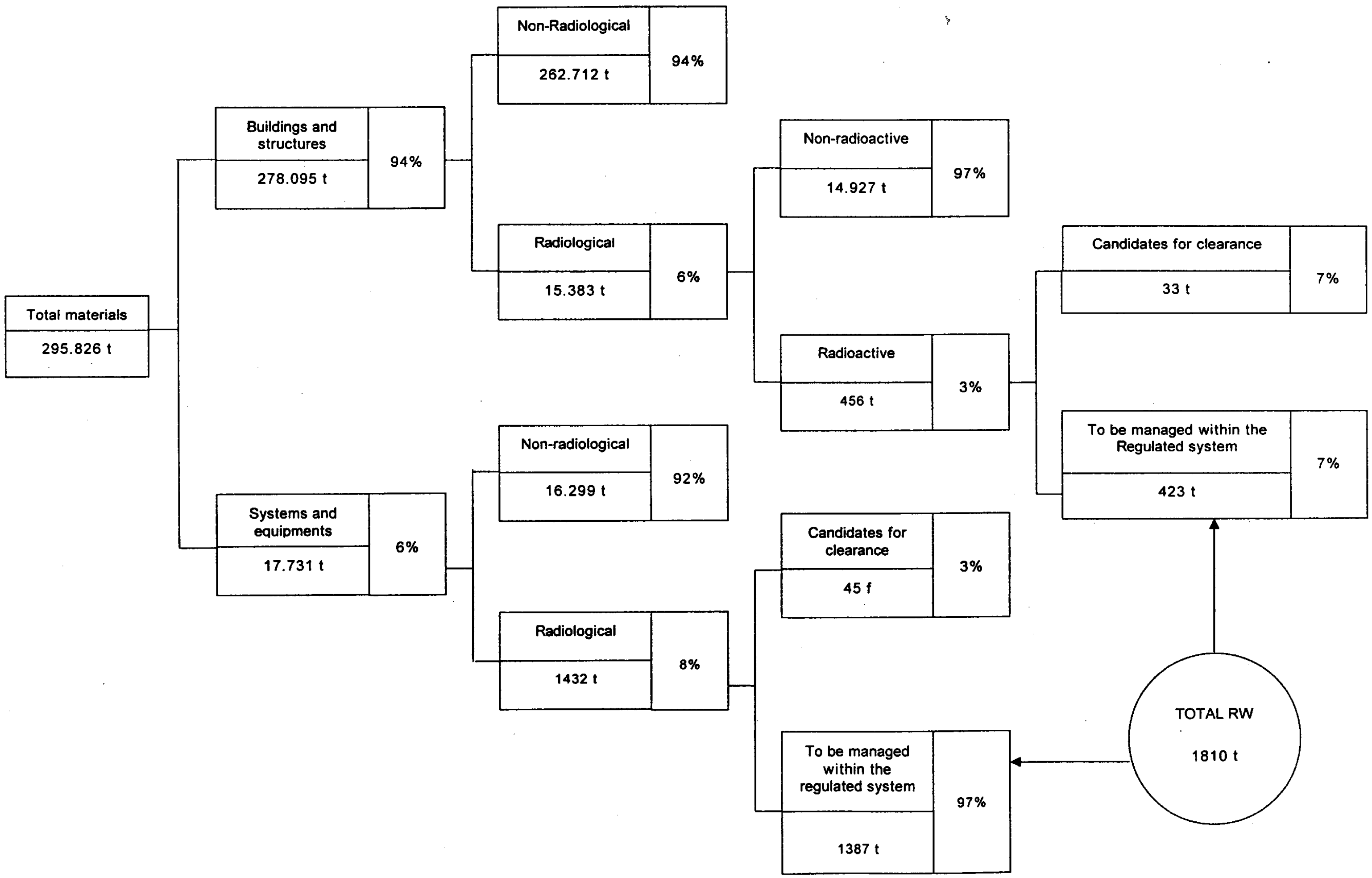


FIGURE 3.3

QUANTITATIVE DISTRIBUTION OF MATERIALS GENERATED IN THE INITIAL PHASE OF THE DECOMMISSIONING OF VANDELLOS 1 (UP TO THE IAEA LEVEL 2)



EXEMPTION, CLEARANCE, AND AUTHORISED RELEASE GERMAN REGULATOR'S VIEWPOINT

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Abstract

This presentation deals with the removal of (nuclear) control of materials from nuclear installations or from practices where radionuclides are involved. The focus lies on clearance and authorised release, but exemption, especially in the context of NORM, is also addressed. Clearance in Germany has been practised successfully for about two decades. Large quantities, including the entire building structures of several NPPs and fuel cycle installations, have been cleared so far. This shows that in the meanwhile, a comprehensive regulatory framework has been devised that covers nearly all aspects of clearance. These guidelines and recommendations are currently being transformed into a new Radiation Protection Ordinance so that clearance will soon be regulated at ordinance level. Comprehensive regulations are also being devised for exemption of NORM.

Germany currently has guidelines for unconditional clearance, clearance of waste for conventional disposal, clearance of metal scrap for recycling and clearance of buildings for reuse or demolition. Guidelines for clearance of nuclear sites and of liquids are being developed. All guidelines contain nuclidespecific clearance levels (mass- and surface-specific) for all nuclides for which exemption levels exist in the EURATOM Basic Safety Standards. The clearance levels have been based on comprehensive radiological models (deterministic and probabilistic calculations) which also take account of recommendations by IAEA and the European Commission. All German recommendations and guidelines for clearance are based on the 10 µSv/a (de minimis) criterion for individual doses. Considerations of collective doses show that the criterion of 1 man-Sv/a is also complied with for each clearance option.

After the material has achieved clearance or authorised release from the nuclear sector, or when the material has been exempted, regulations of the conventional side still apply, e.g. the Closed Substance Cycle and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz). Responsibility for the material is thus transferred from the nuclear authority to the authority dealing with conventional waste. The general approach to clearance (including authorised release) and exemption which has evolved in Germany over the years is fully in line with the approach and modern terminology developed by IAEA and European Commission. When it comes to comparing numerical clearance levels it can be observed that German regulations tend to be generally more conservative.

Introduction

This presentation deals with the various aspects of removal of control for materials from regulated practices, i.e. clearance and authorised release, as well as with exemption of materials from regulatory requirements. Germany has more than two decades of experience with clearance – the word "clearance" understood in a broader sense, covering also aspects, which today would be subsumed under ”authorised release” or ”authorised disposal” in the terminology proposed by the IAEA. One of the reasons why in Germany clearance has been pursued more energetically than in other countries may be that the costs for final disposal are extremely high, making clearance a financially interesting option.

Terminology

The terms that will be used in this presentation are in line with the usage suggested by the IAEA:

Clearance: covers what used to be referred to as ”unconditional clearance”, i.e. the material may be released from radiological control without any requirements concerning its subsequent use. The relevant clearance levels are usually referred to as ”unconditional clearance levels”.

Authorised release, authorised discharge: covers what formerly was referred to as ”conditional clearance”, i.e. the authority prescribes the initial use or destination of the material (e.g. disposal in a landfill) or excludes certain waste management options (e.g. no direct reuse). The relevant clearance levels usually differ from those for ”unconditional clearance”, because certain radiological pathways need not be taken into account.

Exemption: in contrast to clearance, exemption is the decision that the material is not subject to the reporting and authorisation regime. Exemption is usually granted when the material complies with exemption criteria.

The Regulatory Framework in Germany

The German regulatory framework for radiation protection is laid down in the Atomic Energy Act (*Atomgesetz, AtG*) [1]. The Atomic Energy Act empowers the Federal Government to issue ordinances for the achievement of the objectives set out in the Act. So far nine ordinances have been issued, of which the Ordinance on protection against damage caused by ionising radiation (*Strahlenschutzverordnung*, Radiation Protection Ordinance) [2] is the most important one for the purposes of this presentation. Below the ordinance level, there are a few General Administrative Regulations (*Allgemeine Verwaltungsvorschrift*), and below this, on a more technical or scientific level, there are numerous guidelines and recommendations. For the subject of this paper, the SSK recommendations are most relevant. Recently, all SSK recommendations regarding clearance have been amended and compiled in a new and concise recommendation entitled ”Clearance of Materials, Buildings and Sites with Negligible Radioactivity from Practices subject to Reporting or Authorisation” [3].

Materials from Nuclear Installations which are Appropriate for Clearance

Clearance is to a great extent determined by material quantities and management options. In Germany, nuclear power plants and fuel cycle installations are usually dismantled not long after the final shutdown. A prolonged period of safe enclosure is imposed only in special cases, e.g. for the nuclear power plant at Lingen (KWL). Therefore, large quantities of materials have to be managed over a period of perhaps one decade. As shallow land burial is no option in Germany, clearance is the alternative to expensive deep geological disposal.

For one nuclear power plant, clearance is a viable option for around 10,000 Mg of metals and between 100,000 and 200,000 Mg of concrete. In fuel cycle facilities, quantities are smaller, up to around 50,000 Mg per plant. Larger research reactors also contribute several 10,000 Mg of total mass. The quantities that will be finally disposed of usually amount to only a few per cent of the total mass.

At present, it is difficult to give an estimate of how much material will be generated over time. It is, however, a safe estimate that in the near future, a few 1,000 Mg of metal and a few 10,000 Mg of concrete will be generated in Germany per year from all nuclear installations which are currently under decommissioning or which will enter decommissioning in the next few years. The clearance levels which have been developed in Germany take proper account of these quantities.

Clearance Levels

Clearance Criteria in the Hierarchy of German Legislation

The concept of clearance is part of the BSS and is regulated in Article 5, No. 2. Disposal, recycling or reuse of substances or materials outside a regulated practice is possible if these substances or materials comply with clearance levels. However, the BSS only prescribe that these clearance levels have to be established nationally by the competent authorities, but do not specify any numerical values. It is further prescribed that the clearance levels must follow the same basic safety criteria that govern exemption, i.e. mainly triviality of individual and collective doses. In Germany, the concept of 10 µSv/a individual dose is used. It is also investigated whether the collective dose criterion is complied with for each option of clearance or authorised release or authorised disposal.

When considering whether substances or materials may be cleared or not, a decision is made whether these substances or materials should be allowed to leave a regulated practice. Clearance levels are therefore not applicable where a decision is to be made whether or not practices should fall within the regime of reporting and/or authorisation.

As I pointed out in section, *The Regulatory Framework in Germany*, clearance has not yet been implemented in the regulatory framework at the level of ordinances or laws, but only in the form of SSK recommendations. The most recent SSK recommendation [3] is the most comprehensive one, because it includes clearance values for all material types and clearance options (see below).

However, the situation will change completely with the new RPO, which will contain detailed regulations for clearance in the future. Thus clearance will play a more significant role in the regulatory framework, reflecting the fact that clearance plays an important role in waste management in Germany. Regulating clearance at the level of ordinances will also help to further harmonise the application of clearance throughout the various Federal States (Länder) of Germany.

Clearance Criteria in the Recommendations of the German Commission on Radiological Protection (SSK)

The first SSK recommendation on clearance of radioactive materials from nuclear installations [4] is now more than a decade old. It applied to clearance of metal scrap from nuclear power plants for reuse or recycling and thus had a similar scope as the corresponding recommendation of the European

Commission, RP 43 [5]. Like RP 43, this SSK recommendation expressed the clearance criteria in terms of mass-specific total activity (0.1 Bq/g total β/γ activity for reuse, 1.0 Bq/g total β/γ activity for melting only, plus surface-specific activity values), which is nowadays regarded as impractical. Moreover, like RP 43, it has now been superseded by more recent recommendations (RP 43 by RP 89 [6], the SSK recommendation of 1987 by the one of 1998 [3]). During the 1990s, several SSK recommendations for clearance have been issued. I will not discuss these in detail here because they have all been integrated within the comprehensive recommendation of 1998, which contains criteria for the clearance of solids (unconditional clearance, clearance for disposal, clearance of scrap metal for recycling), of buildings and of nuclear sites.

Overview of Clearance Levels in Germany

Clearance criteria for solids

Clearance criteria for solids have to be applied when clearing solids generated by practices subject to reporting or authorisation requirements and do not apply to liquid or gaseous substances or to contaminated sites or buildings. In general, compliance with both mass-specific and surface-specific clearance levels is to be verified by measurements (determination of surface contamination is only required if there is a solid surface on which measurements can be taken). Mass- and surface-specific clearance levels are listed in [3] for all the nuclides (approx. 300) listed in Table A of the BSS [7] (a small selection of these clearance levels is given in table-1). A total formula must be applied.

The mass-specific clearance levels are different for unconditional clearance, clearance for disposal, and clearance of scrap metal for recycling, while in the SSK recommendation the surface-specific clearance levels are the same for all these clearance pathways. However, surface-specific clearance levels are under review (see section on *Surface-Specific Clearance Levels*). The following points have to be observed:

- In the case of unconditional clearance, the destination and condition of the solids are immaterial. After clearance, the solids may be reused, recycled or disposed of as normal waste.
- Clearance levels for disposal apply to non-recyclable solid waste. It must therefore be ensured that the waste for clearance is disposed of either on a landfill site or in a thermal treatment plant (or waste incineration plant); in other words, reuse and material recovery must be ruled out. This is to be verified in the individual case. Disposal of toxic waste (i.e. mixed waste) requires case-by-case decisions.
- Clearance levels for metal scrap applies to all types of metal that are cleared as scrap for melting down. They do not apply to metals that have been melted down under an authorisation before clearance. It must be ensured that after clearance the scrap metal is actually melted down. Composite materials, such as electrical scrap, electrical cables or reinforced concrete have to be separated before clearance.

Table-1: Mass- and surface-specific clearance levels from [3] for selected nuclides

Nuclide	mass-specific clearance levels [Bq/g] for			surface-specific clearance level [Bq/cm²]
	unconditional clearance	clearance for disposal	clearance of metal scrap f. recycling	
H 3	1,000	1,000	1,000	5
C 14	80	2000	80	5
Co 60	0.1	4	0.6	0.5
Ni 63	300	3,000	10,000	5
Sr 90+	2	2	9	0.5
Tc 99	10	10	40	5
Ag 110m	0.1	3	0.5	0.5
I 129	0.4	0.4	0.4	5
Cs 137+	0.5	10	0.6	0.5
Eu 152	0.2	8	0.5	0.5
Ra 226+	0.03	0.1	0.4	0.05
Th 228+	0.1	1	0.4	0.05
Th 232	0.03	1	0.3	0.5
U 238+	0.6	10	2	0.5
Pu 241	2	100	10	0.5
Am 241	0.05	1	0.3	0.05
+ indicates: with progeny				

Clearance criteria for buildings

Buildings of nuclear installations and buildings in which other radioactive substances subject to reporting or authorisation requirements have been handled may be cleared if the following criteria are fulfilled:

- The contamination on the building's surfaces is lower than the surface-specific clearance levels in the last column of table-1 above (i.e. those surface-specific clearance levels which also apply to the clearance of solids).
- The contamination on the building's surfaces is defined as the ratio of the sum of the fixed, non-fixed and penetrated activity that is under the area to be measured for clearance, divided by the area to be measured for clearance.
- A total formula must be applied.

The term "building" comprises individual buildings, rooms, parts of rooms and building components. The procedure for verifying compliance with applicable clearance levels is to be defined in the context of the authorisation and chosen appropriately having regard to the situation in the buildings to be cleared. As a rule, the averaging area should not exceed 1 m². If it is ensured that the building will be demolished after clearance, the averaging area may also be larger than 1 m². The averaging area may consist of individual contiguous surfaces, such as walls, ceilings or floors. The measurements on which the decisions are to be based may be taken using a suitable random sampling method.

The clearance levels for buildings are also currently under review in Germany. It is intended to implement the clearance levels recently developed by the European Commission [8] (draft recommendation) in German legislation.

Clearance criteria for nuclear sites

For unconditional clearance of contaminated sites, compliance with the guide value of 10 µSv for one particular year must be verified by means of relevant calculations. This means that no nuclide-specific clearance levels are available yet but that case-by-case assessments have to be carried out.

Consideration must be given to the suitable options for using the land after clearance, which must be realistic for the location in question, as well as to the relevant exposure paths. Compliance with the guide value of 10 µSv/a is to be verified by carrying out dose calculations under realistic conditions. Conditional clearance of a contaminated site may be considered if certain requirements are satisfied even after that site is released from the scope of the Atomic Energy Act. Currently, investigations are under way to develop appropriate clearance values or at least calculation schemes for nuclear sites.

Other Matters

The SSK recommendation [3] also provides general prerequisites and protection targets, the most important ones being the following:

- Before clearance is given for solids, buildings or sites with negligible radioactivity, the question of whether reuse or recycling within the nuclear sector is possible under reasonable conditions should be investigated.
- Clearance requires authorisation.
- Compliance with the criteria listed above is regarded as verification of the negligibility of the radioactivity of the material in question.

In justified individual cases, verification of negligible radioactivity may be ensured by means of procedures and criteria other than those described here.

If materials, buildings or sites for clearance contain radionuclides that make only a very small contribution to the total activity, such radionuclides may be neglected where their *total* contribution to the individual dose is less than 10 per cent.

Deliberate mixing of contaminated or activated substances with substances that have little or no radioactivity for the sole purpose of obtaining clearance is unacceptable.

For liquids (oil, scintillation cocktails), the unconditional clearance levels can be used. Clearance of radiation sources is not permitted in Germany, which is why there are no clearance levels for sources.

Surface-Specific Clearance Levels

The surface-specific clearance levels listed in table-1 above have not been derived specifically on the basis of radiological scenarios but have been taken directly from the Radiation Protection Ordinance [2]. Therefore, these clearance levels do not properly reflect the radiotoxicity of each nuclide; especially, levels are too low for weak emitters like H 3, C 14, Ni 63 etc. However, new surface-specific clearance levels have been derived recently which take proper account of the radiological properties of all nuclides; they are to replace the old values as part of the new Radiation Protection Ordinance (see section on *Implementation of Clearance in the New Radiation Protection Ordinance*). Table-2 shows a comparison between the old and the new values. As you can see, clearance levels for gamma and alpha emitters will change only slightly (exception: Cs 137), while there is a considerable increase for weak emitters.

Table–2: New and old surface-specific clearance levels in Germany for selected nuclides

Nuclide	surface-specific clearance level of current RPO [Bq/cm²]	new surface-specific clearance level [Bq/cm²]
H 3	5	1000
C 14	5	1000
Co 60	0.5	1
Ni 63	5	1000
Sr 90+	0.5	10
Tc 99	5	1000
Ag 110m	0.5	1
I 129	5	10
Cs 137+	0.5	10
Eu 152	0.5	1
Ra 226+	0.05	1
Th 228+	0.05	0.1
Th 232	0.5	0.1
U 238+	0.5	1
Pu 241	0.5	10
Am 241	0.05	0.1
+ indicates: with progeny		

Derivation of Clearance Levels

As already indicated, experience with the derivation of clearance levels has a long tradition in Germany (see e.g. [9], which was the basis for the first SSK recommendation on clearance [4]). Additional studies followed, covering all options and materials. On the basis of these numerous scenarios, also taking into account recommendations by the European Commission and the IAEA, a new approach was chosen for the derivation of clearance levels for unconditional clearance in the SSK recommendation of 1998 [3]: so-called "enveloping scenarios" for external irradiation, inhalation and ingestion from which all clearance levels were calculated were agreed upon. Although these "enveloping scenarios" are of very simple type, this is a valid approach, as numerous studies are available that provide all the details of more sophisticated scenarios. Since this approach also recently led the IAEA to develop a new version of

TECDOC 855 [10], the scenarios that were used for deriving the unconditional clearance levels in [3] are summarised below:

The "enveloping scenario" for external irradiation describes irradiation from a large item or device with no shielding. The item is assumed to have a quantity of 3 Mg of steel ($\rho = 7.86$ g/cm³). It is modelled as a cylinder with a radius of 0.5 m and a thickness of 0.5 m.. The exposure time is set to a full working year (1800 h/a), the distance from the exposed person to the item being 1 m. The material is assumed to contain no dilution (i.e. activity at 100% of CL for each nuclide).

The "enveloping scenario" for inhalation describes inhalation of small radioactive particles released into the air in the form of aerosols (dust) from the contaminated material during use, handling, segmenting etc. The exposure time is set to a full working year (1800 h/a); the breathing rate is 1.2 m³/h, the average dust concentration 1 mg/m³. The dust is assumed to originate solely from the contaminated material. The material is assumed to contain no dilution (i.e. activity at 100% of CL for each nuclide). Any concentration processes leading to higher concentrations in the dust than in the original material are assumed to be covered by the rather high average dust concentration.

The "enveloping scenario" for ingestion describes direct ingestion of 20 g/a of the contaminated material (transfer from dust-covered hands to the mouth etc.). As the dust which is swallowed may arise from processes where concentration of activity depends on the original material (e.g. slag from melting of contaminated metals), a concentration factor of 10 is assumed for all nuclides. The material is assumed to contain no dilution (i.e. activity at 100% of CL for each nuclide).

These scenarios are considered to cover all exposure situations which are reasonably conceivable by using a long exposure time in conjunction with a rather high inhalation or ingestion rate or an unfavourable irradiation geometry.

Clearance levels for buildings, for conventional disposal, etc., are of course based on more sophisticated scenarios taking proper account of all exposure pathways to workers and to the general public. However, it is impossible to describe these scenarios here in more detail.

Application of Clearance

The fact that clearance requires authorisation means that each operator will have to apply for clearance authorisation. Therefore, even if a set of common clearance levels is implemented on a national level, the authorisations themselves will be given on a case-by-case basis. Since no binding clearance levels exist within the EU, each authorisation may in principle have a different set of clearance levels. In Article 5 (2) of the Basic Safety Standards, the members of the EU are required to consider technical advice given by the EU with regard to clearance, the goal being to harmonise clearance within the EU (RP 89 [6] and the draft recommendation on buildings and rubble [8]).

Materials generated during the operation or dismantling of nuclear installations are first characterised according to type, origin, quantity, activity content and history. This information must be documented and made available to the competent authorities under nuclear energy law. On the basis of this characterisation, it is decided whether the material must be conditioned for disposal as radioactive waste or whether it is potentially clearable.

If the activity concentration in the material is below the authorised clearance levels for that material, it can be cleared. Cleared material is legally considered not radioactive and therefore does not fall within the scope of the Atomic Energy Act and, unlike radioactive waste, does not require disposal (in Germany, all heat-generating and non-heat-generating radioactive waste must be disposed of in an authorised deep geological repository). After clearance, the material formally comes under the Closed Substance Cycle and Waste Management Act (*Kreislaufwirtschafts- und Abfallgesetz, KrW-AbfG*), and the producer must also meet the requirements laid down in this act. These requirements have been reviewed by the radiation protection authorities and taken into consideration in deriving clearance criteria. Therefore no further control by these authorities is necessary after clearance.

Besides containing the results of the clearance measurements and the characterisation of the material the documentation also contains an indication of the first recipient. If the clearance licence prescribes the first use of the material (conditional clearance), the waste producer must provide proof that the material is put to the intended initial use. The Closed Substance Cycle and Waste Management Act provides for the possibility of documenting the destination of the material, which can be used in a contractual agreement between the waste producer and the waste recipient. A copy of this documentation would then be given to the radiation protection authority as proof of the initial use. Of course it is necessary that the material fulfil all requirements of the Closed Substance Cycle and Waste Management Act if such an agreement is to be concluded.

This discussion makes it clear that in Germany there are two competent authorities dealing with the material to be cleared: firstly, the competent authority under nuclear energy law, which has to deal with radiological properties, compliance with clearance levels and all other matters regarding clearance and authorised release or disposal; and secondly, the authority responsible for conventional waste

Quality Assurance Measures for Clearance

The act of clearance requires active participation on the part of the radiation protection authorities. In particular, a system of quality assurance (QA) measures is an essential part of clearance procedures, which ensures that all clearance criteria are complied with. The importance of QA measures and the responsibility of the authorities to supervise clearance are explicitly mentioned in the recently published recommendation for clearance of metal from the Article 31 Group of Experts [6]:

> ”The structure of the BSS implies that clearance must be placed within the system of reporting and prior authorization since clearance endeavours to remove regulatory controls from material belonging to a regulated practice. Therefore it can be expected that the national authorities will authorize or license clearance either on a case by case basis or within national legislation. In both situations the process of clearance remains under the control of the authorities and therefore it is expected that they will carry out audits to ensure compliance with the clearance criteria. A means should also be established to verify that the operator continues to comply with the authorized clearance criteria, normally by a national programme of inspection and the requirement to maintain records.”

The implementation of such quality assurance measures is very advanced in Germany. The SSK recommendation [3] states:

”The clearance procedure should in particular include the report or application to the competent authority, clearance measurement and documentation of the measurement results. The method of measurement should yield representative results. For every clearance a suitable bookkeeping or documentation system should register and document all materials, buildings and sites for clearance. In particular, the nature, quantity, activity concentration, destination (consignee) and time of transfer of the substances for clearance are to be documented.”

The QA and documentation requirements for clearance are prescribed in greater detail by the radiation protection authorities in each individual case of clearance authorisation, which is generally based on published standards [11]. Waste arising during the operation or dismantling of nuclear installations is characterised according to the type of material, as well as its origin, quantity, activity content (or estimated content) and history. On the basis of this characterisation, it is decided if the material is potentially clearable and the measuring efforts for clearance are determined. A number of documented steps are taken to ensure that the activity measurements are reliable; these steps typically include the following:

- Documented preliminary characterisation
- description of the material and its origin
- pre-dismantling investigation
- clear identification of samples taken from the intact object
- description of the measuring procedure (e.g. wipe test)
- documentation of measurement results
- description of any treatment procedures such as decontamination
- summary including: radionuclide spectrum and key nuclides, scaling factors, activity distribution, planned clearance measurement technique
- Documented clearance measurements
- material to be cleared (origin, type, quantity, surface, preliminary characterisation)
- measuring equipment (type of detector, electronic devices, data processing equipment and software)
- calibration (geometry, radionuclides, calibration factors)
- clearance measurement (geometry, background effect, total counts, time)
- clearance measuring results (scaling factors, mass- and/or surface-specific activity)
- clearance (quantity of material, total activity, responsible person, date , intended first recipient of material)

Depending on the clearance authorisation, the documentation must be kept for a period of 3 to 30 years during which the competent authority under nuclear energy law may demand to see the documentation.

The act of clearance involves sending the documentation to the competent authorities under nuclear energy law for inspection. The competent authorities under nuclear energy law have the right to carry out their own measurements or request an expert to carry out measurements independently. The authorities may reject the clearance application after review. Only if the authorities have no objections can the material leave the nuclear site.

Implementation of Clearance in the New Radiation Protection Ordinance

Clearance will be implemented in the new RPO in Germany. The basic aspects are the same as in the SSK recommendation [3]. The following issues will be regulated:

- Necessity of a licence for clearance and authorised release or authorised disposal and prerequisites for obtaining such a licence;
- Interdependence between a licence for clearance and other types of licences;
- Clearance levels (mass-and surface-specific) and their application;
- Requirements for documentation and bookkeeping;
- Other requirements for application of clearance levels;
- Tables with the clearance levels themselves;
- New surface-specific clearance levels.

The great benefit of anchoring clearance in the RPO lies in the fact that it forms an integral part of the legal framework, i.e. that it can be directly linked to other parts of the regulations and that the regulations for clearance become legally binding.

Exemption

General

According to Annex I No. 2 of the BSS [7], the basic criteria for exemption of a practice are the triviality of the resulting exposure to individuals and to society as a whole and the fact that the exempted practice is inherently without radiological significance, with no appreciable likelihood of scenarios that could lead to a significant increase of individual or collective doses. When a specific practice is "exempted", it does not require reporting or authorisation. According to Articles 3 and 4 of the BSS, exemption is possible for practices where the radioactive substances involved do not exceed in total the exemption values set out in column 2 of Table A of Annex I of the BSS, or where the activity concentrations per unit of mass do not exceed the exemption values set out in column 3 of this table.

When considering whether a practice may be exempted or not, a decision is made whether this practice should *enter* the regime of reporting and/or authorisation. Exemption values are therefore not applicable to any material that is already *within* a regulated practice; for material from such a practice, it must be considered whether it could be *cleared* from this practice.

Application of Exemption Criteria in Germany

In Germany, the reporting and authorisation regime is laid down in the Radiation Protection Ordinance (RPO) [2]. Section 3 defines practices for which authorisation is required. Anyone handling other radioactive substances or nuclear fuels needs a licence. However, Section 4 of the RPO defines the cases in which no licence or even no reporting is required, i.e. the practices exempted from the reporting and authorisation regime. Because of its importance to exemption, I will outline the content of Section 4 of the RPO in more detail (the following list is simplified):

- Practices requiring no reporting or authorisation (Section 4 No. 2 RPO): handling of radioactive materials as laid down in Appendix III of the RPO, for example
  - radioactive material with a specific activity of less than 100 Bq/g;
  - solid radioactive material with a specific activity of less than 500 Bq/g of radionuclides of natural origin.
- Practices requiring reporting, but no authorisation (Section 4 No. 1 RPO): handling of radioactive material as laid down in Appendix II of the RPO, for example
  - handling radioactive material whose activity does not exceed ten times the allowances specified in Appendix IV, Table IV 1, Column 4;
  - use and storage of test emitters and of devices into which sealed radioactive substances have been introduced whose design is approved (certain additional conditions apply);
  - use and storage of devices which contain unsealed or sealed radioactive substances, if the design is approved (certain additional conditions apply);
- other practices.

The most important aspect of the current regime is the fact that materials with a specific activity of less than 100 Bq/g (total activity), or 500 Bq/g in the case of natural radioactivity, will not enter the reporting and authorisation regime at all, which corresponds to the requirements of the old BSS [12]. However, this does of course not apply to those practices which require a licence anyway, like operation of nuclear installations, storage of nuclear fuel, etc., which are subject to the provisions of the Atomic Energy Act [1].

It has emerged that a value of 500 Bq/g for natural radioactivity is no suitable concept for the case of NORM in large quantities (see section on *Exemption of NORM*). It is therefore beneficial that the current BSS [7] which form the basis for the new RPO have introduced a more flexible concept.

In the new RPO, the provisions on exemption will be changed and simplified. First of all, the exemption levels are now directly taken from Table A of the EURATOM BSS [7] (in terms of nuclide-specific total and mass-specific values), thus eliminating the 100 Bq/g and 500 Bq/g referred to above. In addition, the list of practices for which no licence is required is simplified, putting more emphasis on exemption levels than on exemption of certain types of devices or materials.

In total, the new regime will make easier the decision whether or not a practice which is not yet regulated should come under the reporting and authorisation regime and helps to draw a clearer distinction between NORM and other materials.

Relationship between Exemption and Clearance

Exemption and clearance (as well as authorised release and authorised disposal) are two different concepts which are both necessary to deal with all aspects of radiation protection but which are in no way interchangeable. In other words, the concept of exemption governs the *beginning* of the control of a practice, the concept of clearance the *termination* of the control. Both clearance and exemption are based on the concept of *de minimis* (Article 5 BSS in conjunction with Annex I), but apply to a completely different area. Exemption criteria are derived to keep practices which cause only low doses *out* of the regulatory system, while clearance criteria are used to keep material which has a significant exposure potential *in* the reporting and authorisation regime.

Although, as I pointed out earlier, both concepts are based on the same basic radiological criteria (triviality of exposure, individual dose ”of the order of 10 µSv/a”), the numerical values of clearance and exemption levels, which are derived from radiological analyses, are quite different. These differences are mainly due to differences in the underlying radiological scenarios. Scenarios relevant to clearance may for example require consideration of different exposure situations and use of different values for parameters such as quantity, exposure time, distance, etc., than for scenarios relevant to exemption. Indeed, it would be surprising if clearance and exemption values were the same. The only statement that can be made regarding both sets of values is that clearance levels must not exceed exemption values because, otherwise, there would be the risk that materials being cleared using those clearance values could not automatically be exempted.

Establishment of clearance levels in Germany was based on the principle that clearance values must not be higher than the exemption levels (see section on *Exemption*). In particular, any clearance level that applies a particular type of authorised release or authorised disposal should lie between the clearance levels for unconditional clearance and the exemption levels.

Exemption of NORM

Various human activities involve the use of large amounts of materials containing non-negligible quantities of natural radionuclides. Although these radionuclides are present in virtually all materials we deal with every day, large quantities of materials and high specific levels of activity can make certain types of materials radiologically relevant. If, in addition, there are certain exposure situations at workplaces where people come into close and prolonged contact with those materials or inhale dusts generated by it, the resulting dose commitment may be relevant involving the regulatory authority. Special consideration has to be given to radon and its decay products.

Investigation of the radiological consequences of NORM has been the aim of the German Commission on Radiation Protection (SSK, Strahlenschutzkommission) for several years [13]. In addition, the competent regional ministries as well as the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety have commissioned several studies dealing with the overall situation in Germany as well as with special aspects [14], [15], [16]. The situation in the European Union has been investigated in [17] and [18].

In the past, the radiological implications of NORM have largely been ignored, and therefore, evaluations of such problems, which could have been used to develop solutions, have not been carried out for many years. The necessity to implement the new Euratom BSS [7] in national legislation, however, has fostered both investigations and solutions. The BSS address NORM in Title VII, ”Significant Increase in Exposure due to Natural Radiation Sources”. According to Article 40, these regulations “apply to work activities not covered by Article 2(1) within which the presence of natural radiation sources leads to a significant increase in the exposure of workers or of members of the public”, in other words, those work activities, which are not yet regulated because of the involvement of artificial sources. It is left up to the Member States to identify the natural radiation sources which require attention and have to be subject to control. The Member States further have to provide appropriate means for monitoring exposure and have to ensure application of radiation protection measures as required by Article 41 of the BSS. From this, it can be concluded that the upper dose level for members of the public of 1 mSv/a according to Article 13 of the BSS would also apply to NORM.

The BSS, however, do not provide further quantitative guidance on NORM; they do not contain numerical exemption levels. However, the investigations cited above clearly indicate that no uniform and commonly applicable numerical exemption levels could be established that are valid for all kinds of workplaces and materials. Numerical exemption levels would only make sense if they were available for each type of workplace or industry or for each product or waste category. This is a major difference between NORM and artificial sources for which generally applicable, nuclide-specific exemption levels are provided in Table A of Annex I of the BSS.

If the annual dose arising from a certain practice for a worker dealing with NORM (or, likewise, for other persons of the general public) remains below 1 mSv/a, no action needs to be taken at all; in particular, there is no need to apply the reporting and authorisation regime.

If the annual dose is in the range between 1 and 6 mSv/a, it is generally considered adequate to apply conventional measures for good health and safety practices, thereby minimising exposures. Health and safety practices may for example comprise additional ventilation systems at workplaces where high radon levels persist (water supply stations, underground workplaces etc.), or it may be considered to gradually change the material composition of products to reduce the nuclide content. Case-by-case investigations and decisions will usually be required.

If the annual dose is above 6 mSv/a, it is usually necessary to introduce an appropriate radiation protection system. Here again, case-by-case investigations and decisions may help to reduce exposure.

It is against this background that Germany has chosen the following, rather pragmatic approach with respect to NORM:

If for members of the general public the annual dose caused by NORM remains below 1 mSv/a, no further action is required. This dose level thus takes the role of a kind of ”exemption level” in the case of NORM (bearing in mind that the actual concept of exemption is linked to trivial exposure which is associated with the *de minimis* concept).

Likewise, no action needs to be taken for workers for who the annual dose arising from a certain practice involving NORM remains below 1 mSv/a.

Conclusions

Clearance and Regulations on the Non-Nuclear Sector

In Germany, clearance is a very advanced concept. Clearance levels are available for unconditional clearance as well as for authorised release and authorised disposal (new IAEA terminology; ”specific clearance” in new EU terms). It has been shown what kinds of clearance levels are available and on the basis of which scenarios they have been derived. These clearance levels are in full compliance with EU Basic Safety Standards and EC recommendations; they are also comparable with the clearance levels used in other countries in Europe, the USA or Japan.

When applying the concepts of clearance, authorised release and authorised disposal, we must bear in mind that not all aspects of the future fate of the material come under the competence of the competent authorities under nuclear energy law, which may be a peculiarity of the German system and has led to some confusion in the past. After the competent authority has given its consent to clearance, responsibility for the material is taken over by the authority responsible for conventional waste which deals for example with disposal of the material in a landfill site or with its recycling etc. Thus, quality assurance aspects apply both to the nuclear and the non-nuclear sector.

The Need for Harmonisation

Experts in Germany agree that a global harmonisation of unconditional clearance levels is desirable. In this context, IAEA TECDOC 855 is regarded as a very important step in the right direction. Application of these unconditional clearance levels would greatly facilitate transboundary movement of cleared material. However, harmonisation cannot be achieved for all types of clearance levels. The scenarios which are, for example, necessary for deriving levels for authorised disposal are totally different in dry, warm countries than in more humid, colder regions, because water pathways and people's diets differ greatly. The same applies to a certain extent to metals, for which harmonisation within the EU is promulgated by the recent EC recommendation RP 89, but where countries are free to adopt their own approaches because of material quantities involved, types of furnaces in the foundries etc. Furthermore, it should be emphasised that no attempt should be made to bring clearance levels and exemption values to the same numerical values, as has been proposed from time to time, since clearance and exemption are two different concepts.

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GERMAN DECOMMISSIONER VIEWPOINT

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1 Introduction

This paper focuses on the decommissioning of Nuclear Power Plants (NPP). Especially the release of building structures and sites. The measuring strategies dealing with these parts of a nuclear facility are of larger interest due to the fact that very high masses have to be handled and the measuring techniques differ significantly from those in an operating facility.

Several criteria of assessment concerning the decommissioning of nuclear facilities (especially NPP´s) exist in Germany. Examples therefore are the Recommendation of the Commission on Radiological Protection concerning the "*Clearance of Materials, Buildings and Sites with Negligible Radioactivity from Practices subject to Reporting and Authorisation*" based on the IAEA "10 µSv-concept" (safety series #89) and the "*Guide to the Decommissioning of Facilities as Defined in Article 7 of the Atomic Energy Act*" given by the Federal Ministry for Environmental Protection. These topics are discussed in other presentations (3.8a, 4.2) of this workshop and outside the scope of this paper. Also the content of German standards like DIN 25457 ("*Activity Measurement Methods for the Release of Radioactive Waste Materials and Nuclear Facility Components*") must be neglected here.

Two originally neighbouring facilities will be presented: "The Hot-Steam Reactor Großwelzheim" **(HDR)**, which is – after the Nuclear Power Plant Niederaichbach (KKN) – the second Bavarian NPP released from the German Atomic Energy Act in 1998 leaving a "green field" on the site. The second plant is the "Versuchsatomkraftwerk Kahl" **(VAK)** which has been shut down after 25 years of operation and which is now in a late phase of decommissioning.

It is practice in Germany, to split up the licensing process of the decommissioning of a facility into several steps. With respect to the release of building structures and site the last licenses are of importance. Subject of the final license for HDR was the release of buildings from the Atomic Energy Act after performing release measurements and subsequent dismantling by conventional techniques. The gained experiences are discussed from the point of view of a Technical Support Organisation (TÜV) with the particular task to perform independent measurements to assess the radiological state of the facility (Chapter 2).

The experiences and results gained in HDR lead to an outlook on the decommissioning of the buildings and the release of the VAK site. Chapter 3 considers these facts, presenting the future activities in the decommissioning of VAK.

2 Decommissioning of HDR

2.1 Basics

The HDR plant showed contamination in parts of the building structures and the site, which have been removed before release measurement took place. The total inventory of the plant before decontamination was estimated to be in the order 10^{10} Bq. The decontamination procedures reduced the inventory significantly (see e.g. Diagram 1). In total 28.000 Mg of concrete, 31.000 m² of steel and other surfaces and more than 6.000 m² outside areas had to be released.

The licensing authority contracted TÜV as Technical Support Organisation as assistance of the decommissioning process. The duties were e.g. the assessment of the licensees documentation and to carry out independent control measurements. The range of these measurements covered the biological shield as well as the meadows along the perimeter of the site. For the first time in-situ gamma spectrometry was implemented in the complete measuring strategy as a diverse measuring technique.

2.2 Clearance Levels

The evaluation of the clearance levels for the unrestricted release of materials and the site based on the "10 µSv-concep" by the IAEA. Based on this concept the clearance levels are depending on the nuclide vector. Therefore the nuclide vectors where determined for the different materials/areas of the plant from representative samples before licensing. After the evaluation of the nuclide vector the clearance levels were related to mass- or surface-specific activities of the dominating nuclide in each case and used as activity limits during the decommissioning process (Table 1).

0,47 Bq/cm²	β-activity	concrete; reactor building
0,038 Bq/g	Eu 152	concrete; biological shield
0,5 Bq/cm²	β-activity	steel (not-activated) and sealed outdoor grounds
0,03 Bq/g	Cs 137	unsealed outdoor grounds; max. 0,01 Bq/g Co 60; 0,02 Bq/g Cs 137 may be subtracted (Chernobyl)

Table 1: Summarised clearance levels (abridged version)

2.3 Measuring Techniques and Strategies

2.3.1 Building Structures

The performed routine activity measurements will be explained below. Table 2 shows the measuring techniques used.

	Decommissioner	TÜV # Building / # Site
Samples, Gamma Spectrometry	✓	350 / 140
Contamination Monitor	✓	11.000 / 120
Smear Tests	✓	600 / 0
in-situ Gamma Spectrometry		850 / 720

Table 2: Measuring techniques used by the decommissioner and as control measurements. The numbers indicate the rounded sum of performed measurements.

The focus of the following chapter lies on the in-situ technique due to the fact that these measurements are not common yet. The other routine measurements were used without special modifications.

For the first time in-situ gamma spectrometry was used during the entire measuring campaigns accompanying the decommissioning process. In the past in-situ gamma spectrometry was used in several, short-term (max. some weeks) measuring campaigns in the framework of the surveillance of nuclear facilities (especially decommissioning projects). The use of the collimated in-situ spectrometry in decommissioning projects was investigated in a project founded by the EC[1]. Actually a R&D-project[2] covering the whole subject of the use of different release measurement techniques in the buildings of nuclear facilities is in a late stage.

In-situ gamma spectrometry allows nuclide-specific measurements in the proper place. Figure 1 shows the cross section of the two collimated in-situ spectrometers used during the measurements in HDR. Without a collimator the total photon flux from the surrounding building structure is detected. A special calibration technique was necessary to estimate the average surface-specific activity.

Using the collimator, the in-situ spectrometer can detect activity in defined circular areas of about one up to more than 10 m². If the depth distribution of activity in the structure is known, the spectrometer can be calibrated to measure surface- resp. mass-specific activities. Concerning the depth distributions

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[1] *High Resolution in-situ gamma spectrometer for use on contaminated building structures and outdoor grounds under decommissioning*

Report EUR 18349, 1998

[2] Founded by the *Federal Ministry for Education, Science, Research, and Technology* and the *State Ministry for Regional Development and Environmental Protection of Bavaria*.

used inside the reactor building of HDR it was shown by sampling in fine layers that the assumed distribution was conservative.

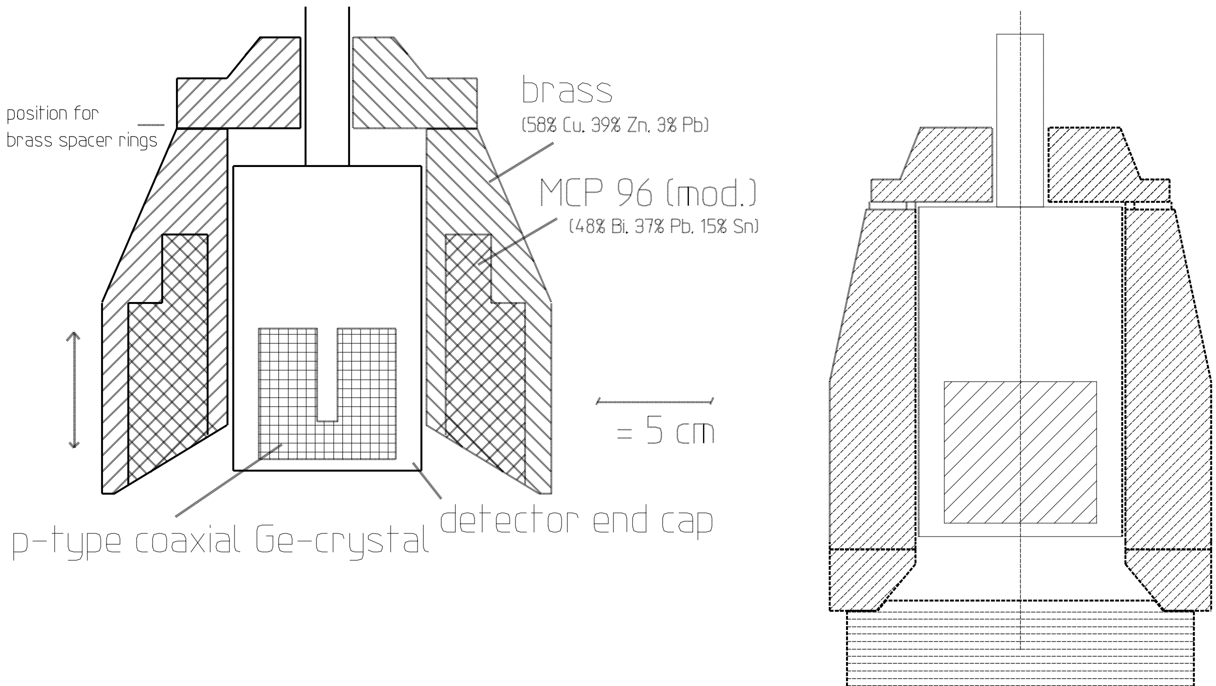

Figure 1: Drawings of the cross section of the two in-situ gamma spectrometers used for control measurements. The right one is an extended range p-type detector with an efficiency of 42%. The right collimator is made of sintered tungsten for an optimum shielding-mass ratio. In the case of strong irradiation from outside the "field of view" a plug can be added to perform a differential measurement.

For determining the measuring strategy of the control measurement it was assumed that all relevant contaminations have been removed during the decontamination process. Therefore localised areas with high contamination levels or large areas with raised contamination level have not been expected during the measurements.

The first stage measurements were one or a set of uncollimated in-situ measurements depending on the extent and geometry of the considered building structure inside the plant.

As a result of these measurements two criteria had to be met:

- Keeping of the clearance level averaged over the entire structure
- Keeping of a "hot-spot-criterion" depending on the nuclide vector

The second criterion was in the range of several 10 kBq, evaluated from radiological reasons. Under normal circumstances (room geometry) this criterion was infringed prior to the first. In practice the first criterion was kept in every case. By keeping both criteria it was stated that there are no indications concerning activities infringing the clearance levels.

Only if the second criterion was infringed, more detailed measurements were performed as a second stage. The following points show several possibilities to choose from in the actual situation:

- Performing several uncollimated measurements to prove "homogeneous activity distribution".
- Collimated measurements to estimate the mid-scale activity (eff. Area: some m^2).
- Measurements with contamination monitors to localise remaining small area contaminations.
- Sampling to verify the assumed depth distribution.

This procedure has one great advantage. The expenditure depends on the existing radiological state of the structure. The number of measurements necessary is decreasing with the difference between measured activity value and clearance level.

Besides the discussion above, the use of in-situ spectrometry for release and control measurements has more advantages:

- The area covered by the measurement is much higher than following a sampling strategy or contamination monitor measurements in a grid.
- The activity ratios of the main gamma emitting nuclides can be verified permanently.
- The artificial part of the activity can be separated easily from the natural background.
- The measuring results due to gamma radiation are nearly independent from the migration of the nuclides into the concrete, compared to beta-sensitive contamination monitors.

In the PC-based documentation accompanying this project the total masses, surfaces and activity levels gained with the different measuring techniques were recorded. Diagram 1 shows a compressed summary of the total artificial inventory of the building and the average contamination level. The decreasing averaged activity level with increasing distance to the former reactor vessel as plotted in Diagram 1 is self-explanatory.

The discussion of the remaining total activity and especially the differences between the measuring techniques is a little more complicated. To understand the result three points must be kept in mind:

- Systematically occurring errors which have no tendency are vanishing comparing a data set of many single results. Therefore only systematic errors with a tendency to over- or underestimate the true value appear in this graphic representation.
- The detection limits of the contamination monitors are higher then those of the in-situ gamma spectrometer. If no activity was detected, the detection limits were summed up.
- As long as contaminations are located on the surface only, the activity will be overestimated due to the conservative calibration procedure of the contamination monitor. On the other hand concrete with activity migrated into the structures (e.g. mechanical decontaminated structures)

will tend to be underestimated with contamination monitors due to the short ranged beta radiation.

So it can be concluded that there is a break-even point where both measuring techniques are leading to the same results. In this context, the good agreement of results for the reactor building inside the safety tank is accidental.

In areas with remaining activity of a higher level (0.2 Bq/cm² or higher) the in-situ results were above the contamination monitor values generally. In contradiction to that the summing of detection limits with contamination monitors led to an overestimation of the remaining activity in the most cases.

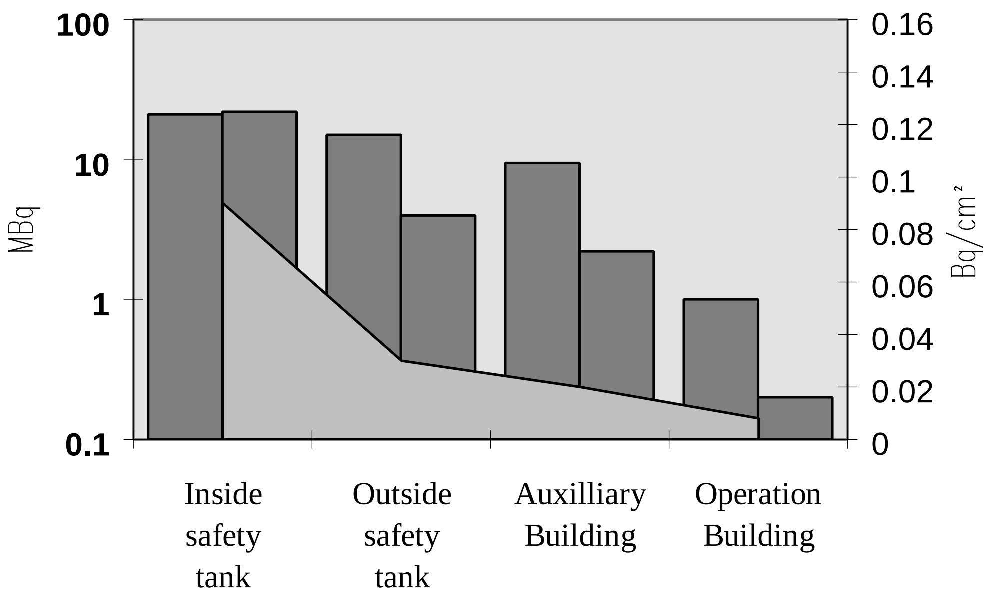

Diagram 1: Total artificial inventory [MBq] of the building structures (bars) measured by the decommissioner with contamination monitors (left) and during the control measurements with in-situ gamma spectrometry (right). The area plot shows the averaged contamination level [Bq/cm²] remaining in the structure decreasing with the "distance" from the former reactor vessel.

2.3.2 Site

Besides the area used for buildings the site of HDR split-up into approximately 3.200 m² sealed grounds (e.g. concrete, asphalt) and also 3.200 m² unsealed areas (e.g. meadow, gravelled). The unsealed areas were divided into 64 sub-areas which had to be treated separately. After the depth profile of possible contaminations has been determined, from each sub-area 20 samples were taken. The sampled soil was crushed, homogenised, dried and then used to create a mixed sample. The mixed sample was analysed with gamma spectrometry in laboratory.

At the unsealed areas 471 collimated in-situ measurements with an averaging area of typically 9 m² were performed as control measurements. The detection limits were below 4 Bq/kg for Co 60 and Cs 137 using a measuring time of 5 minutes. The measurements covered almost the entire unsealed areas.

As mentioned above the clearance level for Cs 137 was 30 Bq/kg. In addition, it was possible to subtract max. 20 Bq/kg Cs 137 due to Chernobyl wash-out. Diagram 2 shows the comparison of the results of the decommissioner using the described sampling strategy with the results gained with in-situ gamma spectrometry by TÜV.

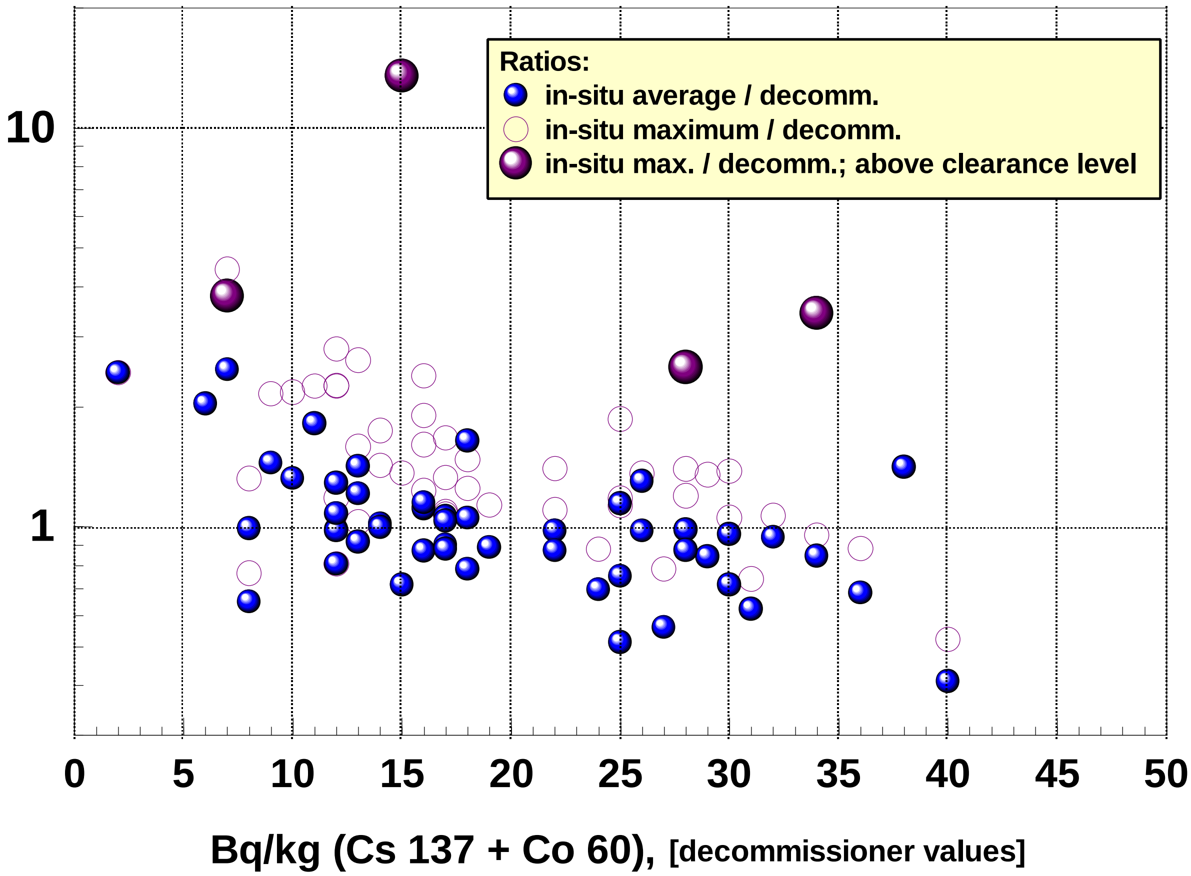

Diagram 2: Comparison of the results of measurements gained by sampling and in-situ gamma spectrometry on the unsealed areas of HDR. Explanation see text.

The diagram 2 shows a scatter plot of the ratios between the activity measured by in-situ gamma spectrometry and the samples for the 64 sub-areas as a function of the mass-specific activity estimated by the decommissioner. The smaller bowls compare the mean values of both measuring strategies. The average value of this data-set and the 1σ-error is 1.02±0.39 and therefore in excellent agreement. However it must be noted, that 4 of the 64 sub-areas (larger bowls) were not used for this comparison (see next section).

The circles and the four larger bowls compare the maximum values of the large scale averaging in-situ measurements with the samples. It is clear, that these values tend to be higher. This tendency is small due to the large measuring area. In four sub-areas values above the clearance level were detected. This result could be confirmed by subsequent sampling.

It can be summarised that two lessons can be learned from that result:

- The overall radiological state can be estimated with sampling and in-situ gamma spectrometry.
- Remaining contaminations which tend to appear inhomogeneous have a significant probability to be overseen by sampling.

2.4 Experiences and Consequences for similar Decommissioning Projects

In the following the experiences concerning the topics discussed above are condensed:

- In-situ gamma spectrometry has a proven capability to verify the clearance levels of the building structures and the site during the decommissioning of a NPP.
- Large-scale averaging measuring devices show advantages as long as the averaging quantities (masses, areas) are radiological tolerable.
- The comparison of the results of different measuring techniques enlarges the quality of release measurement strategies.

STATUS OF NRC EFFORTS ON CLEARANCE RULEMAKING

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Background

Current NRC Regulations for Release of Materials

The NRC has the statutory responsibility for the protection of health and safety related to the use of source, by-product, and special nuclear material under the Atomic Energy Act. The Commission has set standards for protection of the public against radiation. These standards, which are codified in NRC's regulations, limit the radiation exposure (or "dose") that a member of the public can receive from the operation and decommissioning of a nuclear facility, and also require that doses received are "as low as is reasonably achievable (ALARA)". The NRC has used the criteria on public dose limits and ALARA requirements to establish limits on the amount of radioactivity in gaseous and liquid releases that may be released from a nuclear facility to the environment.

However, unlike the standards applicable to gaseous and liquid releases from a licensed nuclear facility, the NRC has not set criteria governing releases of solid materials by licensees. Therefore, if a licensee requests approval of release of solid material, the NRC must consider the request on a case-by-case basis using existing regulatory guidance, license conditions, NRC Branch Technical Positions, etc.

In 1997, the Commission amended its regulations to establish criteria for unrestricted use of facility structures and lands at a decommissioned site. However, the criteria focus on protection of persons entering and using decommissioned structures and lands at a site after a nuclear facility terminates its NRC license, and do not address release of solid materials.

Solid materials potentially available for release.

Solid materials include metals, building concrete, onsite soils, equipment, furniture, etc. that are present at, and/or used in, licensed facilities during routine operations. Most of this material will have no radioactive contamination, although some materials can have radioactive contamination either on their surfaces or distributed within their volumes. The amount of contamination that a material has, if any, depends largely on the type of licensee involved and the material's location in a facility.

For most NRC licensees, solid materials have no contamination because these licensees use sealed sources in which licensed radioactive material is encapsulated. Examples are small research and development facilities and users of licensed gauges.

For other licensees (including nuclear reactors, manufacturing facilities, larger educational or hospital laboratories, etc.), material generally falls into one of three groups based on its location or use in the facility. Material in clean or unaffected areas of a facility would likely have no radioactive contamination resulting from licensed activities. Such areas could include hospital waiting rooms, university office space in a laboratory, or the control room of a reactor facility. Material in areas where licensed radioactive material is used or stored can become contaminated. Because of the NRC's contamination control requirements at licensed facilities, the contamination levels, if any, may likely be very low. Some examples include material in certain laboratory areas in a university or hospital, or in certain buildings of a reactor facility. Finally, material that is used for radioactive service in the facility, or is located in contaminated areas or in areas where activation can occur generally have levels of contamination that would not allow them to be candidates for release unless they are decontaminated.

Current NRC case-by case review of licensee requests for release of solid material

Even though the NRC does not currently have specific criteria covering release of solid materials, licensees have made, and will likely continue to make, requests for their release when they become obsolete or defective or when facilities are decommissioned. The NRC evaluates these requests on a case-by-case basis using either its guidance on "Termination of Operating Licenses for Nuclear Reactors" or other case-specific criteria.

The NRC guidance on termination of operating licenses for nuclear reactors, which was developed by the Atomic Energy Commission in 1974, provides a table of Acceptable Surface Contamination Levels for various radionuclides, including natural and enriched uranium, transuranics, and fission products. These surface contamination levels are stated in terms of measurable radioactivity levels (observed disintegrations per minute per 100 square centimeters of surface area) and were based principally on the capabilities of readily available instrumentation at the time the guide was developed. The guidance does not contain dose criteria.

The NRC guidance only addresses materials having surface contamination; it does not cover volumetric contamination. For some situations, the NRC allows release of volumetrically contaminated solid material if survey instrumentation does not detect radioactivity levels above background. This does not mean that the material is released without any radioactive contamination present on, or in it; instead, it means that the material may be released with very low amounts of contamination that is not detectable with appropriate survey instruments. This method provides inconsistent and generally unsatisfactory licensing guidance because different survey instruments have different levels of detection. This can lead to disagreements and confusion over permissible levels of release and nonuniform levels of protection.

Licensees may request specific approval to dispose of materials containing low levels of licensed material in other than a licensed low-level waste disposal site, e.g., a solid waste landfill, in accordance with our requirements. We require that licensees describe the material to be released and evaluate the doses that would result. Use of this approach requires case- specific NRC review and evaluation of the situation. This approach would likely not be appropriate for evaluating the increased amounts of material that could be available for release during decommissioning.

Commission Direction Regarding Rulemaking on Release of Solid Materials.

As noted above, case-by-case technical reviews, while protective of public health and safety, can cause inconsistencies and confusion. With the potential for increased licensee requests for release of solid materials as more facilities near decommissioning, the Commission, on June 30, 1998, directed the NRC staff to consider rulemaking to establish a dose-based standard for release of solid materials so that licensee considerations of, and NRC review of, disposition of slightly contaminated solid materials are conducted in a consistent manner that protects public health and safety. The Commission also directed the NRC staff to include an opportunity for enhanced public participation, including use of NRC's Internet home page to solicit comments.

The Commission further indicated that, in developing the dose-based standard, the staff should: (1) not develop a detectability standard but rather (using input from the International Atomic Energy Agency (IAEA) interim report, from analyses by NRC's contractor, and from ongoing practice with regard to naturally-occurring and accelerator-produced radioactive material) focus on codified levels above background, for unrestricted use, that are adequately protective of public health and safety; (2) base standards on realistic scenarios of health effects from low doses; and (3) develop a comprehensive rule applicable to all metals, equipment, and materials, however if problems that would delay completing the rulemaking arise in certain categories of materials, then a decision could be made to narrow the scope of the rule.

Current Status of NRC Efforts

In responding to the Commission's direction, the NRC staff is currently involved in three principal efforts. These are preparation of an issues paper, holding facilitated public meetings, and development of additional technical bases.

Issues paper – An issues paper has been prepared to be made available for public comment in the Federal Register. The issues paper describes issues and alternatives related to release of solid materials. The intent of this paper is to foster discussion about these issues and alternatives before any rulemaking to set standards would begin. The issues paper will also be available on NRC's website. More discussion on the issues paper is presented later in this paper.

Facilitated Public Meetings – The NRC plans to enhance public participation in this effort by conducting workshops for interested parties before any rulemaking would begin. The workshops are planned to elicit informed discussions of options and approaches and the rationale for them. Although not seeking consensus on the issues, the workshops are intended to ensure that the relevant issues have been identified, to exchange information on these issues, to identify underlying concerns and areas of disagreement, and, where possible, to identify approaches for resolution. The NRC staff also plans to enhance participation by providing website access to the issues paper and by inviting submittal of comments on the issues paper by e-mail. The NRC will convene facilitated public meetings in four different geographical locations (Chicago, Atlanta, San Francisco, and Washington, DC). Facilitation of the workshops is intended to ensure that there will be broad participation in the meetings to include a range of groups and a variety of viewpoints, and to aid in conducting the meetings so that those viewpoints are heard.

Technical Basis Development – Following the early exchange of ideas (including workshop comments and comments filed by other means such as Internet responses and written comments), the Commission may decide to proceed with rulemaking. If it does so, other rulemaking documents will be prepared. Specifically, the NRC would evaluate the implications of a rule with regard to the National Environmental Policy Act (NEPA) by considering the environmental impacts of rulemaking alternatives in an environmental impact statement (EIS) or environmental assessment (EA). This evaluation would consider both radiological and non- radiological impacts associated with alternative dose criteria for release of materials for unrestricted and restricted use. The NRC would also prepare a Regulatory Analysis to evaluate costs versus benefits of rulemaking alternatives.

The NRC would also publish regulatory guidance to provide licensees with information on how to demonstrate compliance with the regulation. A regulatory guide would provide information on measurement methods for low concentrations of volumetrically contaminated material that may exist in various equipment and material types, shapes, and sizes that are anticipated to be available for release. It is expected that analyses similar to that prepared for the license termination rule in NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys," will be prepared to support a regulatory guide.

As a first step in development of the technical bases, the NRC has issued a draft report for comment that provides a basis for determining potential doses to individuals from a wide range of potential scenarios by which members of the public could come in contact with solid material that had been released for unrestricted use from licensees ("Radiological Assessment for Clearance of Equipment and Material from Nuclear Facilities", NUREG-1640, March 1999). The report contains an analysis of material flow models based on an evaluation of the recycle/reuse industry in the U.S. and of potential scenarios by which a member of the public could reasonably expect to be exposed. Solid materials that are candidates for release that are evaluated in the report include iron/steel, copper, aluminium, and concrete.

Although NUREG-1640 does not include specific analyses for soil, work done previously for NRC's recently issued rule on license termination provides baseline technical information on individual dose factors and environmental analysis for soil which could be adapted for use for this application. This previous work includes NUREG-1496, "Generic Environmental Impact Statement on Radiological Criteria for License Termination," and NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning." NRC is currently working to adapt the information previously developed in this, and other sources, for use in its clearance analyses.

In its efforts to develop both regulatory policy and technical bases, the NRC is also considering policies and precedents set by international agencies, such as the International Atomic Energy Agency (IAEA), and other nations resulting from their considerable effort to set standards in this area.

The Issues Paper

As noted above, the NRC staff has prepared an issues paper which describes issues and alternatives related to the release of solid materials. Three broad issues associated with proceeding with a rulemaking discussed in the issues paper are presented here.

Issue 1 – What are the principal alternatives that should be considered, and what factors should be used in making decisions between alternatives?

Alternatives:

Potential alternatives for rulemaking are:

(1) *Continue the status quo, i.e., continue the current practice of handling of licensee requests for release of solid materials on a case-by-case basis* – As noted above, NRC currently has no specific

requirement in its regulations on limits for release of solid materials. If no NRC rule is prepared, licensees will still continue to make requests for release of solid materials which NRC will have to evaluate on a case-by case basis using regulatory guidance, Branch Positions, license conditions, etc. However, the existing criteria are not dose based, do not contain generally applicable criteria for volumetric contamination, and can provide inconsistent and conflicting guidance. Instead of retaining the status quo, the NRC could proceed with rulemaking to develop dose-based regulations limiting releases of solid material to provide a consistent regulatory framework for releases of all materials that is protective of public health and safety. This would involve conducting a rulemaking under the Administrative Procedures Act, and developing, as regulatory bases, an environmental evaluation under NEPA and an analysis of costs and benefits in a Regulatory Analysis.

(2) *Permit release of materials for unrestricted use if the potential dose to the public from the material are less than a specified level determined during the rulemaking process* – In this alternative, a licensee could release, for unrestricted use, material that meets the permissible level in the standards. Unrestricted use could result in recycle or reuse of the material in consumer products or industrial products, or disposal of the material as waste in landfills. Release of solid materials for unrestricted use is also referred to as "clearance." Potential alternative dose levels resulting from unrestricted use of the material could include doses of 10 mrem/yr, 1 mrem/yr, and 0.1 mrem/yr above background, as well as no dose above background. To provide some perspective on these levels: (a) the dose from natural background to people in the U.S. can vary widely based on the area of the country where people live and is on average about 300 mrem/yr; (b) NRC's public dose limit is 100 mrem/yr,(c) a person receives 10 mrem on a round-trip coast-to-coast flight, and (d) 1 mrem/yr is a level which the National Council of Radiation Protection (NCRP) considers a trivial risk. A 1 mrem/yr value is also the level being considered for unrestricted use (or "clearance") in the European community.

3) *Restrict release of solid materials to only certain authorized uses* – For example, future use of the material could be restricted to only certain industrial uses where the potential for public exposure is small (see more detail below).

4) *Do not permit either unrestricted or restricted release of solid material that had radioactive service in the facility or been in an area where radioactive material has been used or stored* – In this alternative, all such materials in the facility would be required to go to a licensed LLW disposal facility.

5) *Other alternative(s)* – Other alternatives may be presented and considered during the rulemaking process.

Factors in decision-making related to Issue 1:

In evaluating the rulemaking alternatives, NRC would consider potential human health and environmental impacts, cost-benefit aspects, and implementation questions associated with each alternative. The NRC would also consider policies and precedents set by other nations and international agencies, by other Federal agencies and by U.S. States. Some of the specific questions asked in the issues paper regarding this issue are listed in Table 1.

Human health and environmental impacts: In assessing potential rulemaking alternatives, NRC would consider a broad range of possible impacts, both radiological and non-radiological. These could include the evaluation of radiation dose to individuals from release of solid materials (including the potential for exposure to multiple sources of released materials), assessment of collective doses to different population groups from release, transport, processing and disposal, impacts on biota, land use impacts, and societal impacts. Some of these impacts may be competing. For example, a lower dose criterion would result in less material available for release (and instead sent to a LLW disposal site) which, in turn, would lower the radiation dose impact to the public from exposure to that material. However, the lower dose criterion could cause an increase in other impacts, for example those non-radiological impacts associated with mining and transport of fresh metal to replace that sent to a LLW disposal site. Because these impacts would take place over different time periods and expose different populations, a precise comparison is difficult. Nevertheless, the decision-making process could consider these impacts separately and also consider the net collective impact for these disparate factors.

Cost-benefit considerations: In support of its rulemaking decisions, NRC prepares regulatory analyses which evaluate the cost-benefit of alternative courses of action. Benefits would generally derive from the net reduction in environmental impacts discussed above. Costs in a regulatory analysis could include: (1) the costs of alternative courses of action, including surveys at the nuclear facility to verify that permissible release levels have been met; (2) economic impact on recycle/scrap/manufacturing processes, including the potential for having to respond to "false positive" alarms at scrap facilities, (3) replacement metal production; and (4) alternative options for disposing of the material.

Implementation considerations: A potential concern with implementation of a proposed rule is the capability to measure radioactive contamination corresponding to the very low alternative dose levels discussed above. In particular, a rulemaking alternative which would require survey instrumentation to verify that there is no dose above natural background could be extremely difficult to implement because of the variation in natural background and the capability of survey instruments to detect such low levels.

Other international, national, and state standards: There is considerable effort by other nations and by international agencies, such as the IAEA, to set standards in this area. Consistency with standards set by other nations and international agencies is important because materials can be both imported and exported between the U.S. and other countries and differing standards could create confusion and economic disparities in commerce.

The NRC will also closely involve the U.S. Environmental Protection Agency (EPA) in its rulemaking efforts. The EPA, although not a regulator of licensees, is responsible for setting generally applicable environmental standards for radioactive materials under the Atomic Energy Act. The NRC, in regulating its licensees, implements environmental standards that EPA promulgates in the area of radiation protection. In the absence of EPA standards in a particular area, for example in the area of release of solid materials, the NRC has the authority to set radiation protection standards for its licensees. This can cause potential problems with the finality of NRC licensing decisions if EPA later issues standards in a particular area that are different from regulations that NRC has previously issued. Thus, it is important for the NRC to closely involve EPA in developing its standards. In addition, the EPA has completed studies on environmental impacts of clearance of materials. The NRC and EPA have, and plan to continue to have, co-ordinated efforts in this area to ensure that effective and consistent release standards are established, while minimizing duplication of effort. EPA is currently active in the development of standards for import into the U.S. of materials cleared in other countries. EPA has been working with the International Atomic Energy Agency (IAEA) and the U.S. Department of State in these efforts.

The NRC must also consider input of individual U.S. State governments in its rulemaking process. Thirty U.S. States (referred to as "Agreement States") have entered into Agreements with the NRC to assume regulatory authority over by-product, source, and small quantities of special nuclear material. The Energy Policy Act of 1992 grants State governments (Agreement and non-Agreement States alike) the authority to regulate the disposal of low-level radioactive waste if the NRC exempts such waste after the enactment of Act. Several States and locales have, both prior to and subsequent to passage of the Act, established prohibitions against the disposal of radioactive material in landfills. The implications of this authority on NRC's potential alternative courses of action noted above are unclear and may depend on the ultimate nature of any rulemaking that NRC undertakes.

Issue 2 – Could some form of restrictions on future use of solid materials be considered as an alternative?

Alternatives:

Potential alternatives for restricted use of solid materials are described here. Some of the specific questions asked in the issues paper regarding this topic are listed in Table 1.

1) *Restrict the first use of solid material to certain authorized uses* – In this alternative, the release of radioactive material would be restricted to certain authorized uses to ensure that it is processed into one or more specific products. For example, material could be recycled for use for some industrial product such as steel beams that would be designated for use in a foundation or structural support for a bridge or monument. Because of uncertainties related to controlling potential uses of the material after it leaves a licensee's facility, it may be necessary to require that processing of the material for the first use be done under a specific license issued by the NRC. This alternative might be beneficial for materials contaminated by nuclides having short to moderate half-lives, allowing substantial reduction in contamination due to radioactive decay within the lifetime of the structure in which it is placed.

2) *Restrict release of solid material to permitted disposal* – This alternative would restrict release of solid material from licensed facilities to disposal at municipal solid waste landfills. These landfills are issued permits by State regulatory authorities in accordance with our regulations, "Criteria for Municipal Solid Waste Landfills" as well as other State and local regulations. The rationale for this alternative is that exposure pathways at landfills can be fairly well defined and quantified, and that many of the pathways of potential exposure associated with recycle of metal into consumer or industrial products would not be present. Additional restrictions could involve disposal at industrial solid waste facilities rather than at sanitary waste landfills.

Issue 3 – What materials should be covered?

Any alternatives chosen for consideration would be dependent on information available on the various materials. Currently, the NRC has developed technical background information for ferrous metals, aluminium, copper, and concrete in NUREG-1640, and related technical information for soil in NUREG-1496. The materials analyzed in NUREG-1640 and NUREG- 1496 make up the large majority of material that would likely be considered for release from licensed NRC facilities based on staff experience and from information received from licensee groups. NRC does not have similar analyses completed for other materials that could be potentially available for release, e.g., sludge, resins, wood, glass, etc. Although the staff proposes to expand the technical analysis to include these materials, this would require additional time to complete.

Therefore, rulemaking alternatives which NRC has related to this issue include: (1) developing a rule limited to only a select group of solid materials, including certain metals as well as concrete and soil, (2) developing a rule for a wider group of materials to also include other materials under license, or (3) developing the more limited rule of Alternative 1 and conducting rulemaking on other materials at a later time.

Next steps

The NRC will publish the issues paper for public comment after Commission approval. It is planned that public meetings will take place from August through November 1999.

Table 1

Some of the Specific Questions for Discussion Posed in the Issues Paper

Questions Related to Issue 1

1) What pathways of exposure, in addition to those already considered in NUREG-1640, should be considered?

2) What other non-radiological environmental impacts should be considered?

3) How should net environmental impacts from all the radiological and non-radiological impacts be balanced, and how should economic factors be included into that balance?

4) What ways might persons be exposed to multiple sources of released material and what is the probability of such exposures? How should the potential for exposure to multiple sources be considered in setting an acceptable dose level?

5) What societal impacts should be considered and how should they be factored into the environmental evaluation? For example, material released for unrestricted use from licensed facilities could result in concern, confusion, or fear if the public either does not clearly understand that the risk is small or does not accept the risk.

6) What are the major economic costs associated with release of solid materials for unrestricted use either into general commerce and to landfill disposal?

7) What economic risks (and associated costs) are associated with release of solid materials for unrestricted use? For examples, could materials released from a nuclear facility be rejected at a melter, scrap yard, or landfill based on a survey at that point, a landfill? What means could minimize potential problems?

8) What is the potential for build-up of radioactivity in commerce as a result of continued release of solid material for unrestricted use over time and how should such a build-up be estimated?

9) What is the capability to survey materials (both for surface and volumetric contamination) at the different alternative dose levels being considered, and what effect would that have on setting a standard?

10) How should guidelines on unrestricted release, or "clearance," set by international standards-setting bodies such as the IAEA and International Commission on Radiological Protection (ICRP), as well as those set by other countries, be considered in setting a level for release of material from NRC-licensed facilities in the U.S? How should efforts by the U.S. Department of State and the EPA to set import standards be considered?

11) Should existing NRC standards, including the public dose limit of 100 mrem/yr and the dose criterion of 25 mrem/yr for release of decommissioned structures and lands, be considered in setting allowable doses for release of solid material for unrestricted use? A consideration in this question is that there

are different circumstances and issues being discussed in this paper. For example. Current standards limit the dose from the single release of structures and land at a site to 25 mrem/yr. In contrast, unrestricted release of the materials considered in this issues paper could involve periodic releases over the facility lifetime at a dose level to be set in the rulemaking.

Questions Related to Issue 2

1) What types of controls could reasonably be placed on the process of restricting use to assure that the material would not be released for unrestricted use?

2) Would it be necessary to license processing of the material for the first use in order to assure protection of public health and safety? For example, if iron/steel were to be restricted to use in bridge support, should the company processing the steel into bridge supports be licensed by the NRC? Or could sufficient restrictions be placed on the processing company to assure that the steel went where it was supposed to without the company having an NRC license?

3) How long would the material be able to be restricted and what would happen to the material when it reached the end of its useful restricted life?

4) What type of public involvement in decisions concerning restricted use of materials should there be? Should it be similar to the method used in Subpart E of 10 CFR 20 where licensees are required to seek advice from affected parties when placing a site into restricted use?

5) What specific problems are associated with restricting materials to landfill disposal?

THE FRENCH APPROACH TO REGULATING TREATMENT OR RECYCLING OF RADIOACTIVE WASTE ARISING FROM DECOMMISSIONING OF NUCLEAR FACILITIES

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Abstract

The decontamination and dismantling operations occurring prior to decommissioning of nuclear facilities lead to the production of large amounts of nuclear waste, among which a majority of low level and very low level waste. The French Nuclear Safety Authority has promoted and implemented a *regulatory framework* to deal with this waste. According to this framework, each category of waste must be managed through specific, well-identified pathways (recycling, treatment, disposal), for which specific impact studies are conducted. It is insured that the recycling treatment or disposal facilities involved in the pathways comply with the regulations and that the public is informed about their operation. This framework is an alternative to the use of universal unconditional clearance levels which appear to be unacceptable in France.

The framework has been applied in the case of waste arising from dismantling of several nuclear plants. Three examples are given of waste processing facilities of low level and very low level waste by fusion, incineration and vitrification.

Introduction

The decontamination and dismantling operations occurring prior to the decommissioning of nuclear facilities lead to the production of very large amounts of nuclear waste. According to the French regulations, a utility that owns a nuclear facility undergoing dismantlement is responsible for:

- managing its waste exhaustively, properly and safely,
- keeping record of this management in an appropriate way, and
- informing the public about its practices.

This statement implies that each category of waste should be dealt with from production to elimination according to a pre-assessed and controllable scheme. In particular, this approach excludes the use of any unconditional clearance levels because such a practice would mean loss of waste producer responsibility as well as loss of waste traceability.

The French regulatory framework

a) The French regulatory framework for decommissioning

The decommissioning of nuclear facilities can be split into 3 major phases:

- a phase leading to the end of operation of the facility. This phase includes the removal of all the fuel, the removal of the waste produced during normal operation and still present on site, disposal of fluids, some decontamination and drainage;

- a phase leading to the shut down status of the facility. This phase consists in dismantling the equipment outside the nuclear island, which is no longer required for surveillance and safety. The containment is reinforced. At the end of this phase, a complete inventory of the remaining activity is conducted.

- a phase consisting in actually dismantling the facility. This phase can be started as soon as the previous one is completed or can be delayed. Sometimes, this phase is subdivided into two phases leading to IAEA dismantling level 2 then 3. In that case, the intermediate facility may be considered as a new nuclear facility.

Since 1990, the regulation provides that, for the last two phases, the utilities need a formal authorisation given through a decree signed by the prime minister, countersigned by the ministers for industry and for environment, after assent of the minister for health. This general approach through stages proves to be flexible and efficient. It enables to take into account at each stage the experience gained during the previous stage.

b) The French regulatory framework for waste management

In addition, the French Nuclear Safety Authority (DSIN) has developed a regulatory framework that takes into account the above-mentioned principles of waste producers' responsibility, waste traceability and public information. This approach is based on two sets of existing regulations. The first set deals with nuclear facilities and is implemented by the French Nuclear Safety Authority. It empowers DSIN to ensure that all waste created by nuclear facilities are managed properly by the producers. This is done through approval of waste management plans, impact assessments and regular on-site inspections. The second set of regulations deals with industrial non-nuclear facilities. It is implemented by the Ministry of environment and its regional offices. According to this regulation, the operation of an industrial plant requires a licence. These regulations also impose that toxic wastes are traced using a standardised system.

This regulatory framework has been applied in several cases since 1996. In each case, DSIN has required the utility involved to provide, for approval, a detailed waste management plan (called "waste study"), describing and justifying all the steps ("pathways") involved in the management of all category of waste. The utilities were free to choose the pathways they wanted to eliminate the waste, provided the disposal sites, the treatment facilities or the recycling plants chosen were fully licensed, either as a nuclear or as a non nuclear facility depending on the waste specifications. In this process an impact assessment (or "impact study") and public information is necessary.

For managing waste arising from dismantlement, different options can be considered by the waste producers, depending on the origin of the materials and their radioactivity:

- waste arising from areas of the facility that are found to be free from activation and contamination ("conventional waste zones") may be sent to a conventional dedicated facility;
- waste arising from areas of the nuclear plant with possible activation or contamination ("nuclear waste zones") is subject to specific reinforced management procedures. Following a possible decontamination step and according to their radioactivity level, they may be sent, after authorization and with appropriate record-keeping to:

- a conventional plant (VLLW with a specific clearance level) regulated by the ministry of environment (see examples further on);
- a nuclear waste treatment plant (LLW) regulated by nuclear safety authority (see example further on);
- an interim storage site, regulated by nuclear safety authority, for delayed management.

In order to derive a maximum radioactivity level acceptable in the frame of each "pathway", a thorough assessment of the impact on workers, population and environment is conducted on a case by case basis. The impact must be acceptable in any reasonable situation, social and economical aspects being taken into account.

An example: Brennilis NPP decommissioning operations

Commissioned in 1966 and operated until 1985, the Monts d'Arrée nuclear power plant, located in Brennilis in west France, was the industrial prototype for heavy water moderated , carbon dioxide gas-cooled, reactor technology. After all the systems were drained and dried, the spent fuel and heavy water were removed, the operator was authorised in 1996 to partially dismantle the plant to stage 2 on the IAEA scale. Now, all the buildings of the plant are being demolished except for the reactor building which will be prepared to await final dismantling (stage 3). In accordance with the French regulatory framework, the operator has been asked to prepare a waste study.

The waste study consists of:

- a zoning map identifying the parts of the plant giving rise to conventional waste or to radioactive waste. This zoning takes into account the design of the facility, its operating rules and any incidents which had occurred within it, to determine if the content of the different zones are contaminated or activated. An individual file for each of the 346 rooms of the plant was compiled by the operator;
- a description of how waste is generated;
- a description of the interim storage facilities;
- the principles and organisation adopted by the operating organisation for checking and monitoring waste of all categories.

In nuclear waste zones, several waste categories were identified:

- recyclable or non-recyclable low and intermediate level waste;
- recyclable and non-recyclable very low level waste.

Waste management is based on the following principles:

- sorting and packaging at the source according to the specifications of the chosen elimination plant;
- detailed characterisation of the packaged waste on appropriate measuring benches;
- quality assurance and traceability or monitoring from one end of the processing line to the other.

Before defining the steps for waste management, it has been studied how to eliminate waste: in other words, techniques for eliminating the waste of each radiological category were studied in accordance with physical and chemical nature of the waste. For each elimination solution, the waste concerned is identified, the technical and economical feasibility, the contribution to the objective of reducing volumes of secondary waste, the impact on health…is discussed. Once the technique has been chosen, an application is compiled and submitted for approval to the Safety Authority.

In the case of waste arising from dismantling of Brennilis NPP, most of the low and intermediate-level waste will be sent directly to the Aube surface repository designed for short-lived low level radioactive waste. However, this repository is not suitable for some waste, unless the waste is pre-processed. This is the case for instance for stainless steel of the heavy water system, contaminated with tritium, which can be melted in the furnace of CENTRACO facility (see further on), and some other incinerable products.

Some very low-level radioactive waste, with maximum beta/gamma radioactivity level lower than 100 Bq/g, cannot be justifiably sent to the Aube repository. They are not recyclable in the nuclear industry as a general rule, and will be disposed of in a specific repository, to be created for this purpose. While waiting for such a repository to become available, they will be placed in an interim storage at the plant.

Some very low-level radioactive waste which come from "nuclear waste zone", but for which the measurable added radioactivity is minimal or doubtful, can be recycled or treated in conventional industry. This is the case of scrap metal (several hundreds of tons) which can be melted, or asbestos which can be vitrified, in conventional plants.

CENTRACO: a melting-recycling and incineration facility

CENTRACO is a low-level radwaste treatment center, located near Marcoule in southern France. This new processing plant is a nuclear facility and has been recently licensed by the French Nuclear Safety Authority after public enquiry. This plant is now allowed to receive waste coming from dismantling, maintenance and operational activities of French and foreign sites. CENTRACO operates a melting unit for contaminated scrap metal and an incinerator for solid and liquid waste.

In this plant, waste is converted into low level and intermediate level waste to be sent to the existing surface disposal site or recycled in biological shields. The volume of ultimate waste to be stored is reduced in a ratio of ten to one by casting ingots coming from melted contaminated scrap metals and in a ratio of twenty to one by encapsulating bottom ashes and fly ashes resulting from incineration of solid and liquid waste. All packages belong and are allocated to customers in proportion to their inlet processed weight. CENTRACO is legally not producing any waste. The plant is a transformer that only treats and conditions waste that are entirely reattributed to their producers including process waste that are allocated the same way. Traceability is warranted for foreign customers because of batch processing. For French waste, CENTRACO allows a waste blending but an equivalent activity is allocated to the waste producers.

CENTRACO facilities allow three radwaste families to be processed: solid radwaste, essentially technological radwaste and low radioactive ion exchange resins, aqueous or organic radioactive liquids, scrap metal coming from plant maintenance or dismantling operations. Producers declare waste characteristics before sending them to CENTRACO. Acceptance criteria concern, in particular, radioactivity, families mixing, physico-chemical characteristics per package and global acceptance limits, geometry and weight, packaging forms and prohibited substances. An agreement by CENTRACO, according to specifications, is necessary before sending waste to the facility.

Radionuclides accepted on CENTRACO are those accepted in the French surface repository operated by ANDRA, i.e. short-lived radionuclides.

Allowed maximum activity admitted is:

- incinerable solids	3500T/year	beta/gamma<20000Bq/g	alpha<370Bq/g
- non incinerable solids	250T/year	beta/gamma<20000Bq/g	alpha<370Bq/g
- liquids	1500T/year	beta/gamma<20000Bq/g	alpha< 50Bq/g
- metallic solids	4500T/year	beta/gamma<20000Bq/g	alpha<370Bq/g

The average activity admitted is in fact much lower and is used in the design of the CENTRACO processing facilities:

- melting	beta/gamma< 200Bq/g	alpha< 1Bq/g
- incineration/solids	beta/gamma< 1000Bq/g	alpha< 1Bq/g
- incineration/liquids	beta/gamma< 2500Bq/g	alpha< 1Bq/g

Maximum activity levels per package are:

- solids	beta/gamma<20000Bq/g	alpha< 370Bq/g
- liquids	beta/gamma<20000Bq/g	alpha< 50Bq/g

Products coming from melting and incineration processes are recycled in casks such as drums and biological shields (melting) and encapsulated in bottom and fly ashes packages (incineration). The biological shields are inserted in concrete casks on the CENTRACO site, then sent to the utilities to be used later to make up low level waste packages to be sent to the ANDRA surface disposal center.

INERTAM: an asbestos waste vitrification plant

INERTAM brings a solution for processing asbestos and artificial fibers waste by vitrification. This conventional industrial facility is located in south-west France and has been licensed by local authorities since 1995, after a public enquiry. Beside waste coming from classical industries, waste coming from nuclear plants are admitted: waste from "conventional areas" and also waste from "nuclear areas" as soon as radiological criteria are respected, and in particular, waste from thermal insulation containing asbestos, glass wool and mineral wool.

Traceability is held on all along the treatment. Waste coming from "nuclear zones" of nuclear plants is kept separated from any other waste. A health impact study has been carried on to assess the potential radiological outcome on workers and people involved in the whole "pathway" (including road freight, interim storage on the INERTAM site, furnace processing and maintenance, removal and following use (road construction) of vitrified products. The radiological individual impact on workers in normal operation is very low (a few microsieverts/year) except for transportation and interim storage on site (a few tens or hundreds of microsieverts/year which can be greatly reduced by easy measures: number of drivers, railroad, immediate treatment of VLLW). In case of accident, the impact is always calculated to be lower than 1 microsievert/year.

ASCOMETAL: an implementation in the case of metallic materials

ASCOMETAL is a conventional steel plant located in south France. This facility has been recently authorized to introduce in the process (in a maximum ratio of 30% but rather 5%) some decontaminated and controlled metallic waste arising from dismantlement of UF6 transport containers (enriched U < 1%). The residual radioactivity after decontamination is less than 0,37 Bq/g. The steel plant has not been modified for this purpose and is already equipped with a radioactivity detection device at the entrance (like any French steel-works of USINOR Group). The calculated radiological impact is negligible (0,01 microsievert for 700 tons) and each casting is controlled at the end of the process. The public has been informed through a wide-opened local debate.

Conclusion

The French regulatory framework provides the basis for having an exhaustive and safe management of all the categories of waste (nuclear or non nuclear) arising from decontamination and dismantlement of nuclear facilities. In a pragmatic approach, each category of waste is managed through pathways adapted to the characteristics (origin, radionuclide composition,…) and toxicity (radioactive, chemical,…) of the waste. Each pathway requires an assessment in which public is involved. Noticeably, this approach excludes the use of any unconditional clearance levels. The above-mentioned examples of waste processing facilities in operation have shown that this French low level waste post-production managing concept (“gestion par l’aval”) has received a rather good welcome from the public.

REGULATORY AND RADIATION PROTECTION QUESTIONS IN THE RECYCLING OF IRON AND STEEL

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Identification of the Problem

The principal risk of radioactive contamination is not from the greater nuclear industry, but from the many sealed sources found in what can be called the "diffused nuclear industry". These sources, used in numerous branches of industry and in medicine, are very active, however because of the design of their shielded containers the dose rate at their exterior is generally very small. As such, these sources are very difficult to detect when in the centre of an incoming batch of scrap metal.

The use of sealed sources is highly controlled, particularly in France, but this does not prevent some sources from being lost or stolen, and eventually finding their way, untraceably, into the recycled metal stream. Examples of such sources being melted in electric furnaces in the United States have shown that the financial consequences for the installation involved, mostly linked to site and facility decontamination, are very high. Thus, even if the probability of such events is small, and even if no health consequences can be detected, such incidents must be prevented.

The sensitivity of the media to the presence of radioactivity cannot be overstated, no matter what level, and in spite of declarations from responsible national authorities that no health dangers exist in such cases. In order to preserve the steel industry's reputation and image, we are obliged to take the views of the media into account, even if this means acting outside of accepted technical rational.

Preventative Actions

The steel industry's internal programme of protection against the risk of radioactive products in steels began, concretely, in 1990 following an agreement among several professional organisations: The Union of Steel Consumers of France; The Steel Industry Technical Association; and The National Federation of Recycling Industries and Businesses.

Since 1975, the recycling industry and the steel industry have had a convention for the prevention of explosions. An amendment was signed in 1990 enlarging the preventative actions of the 1975 convention to include risks which might come from the presence of radioactive bodies in the steel.

Following the example of that which had already been established for bodies which could potentially cause dangerous explosions when put into a furnace; simple detection methods which can be put in place without particular technical understanding have been stressed. These include knowing the origin of steel entering a facility, and the recognition, by shape, of the most common types of sealed source containers. With the assistance of the CIREA and of ANDRA (the French waste disposal organisation), who have provided photographs of the most common containers, a brochure was produced in 1995 and widely distributed throughout the recycling industry. Distribution was also made as far "upstream" as possible in the collection and demolition industries where such sealed source containers are most likely to appear as isolated objects and thus be recognised more easily. Of course, the Brochure was also distributed within the scrap metal portion of the steel industry.

Training sessions were also held on all steel industry sites. As of today, all sites have at least one person on staff who is capable of managing a situation involving the detection of a radioactive anomaly.

Detection Technologies

Portal detectors, over which transport trucks are required to pass, are the most widely used means of detecting incoming radioactive materials. The principal advantage of such systems is that they work automatically and are uniform for all incoming vehicles.

Portable detectors are utilised, after the portal detector has given a preliminary alarm, to confirm that unauthorised materials are present, to define a security perimeter, and to clearly identify the radioactive material. Such detectors can be quite effective, assuming that they are correctly used by competent personnel. Portable detectors can also be used for the routine monitoring of small tonnage loads.

The continuous monitoring of furnace dust filters have been developed to detect sealed sources which may have been missed by the monitoring of steel entering a melting facility. The need for such monitoring is becoming more and more theoretical, given the high sensitivity of portal monitors, assuming that they are correctly installed and maintained, and given the possibility of visual recognition of sealed source containers (the shape, weight and volume of a container can classify it as potentially dangerous and to be separated for further investigation).

Another technique which is systematically employed is the measurement of metal sample ingots from each batch of melted steel. These sensitive measurements are performed in laboratories thus allowing the guarantee, for our clients, of the absence of added radioactivity in our delivered products.

Determination of Alarm Threshold

This is the first problem to resolve in establishing a measurement procedure. Recommended radiation protection criteria for recycled metals (for example, expressed in Bq/g for each radionuclide, as described in documents of the European Commission or the International Atomic Energy Agency) are not practically usable as measurement criteria for metals entering steel recycling/melting facilities. In effect, one does not know the type of radionuclides which might be present in scrap metal, their activity, or their physical form. It is thus impossible to calculate an alarm level on this basis.

Thus in practice, the detection of abnormal radioactivity in metals is thus based on ambient radiation levels. The ambient level, however, may not be considered as an acceptable threshold which can be generalised for all products. Ambient levels vary significantly with location and with time, by a factor of up to three. It should also be remembered that all products have some level of natural radioactivity, which can be quite variable. The natural radiation from some of these products, when added to the ambient radiation levels, can be significant, however this is no reason to consider them dangerous (the classic example of this is some granite samples, and certain natural sands).

Using natural ambient levels as a reference can thus create incoherences in alarm levels between a supplier of scrap metal and a receiver each situated in a different location. This incoherence is made worse by the multitude of materials which are treated, and by the procedures which are left to the discretion of each metal receiver.

For our portal-detector entry measurements of trucks and rail cars of scrap metal, we have used the difference in the ambient radiation level, expressed in counts per second, with and without the truck or rail car present in the portal detector. Trucks and rail cars loaded with non-radioactive scrap metal act as shields over the portal detector. This shielding effect is characterised by looking at the highest count rate with the vehicle in place over the portal detector, and the level immediately preceding the vehicle's arrival. This difference is thus a unitless number.

We have noted that these differences are independent of the location of where the measurement is made, and are well described by a Gaussian distribution. This relationship holds for trucks as well as for rail cars.

It has thus been possible to use this to establish an alarm threshold using classic statistical methods: the threshold used is the average of the Gaussian distribution plus five standard deviations. This has been generally accepted as a good compromise between the rate of non-detection of anomalies and the rate of false alerts. This value is being used on all our metallurgical sites, which are all equipped with identical measurement equipment.

This method does not allow the measurement of the level of extra activity in terms of Bq, and provides no information concerning the radionuclides present. In a given configuration, however, it does assure that the probability of an anomaly is great when the alarm threshold is exceeded. In such cases, the vehicle is taken aside, and complementary investigations are performed by specialists who can confirm the presence of dangerous materials, and who can take appropriate measures.

This experimental method, in defining a reference population for a given product, avoids the unreasonable search for absolute zero in terms of radioactive material present, to which one might be tempted given the continuous development of detectors of ever-increasing sensitivity. Such increased detection sensitivity should, however, be used to better detect the presence of anomalies.

Unaccepted Vehicles

What is done with suspect vehicles? The first reaction is to send it back to the supplier. But does one have the right to send back a shipment, via public roads, once it is known that it is potentially dangerous?

Currently, in order to send a vehicle back to its supplier in total compliance with the law, it must be put into compliance with the rules governing the transport of dangerous materials. This is somewhat complex, requiring a knowledge of the nature of the radioactive material, its activity and its physical form: this, of course, puts us back into the contradiction previously mentioned in the case of the alarm threshold regarding the measurement technique's lack of ability to identify specifics regarding the radioactive material present.

Expert Assessment of the Vehicle

In the case where the first verifications after an alarm confirm the presence of notable radioactivity, it is then impossible to simply send the vehicle back to its supplier and further analyses are necessary on site. In general, the competence necessary for such analyses is not maintained on site. We must thus formalise a network of specialists who are capable of locating, identifying (physical form, chemical nature, activity), and conditioning the radionuclides which are discovered.

Final Disposition of Detected Radioactive Products

The final disposition of radioactive products which are identified on site, because of the very low alarm threshold used, is a significant problem whose resolution can not remain undefined.

Low level radioactive products identified on entry by our measurements are of many different types. These can be scales, on pipes or other metal pieces, of naturally radioactive salts caused by earlier industrial processes (having nothing to do with the nuclear industry per se), or non-metallic products present in the form of undesirable earth or ceramics in the scrap metal, or finally these can be classic radioactive products, for example radium seeds used in the construction of “paratonnerres”.

For the moment, in France, only those litigious products which are within the purview of the ANDRA have precise final destinations, but only through very long formal procedures (for example, the debris from “paratonnerres”). All other products are in temporary storage on our sites, for indefinite periods. In some cases, these may be sent back to the supplier after appropriate conditioning, but this is not a final solution. Simple storage on site is de-motivating.

Associated Costs

The storage of radioactive products on a site immediately raises the difficult question of who will assume the burden of any associated costs.

The polluter-pays rule, which is generally used in situations of waste, is unfortunately not always applicable because “orphan” products are quite numerous within the recycling industry. In these cases, the polluter is replaced, in the eyes of the law, by the last person to be in possession of the radioactive product, a fact which is generally badly accepted by those affected.

The example of the procedure used for explosives (the expense-free intervention of national explosive experts – Services Officiels de Déminage) would be, in our view, an adequate solution. But given the vast context of radioactivity, the large number of individuals, organisations and material origins involved, it is unreasonable to imagine that the “all-providing State” will be willing to assume total responsibility provide solutions in such situations. It is necessary, therefore, to define together an acceptable solution for these orphan products in order to avoid the implicate encouragement of simplistic behaviours.

Media Management

The media impact of a radioactivity incident on the steel and scrap metal recycling industries is would be very significant. The sensitivity of the public and the media to such events must be taken into account. Once detection equipment and procedures have been put in place at the entry to a facility, the facility becomes, de facto, responsible for defining and managing the process of communication. In case of an incident, it is important to communicate on the basis of facts and to discuss objectives, all in real time in order to avoid dissatisfaction on the part of the press, rumours and disproportionate reactions.

Experience and Lessons Learned

The present situation is not satisfactory, and the French national authorities are aware of this. Working groups met during the 1996 – 1997 time frame, initiated by the Minister of Health, Office of Radiation Protection, to move these questions forward. Professionals from the Recovery and Metal Recycling industry actively participated in these working groups.

For understandable reasons, mostly with respect to reputation and risks of media hype, very few discussions of these subjects took place before the government-initiated working groups. However, based on this work a common understanding was developed of external constraints, of imposed or self-initiated detection methods, and certainly of the typical problems encountered. This common understanding resulted, at the end of 1997, in the development of several very positive conclusions:

- The search for a universal exemption level does not appear credible. The existence of natural products which are slightly radioactive is well accepted, and their disposal in the "normal" waste stream would be possible by means of a pre-determined convention, between sender and receiver of the products, defining alert threshold specifications. One solution could be the development of an internationally recognised catalogue, giving the radiological characteristics of each family of products. It seems reasonable to define the level of an anomaly experimentally, by comparison with values normally obtained from such products. Statistical techniques are available for assistance in this area.
- Our statistical method for determining the alert threshold is recognised. This allows the definition, in a quantifiable manner, the number of counts per second which represents for us the "added radioactivity" by the measurement of the "vehicle shielding factor" with respect to ambient radiation.
- A draft procedure, prepared by representatives of the Ministry of Health, the OPRI, defines the approach to be taken when the portal alarm sounds. The organisations to be contacted are well defined, and except in complicated cases, the management of the incident is delegated to the on-site competent person.
- It is possible to send a suspicious vehicle back to its sender with the agreement of the local representative of the responsible national authority (DRIRE). This criteria which was considered essential in order to make such a decision to send a vehicle back to its sender is the dose rate on the exterior of the vehicle, and at the driver's seat. This measurement is easily made by the competent person on site. The French Nuclear Safety and Protection Institute (IPSN) has been asked to specify such a number, however, while waiting for their response, it seems reasonable to use the value given by the OPRI as the limit for the security perimeter, 1 μSv/h.

- The idea of Quality Assurance audits of installations is accounted for by such an approach.
- Without going as far as placing all costs under the responsibility of the national government, it is seen as possible to finance such costs by a distribution of costs among the professionals who are most at risk.
- Finally, the necessity of avoiding the storage of radioactive products at "non-nuclear" sites was mentioned, and it is hoped that this will be taken into account.

For now, these propositions have not, to our knowledge, been officially recognised in the form or regulatory text. The industries concerned, preoccupied with every-day problems, cannot wait. This working group, which brought together a wide range of specialists from many areas, has allowed the definition, with a large consensus, of reasonable rules of conduct which can be immediately applied.

Conclusions

The iron and steel industry has had in place for many years, on all its sites, systems for making systematic radioactivity measurements of incoming vehicles. In the absence of usable regulations, defining exactly what is radioactive material, the utilisation of experimental reference levels, derived by industry initiative, currently allows the confirmation of the absence of added radioactivity in incoming products, and the assurance of the safety of plant personnel, clients and installations.

The difficulties enumerated here come, for the most part, from an inappropriate regulation and from insufficient common structures. The complete management of radiological risks requires the implication of the administration in order to perform a global synthesis of the different individual initiatives, and to provide an official structure allowing the resolution of pending problems. Once such a structure is in place, there is no reason to implement two solutions: for us, the recycling of metals coming from the decommissioning of "nuclear installations" should be handled in exactly the same fashion.

THE RECYCLING OF ALUMINIUM AND ITS ALLOYS FROM DECOMMISSIONED NUCLEAR FACILITIES – A VIEW FROM THE UK RECYCLING INDUSTRY

Mark Askew
Aluminium Federation, UK

Read by Dr Ted Lazo

The particular properties of aluminium have led to a year on year increase in consumption since the economic extraction was developed over a century ago. Its' lightweight, strength, corrosion resistance and ease of recycling all contribute to this popularity.

The Aluminium Federation is an UK based Trade Association which represents the interest of its membership in a number of areas. This Federation consists of a number of individual Trade Associations that represent a broad cross section of the UK Aluminium Industry. In particular, two associations deal specifically with the recycling of new and old scraps into other products.

The Aluminium Federation has always strongly supported the fullest possible recycling of end of life scraps, indeed, has always considered it to be one of the material's strong positive points. Recycling saves natural resources and requires only about 5% of the energy used during the primary extraction. With the well-developed recycling systems that are in place, aluminium can be recycled with no degradation in its properties or performance – a truly sustainable material.

Alfed has had an awareness of a specialist recycling centre based at Capenhurst in the UK. The installation recycles materials from decommissioned nuclear facilities and sells the resultant materials into the market. We would consider this to be a laudable undertaking but have some reservations.

Whilst we have no detailed knowledge of the process route employed within Capenhurst, aside from the details incorporated into news articles, we do have first hand knowledge of how a public relations exercise can quickly spiral out of control and, ironically, represent the whole of the recycling sector in a very poor light.

In 1997, Capenhurst issued a press release that claimed that it had produced and sold some several thousand tonnes of aluminium from decommissioned nuclear facilities. The press release went on to say that the quality of this aluminium was so good, it could be used for beverage cans. This was widely misinterpreted by the national and local press into stories, which claimed that this material had been used in beverage cans. Quotes from Friends of the Earth included, "It is outrageous that anything like this should come into contact with food". The National Food Alliance is quoted as saying, "The food industry needs this like a hole in the head. It is an unnecessary risk".

The Aluminium Federation was besieged with numerous telephone calls and faxes asking for clarification and advice regarding this matter. Consequently, much time was spent trying to trace the material, placate the public and inform the media regarding the whole matter, regarding a non-existent problem which we had not caused. All this work and anxiety generated by one press release and media overreaction.

The problems caused by such politically sensitive, untraceable material entering the market have been experienced in a single instance in the UK. The potential knock on effects of what would happened if finished products had been made from this material in the UK, especially in the packaging, building or automotive markets, are incalculable. Whilst the Environment Agency in the UK have provided a permit to operate this plant, and Competent Authorities recognise the negligible risk linked to the levels of radiation exhibited by such reclaimed material, the public at large, with help from environment lobby groups, can easily overreact. The ensuing damage caused to the image of aluminium, as a 'green' metal would be not only disastrous, but also completely unfounded. We are aware of examples in other countries where radioactive aluminium scrap was processed, melted and converted into ingot before anyone realised that the material was radioactive. In fact this radioactivity was only detected when run-off water from the site contaminated a local river where radioactivity was being monitored. The company was forced to shut all operations for a considerable time while furnaces were re-built. This had significant financial implications. Secondary refiners are now fitting weightbridge detecting devices to alert them to potential problems.

Lessons to be learnt from this experience.

The recycling of potentially radioactive materials must be carried out at dedicated facilities.
Any materials produced from these facilities must be traceable.
Purchasers of the recycled material must be aware of its origin.
These materials should be used in market sectors which will not cause the populace any anxiety.

As responsible aluminium companies in the UK have no control on the release of such material the Aluminium federation have sponsored a project to reduce the risk of such materials entering the product stream. This project has two specific aims:

Firstly, the publication of an information pack for secondary aluminium producers covering current legislative requirements, monitoring equipment and best practice regarding sampling and analysis of incoming materials.

Secondly, the project team is looking to establish an industry wide agreed limit to the level of radioactivity of outgoing products.

Ideally, we would like to liaise with representatives of other metals sectors in an attempt to reach an agreement covering the whole of the metals sector.

In summary we can say:

1. The recycling of aluminium from decommissioned nuclear facilities is acceptable if:

   - the material is traceable;
   - is identified to purchasers;
   - is carried out by dedicated facilities;
   - untreated scraps are not sold into the open market.

2. PR needs to be carefully considered.

3. The aluminium industry in the UK is taking the lead in protecting its interests and those of its customers.

SESSION 4

MANAGEMENT OF SITE DECOMMISSIONING

AN AMERICAN DECOMMISSIONER'S VIEWPOINT

Michael B. Lackey
Enron-Portland General Electric
Trojan Nuclear Plant

Introduction

The Trojan Nuclear Plant is an 1160 Mwe, four loop PWR located in Rainier, Oregon, USA. The plant was permanently shutdown in 1993 after approximately 17 years of commercial operation. The early plant closure was an economic decision. The key factors in the closure analysis were escalating costs associated with steam generator tube cracking and the projected availability of inexpensive replacement power in the Pacific Northwest region of the United States. Since the plant closure, Portland General Electric (PGE) has been actively engaged in decommissioning.

At the time of Trojan's closure, there was relatively little decommissioning experience within the United States. Trojan is the first large commercial reactor to undergo decommissioning. It is being decommissioned in an environment of changing regulations. Most, if not all, of the regulatory changes have been positive, but often these changes have come too late to benefit the Trojan Project.

This paper addresses three critical aspects of decommissioning that are impacted by current regulations within the United States. The first aspect is decommissioning in accordance with the revised Decommissioning Rule, Title 10 Code of Federal Regulations 50.82 (10CFR50.82), implementing a Post-Shutdown Decommissioning Activities Report (PSDAR) and allowing the use of 10CFR50.59. The second is the planned performance of the final site radiological survey in accordance with new regulatory guidance. The third aspect addresses the benefits of designing a regulatory framework that allows shipment and disposal of highly radioactive, large components such as reactor vessels.

Revised Decommissioning Rule

At the time of the Trojan Plant closure, the decommissioning regulations required Nuclear Regulatory Commission (NRC) approval of a comprehensive decommissioning plan prior to commencement of any significant decommissioning activities. This document took PGE 24 months to prepare and the NRC 15 months to review. During this time, it was unclear whether Trojan could remove equipment from the plant that ordinarily would have been allowed prior to the plant closure via the 10CFR50.59 safety evaluation process. This ambiguity opened the door for numerous lawsuits by anti-nuclear activist groups and resulted in both project delays and increased project costs. The revised Decommissioning Rule makes two significant improvements to this process. First, the detailed decommissioning plan is replaced with a much less detailed PSDAR. The rule recognizes the fact that a slightly modified 10CFR50.59 review process, which provides guidance for the licensee to determine what decommissioning activities are safe to perform without prior NRC approval, not only establishes a more appropriate level of oversight for a de-fuelled reactor, but is also a much more efficient process for the licensee.

The second improvement is that it defines a public process and requires a public meeting in the vicinity of the plant shortly after plant shutdown. This meeting is designed to inform the local public about the decommissioning process and the licensee's plans. The closure of a nuclear plant is almost always a significant impact to the local area with the loss of many well paying jobs and the reduction in tax revenues. There is typically much interest in the future of the site and a level of concern for the site clean-up plans and the public safety aspects of decommissioning. These meetings are often painful for the utility and the regulators, but they are an important part of an open and informative public process. Unfortunately, the public meeting can be subverted by anti-nuclear activists who use it as a stage to voice their often unreasonable opinions and demands. Their stated objective is to impede progress and drive up the cost of decommissioning. Unfortunately, they are correct in their strategy; the more expensive decommissioning becomes, the less likely future nuclear plants will be built. Therefore, the public meeting must be conducted in an orderly manner as it attempts to resolve legitimate issues of the concerned public.

Final Site Survey

The revised Decommissioning Rule allowed plants that submitted a decommissioning plan prior to the effective date of the rule (August 28, 1996) to credit their decommissioning plans as satisfying the requirement for the less detailed PSDAR. However, in addition to requiring a PSDAR, the revised Decommissioning Rule imposed a second document called the License Termination Plan (LTP), which must contain practically all of the detail that is in the decommissioning plan. An important section of an LTP is the final survey plan for confirming the radiological release status of a facility prior to license termination.

In August 1997, the NRC published a License Termination Rule, which set release criteria for license termination. The criteria provide for either unrestricted release of the site, or restricted release with perpetual control over areas that do not meet the criteria for unrestricted release. The dose criteria for unrestricted use are; (1) a limit of 0.25 millisieverts per year to a member of the public; and (2) the site cleanup has reduced potential exposure from residual radioactivity to As Low As Reasonably Achievable (ALARA). PGE intends to meet the criteria for unrestricted release of the Trojan Plant site so that ongoing controls will not be required beyond license termination.

PGE personnel were active in development of the License Termination Rule and have continued to participate in the development of NRC guidance for implementing the rule. However, the time line for publishing the rule and associated guidance for meeting the rule presents a difficult challenge for the decommissioning of Trojan. Although the rule was published in August 1997, the NRC is not planning to have final guidance on meeting the rule available until August 2000. With major decontamination and dismantlement of radioactive systems at Trojan approximately 75 percent complete, PGE is preparing for the final survey well in advance of this guidance. To support the Trojan license termination by the end of 2002, final surveys are scheduled to be completed by the middle of that year. To allow time to obtain NRC approval of the LTP prior to significantly starting final surveys, PGE recently submitted the LTP for the Trojan Plant to the NRC. The LTP was based on the available guidance and knowledge gained from participation in the development of NRC guidance for implementing the rule. In late April the only two license termination plans submitted to the NRC under the new rule were rejected. This is an indication that better guidance is needed and that this guidance is needed now.

In some cases, PGE has observed significant co-operation from the NRC in addressing decommissioning issues for which guidance is yet to be written. However, in regard to the survey, PGE has experienced a level of reluctance to work together to create and approve the first final survey plan under the License Termination Rule. The impression is that the staff is somewhat uncomfortable approving the final survey plan PGE has written since the guidance for implementing the License Termination Rule will not be finalized for another year.

Decommissioning costs are driven higher by delays, as the industry is forced to wait for regulation and associated guidance for implementation to catch up. PGE is currently working with an industry advocate, Nuclear Energy Institute, to address such policy issues, while also trying to make steady progress at the working level to obtain final survey plan approval in a time frame that will support the Trojan site cleanup and license termination schedule.

Single Piece Reactor Vessel Disposal

PGE has received regulatory approval of an innovative approach for disposing of the Trojan Reactor Vessel. Although the review process required over 19 months to complete, the benefits far outweigh any impact of the delay.

Trojan is in the process of removing the reactor vessel with all of its internals intact and preparing it as its own shipping container. This has required cutting and welding closures over all vessel penetrations, filling the vessel with a low-density cellular concrete, attaching up to five inches of external steel shielding, and installing impact limiters.

Once prepared, the two million-pound reactor vessel package (RVP) will be secured onto a multi-wheeled transporter. The transporter and RVP will be secured to a barge specifically designed and built for this project. The barge will travel 435 kilometers up the Columbia River where the transporter will be off-loaded and travel overland approximately 48 kilometers to the low-level radioactive waste (LLRW) disposal site.

This approach is a first of a kind for a large commercial reactor and is considered a major improvement over the conventional approach of internals segmentation. The project is expected to reduce exposure by more than 50 percent to occupational workers, 90 percent to transportation workers, and 95 percent to the public. It is projected to prevent over 100 personnel contaminations; reduce costs by over $15 million, and eliminate any long-term disposal issues with waste that would be classified as greater than class C (GTCC) if it were segregated.

The two critical regulatory approvals needed were NRC approval of vessel transport under 10CFR71 and the State of Washington's Department of Health approval of disposal under state rules equivalent to 10CFR61.

The transportation approval required two exemptions from the standard requirements of 10CFR71. Based on a route specific hazards analysis, specially designed transport equipment, and extensive transportation controls; PGE was granted approval of its request to reduce the hypothetical accident drop height from 9 meters to 3.4 meters and to limit the drop orientations for both the 9 meter and 0.3 meter drop scenarios. Exemptions were needed because the current transportation regulations were developed for designing transport packages that are used for frequent shipments at nominal speeds on public highways over many years of service. Transportation regulations should be flexible enough to permit safe, highly controlled, one-time shipments. However, approval must be based on the specific package design coupled with the potential hazards along the specified transportation route and the proposed transportation controls to be applied. Built on this comprehensive case-by-case approach, clear regulatory guidance should be developed that will allow the industry and regulators to proceed with confidence through a timely review process.

The disposal approval required a detailed performance assessment to demonstrate that the RVP meets the performance objectives of state rules equivalent to 10CFR61. The activation analysis performed identified over two million curies of activated metal. With this source data, dose models were developed and pathway analyses were performed for a group of hypothetical radiation release scenarios following RVP disposal. Even with conservative assumptions incorporated into the evaluations, the results of the dose calculations are small fractions of the prescribed regulatory limits of .75 millisieverts per year to the thyroid, .25 millisieverts per year to the whole body, and .25 millisieverts per year to the body organ receiving the most dose in a given scenario.

While all the needed approvals are in place for disposing of the Trojan reactor vessel in the safest, most economical way, it may be one of only two vessels in the United States to gain these approvals. Under the current LLRW compact system, only two reactors have access to the Washington disposal facility. The rest of the reactors must ship waste to a disposal facility in South Carolina which has objected to these types of packages.

Conclusions

The decommissioning industry is a relatively young industry in the United States. Early experience is leading to significant changes in decommissioning-related regulations. While changes are usually for the better, it is a slow process that often culminates too late to benefit the early entrants. To encourage future innovation that can save a significant amount of dose and money, the regulatory guidance needs to be clear and flexible and the regulators need to be open-minded and responsive. This will help eliminate one of the Decommissioning Manager's greatest worries – regulatory uncertainty.

GUIDE TO DECOMMISSIONING OF NUCLEAR INSTALLATIONS IN GERMANY

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Abstract

More than 20 nuclear facilities are in the state of decommissioning in Germany. Laws and regulations contain only very few stipulations specific to decommissioning. A large number of technical rules address design, construction and operation but not decommissioning.

Nevertheless, from the decommissioning of nuclear facilities which has so far taken place, it has been demonstrated that, both from the point of view of technical execution of this work and also the technical rules and legal regulations which must be applied, existing means allowing decommissioning projects to be licensed and decommissioning procedures to be carried out safely.

In the licences which have so far been issued, the licensing authorities stipulated the requirements for decommissioning, with appropriate application of the existing rules. The relevant parts of the requirements were tailored to suit the specific characteristics of decommissioning of the facility.

In view of this situation the guide to decommissioning of nuclear facilities was developed. It is based on a systematic collection and investigation of all aspects relevant to decommissioning.

The main points are:

- framework conditions for decommissioning concerning existing laws, regulations and technical rules;
- safety considerations;
- licensing and supervision of decommissioning.

Consequently the decommissioning guide contains proposals for an appropriate procedure for the decommissioning of nuclear facilities, in respect of the application of the technical rules, for the planning and preparation of decommissioning work as well as for licensing and supervision. These proposals are primarily aimed at the decommissioning of nuclear power stations.

It may be that the conditions are different for research reactors and nuclear fuel cycle facilities and these need to be considered specifically for these facilities.

The aim of the guide is to:

- summarise the aspects of licensing and supervision which are relevant for decommissioning;
- harmonise the application of procedures and the interpretation of existing rules where possible.

This guide does not constitute an administrative provision which must be used on a mandatory basis for the actual licensing procedure, but rather a collection of the relevant aspects which can be used as an aid for decommissioning projects.

Introduction

At the beginning of the nineties, six nuclear power plants and some research reactors were in the state of decommissioning in the Federal Republic of Germany.

From the decommissioning of these facilities it has been demonstrated that, both from the point of view of technical execution of this work and also the technical rules and legal regulations which must be applied, adequate means exist to allow decommissioning projects to be licensed and decommissioning procedures to be carried out safely.

In the licences which have so far been issued, the licensing authorities stipulated the requirements for decommissioning, in some cases with appropriate application of the rules and guidelines which exist for construction and operation of the facilities. The relevant parts of the requirements were tailored to suit the specific characteristics of decommissioning of the facility.

At that time it was decided to shut down and decommission the six power reactors of the former GDR and the two prototype high temperature gas-cooled reactors in Hamm-Uentrop and in Jülich, as well as two fuel fabrication plants.

In view of the number of decommissioning projects which are to be carried out in this situation, and in the future, a systematic collection and investigation of all aspects relevant to decommissioning was performed.

The main points were:

- framework conditions for decommissioning, concerning existing laws, regulations and technical rules and standards;
- safety considerations;
- licensing and supervision of decommissioning.

Available experience and the results of special scientific investigations were taken into consideration. As a result, the "Guide to Decommissioning of Nuclear Facilities" was developed.

The work was done by a group of representatives from the Federal Ministry of Environment, Nature Conservation and Reactor Safety, and from responsible authorities in the federal states, with scientific support from the Federal Board of Radiation Protection.

The decommissioning guide includes proposals for an appropriate procedure for the decommissioning of nuclear facilities in respect of the application of the technical rules for the planning and preparation of decommissioning work, as well as for licensing and supervision. These proposals are primarily aimed at the decommissioning of nuclear power stations. It may be that the conditions are different for research reactors and nuclear fuel cycle facilities and these need to be considered specifically for these facilities.

Framework Conditions for Decommissioning Concerning Existing Laws, Regulations and Technical Rules

Legal regulations

The legal bases for decommissioning procedures are the Atomic Energy Act, the associated legal ordinances and a few general administrative provisions. There are no other laws and regulations specific to decommissioning.

The regulations which are of particular importance for decommissioning projects are outlined briefly below.

Atomic Energy Act

Article 7 of the Atomic Energy Act includes the basic provisions for licensing of the decommissioning of nuclear facilities.

Article 7, para.1: Licencing of installations

"Whoever erects, operates or otherwise holds a stationary installation for the production, treatment, processing or fission of nuclear fuel or the reprocessing of irradiated nuclear fuel or materially alters such installation or its operation, shall require a licence."

The term "facility" (so-called Article 7 facilities, often only "facility") follows from this statement.

Article 7 , para 3 AtG : Decommissioning

"The decommissioning of an installation as defined in para. (1), as well as the safe enclosure of an installation, or the dismantling of an installation or of parts thereof shall require a licence. Para. (2) shall apply accordingly."

Article 7, para 2 AtG

" A licence may only be granted if…"

Prerequisites: reliability of the applicant; qualification; precautions to prevent damages; the necessary financial security has been provided to comply with the legal liability to pay compensation for damage; the necessary protection has been provided against disruptive action or other interference by third parties.

Article 7, para. 3, is the only provision of the Atomic Energy Act which relates specifically to decommissioning for facilities as defined in Article 7 Para. 1.

The basic provisions of Article 9 apply for the reuse of radioactive residues, radioactive components which have been dismantled or removed and the disposal of radioactive wastes. In addition, the general provisions of the Atomic Energy Act apply.

Ordinance on the Procedure for Licensing of Installations under Article 7 of the Atomic Energy Act (Nuclear Licensing Procedure Ordinance) AtVfV

The licensing procedure for decommissioning, safe enclosure and dismantling of nuclear facilities is based on the Nuclear Licensing Procedure Ordinance (AtVfV). It contains general provisions for all licensing procedures as well as provisions which are specific to decommissioning, in particular for the involvement of third parties and for assessing the environmental impact.

Ordinance on the Protection against Damage and Injuries Caused by Ionizing Radiation (Radiological Protection Ordinance) StrlSchV

The Radiological Protection Ordinance (StrlSchV) is of particular relevance for decommissioning and the provisions contained according to Article 1, para. 1 No. 2 thereof apply to decommissioning, safe enclosure of a facility and the dismantling of a facility or parts of a facility as defined in Article 7 of the Atomic Energy Act and therefore to a large extent determine the technical and operational measures, procedures and precautions for protection against damage from ionising radiation.

Ordinance Concerning the Financial Security Pursuant to the Atomic Energy Act (Nuclear Financial Security Ordinance AtDeckV)

Article 12 of the Nuclear Financial Security Ordinance (AtDeckV) represents a specific provision for decommissioning.

Annex 2 of the AtDeckV evaluates the residual activity remaining in the facility as a multiple of the exemption limits defined in Annex IV Table IV 1 of the Radiological Protection Ordinance for the purposes of establishing the regulatory amounts of cover.

Other nuclear ordinances

Other nuclear ordinances, which are applicable to decommissioning, are:

- Cost Ordinance to the Atomic Energy Act (AtKostV)
- Nuclear Safety Officer and the Reporting Ordinance
- Ordinance for Provision Fund for Final Disposal.

Technical rules

In addition to laws and regulations, a comprehensive set of guidelines, technical rules, standards, specification and safety criteria exists, such as:

- Announcements (criteria, principles, guidelines, recommendations) of the Federal Ministry of the Interior (BMI) and of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).
- Regulations of the Kerntechnische Ausschuß [Nuclear Technical Committee] (KTA Safety Standards).
- Technical standards.

- Recommendations of the Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK).

They were primarily created for the design, construction and operation of these facilities and specify a.o:

- information to be submitted in support of a licence application;
- safety requirements;
- radiation protection requirements;
- requirements concerning the specific qualification of personnel;
- requirements to ensure physical protection of the facilities.

These guidelines, rules and criteria are not mandatory. They become binding only when used by authorities in the safety assessment and licensing process.

In the course of decommissioning nuclear power plants, they have been applied, partially or as appropriate, with the aim of achieving a sufficient degree of protection.

There are no such guidelines, rules and criteria with specific requirements for decommissioning.

This situation concerning laws and regulation, as well as guidelines, rules and technical specifications, provides room for individual, not fully uniform, behaviour from the authorities in the federal states who are responsible for licensing and surveillance.

Announcements of the BMI/BMU and KTA Safety Standards

The BMI/BMU announcements and the KTA Safety Standards are the most relevant nuclear related rules. They were assessed for their applicability to the decommissioning of nuclear facilities and were divided into the following three categories:

1. The rule is generally applicable and must therefore be taken into account for decommissioning.
2. The rule is not relevant to decommissioning
3. The rule is applicable if adapted to the protective aims or is partially applicable, taking account of the different potential hazard and the altered requirements, which are in many respects reduced relative to construction and operation.

The rules were carefully analyzed and assigned to the different categories.

For all rules assigned to category 3, comments were elaborated in which way they should be applied to decommissioning. These comments were based mainly on the experience gained by their application to decommissioning projects so far.

Annex 2 contains the classification of rules by categories and Annex 3 the comments on application of rules assigned to category 3.

For some rules it is very difficult, due to their structure or aim, to apply them to decommissioning. This is especially the case concerning information to be submitted in support of a licence application and, to some extent also, concerning the requirements for specific knowledge and qualification of plant personnel. In these fields, big differences exist between requirements for design, construction and operation at one site and for decommissioning at the other site. Therefore for these fields the development of new rules specific to decommissioning was proposed. But there was no support for this idea by the authorities concerned. The actual trend is deregulation but not development of new additional rules.

Due to this situation two different ways were followed. So more extensive comments have been written and included in the commentary (Annex 3) and, in addition, concerning information to be submitted in support of a licence application, an elaborated text has been included in chapter 3: "Decommissioning planning and application documents" of the guide. It describes the requirements as follows:

All of the documents conformable to Article 3, para. 1 of the AtVfV which are necessary to check the preconditions for approval as defined in Article 7 Para. 2 of the Atomic Energy Act must be attached to the application for the issue of a licence under the terms of Article 7 Para. 3 of the Atomic Energy Act.

Together with the application, information should also be provided about the overall decommissioning project. This should outline in what application and licensing steps the decommissioning should take place, taking into account the licensing situation, defined in Article 7, para. 3 of the Atomic Energy Act (decommissioning, safe enclosure, dismantling of the facility or of parts of the facility). This information should provide a basis for assessing, in particular, if further measures are hampered or prevented and whether the dismantling measures are planned in a sensible sequence also from point of view of radiological protection.

As regards the technical content of the application documents the following details are particularly required:

a) Description of the facility, the site and the surrounding area as well as the operating history of the facility, where this is relevant for decommissioning, and possibly a preview of the subsequent use of the site.

b) Legal provisions, technical rules and other provisions which have been taken into account for decommissioning.

c) Description of the decommissioning procedures applied for and their sequence.

d) Description of the planned decommissioning techniques such as decontamination methods, cutting techniques, remotely controlled dismantling techniques.
e) Description of new systems or systems which are to be altered.

f) Safety studies including accident analyses, taking account of the accident planning values of Article 28, para. 3 of the Radiological Protection Ordinance for the planned decommissioning activities and the operation of new or modified systems and with a view to fulfilling the minimisation requirement in Article 28, para. 1 of the Radiological Protection Ordinance and other radiological protection principles and radiological protection provisions for workers, the environment and the population. It must be demonstrated how the necessary provisions against damage are guaranteed.

g) Registration and evaluation of the radioactive inventory and, where applicable, of dangerous substances, proofs of this.

h) Description and classification of the radioactive wastes which arise, their conditioning and disposal, procedures for clearance of radioactive materials and their recovery.

i) Description of the radioactive discharges with the exhaust air and liquid effluent, application values for discharges and radiological exposure calculated therefrom.

j) Programme for environmental monitoring.

k) Precautions for protection of workers and radiological protection during performance of the decommissioning work including the construction of new facilities or the modification of existing ones, estimates of service time and collective doses.

l) Description of the operational organisation and responsibilities for decommissioning, proofs of the specialist knowledge of the personnel responsible and the receipt of specialist knowledge and necessary know-how by other individuals involved.

m) Description of accompanying controls (quality assurance) and their performance (e.g. by means of work schedules).

n) Planned measurement programme for the clearance of the site where applied for.

o) Planned reporting to the supervisory authorities.

p) Outline of security measures

Where a state of safe enclosure is brought about, corresponding statements are to be made in the application documents, both for the safe enclosure phase and also for the phase during which this is being achieved.

Technical explanations of some of the topics and an indication of the depth of information required for a safety assessment are provided in Annex 4 of the guide.

Safety Considerations

Most of the safety criteria and requirements established for design, construction and operation are not, or not fully, applicable to decommissioning.

Therefore the safety analysis reports of already licensed decommissioning projects were analyzed and a special study on necessary safety considerations for decommissioning was performed. The results are described in the guide.

The potential hazard of a decommissioned nuclear facility depends almost exclusively upon its activity inventory and the possibilities of a release associated with decommissioning. Unlike during the operation of the facility, there is practically no energy potential for releases resulting from criticality and decay of radioactive substances or inherent in the pressure and temperature conditions of the operating media.

In the case of facilities for fissioning nuclear fuel, removal of the fuel elements alone brings about a considerable reduction in the activity inventory. The possibility of criticality is excluded; activation activity is safely contained in the activated components themselves. The contamination which is present in the facility and the activation products which could be converted into a releasable form by the dismantling activities are therefore the main starting point for accident analyses for the work involved in decommissioning.

The radioactive inventory of nuclear fuel-cycle facilities is very different from that of reactor facilities. There are no activation products. The most significant potential hazard in nuclear fuel cycle facilities is radioactive material in dispersible form and the possibility of a criticality. Removal of the nuclear fuel from the facilities reduces the potential hazard significantly. The alpha-emitters which remain in the facilities result in radiological exposures following intake, which are predominant in the facility and in the event of releases.

Some of the safety assessments (accident analyses) which have already been done for the construction and operation of the decommissioned facility can continue to be used. So long as there is still a relevant quantity of nuclear fuel in the facility during decommissioning, all of the necessary safety precautions must continue to be observed and must be included in the corresponding assessments.

Many decommissioning activities, particularly those involving the dismantling of parts of facilities, involve very similar techniques to those of the previously licensed maintenance procedures. In this respect special safety assessments or accident analyses are only required if the status of the facility is altered, for the dismantling of components, for new technical processes. These should be based on the current state of science and technology, where this is required for accident prevention.

As a rule the following occurrences during decommissioning projects are to be considered and evaluated from the point of view of safety:

- Fire in the facility.
- Leakage of vessels or systems.
- Falling of loads.
- Failure of supply installations.
- Criticality accident (where a relevant quantity of nuclear fuel remains).
- Penetration of water into the containment.
- External impacts (e.g. earthquakes, storms, floods, and penetration of gases).

Apart from the radiological loads, hazards can arise from the chemicals which are present in the facility or which are used for decommissioning purposes (residues from plant operation, decontaminating agents).

The barrier system present during operation of the facility to prevent the escape of radioactive substances into the environment is modified during decommissioning (for example in nuclear power stations the core internals and primary circuit are thermally or mechanically broken down during the course of dismantling work. In the case of an accident, these alterations to the barrier system can influence the release of activity into the atmosphere within the facility. Since the building structure will probably be released before it is dismantled, the safety vessel and reactor building often remain intact right up until the end of the decommissioning work.

Nearly all of the accidents within the plant can be assigned to the "basic types", fire, leakage of a vessel containing radioactive fluid and falling loads. The accident fire in the facility is radiologically representative of these, in particular if failure of the filter system has to be assumed.

Licensing and Supervision

Licensing

The decommissioning licences as defined in Article 7, para. 3 of the Atomic Energy Act are formulated on the basis of the licence application by appropriate application of Article 7, para. 2 of the Atomic Energy Act, taking account of the potential hazard of the facility. These licences contain permissions and conditions.

Depending upon the type of application, the decommissioning of nuclear facilities can be regulated by a single licence or can be divided into sections which are licensed separately with their own licences as defined in Article 7, para. 3 of the Atomic Energy Act. In addition to this, licences can be broken down into part licences on request.

On the basis of experience with procedures which have taken place so far, it is recommended that, for large projects, such as the dismantling of nuclear power stations or nuclear fuel cycle facilities, decommissioning work be divided up into technically delimited sections, which can be licensed separately. This allows use of a licence and in parallel preparation of the application for a next one. In view of the licensing practice in Germany it is impossible to provide with a first application all necessary information required for a single licence covering the entire decommissioning.

A comprehensive decommissioning licence could be advantageous for smaller projects, e.g. for research reactors, or possibly for bringing about a state the safe enclosure.

Transition from operating licence to decommissioning licence

After operation of a facility has finally ceased, activities can be carried out in the post-operational phase under the terms of the operating licence which are covered by this licence and which are essentially a component part of operating practice. As a rule these include:

- Unloading and disposing of the fuel elements, removal of nuclear fuel,
- Recovery of radioactive materials and disposal of radioactive wastes arising from the operational phase,
- Decontamination of the plant.

The required availability of systems during this transitional phase is based on the stipulations in the operating manual (BHB) for the outage of the facility. The operator retains the right to apply for further adaptations to longer-term outages, taking particular account of the related nuclear hazard. Simplifications in the area of safety specifications (SSP), e.g. availability of systems or reduction of in-service inspections, are also possible. Under certain circumstances measures which could also be included in the post-operational phase might be preparations for the safe enclosure or for disposal, in so far as these are covered by the operating licence or do not represent significant changes. They can be carried out in accordance with the operating manual as insignificant changes.

If the operating licence is suspended on issue of the decommissioning licence, then conditions and regulations of the operating licence which continue to be applicable must be incorporated in the decommissioning licence.

If the operating licence is not completely suspended on issue of the decommissioning licence, then the unaltered conditions and regulations of the operating licence remain in force.

Where applicable, the decommissioning licence can stipulate that the facility can not be put back into power operation or production without a new nuclear licence as defined in Article 7, Para. 1 of the Atomic Energy Act.

Licensing procedure with several steps

In this type of licensing procedure the decommissioning sequence is divided up into individual sections which are applied for and licensed separately.

Unlike in the construction phase, the steps in the dismantling phase are not directed at a similar aim such as for achieving safe operating. They are not so closely interlinked with each other that one step must necessarily follow from the previous step. There is no linking function such as in the construction and operational phase requiring a prior positive overall assessment in the case of the individual part licences. There are therefore no requirements for documents for a prior positive overall assessment. It is, however, necessary to demonstrate the compatibility of the planned decommissioning measures.

Dividing up the decommissioning sequence means that new techniques can be introduced and experience which has been gained in the previously completed phases can be applied. Application for and assessment of the next step can also take place in parallel to execution of the phase which has already been licensed. In certain circumstances these can also result in a time saving on the overall project.

With the separate licences defined in Article 7, para. 3 of the Atomic Energy Act it is possible to establish conditions for releasing plant components or ancillary installations, which are no longer required for safety purposes during decommissioning and which are to be used elsewhere, from nuclear supervision and thus redefining the scope of the facility and also the limits of the controlled area under the terms of the Radiological Protection Ordinance.

The issue of licences as defined in Article 7, para. 3 of the Atomic Energy Act in part licences is possible if an application has been made, which is to be decided in part licences on request of the applicant.

Involvement of third parties and environmental acceptability study

Public involvement in accordance with the AtVfV cannot be disregarded in the process of issuing decommissioning licences, if this is necessary to protect the rights of third parties or because of the environmental consequences arising from the planned activities.

If after preliminary inspection the licensing authority can see that there are no additional or other circumstances which could have adverse effects upon third parties or considerable adverse effects upon the property mentioned in the AtVfV, which require consideration in the safety report or in the other documents which are to be submitted, then the decision regarding involvement of the public remains at the discretion of the authorities. Such circumstances will not require consideration if it is clear that the possibility of such effects is ruled out by the precautions against damage which have been taken by the owner of the project or if the safety-related disadvantages are slight compared with the safety-related advantages.

Conclusion of supervision under nuclear legislation

The following alternatives are possible for the ending of nuclear supervision of a facility as defined in Article 7 of the Atomic Energy Act:

a) Clearance of the site after total removal of the facility for unrestricted use without radiological supervision.
b) Clearance of the site and remaining structures (buildings, systems) for another commercial use without radiological supervision.

In addition to this, the site and remaining structures (buildings, systems) can be converted into another facility which is licensed under nuclear legislation (as a new facility or by joining it onto an existing neighbouring facility) without radiological clearance.

Release of the facility requires a comprehensive measurement programme based on clearance criteria which are to be laid down in the licence and confirmation of the measured results by the authorities. On this basis the clearance is then a determining administrative act, announcing the end of the procedure under nuclear legislation and associated supervision.

Two routes are possible for clearance of buildings in association with their demolition:

1) The building is surveyed, discharged from the competence of the Atomic Energy Act and then conventionally demolished.
2) The building is demolished under the nuclear procedure observing the necessary protective measures and the residues (building rubbish) are surveyed and released for harmless recovery as far as possible.

Supervision

Article 19, para. 1 of the Atomic Energy Act stipulates, amongst other things, that the handling of radioactive substances and the ownership of facilities of the type designated in Article 7 are subject to state supervision. Thus the decommissioning of nuclear facilities and all other measures associated with safe enclosure or dismantling are subject to supervision under nuclear legislation, as was the operation of the facility before its decommissioning.

The nuclear supervisory authorities are especially responsible for monitoring to ensure that the conditions of the licences as defined in Article 7, para. 3 of the Atomic Energy Act have been observed. The object of the licensing procedure was to make sure that the subject of the licence is adequately defined and the necessary precautions against damage are guaranteed during execution of the planned decommissioning work. The licensing procedure also checks that the planned procedures and sequences are appropriate and are clearly enough defined and to what extent it is admissible to decide at a later stage what methods to apply during the individual work steps in the context of the working permit procedure.

Working procedures, work schedules, the working permit procedure, the free release procedure for radioactive residues and documentation of decommissioning activities play a significant role in supervision (accompanying controls) of the decommissioning sequence, in particular for dismantling of the facility or parts of the facility.

The supervisory authorities must monitor execution of the measures laid down in the licence, inspect any deviations and check that the provisions of the Radiological Protection Ordinance are observed.

So long as an inadmissible amount of the subject of the licence is not displaced into the supervisory process, the licence can be based on work sequences which are subsequently detailed and clarified as part of the supervisory process. The work sequences must give details of the concrete work steps and auxiliary equipment, cutting methods, devices which are to be used, decontamination techniques, measures for handling residues, preparation for transport, transport procedures, radiological protection measures and radiological protection equipment, taking account of the activity concentration and nuclide distribution for each component.

A work permit procedure can be stipulated in the licence. In this case it can be assumed that such a procedure was introduced during power operation of the facility in accordance with the regulations laid down in the operating manual. During the course of decommissioning this organisational instrument on the part of the operator is of particular importance in guaranteeing radiological protection and protection of workers. All relevant activities in the facility which is to be decommissioned should therefore be subject to this procedure in order to take account of the requirements of radiological protection, protection at work and fire protection, protection of property and all other protective aims related to safety.

The documents and auxiliary means used in the work permit procedure can be used to document all decommissioning procedures, experience during decommissioning and the collective dose of staff for the individual work sequences.

As part of the supervisory process it is necessary to monitor to ensure that the clearance criteria and methods of sampling and measurement stipulated in the licence are observed, as are the other conditions of the licence.

Clearance measurement is done by the operator. The procedure should provide for announcement of the intention to free release materials by the operator to allow checks by the authority. Official control includes:

- Checking the documentation,
  Checking suitability of the measurement techniques, measuring devices, the use of the measuring devices and specialist qualification of personnel,
- Performance of control measurements,
- Where applicable, approval for clearance under the terms of the licence.

Documentation During and After Completion of Decommissioning

The measures which are to be carried out during decommissioning, e.g. during the process of safe enclosure and dismantling of parts of facilities, are to be documented in accordance with the terms of the licence. This documentation must ensure that the current status of the facility in respect of:

- the radioactive inventory and its distribution,
- the condition of the buildings, systems and components still present

is clear at any point in time and is accessible for official inspection. In addition to this, data concerning radiological protection of the staff and the discharge of radioactive and nonradioactive materials including methods of measurement and clearance procedures must be documented.

In the case of safe enclosure, the documentation should be compiled in such a way that, even if there is a change in licensee during the course of the decommissioning work (dismantling of the facility) all of the necessary information which is important from a safety point of view, is available.

This does not affect the radiological protection documentation required by the Radiological Protection Ordinance.

For the purposes of discharge from nuclear legislation after clearance (completion of dismantling of the facility in the scope described in the licence) the competent authority must be provided with a set of documentation under the terms of the licence. This documentation must give:

- a description of the status of the site on completion of decommissioning work,
- the clearance criteria, methods of measurement used and the results for all of the structures remaining on the site and for the area of the site itself.

The Italian Regulator's Viewpoint

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1. Italian nuclear history and policy

In Italy the pacific use of nuclear fission for energy supply started in the early sixties. Three nuclear power plants, 160 MWe GCR at Latina, 270 MWe PWR at TRINO and 160 MWe BWR at Garigliano, were in operation since the year 1964.

The Garigliano power plant was shut down in the year 1978 in order to undergo major modifications, but since then it has never restarted. In the year 1981, a fourth unit, 882 Mwe BWR at Caorso started its commercial operation, and in the following years began the construction of two 1000 Mwe BWR units at Montalto (Alto Lazio NPPs).

The nuclear programme, in the middle of the eighties, foresaw the further realisation of at least 4 1000 Mwe PWR units, according to the new national project named PUN (Nuclear Unified Project). In addition, two experimental reactors were developed since the early seventies: the CIRENE reactor (natural uranium, heavy water, 60 Mwe) and the prototype fast reactor named PEC (Fuel Elements Test Reactor). At the same time, fuel cycle activities were developed in industrial and/or experimental-pilot scale, such as uranium fuel fabrication (FN, at Boscomarengo, for BWR and PWR assemblies; IFEC, at Saluggia, for MTR and CIRENE fuels); fuel reprocessing (EUREX, at Saluggia, for MTR, CANDU and LWR fuels; ITREC, at Trisaia, for uranium-thorium fuel cycle); plutonium fuel fabrication (Plutonium Plant at Casaccia).

After the Chernobyl accident, a general public debate took place in Italy on the implications of the use of nuclear energy. In November 1987, a referendum was passed: this vote was formally limited to specific aspects of siting in the nuclear legislation in force at that time, but the results represented the negative attitude of the public for nuclear technology.

As a consequence, the new National Energy Plan called for the abandonment of nuclear power, and a decision was taken to close the Latina, Trino and Caorso power plants, as well as the CIRENE and PEC experimental reactors, and to halt construction of the two 1000 Mwe BWR units at Montalto (which were 70 percent complete).

From then on, no change of policy has occurred on this matter: management of radioactive waste and decommissioning are the main tasks facing the Italian regulatory system and licensees.

On the other hand, specific policies were issued by the Government addressing to keep up-to-date the competence and capabilities on the technologies of nuclear installations of National State R&D organisations, as well as of the National Regulatory Body and concerned industries. This goal is mainly achieved by means of international cooperations, in particular within the European Commission programmes of assistance to Eastern European Countries in the field of nuclear safety.

2. Italian decommissioning policy.

As previously said, in Italy the political decisions to close the existing nuclear power stations, as well as to stop the construction of new power plants, was taken in the years 1987-1990.

Together with the decisions of the closure of power plants, the Interministerial Committee for the Economical Planning (CIPE), the Governmental Body encharged, inter alia, with issuing resolutions concerning nuclear power plants, instructed the National Electric Company ENEL (owner of all nuclear power plants) to start the actions for decommissioning. However, there were not consequent specific acts to define the national policy of decommissioning, and to allocate specific financial resources for the relevant operations.

Other difficulties were (and still are, regretfully):

- The lack of a national site for the disposal of low and intermediate level waste;
- the lack of a centralised interim storage facility for spent fuel and high level waste;
- the uncertainty of the definition, at national level, of the policy of management of the very low level waste (clearance levels).

A substantial novelty in the fiel was the entry into force, in January 1996, of the Legislative Decree no.230, which replaced the previous Decree of the President of the Republic no. 185 of 1964, and introduced, as is better shown in the next paragraph, new regulations in the field of radiation protection providing, inter alia, for stricter dose limits for workers and public; the decree also provided for new, specific rules on the decommissioning of nuclear plants; as a consequence, the licensees were required to replace or adjust, according to the new provisions, the applications and the relevant assessments produced under the rules previously in force.

In this situation, the decommissioning operations on shut down power plants did not progress smoothly and underwent significant delays, so that, as far as the achievement of the "safe enclosure" state is concerned, the forecasts are, at present, for the year 2003 for Garigliano, for the year 2005 for Trino, for the year 2006 for Latina and for the year 2010 for Caorso.

In order to overcome these difficulties, ANPA, the Italian State Agency for Environmental Protection, which, inter alia, is the National Technical Body responsible for Regulatory Procedures, Nuclear Safety and Radiation Protection, in two National Conferences held in Rome in July 1995 and in November 1997, called the attention of the Government, of the Parliament, of the media and of the general public on the urgency of solving the problem of the proper and timely management of the heritage of closed national nuclear programs.

Key points of the position of ANPA in this connection are the following:

- The definition of the **policy of management of spent fuel** still present in Italy;
- The definition of the **policy of decommissioning;**
- The realisation of a **national site for disposal of low and intermediate level waste and a centralised interim storage facility for spent fuel and high level waste;**
- The identification of relevant **National Operator(s)** and the appropriation of relevant **financial resources.**

These points will be briefly discussed in the following.

I. The definition of the **policy of management of spent fuel** still present in Italy.

Since the beginning of nuclear activities, Italy pursued the reprocessing option, by sending the spent fuel of the power stations at foreign reprocessing facilities. The adoption of the reprocessing option, supported also at national level by the realisation and operation of two pilot reprocessing plant at Saluggia (Eurex) and Trisaia (Itrec) sites, was justified by the strong involvement of Italy in the fast reactor programme. In this connection, “service agreement” contracts were stipulated by ENEL with BNFL.

After the political decision to stop all nuclear power activities in Italy, the shipments of spent fuel were suspended, so that some 350 tons of spent fuel are still stored in Italy, at the reactor storage pools (220 tons at Caorso site, 41 tons at Trino site) or at away from reactor sites (of which 82 tons at Avogadro storage pool). At present, there are no specific reasons to maintain the reprocessing option, due to its very high cost and due to the complete lack of interest in the plutonium which would be recovered and which would represent, moreover, a first degree problem. Therefore, ANPA believes that the national policy of management of the spent fuel still stored in Italy should be the dry storage in a centralised interim storage facility.

This operation should be realised in two phases:

- in the first phase, to be started immediately and to be completed within five years, the spent fuel stored in the reactor pool at Caorso and Trino should be transferred in dual purpose (storage and transport) metallic casks, to be temporarily stored on site;
- in the second phase, all metallic casks should be transferred to a centralised interim storage facility, to be constructed, within the next decade.

II. The definition of the **policy of decommissioning**

In 1990, according to a resolution of the interministerial Committee for the Economical Planning (CIPE), the National Electricity Company ENEL, was instructed to close its nuclear power stations and to start the actions for their decommissioning, performing the operations necessary to lead the nuclear power plants to the “safe enclosure” stage. At that time, therefore, the “deferred decommissioning” (SAFSTOR, safe storage and delayed dismantling) was the reference option.

Now, after more than 13 years since the shut down of the Italian power stations (more than 20 for Garigliano), the “safe enclosure” stage, as already said before, is still far from achievement (at least 5-10 years, depending on the plant concerned). In this situation, ANPA believes that the “deferred decommissioning” option should be reconsidered, the following reasons, inter alia, being in favour of the “prompt decommissioning” option:

- there are no more significant dose constraints in favour of the selection of deferred decommissioning;
- it is necessary to take advantage of the reactor work force still available that is highly knowledgeable about the facility, especially considering that, after the decision of Italy to

abandon the nuclear energy source, it will be difficult to find new personnel with adequate know-how, and therefore to ensure an adequate turnover;

- the local authorities, in the absence of any further nuclear programme at national level, claim a rapid availability of the site for other purposes.

III. The realisation of a **national site for disposal of low and intermediate level waste and a centralised interim storage facility for spent fuel and high level waste.**

The radioactive waste originated in the past from the operations of the Italian nuclear installations total to some 27.000 cubic metres, including the dismissed sealed sources and the radioactive waste coming from industrial and medical applications. Most of these wastes, including spent fuel, are at present stored in the sites of origin, in facilities that were not designed and realised for long term storage, so that many of these temporary storage facilities are near the end of their working lifetime.

In this connection, the urgency of the availability of the national site for disposal of low and intermediate level waste and of the centralised interim storage facility for spent fuel and high level waste has been strongly emphasised by ANPA. Moreover, this availability is of paramount importance to make possible the implementation of the "prompt decommissioning" strategy.

IV. The identification of relevant **National Operator(s)** for waste management and decommissioning, and the appropriation of relevant **financial resources.**

Until now, the activities in the field of waste management and decommissioning of the owners of shut down nuclear installations (mainly ENEL for power plants and ENEA for pilot experimental facilities) have been carried out on individual basis, without a common co-ordination and in the absence of strategy defining the reference objectives and the relevant time schedule. The need of an ad hoc legislative act defining the National Programme of Waste Management and Decommissioning, identifying the National Operator(s) entrusted with its co-ordination and fulfilment, and allocating the appropriate financial funding has been pointed out by ANPA.

3. Italian decommissioning regulation

In Italy the regulatory regime for nuclear activities is largely based on two enactments.
The first is the Act n° 1860 of 31 December 1962 on the Peaceful Uses of Nuclear Energy; the Act introduced a general regime based on a series of administrative and procedural requirements including notification and licences.

The second basic text is Legislative Decree n° 230 of 17 March 1995, replacing the decree of the President of the Republic (DPR) n° 185 of 1964. This new Legislative Decree, which came into force on 1 January 1996, provides for the transposition of six EURATOM Directives concerned with radiation protection. In particular, the Legislative Decree no. 230 of 1995 enacts specific provisions as far as decommissioning of nuclear installations is concerned. An outline of these provisions is presented.

Operations for the decommissioning of a nuclear installation are subject to prior authorisation by the Ministry of Industry, acting in consultation with the Ministries of Environment, Interior, Labour and

Health, ANPA and the region concerned. Such authorisation can be issued for intermediate stages leading up to a planned final state. This subdivision into intermediate stages must be shown to be part of an overall decommissioning plan, to be enclosed with the application for the authorisation concerning the first stage.

For each stage the above bodies are sent:

- a plan of the operations to be carried out;
- a description of the state of the installation, including:
- an inventory of the radioactive materials present;
- a description of the state of the installation itself at the end of the stage in question,
- a safety analysis concerning the operations to be carried out and the state of the installation itself at the end of the stage in question;
- the intended destination of the resulting radioactive materials;
- an assessment of the effects of the decommissioning operations on the environment;
- a radiation protection programme for emergency situations.

The licensee is also required to analyse in the plan the situations in which it will be no longer needed to guarantee the technical conditions necessary for compliance with the individual provisions of the Decree no. 230/1995 and with the rules governing plant operations.

Sixty days after receiving the documentation, the other bodies (Ministries of Environment, Interior, Labour, Health, and the Region concerned) transmit their observations to ANPA that elaborates a safety and radiation protection assessment, taking account of such observations, indicating conditions and specifications.

Thirty days after receiving ANPA's assessment, the other administrations send ANPA their final observations.

After seeking the advice of the National Technical Commission set up under article 9 of the Decree no. 230, ANPA sends its advice, together with technical specifications, to the Ministry of Industry.

The Ministry grants the authorisation prescribing compliance with ANPA-stated technical specifications.

Decommissioning operations are carried out under ANPA surveillance; at the end of the decommissioning operations the licensee sends ANPA its assessment on the operations and the state of the site and of the environment.

After obtaining the advice of ANPA and of the other bodies, the Ministry of Industry can state specifications concerning the state of the site and of the environment at the end of the decommissioning operations. At present, no complete decommissioning programmes or plans have been agreed to by the regulatory body.

The application for decommissioning of the ENEL four shut down power station as well as of the FN LWR fuel fabrication plant, issued according to the new rules stated by the Legislative Decree 230/95, are at present under evaluation.

Some points may be highlighted that are characteristic of the Italian decommissioning situation.

All applications refer to the authorisation concerning the first stage ("safe enclosure"), thus requiring that such subdivision into intermediate stages must be shown to be part of an overall decommissioning plan.

According to the definition in Article 7 of the Legislative Decree 230/95, " decommissioning means the whole planned actions … up to the final dismantling or in any case up to unconditional release (release of site and/or buildings with no radiological constraints)".

Now, the licensees claim that it is difficult for them to deliver an overall decommissioning plant under which the "unconditional release" can be guaranteed until the national radwaste disposal site is available. While this is certainly a necessary element to ensure compliance with decommissioning requirements laid down in law, it must be pointed out that the difficulty could be overcome by reserving, in the application for the decommissioning licence, to mention the final destination of the waste.

Another feature of the Italian administrative system is that a plurality of bodies have a role in the same matters, as each administrative body has to be a guardian of the public interest from its own view point; furthermore, in the Italian system licenses, permits and authorisations are granted by Ministries, even though Agencies such as ANPA are thought as specialised State instruments to which care and supervision of certain highly technical matters are confided.

On the other hand, the licensing procedure involves the need for ANPA to collect the opinion of four Ministries (Environment, Interior, Labour, Health) as well as of the region concerned; this procedure must be reiterated twice, before ANPA can deliver its assessment to the National Technical Commission; only when this Commission has delivered its comments, ANPA can send its advice to the Ministry of Industry, who grants the authorisation.

One can note that this system provides for a high degree of guaranty even though ways can be found to make it more agile while maintaining its essential feature of seeking the opinion of all public bodies concerned.

A short outline of the present state of licenses will be given.

After two years of implementation (the first applications for the authorisation of decommissioning have been presented by licensees in the middle of 1997), not all Ministries involved have actually delivered their first evaluation, and the regions concerned (Emilia-Romagna for Caorso power station, Piemonte for FN fuel fabrication plant) expressed several remarks about the completeness and conformity of the "overall decommissioning plan", the region's approval being considered an essential condition for granting the license even of the first phase.

In addition, both regions and those Ministries which have already delivered their opinion, expressed their disappointment on the strategy of deferred decommissioning again proposed by the licensees, being strongly inclined towards the prompt decommissioning option.

For these reasons, licensees will have to submit a revised version of the overall decommissioning plan, as well as a revised version of the plan dealing with the first phase, in which those operations incompatible with the “prompt decommissioning” strategy should be deleted.

At present, only limited activities (such as the management of spent fuel and of operational radioactive waste, togheter with other operations preliminary to decommissioning) are carried out in the frame of to the existing licenses, or on the basis of their modifications.

4. Conclusions.

The management of radioactive waste and of decommissioning, that is the heritage of ceased Italian nuclear activities, needs the adoption, by the Government and by the Parliament, of decisions of level comparable to those previously adopted for the closure of the nuclear power stations.

In this connection, it is worthwhile mentioning the following positive outcomes.

- The Parliamentary Commission of Inquiry on Waste Cycle, chaired by Mr. Scalia, has recently approved a final document on safe management of radioactive waste and on decommissioning of nuclear installations; this document points out the urgency of realisation of the national disposal site for low and intermediate level waste, and includes a bill which, following the example of several other European countries, deals with the creation of a National Agency for the Management of Radioactive Waste, having also the task of National Operator for the decommissioning of nuclear power stations.
- The Ministry of Industry, Mr. Bersani, has announced that, within the next few months, a document will be presented to the Parliament for approval; this document, starting from the analysis of the present situation, defines the guidelines of the national strategy of management of post-closure nuclear heritage, and in particular:
- The objectives to be pursued (treatment and conditioning of radioactive waste; selection, qualification and operation of national site for LILW disposal; decommissioning of nuclear installations);
- The financial resources needed;
- The organisational framework (National Operator(s);
- The co-operation between central and local authorities.

The implementation of this programme implies a very strong national effort in terms of human and financial resources, requiring the involvement not only of the scientific and industrial world, but also of the local authorities and the general public, in order to gain the consensus.

On the other hand, the efficiency and effectiveness of the national regulatory regime as well as of the regulatory body itself (ANPA) plays a key role.

In this connection, an important objective should be pursued, that is to make the present decommissioning licensing procedure more agile (the bill of the Parliamentary Commission of Inquiry mentioned before includes an article which modifies appropriately the relevant provisions of the Legislative Decree 230 of 1995).

THE ITALIAN EXPERIENCE:
THE DECOMMISSIONING ACTIVITIES AT GARIGLIANO AND LATINA NPPs

Oreste. Contino, ANPA and Gaetano. Ruggeri, ENEL

1. Legislative framework

The old Nuclear Law (Decree of the President of the Republic D.P.R. n° 185 of February 1964) was in force till 31.12.95 and addressed mainly towards the *commissioning* of nuclear installations.

The new Law (Legislative Decree n. 230 of March 1995) is in force since 1.1.96 and contains *specific articles about decommissioning.*

In accordance with the new Law the activities, and related plans, concerning decommissioning of nuclear installations are subjected to the approval by the Ministry of Industry, on the basis of the assessment of ANPA which takes into account the advises provided by many and different Authorities:

- Ministry of Environment
- Ministry of Internal Affairs
- Ministry of Labour
- Ministry of Health
- Regional or Provincial interested Bodies
- National Technical Commission for Nuclear Safety and Radiation Protection.

The decommissioning operations until now carried out at Garigliano and Latina power plants have been performed on the basis of the provisions of the Decree of the President of the Republic D.P.R. n° 185 of February 1964.

On July 1997, ENEL submitted to the Ministry of Industry a new decommissioning application for both plants, based on the new rules arising from the new Legislative Decree n° 230 of March 1995. These applications are at present under evaluation by the different Bodies before mentioned.

2. Decommissioning strategy

According to the resolution of the Interministerial Committee for Economical Planning (CIPE), ENEL, the owner of the Italian nuclear power plants, was charged to perform the decommissioning operation necessary to reach the “Safe Enclosure” condition. In this connection, the decommissioning strategy, proposed by the owner and approved by the regulatory body was that of the “DEFERRED DISMANTLEMENT” (SAFSTOR), consisting on the following groups of activities:

- Preliminary Activities;
- Actions to lead the Plant to the “Safe Enclosure” condition;
- Maintenance of the “Safe Enclosure” condition for some decades;
- Decontamination and/or Dismantlement of Plant Structures and Buildings, up to unconditional release (release of site and/or buildings with no radiological constraints).

3. Licensing procedure

The previous legislative regime (DPR 185/64) did not consider specific provisions for the decommissioning of nuclear power plants, so that the relevant operations had to be performed in the frame of the existing licences or on the basis of their appropriate modifications.

This was the case for the decommissioning activities at Garigliano and Latina power stations. In this connection, the following procedure has been agreed by ANPA.

The owner presented an application to the Ministry of Industry addressed to the modification of the existing plant operating licence, in order to get the authorization for all the activities necessary to reach the "Safe Enclosure" state.

This application was supported by a General Technical Report (''Rapporto Quadro'') in which:

- was illustrated the global decommissioning strategy;
- were defined the safety-related plant systems, components and structures to be maintained operable in the different phases of the decommissioning process;
- was proposed a new framework of operating technical prescriptions in accordance with the modified plants needs.

The Regulatory Body examined all the nuclear safety and health protection aspects, connected with the activities proposed by the operator in view of the achievement of the "Safe Enclosure" condition at the shut down power plants of Garigliano and Latina.

Safety assessments were performed by the Regulatory Body considering not only the safe management of the normal plant conditions but also examining potential abnormal occurrences. In this way it was possible to identify all the plant systems to be maintained operable, in order to manage safely the routine plant activities as well as to face adequately all the hypothetical accidental events.

In conclusion the Regulatory Body approved the owner proposal of " new operating" prescriptions and the Ministry of Industry issued a new operating licence.

Besides the operating license, other legal documents were modified and in particular:

- Technical basis for the plant external emergency plan;
- Surveillance rules;
- Operational Regulation (Organizational structure).

4. Main activities to be performed.

The main activities identified to lead the Garigliano and Latina power plants in the "Safe Enclosure" condition essentially consist of the following operations:

- Removal and transport of all the nuclear fuel elements away from the plant site;
- Total radiometric plant recognition and compilation of the inventory of the residual radioactivity at the plant site;

- Treatment and conditioning of the operational radioactive wastes in order to put them in a safe state, preventing leaks of radioactive products in the environment;
- Elimination of plant structures and parts no more useful and potential risk sources;
- Storage of the radioactive wastes in adequate storage facilities, taking into account the duration of the “Safe Enclosure” condition.

5. Activities at Garigliano plant

5.1. Foreword.

Garigliano nuclear power plant is located near Sessa Aurunca, at about one hundred seventy kilometres to the south of Rome.

The plant was equipped with a General Electric BWR of the first generation and was designed for an electrical output of 160 MW.

It was in commercial operations since April 1964 until August 1978. Since then, due to technical and economical reasons, it never restarted, so that in 1982 the owner decided to put the plant out of service and, in view of its decommissioning, requested the Ministry of Industry a new “operating” license dealing with operations directed to the achievement of the “safe enclosure” condition. The Ministry of Industry issued this new “operating” license in September 1985.

5.2. Operations for “safe enclosure”.

Within the limits of this new license, the following operations to be performed were identified:

- Removal and transport of spent fuel away from the site.
- Treatment and conditioning of operational radioactive waste deriving from plant operations.
  - High level waste stored in a pit called “FAT”;
  - Low and intermediate level waste (spent ion exchange resins, evaporator concentrates, filter sludges).
- Operations aimed at ensuring a “safe storage” of reactor building and also of liquid radioactive effluents building.
- Controlled demolition of the off-gas stack.

6. Activities at Latina plant.

6.1. Foreword.

Latina nuclear power plant is located near Borgo Sabotino, at about seventy kilometres to the south of Rome. The plant was equipped with a single MAGNOX reactor similar to the British Bradwell and Dungeness stations. The electrical output was initially of 210 Mwe, and it was subsequently reduced to 160 Mwe. It was in commercial operations since January 1964 until November 1986.

In December 1987 the Italian Government decided to close the plant definitively and asked the operator to undertake the actions necessary to lead the plant to the “safe enclosure” condition. In this connection, the utility requested the Ministry of Industry a new “operating” license, and presented a Technical Report in which, inter alia, it described the decommissioning strategy and identified the safety-related plant systems and structures.

Moreover, the utility proposed new “operating” prescriptions, taking into account the modified plant needs. The Ministry of Industry issued the new “operating” license in April 1991.

6.2. Activities carried out.

All nuclear fuel, fresh and irradiated, was totally removed from the plant site and the spent fuel elements were transported to the Sellafield reprocessing plant (BNFL, UK).

Some preliminary actions of the decommissioning process began since 1992 and concerned the disassembly and removal of some structures and parts of the plant considered no longer safety-related such as:

- Water-steam piping,
- Fuel charge/discharge machines,
- CO_2 production and storage system,
- Auxiliary piping.

In 1995, the Regulatory Body approved the “Preliminary General Design” (“Progetto di Massima”) which represents the reference document for all the actions necessary to lead the plant to the “safe enclosure” condition and comprises the radiological characterisation of the plant, the inventory of all the radioactive materials on site and the criteria of management of radioactive wastes, including those to be returned to Italy after reprocessing at abroad facilities of the spent fuel.

According to the Italian licensing practice, for the activities included in the “Preliminary General Design” that are defined by the Regulatory Body as “relevant to safety”, the licensee must produce “Detailed Designs”, which have to be submitted to the Regulatory Authority for approval. Among these activities can be mentioned:

- Dismantling of primary circuit ducts,
- Sealing of primary biological shield
- Conditioning of Intermediate-Level Wastes (such as splitters and sludges)

In the meanwhile, the Regulatory Body authorized some activities addressed to demonstrate the feasibility of some considerable operations and also to test in field the adequacy of the operational procedures. These activities were:

- The decontamination of two sections of the spent fuel pool;
- The dismantling of two “by-pass” ducts of the primary circuit.

These two activities have been performed with positive results, so that the utility has acquired useful experience in the implementation of decontamination techniques of concrete structures and steel components as well as in the field of thermal cutting and in particular in plasma cutting.

7. Examples of relevant activities

7.1 Primary Circuit Dismantling

The primary ducts connect the reactor vessel to each of the six boilers, these ducts have a nominal diameter of 1676 mm and a thickness of 16 mm. Their relatively small thickness suggests to remove them.

In particular the project foresees that after removing the thermal insulation of the ducts, their internal surface must be decontaminated using water jet (150÷200 ata) and that the ducts can be cut into square pieces 67x67 cm using oxyacetylenic and plasma cutting.

The total working time has been estimated in 5600 man-hour with a dose commitment of 0,38 man.Sv.

7.2 Boilers Seismic Improvement

The boilers are cylindrical, vertical axis 25 m high, 5,6 m diameter shell and 8 tube bundles. Their empty weight is about 500 ton. The contaminated surfaces are those internal to the shell and external to the finned tube bundles. The internal content of radioactivity for each boiler is about 1010Bq. The thickness of boilers is of 55 mm and therefore large enough to prevent releases of radioactivity during the safe enclosure state.

The "Preliminary General Design" for these components foresees that they may be left in their present location, without any internal decontamination.

The only actions already performed have been the seismic reinforcement of the structures supporting the boilers and the protection of their external surface through sanding and repainting.

7.3 Decontamination Of The Spent Fuel Pond.

The Regulatory Body authorized the decontamination of two sections of the spent fuel pond, the decay bay and the emergency bay. This activity was carried out reducing the water level in the section of the pool in steps and then removing layers of contaminated material from the concrete wall of the pool. It was used a specific tool, a scabbling machine (Pentek), consisting of an ultra-high performance vacuum/drumming unit with pneumatically operated scabbler. This system has allowed to minimise radioactive waste, airborne radioactivity and operator exposure. It does not use water, abrasive, chemicals and therefore dust and debris were captured as soon as they were generated and deposited directly into disposable waste drums.

REGULATORY ASPECTS OF DECOMMISSIONING IN THE UK

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Abstract

This paper discusses the regulation of decommissioning in the United Kingdom and identifies the factors used by HM Nuclear Installations Inspectorate to examine the adequacy of decommissioning and radioactive waste management on nuclear licensed sites.

The principal requirements are for decommissioning to be undertaken as soon as reasonably practicable; for the generation of radioactive wastes to be minimised; for wastes to be disposed of when facilities are available and in the meantime to be stored in a passively safe form. However, these requirements have to be considered in the context of major organisational changes in the UK nuclear industry and the non-availability of disposal routes for intermediate level waste, which includes much of the waste generated by decommissioning activities.

Introduction

In the UK we have already decommissioned and returned to so-called green field status some early research reactors and parts of nuclear chemical plant sites. Currently some early nuclear chemical plant, power stations and research reactors are being decommissioned. In itself, this represents a wide range of technical challenges which need to be solved at a time when there are fundamental developments affecting the industry. For example, the major portion of the UK's nuclear generating capacity has been sold to the private sector and more recently the failure to secure planning permission for[HSE2] the development of a rock characterisation facility means that Intermediate Level Waste (ILW) needs to be stored for an indeterminate period[HSE3]. The key issues concern the regulatory requirements for nuclear safety, the personnel and financial resources needed to undertake decommissioning, and the principles and standards which apply to this work and in particular the management of radioactive waste.

This paper discusses the regulatory approach in the UK to decommissioning and how each of the key issues is being regulated.

Regulation of decommissioning

The Nuclear Installations Act 1965 (as amended) is used to regulate the decommissioning of nuclear installations along with other activities. Under this Act, a Site Licence is issued in respect of a site to enable prescribed activities to be undertaken. The site licence remains in force and the licensee has a continuing period of responsibility until there has ceased to be any danger from ionising radiation from anything on the site. The Act allows the Health and Safety Executive (HSE), of which NII is part, to attach conditions to the site licence in the interests of safety or in respect of the handling, treatment and disposal of nuclear matter. HSE delegates such functions to NII. The NII is responsible for regulation of the management of radioactive wastes on nuclear licensed sites. Discharges to the environment and the disposal of radioactive wastes off the licensed site are regulated under the Radioactive Substances Act

1993 by the Environment Agency or in Scotland by Scottish Environment Protection Agency. Close liaison between the NII and the two Environment Agencies is maintained in addition to the requirement for statutory consultation.

The conditions which are attached to a licence are essentially non-prescriptive and generally require the licensee to make and implement adequate arrangements to address a number of issues, including those relating to safety and waste management. The licence conditions apply equally to operating and decommissioning sites. They form a continuous and flexible form of regulation which applies throughout all stages in the life of a nuclear installation.

A fundamental requirement is for licensees to produce safety cases for all operations which can affect safety. This applies to the construction, commissioning, operation and decommissioning of plant. Provisions should be made for the decommissioning of plant at the design stage and the arrangements for decommissioning should progressively be developed throughout its life. These arrangements should provide for the technical aspects of decommissioning as well as planning of the necessary staff and resources needed to do the work.

Our licensees are required to periodically review their safety cases. These reviews take two forms. Firstly on a regular basis, typically once a year, they verify that the plant and its future operations conform to the description of plant and the limits and conditions set out in the safety case. Secondly, and on a longer timescale, each licensee carries out a much more comprehensive review of its safety cases to consider previous operational history, validate the case against modern safety standards and justify any differences or concerns. These reviews continue throughout the decommissioning phase until such time as a final case is submitted which substantiates delicensing.

The conditions which relate to radioactive waste management require arrangements to ensure that generation of waste is minimised and waste is properly contained, stored on the site in a controlled manner and, where possible, disposed of via authorised disposal routes.

There are other conditions which require the licensee to prepare decommissioning plans. The Inspectorate can approve these, thereby freezing the plans. We can use the powers of the licence to enforce their implementation.

Decommissioning and Waste Management Guidance

Decommissioning

Decommissioning concerns the systematic and progressive reduction of all hazards on a licensed site until there remains no danger from ionising radiation. This represents a change in approach away from the optimisation of operational risk, so that it is as low as reasonably achievable (ALARP), toward a deterministic requirement to completely remove a hazard. However, it is still necessary to ensure risks are optimised at each stage of hazard reduction.

Each country will have its own regulatory basis for determining what constitutes the end point of decommissioning. For some, there may already be a definition of the level of risk that is of no concern within the law (De minimis non curat lex). However, in the UK the Nuclear Installations Act requires that there is no danger from any radioactivity on a licensed site before that site can be delicensed and the operator released from its period of responsibility for any nuclear liability. In practice, what we have done is quite pragmatic and requires a comparison of the levels of radioactivity associated with a site or facility to be delicensed with local natural background radiation in order to demonstrate that there is no measurable artificial radioactivity present. For some sites where there has been contamination of the ground or subsoil, these criteria cannot be applied and the criteria and actions in such cases have yet to be decided.

The current UK government policy on the timing of decommissioning is that it should be undertaken as soon as reasonably practicable, taking account of all relevant factors(1). The policy of the Health and Safety Executive, of which HMNII is a part, has been based on that of Government(2). However, what constitutes a relevant factor and exactly how this is taken into account has been left to the regulators and industry to determine by reasoned argument and, if necessary, by case law. In light of recent developments, progress made on decommissioning and based on our own experience, NII has been developing its expectations to guide inspectors and assessors.

Money is an essential resource which has to be available on a timely basis to enable work to proceed. The Government placed a duty on HSE to undertake a quinquennial review of each licensees' arrangements and provisions for decommissioning(1). The first of these reviews, in effect at time zero, simply ensures that outline plans and arrangements for provisioning are in place. This was the case for the newly privatised nuclear power generators in the UK. Subsequent reviews will examine the adequacy of the financial arrangements and start to challenge the decommissioning plans in light of regulatory requirements and current policies on decommissioning and radioactive waste management. Later on, we will use these reviews to look in detail at specific provisions against particular decommissioning objectives in order to provide confidence that plans can be or are being implemented without problem.

An aspect of financing is the application of discounting. A penny invested today will be worth the pound needed for tomorrow. Some have argued that not only can money be saved but that technology will be better and cheaper in the future. The UK government has issued Treasury guidance on discounting and the uncertainties which can prevail. From a nuclear regulator's perspective, decommissioning must be based on currently available technology and discounting is a technique which should only be applied after a particular technical solution and its timing has been chosen, so that adequate funds can be provided in the future. It is not a technique which can be applied to speculative options. This will simply lead to the indefinite deferral of decommissioning and will ignore other important factors which should be taken into account.

If a licensee wishes to defer stages of decommissioning it must demonstrate substantial safety benefits in doing so. The test must be to show a gross disproportion between the benefits and detriments of undertaking the work later rather than sooner. One persuasive factor in this will be the reduction in doses afforded by radioactive decay; however, this must be challenged from the position that each option under consideration has had its respective dose uptake optimised to be ALARP. The safety benefits may not be directly associated with worker doses, for example, deferral may allow the use of simpler techniques which are currently available. These may be inherently safer to implement, for example from the point of view of accident risk. However, if the deferral of decommissioning does not result in such a benefit then it should be undertaken sooner rather than later.

One resource which must not be underestimated in planning for decommissioning is local and corporate plant knowledge and the availability of the staff who have that knowledge. There is a growing body of evidence to show that earlier dismantling may benefit from local knowledge and understanding of the plant and this is one of the factors to be taken into account in determining the timing of the work. This is the case not only for nuclear plant, but also for conventional plant and civil structures (3,4). Furthermore, the skills and knowledge required for decommissioning need to be factored into decommissioning planning at an early stage. In the UK we require each licensee to produce safety cases for those operations which can affect safety, and that these safety cases are subject to regular and periodic review. This also applies to decommissioning. Initially it is acceptable for decommissioning plans which are included in safety cases to concentrate on the technical issues and logistics of decommissioning. This will make use of the provisions made at the design stage of a plant. Subsequently, this planning will start to look at the management of staff and corporate knowledge. This must be described and its proposed application justified within the safety case. The aim here is to have a clear picture of the initial stages of decommissioning and the role which can be played by existing staff. This helps manage staff morale by demonstrating the certainty of the programme of work required to dismantle plant and delicense a site. This subject has been a topic of extensive debate prior to this workshop(5).

Decommissioning should also make full use of all available disposal routes. This includes the disposal of non-radioactive wastes, the recycling of scrap and the disposal of radioactive wastes. In the UK, for example, non-radioactive steels have been recycled and aluminium from a fuel cycle plant has been recovered, decontaminated and recycled. However, there is only one national facility for low level radioactive waste. This is the Drigg site in Cumbria. It is used in preference for operational wastes, although some decommissioning wastes have been disposed of. Wastes are classified according to their specific activity and rate of heat generation. This means that short-lived radionuclides such as cobalt-60, an activation product in steel scrap from nuclear power reactors, may be too radioactive for disposal as LLW. This is the case for parts of the contaminated steam generating units and the steel pressure vessels of the Magnox reactors. There is currently no disposal facility for intermediate level wastes or high level wastes in the UK. This presents a problem for the timing of decommissioning. There is a balance to be struck between the multiple handling of materials, the constraints of future disposal options and the deferral of decommissioning until a disposal route becomes available. On the other hand, there are powerful arguments in favour of early decommissioning so that full use can be made of local and corporate knowledge, and so that the technical complexity of the final job is reduced to the minimum. As a result, all that future generations would inherit are waste packages that are well characterised and passively safe. The problem of final decommissioning phase will therefore be reduced to its simplest form. Keep it safe and simple is a good principle. This is a truly precautionary approach and one which minimises the amount of information and technology which has to be handed down from this generation to the next and so-on until either the radioactivity has decayed or the waste has been disposed of. Nevertheless, throughout the duration of decommissioning, sufficient and suitable qualified and experienced staff, supported by similar corporate resources, need to be provided to respond to emergency requirements, undertake surveillance and provide security for the decommissioning or decommissioned facility.

The House of Lords Select Committee on Science and Technology has recently published its review of radioactive waste management in the UK(6). The Committee has recommended to Government that the UK should work to establish a deep repository for ILW within the next 50 years. The Government is considering its response to this report. There are a number of steps to be taken before such a repository becomes reality, not least of which is a need to involve the public in the decisions which have to be taken. From the NII perspective, we have considered the implications of a long term delay in the availability of an ILW disposal route (7) and have concluded that there are significant safety benefits in the conditioning of raw operational wastes in to a passive safe form for a period of long-term on-site storage in purpose built facilities. We are also developing guidance for our assessors and inspectors on our requirements for future radioactive waste management. The conditioning of radioactive wastes is one of the preparatory steps in removing hazards from each decommissioning site. This guidance has therefore a particular bearing on decommissioning in relation to passive safe storage and the inspectability of radioactive wastes.

Radioactive Waste Management

A primary requirement is for the generation of radioactive wastes to be minimised(7). This is done by avoidance at source, the prevention of cross-contamination and the characterisation and segregation of wastes consistent with current waste classification and available disposal routes. Should the UK develop additional low level disposal facilities in the future, there would be merit in segregating and classifying wastes according to half-life as is done in France and in other countries. This would have implications for the extent and timing of decommissioning for the short half-life wastes arising from power reactors in particular.

However, in the UK intermediate level radioactive wastes will have to be surface stored for long periods of time in conditions which will enable them to be subsequently handled and disposed of. We conservatively assume this to be 100 years on site plus 50 years in repository. It is our policy that these wastes should be stored in a passively safe form(7). By this, we mean that the wastes must be physically stable, chemically inert, and that potential energy is removed from the wastes and storage system so that the need for active safety systems, surveillance and intervention is minimised. Similarly the need and reliance on human intervention should be minimised.

The stores for these wastes will need to remain fit for purpose for a considerable period (up to 100 years) and this will require careful design to ensure containment and protection of the wastes, longevity of the store fabric and/or periodic maintenance and refurbishment of the store and its contents.

For decommissioning sites, our waste management criteria require that raw wastes are conditioned into a passive safe form and that stores capable of providing long term passively safe storage are provided.

A final requirement is that all radioactive waste should be inspectable and retrievable. This is so that the licensees can provide confirmation and reassurance that wastes remain in a suitable condition and can be retrieved for detailed examination, inspection maintenance or testing or be consigned for disposal.

Conclusion

In the UK we have drawn upon our experiences of radioactive waste management and decommissioning and in the light of realistic forecasts for the availability of routes, radioactive waste disposal routes, have developed guidance for the information of our licensees and the use of our inspectors and assessors. In summary[HSE4] we expect:

Decommissioning

- Decommissioning should involve the systematic and progressive reduction of hazard until there remains no danger from ionising radiation;
- Decommissioning should be undertaken as soon as reasonably practicable;
- Decommissioning should only be deferred if there are substantial safety benefits in doing so;
- Decommissioning costs can be discounted once the methods to be used have been chosen and proven and the timing substantiated;
- If the chosen technique is unlikely to be significantly improved as a consequence of deferral, then dismantling should be undertaken sooner rather than later;[HSE5]
- Full use should be made of existing knowledge to undertake decommissioning safely and to minimise the need to transfer information to future generations;
- Decommissioning must make full use of available disposal routes;
- Decommissioning must achieve a passive safe state as soon as reasonably practicable;
- Decommissioning plans should be kept under continuous review to ensure best options are selected;
- Decommissioning plans should be included in safety cases, which should address the provision of staff and the adequacy of plant knowledge: these safety cases should be reviewed at least every 10 years until the site is delicensed.

Radioactive Waste Management

- radioactivity should be immobilised;
- waste forms should be physically stable and chemically inert;
- potential energy acting on stored waste and its storage environment should be minimised;
- a multibarrier approach should be taken to containment;
- the waste form and package should be resistant to degradation;
- the waste package and storage system should be resistant to foreseeable hazards;
- the need for active safety systems should be minimised;
- the need for monitoring and maintenance should be minimised;
- the need for human intervention to ensure safety should be minimised;
- the waste should be inspectable;
- the waste should be retrievable;
- the waste should be accessible to enable corrective action to be taken should this be needed;
- the storage arrangements should facilitate retrieval for final disposal;
- the lifetime of the storage arrangements and waste package should be appropriate for the planned storage period and for the chosen method of disposal operations;
- there should be no requirement for prompt remedial action;
- the waste store should be designed to allow periodic and continual refurbishment.

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views expressed in this paper are those of the author and do not necessarily represent those of the Health and Safety Executive.

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GUIDANCE DEVELOPMENT TO SUPPORT NUCLEAR REGULATORY COMMISSION'S LICENSE TERMINATION RULE

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Introduction

The US Nuclear Regulatory Commission (USNRC) published a final rule setting radiological release criteria for license termination in August 1997. The criteria apply to release of buildings and land for restricted or unrestricted use, but not to the release of equipment and materials. In August 1998, the staff published the first part of this guidance as a draft report for public comment. The USNRC intends to have final guidance on meeting the rule available by August 2000. This work will involve the review and discussion of several key technical issues that require resolution prior to August 2000.

Key Issues Requiring Resolution

There are two major issues being addressed at the present time. These are measurements of radioactivity at or near background levels, and realistic modelling of radiation dose for hypothetical populations. The dose criterion set by the USNRC is 0.25mSv/year for unrestricted release. In order to demonstrate compliance with this dose limit licensees will need to be able to distinguish licensed materials from background radiation and will need to estimate doses on the basis of future land uses. Both of these issues raise challenging questions for the developers of the guidance. The current staff efforts to address these issues will be discussed in this paper.

Two other issues will also be addressed during the coming year. These issues consider the role of institutional controls and how to demonstrate that radiation doses from released sites are as low as reasonably achievable (ALARA). Both of these issues are covered in some detail in the draft guidance published in 1998 but have yet to really be tested by licensees implementing the regulations. As more licensees begin to use the draft guidance modifications to each of these areas may be needed.

What is the Guidance that is Being Developed?

The first documents prepared addressed methods for conducting surveys of facilities sufficient to demonstrate compliance with the rule requirements. The key document in this area is the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). This was a co-ordinated effort among the key US agencies having authority and control over the use of radioactive materials. The purpose behind this effort was to develop a consistent approach for planning, performing, and assessing building surface and surface soil final status surveys to meet dose-based release criteria. In addition, the USNRC published several supporting documents that address specific aspects of MARSSIM. These documents are titled, NUREG 1505 - A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys, NUREG 1506 - Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria, and NUREG 1507 - Minimum detectable concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. The key component of the methodology addressed in these documents is to demonstrate that a given facility meets the release criteria, at a reasonable cost.

Some of the other documents prepared to support the final rule included a draft regulatory guide, DG-4006, titled, Demonstrating Compliance with the Radiological Criteria for License Termination; and documents describing the dose modelling developed to provide the technical basis for the final rule. The first of these is titled, Residual Radioactive Contamination From Decommissioning, NUREG/CR-5512, Volume 1, and will be comprised of 4 volumes. The first volume was published in 1992; the other volumes will be published this year. The remaining document is titled, Decision Methods for Dose Assessment to Comply With Radiological Criteria for License Termination, NUREG-1549, and provides a logical approach to decision-making that is intended to assist licensees in determining how to achieve the dose levels required by the rule in a cost-effective manner.

Demonstrating Compliance with Cleanup Standards at or below Background Levels

This was one of the major issues facing the staff as the guidance was being developed. When the rule was proposed in 1994 with a 0.15mSv/year dose limit, the staff recognized that measuring such low levels in areas where there was significant background radiation could create an implementation problem. To ensure that the costs to meet such a standard would not be prohibitive, a new way of conducting radiation surveys was sought. The method developed by the staff was to utilize the Data Quality Objective process. This process uses statistical hypothesis testing rather than the more traditional process of constructing confidence intervals. This allows a balance to be reached between the risk of possibly releasing an incompletely remediated site and the risk of possibly requiring further remediation at an already adequately remediated site. The DQO process is used to incorporate site-specific information and sound scientific judgement into the survey design and data analysis so that the objective of safely releasing a site can be met while reducing the number of arbitrary and conservative assumptions that are sometimes invoked in the face of uncertainty. Three classes of survey units are used to direct the survey effort at a level commensurate with the potential for residual radioactivity in excess of the release criterion. Acceptable areas of elevated activity are determined by radionuclide-specific area factors derived from an appropriate dose model. The use of nonparametric statistical techniques do not require data to be normally or log-normally distributed, and are therefore, more appropriate for determining the number of samples required for radiological surveys at or near background levels. These tests are less sensitive to outliers, and are better able to handle data sets that include non-detectable activities.

Developing Realistic Dose Models

One of biggest issues is how to model doses due to residual radioactivity. Currently, USNRC is funding work on two modelling codes: DandD and RESRAD. DandD was developed for USNRC using the model in NUREG/CR-5512, Volume 1, (mentioned previously) as primarily a screening model. The concept behind this approach was to develop a simple tool based on a reasonably conservative model that would eliminate the need for licensees to collect any site data. However, the use of such a simplistic tool will likely be limited to those licensees with little, if any, ground contamination, and little building contamination. The models in NUREG/CR-5512, Volume 1, assess dose for four cases: residential farming, commercial building occupancy, drinking water, and building renovation. For the current version of DandD only the first two scenarios are included. The groundwater model used in NUREG/CR-5512, Volume 1, is fairly simplistic because of the constraints of screening, so that licensees with the potential for ground-water contamination would most likely need to use more sophisticated modelling. DandD Version 1.0 was released in 1998. The current effort will result in a modification to the code to support Monte Carlo analyses that will enable licensees to input some site-specific parameters without re-evaluating all default parameters.

The model used in RESRAD was developed by Argonne National Laboratory for use at USDOE sites in a site-specific manner. As such, it was not really intended to be used as a screening model. To assist the USNRC staff in evaluating licensee submittals using the RESRAD code, a probabilistic version of RESRAD is being developed concurrent with the revisions to DandD that will enable the user to incorporate site-specific information and be able to assess parameter uncertainty.

NRC's Path Towards Resolution of Issues

The most significant issue facing the USNRC really lies in the area of model uncertainty. More work is clearly needed to assess the level of realism in existing models. The ability to easily and cost-effectively increase the accuracy of the dose estimate supports the goal of more flexible balancing of the costs of data collection with the costs of remediation while preserving the regulatory agency's confidence in the result. NUREG-1549, mentioned above, currently incorporates the concept of the intelligent progression in increased realism with reduced conservatism. The associated models and parameters are expected to continue to evolve to support the decision methodology described in NUREG-1549. Both of the current models in use by USNRC (DandD and RESRAD) were designed to be conservative. Unfortunately, we don't really know the level of conservatism in these models. This is AN area of work that the Office of Research in USNRC will be focusing its efforts on in the future.

Another issue that will need to be addressed is the measurement of sub-surface contamination. This is an issue for decommissioning of certain sites where significant contamination may exist below the surface and when buildings are left in place where piping and other structures could have inaccessible contamination present. It is an issue that will also need to be addressed if USNRC decides to develop a standard for clearing material from licensed control, where contamination could be buried within scrap metal or rubble.

An important part of the resolution of these technical issues is continued information exchange with the public and industry. Major initiatives in this area include the scheduling of a series of public meetings to discuss implementation issues, and the publication on the internet of draft documents, meeting summaries, and discussions. The web site address is http://techconf.llnl.gov/index.html

SESSION 5

LIABILITY AND FINANCIAL ASPECTS

PROPOSAL FOR INTERNATIONALLY STANDARDISED COST ITEM DEFINITIONS FOR THE DECOMMISSIONING OF NUCLEAR INSTALLATIONS

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Abstract

Various international studies of decommissioning projects have shown that there are substantial variations in cost estimates for individual installations. Studies attempting to understand the reasons for these differences have been somewhat hampered by the fact that different types of costing methods are used, having different data requirements. Although some uncertainty is inevitable in any costing method, an understanding of the costing methods used in particular projects is useful to avoid key uncertainties. Difficulties of understanding can be encountered and invalid conclusions drawn in making cost comparisons without regard to the context in which the various cost estimates were made.

The above-mentioned difficulties are partly due to the lack of a standardised or generally agreed-upon costing method that includes well structured and defined cost items and an established estimation method. Such a structure and method would be useful not only for project cost comparisons, but would also be a tool for a more effective cost management.

The European Commission (EC), the International Atomic Energy Agency (IAEA), and the OECD/Nuclear Energy Agency (NEA) have ongoing activities addressing various aspects of decommissioning and decommissioning costs. Based on these activities and common objectives, and on the advantages of having standardised cost items, they agreed to prepare a common list of cost items and related cost item definitions for decommissioning projects. The work was carried out by Belgoprocess (Belgium) in the framework of a shared-cost contract with the European Commission (Nuclear Fission Safety Programme 1994-1998).

The paper presents the result of this co-operative work.

1. Introduction

For nuclear facilities, decommissioning is the final phase in the life cycle after siting, design, construction, commissioning and operation. It is a process involving operations such as decontamination, dismantling of plant equipment and facilities, demolition of buildings and structures and management of resulting materials. All these activities take into account health and safety requirements for operating personnel and the general public, and any implications for the environment.

In several projects to decommission various types of nuclear facilities, it has been shown that technical methods and equipment are available today to dismantle safely nuclear facilities, of whatever type or size. Much experience in the use of these techniques has resulted from maintenance and repair work, and from the decommissioning of prototype, demonstration, and small power reactors or other nuclear facilities.

The decommissioning projects have also demonstrated that decommissioning costs can be managed. However, comparisons of individual cost estimates for specific facilities may show relatively large variations, and several studies have attempted to identify the reasons for these variations.

In the past, the basis of the cost estimates for decommissioning projects lay in the world-wide experience obtained either in decommissioning projects or in maintenance and repair work at operating nuclear facilities where conditions are similar to some extent. This experience was utilised directly or as an analogue for estimating the costs of similar tasks in current decommissioning projects, or indirectly for the assessment of unit costs for basic decontamination and dismantling activities.

Different costing methods have different data requirements, however, and consequently, their reliability depends on the extent to which various data are available and applicable to the specific case being considered. Independent of the assessment method, some uncertainty is inevitable in all estimates of future costs, and no costing method may generally be superior to others in this respect. However, analysis of the costing method is useful in order to locate the key uncertainties in each specific estimate. It has been shown, indeed, that there is a potential for making errors, and that difficulties can be encountered in performing quick international cost comparisons. Numbers taken at face value, without regard to their context, are easily misunderstood and misinterpreted. This is due, among other things, to the fact that there has been no standardised listing of cost items established specifically for decommissioning projects. Such a standardisation would be useful not only for making cost comparisons more straightforward and meaningful, but should also provide a good tool for cost effective project management.

In the past, a Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects had considered and evaluated the reasons for the large variations in reported cost estimates from decommissioning projects[1]. In November 1994, a new Task Group on Decommissioning Costs was set up with similar objectives, looking this time (specifically and separately) at power reactors and fuel facilities.

Similarly, in 1995 the International Atomic Energy Agency began developing a technical document on cost of radioactive waste management and decommissioning of nuclear facilities, and called international experts to form a Consultants Group on Decommissioning and Waste Management Costs.

In its 1994-1998 Nuclear Fission Safety Programme, the European Commission decided to continue its developments of the database on unit costs in the decommissioning of nuclear installations.

Based on these parallel activities and their similar aims, the three organisations agreed to start a co-ordinated action in order to produce a standardised list of cost items and related cost item definitions for decommissioning projects. Such a standardised list would facilitate communication, promote uniformity, and avoid inconsistency or contradiction of results or conclusions of cost evaluations for decommissioning projects.

2. Objectives and Scope

The objectives of the actions are the identification, definition, harmonisation and verification of general and specific decommissioning tasks and relating cost items to create a standardised and uniform list of cost items and their respective definitions for decommissioning projects.

The above-mentioned list as well as underlying principles was discussed with representatives of the organisations in view of general harmonisation and completeness in order to obtain a standard for a decommissioning cost structure that could be acceptable to the three organisations. The outcome will be described in a final report including:

- The methodology and the terminology used;
- The methodology for managing decommissioning projects at different stages;
- A glossary of terminology used in the decommissioning and waste management sector.

3. History and Initiation of the Co-Ordinated Action

In the following sections, an overview is given of the historical steps that contributed to the decision taken to start the co-ordinated action with the European Commission (EC), the International Atomic Energy Agency (IAEA), and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), in order to adopt a similar (standardised) or uniform list of cost items and related cost item definitions for decommissioning projects. In addition, a description of how the tasks were organised is provided.

3.1 Activities carried out within the OECD/NEA

In 1989, the OECD/NEA Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects set up a Task Group on Decommissioning Costs in order to identify reasons for the large variations in reported cost estimates of decommissioning projects. The Task Group gathered cost data from 12 projects in the Co-operative Programme, established a basis for comparison of decommissioning tasks adopted in all projects, prepared a matrix of cost groups and cost items with a cost breakdown in “labour costs”, “capital equipment and material” and “expenses”, and incorporated the project cost data into this matrix.

Cost data was progressively refined by discussions between Task Group and project managers to improve the basis of comparison and to make the data more uniform. Real project specific discrepancies were identified and analysed without bias resulting from inconsistent or inappropriate data.

In addition, the Task Group reviewed some general factors identifying issues dealing with political/geographical, technical and economic/financial aspects causing variations in estimated costs. These factors were only treated qualitatively, since data could not be separated to analyse their quantitative effects.

One of the lessons learned by the Task Group was the potential for making errors and the difficulties encountered in performing quick international cost comparisons. It was evident that the answers to any cost questionnaire must be analysed and refined by follow-up questionnaires to understand the real contents. Numbers taken at face value, without regard to their context, are easily misunderstood and misinterpreted.

Another important observation the Task Group made is that there was no standardised listing of cost items or estimating methodology established for decommissioning projects. In their report, the Task Group made a proposal for a listing of cost items and cost groups that could be the framework for such a standardisation[1].

In 1994, the Liaison Committee of the Co-operative Programme decided to re-start the work of the Task Group on Decommissioning Costs. The terms of reference/programme of work for the new study were decided as follows:

- Structure/break down the costs in cost groups/cost items/cost factors; clearly define the scope of each of these, compare the results with other lists (from current studies), and prepare a new "standardised" list;
- Compare/contrast/explain differences in results presented in various countries/projects, looking specifically to commercial nuclear facilities/projects in or related to the Co-operative Programme, separating reactors and fuel facilities in two groups;
- Prepare a questionnaire, and ask participating organisations to provide their relevant cost figures in the standardised list, producing a new inventory of cost estimates (at least six reprocessing plants and over a dozen reactors of various sizes and types, including commercially operated plants, are involved, and also other organisations have shown interest in a co-operation);
- Analyse and scrutinise the cost inventory in order to identify aspects of discrepancy and the reasons for these.

In its early meetings, the Task Group reviewed the list of cost items proposed by the former Task Group. Definitions (a library) at cost item and/or sub-item level were prepared, including a description of the technical activities considered in each cost item.

In a later phase, the list of cost items was adapted and was made completely similar to the list of cost items proposed by the IAEA Consultants Group on Decommissioning and Waste Management Costs (see next paragraph). As a result of the decision to start the co-ordinated action with EC, IAEA, and OECD/NEA, the Task Group also decided to adapt its schedule of work, waiting for preliminary approval on the list of cost items and cost item definitions within the international co-operation.

3.2 Activities carried out within the International Atomic Energy Agency

In its 1995-1996 programme, the IAEA initiated a technical document on cost of radioactive waste management and decommissioning.

The aim was to create a comprehensive list of cost groups, cost elements and cost factors (factors that influence costs) related to waste management and decommissioning from a waste generator/owner point of view.

It was thought beneficial to establish a "standard" glossary, providing definitions of technical and cost terms and cost items. It was expected that such a list would facilitate communication, and possibly, encourage common usage among Member States.

A Consultants Group agreed on the definitions of "cost group", "group of tasks", "cost element", "cost factor", and "cost breakdown units" as "labour cost", "plant & capital equipment" and "expenses". In addition, a list of cost groups and cost items (defined by activities/steps) has been defined for both radioactive waste management and decommissioning, being very similar to the list prepared by the Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme[2].

The following activities were planned:

- To prepare definitions of the technical cost groups, cost elements, and cost factors;
- To prepare a questionnaire, send it out to volunteer organisations from Member States, review responses, review and analyse data for consistency and determine if additional clarification is required;
- To edit a technical document, including an introduction, analysis of collected data, and case studies.

3.3 Activities carried out within the European Commission

In its 1994-1998 specific programme on Nuclear Fission Safety (section C.4, "Decommissioning of Nuclear Installations"), the European Commission continued the setting up of decommissioning databases, as well as research and development in the field of the dismantling of nuclear installations, particularly relating to issues of environmentally compatible conditioning of radioactive dismantling wastes, the minimisation of radiological impact and the reduction of costs, e.g., by the application of innovative techniques[3, 4].

Objectives of the programme were to develop relevant methodology, to collect, analyse and qualify relevant decommissioning data, to identify, test and evaluate decommissioning strategic planning tools, and to stimulate the exchange of experience from the decommissioning of nuclear installations.

The existing EC DB COST database (costs, occupational doses, waste arising from decommissioning), set up with the co-operation of various partners within the European Union, was improved in an Oracle 7 environment, allowing "Windows" like concepts, which are easier to apply by common PC-users.

3.4 Initiation of the co-ordinated action to develop standardised decommissioning cost items

Based on the concurrent activities mentioned in the foregoing sections, a co-ordinated action was started with the three organisations (EC, IAEA, OECD/NEA) to develop a standardised list of decommissioning cost items.

At a meeting in October, 1995, the Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme fully supported the idea, considering that they had already adapted their own list to make it completely similar to the list of cost items proposed by the IAEA Consultants Group on Decommissioning and Waste Management Costs.

The results of the discussions within the Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme were communicated to the technical secretary of the IAEA Consultants Group on Decommissioning and Waste Management Costs, and the proposal to develop a common standardised (uniform) list of decommissioning cost items was presented. The technical secretary considered that this proposal could be a unique contribution to have IAEA Member States talking the same language, also in discussing decommissioning cost items.

The European Commission, Directorate-General "Science, Research and Development" also fully supported the idea.

In a letter of intent exchanged between the EC, the IAEA and the OECD/NEA, the organisations agreed on setting up a common list of cost items for decommissioning operations. Because the work done by the OECD/NEA Co-operative Programme, Task Group on Decommissioning Costs had advanced very well in this area and was, as to the structure, very close to the work done in the IAEA Consultants Group on Decommissioning and Waste Management Costs, the work of the OECD/NEA Co-operative Programme, Task Group on Decommissioning Costs was used as the basis for further discussions.

It was agreed that the three organisations had very similar objectives with respect to cost items for decommissioning operations, i.e.:

- To facilitate communication;
- To promote uniformity;
- To encourage common usage;
- To avoid inconsistency or contradiction of results/conclusions of cost evaluations;
- To be of interest to all decommissioners.
- General principles on co-operation were developed, to be carried out on two levels:
- A technical level, including the work carried out by experts in working sessions;
- A higher level, including follow-up of the co-ordinated action which should be done in a project committee; the director level of the three organisations could join the working party at topical meetings.

The contribution of the European Commission could be incorporated within the EC 1994-1998 Nuclear Fission Safety Programme. As per EC formalities, the IAEA as well as the OECD/NEA would be listed as associated partners, having no financial support from the EC, and being in charge of their own technical secretaries and experts.

A common final document, including the standardised list of cost items and cost item definitions, should be published.

The representatives also agreed that co-operation could be concluded by organising a common seminar or workshop, where the results of the work could be presented, discussed and demonstrated.

A detailed review of a working document was made, including proposed objectives, work content, project milestones and deliverables, benefits, economic and social impacts, project management structure and partnership. After evaluation, the representatives of the three organisations agreed on the contents of the work programme, and appointed Mr. L. Teunckens from Belgoprocess (Belgium) as the project co-ordinator.

It was concluded that the co-ordinated action to produce a standardised listing of cost items for decommissioning projects with related cost item definitions could start officially on January 1, 1997.

4 Development of a Standardised List of Decommissioning Cost Items and Their Definitions

Achieving the objectives of the co-ordinated action required identification, definition, harmonisation and verification of the general and specific activities carried out during the decommissioning of nuclear facilities, as well as their relating cost items, for inclusion in a standardised list of cost items for decommissioning projects. The tasks were subdivided into seven areas:

- Identification of decommissioning activities and related cost items,
- Harmonisation of decommissioning cost items,
- Grouping of decommissioning cost items,
- Identification of definitions of decommissioning cost items,
- Harmonisation of decommissioning cost item definitions,
- Identification, definition and harmonisation of cost categories for decommissioning activities,
- Final report on the standard structure and the list of decommissioning cost items.

4.1 Identification of decommissioning activities and related cost items

The general and specific decommissioning activities and relating cost items considered in the evaluations or specific projects carried out by the individual participating organisations were identified and listed.

The Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme on the Decommissioning of Nuclear Facilities provided its list of cost items for decommissioning projects.

Similarly, the International Atomic Energy Agency provided the list of cost groups and cost elements for radioactive waste management and decommissioning defined at the IAEA consultants meeting of June 1995 in Vienna. When considering the structure, this list proved to be very similar to the list prepared by the Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme. It was assumed, therefore, that this list could be used as the basis for further discussions.

Preliminary comments on the list of cost items from the OECD/NEA Task Group on Decommissioning Costs and the IAEA Consultants Group were obtained from the European Commission with reference to the database on decommissioning costs (EC DB COST), as well as two documents giving a description of the structure of EC DB COST.

The provided information was the basis on which to prepare a standardised list of cost items, cost groups and cost item definitions for decommissioning activities.

4.2 Harmonisation of decommissioning cost items

The information received on decommissioning cost items and considered by the three organisations had to be incorporated into one single and uniform list. Specific meetings were organised, and extended information was exchanged by letter in order to discuss this list with representatives of the three organisations with a view to achieving harmonisation and completeness. After discussion, it was considered that the resulting list was a good basis for a single, uniform and agreed reference list of decommissioning cost items for which specific definitions had to be prepared.

4.3 Grouping of decommissioning cost items

After harmonisation of the information received about decommissioning cost items discussed in the individual organisations, an overall concept was provided to concentrate the decommissioning cost items of the reference list into groups.

The concept is based on the approaches adopted within the OECD/NEA Task Group on Decommissioning Costs and the IAEA Consultants Group, in which cost items are grouped that are related to activities that are carried out with a similar emphasis, whether or not tied to a similar time schedule for decommissioning, or that are based on overall activities that cannot be categorised in a specific time period.

It is considered that these principles are not in contradiction to the approach adopted in the EC DB COST, in which a number of work packages are defined with a description of decommissioning tasks and related costs. A work package is considered to be a coherent set of selected decommissioning activities or tasks carried out as a part of a decommissioning project or as a decommissioning project itself. It seemed easy to bring the EC DB COST in line with the requirements discussed in order to achieve internationally harmonised cost items.

Based on these considerations, eleven cost groups were identified:

- Pre-decommissioning actions,
- Facility shutdown activities,
- Procurement of general equipment and material,
- Dismantling activities,
- Waste treatment and disposal,
- Security, surveillance and maintenance,
- Site clean-up and landscaping,
- Project management, engineering and site support,
- Research and development,
- Fuel,
- Other costs.

This list of cost groups was discussed and adopted by the representatives of the three co-operating organisations.

4.4 Identification of definitions of decommissioning cost items

As a next step, the identification and listing of the definitions of the general and specific decommissioning activities and relating cost items considered in the evaluations or specific projects carried out by the individual participating organisations was started.

The Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme on the Decommissioning of Nuclear Facilities, provided definitions for the decommissioning activities considered in their evaluations. These definitions were elaborated at cost item and/or sub-item level.

Together with the list of cost groups, cost elements and cost factors for radioactive waste management and decommissioning defined at the IAEA consultants meeting in June, 1995 in Vienna, the IAEA also provided a publication entitled "IAEA Waste Management Glossary", as well as glossaries in Safety Series No. 111-F, "The Principles of Radioactive Waste Management", and No. 111-S-1, "Establishing a National System for Radioactive Waste Management", in order to be used when preparing a draft of decommissioning cost item definitions based on the proposed standard terminology.

Similarly, the EC provided an overview of the working groups (elements of cost item definitions) and related work packages (cost items) considered in the EC DB COST, as well as a description of its structure.

As this was the main information existing within the three co-operating organisations, it was considered the basis for developing the definitions for the proposed single and standardised list of cost items for decommissioning operations.

4.5 Harmonisation of decommissioning cost item definitions

The information received from the individual organisations was evaluated, compared and compiled into one document in order to present a draft for a single and standardised list of cost items, cost groups and cost item definitions.

It should be re-emphasised that, as indicated in Section 4.3, the concept is based on the approaches adopted within the OECD/NEA Task Group on Decommissioning Costs and the IAEA Consultants Group, and that the principles are not in contradiction to the approach adopted in the EC DB COST.

As a result, definitions for the cost items in the standardised list were prepared considering that:

- Decommissioning activities include an inventory of a coherent set of tasks, that cover the specific aspects that may have to be dealt with during the decommissioning of a nuclear facility, whether or not a specific task will be executed in a specific decommissioning project;

- Processes or work packages comprise a selection of a coherent set of decommissioning activities or tasks that must be carried out as a part of a decommissioning project or as a decommissioning project itself;
- A global decommissioning project with a specific cost comprises a selection of processes or work packages, being as such a collection of dedicated decommissioning activities grouped in specific processes/work packages, that may be universally and independently selected from the standardised list of decommissioning cost items based on the specific application defined in the project itself.

A fair agreement was obtained with the OECD/NEA Co-operative Programme on the Decommissioning of Nuclear Facilities. Written comments were also received from representatives of the OECD/NDC, as well as from the IAEA.

To fit EC DB COST, subdivision of cost item definitions into sub-items in order to allow specific identification and comparison of the available information was required. Also additional considerations were received from the EC DB COST group.

Based on the comments and the additional considerations received, a new version of the proposed standardised list of decommissioning cost items and related cost item definitions was prepared, including the comments and considerations received, except for the ones not in harmony with the general concepts described in the foregoing sections of this document.

4.6 Identification, definition and harmonisation of cost categories for decommissioning activities

In the evaluations or specific projects carried out by the individual participating organisations, the costs resources for the general and specific decommissioning activities and relating cost items are mostly divided into cost categories. A cost category specifies the nature of the cost (e.g., depreciation costs, salary costs, building rent, etc.), and related cost categories may be grouped. The identification and listing of these cost categories and their specific definitions was also completed.

The Task Group on Decommissioning Costs of the OECD/NEA Co-operative Programme on the Decommissioning of Nuclear Facilities provided its list of cost categories compiled into groups as well as definitions for the cost categories or groups involved.

Similarly, the International Atomic Energy Agency provided the list of cost categories and the definitions related to radioactive waste management and decommissioning proposed at the IAEA consultants meeting of June, 1995 in Vienna.

As mentioned before, also a description of the structure of the EC DB COST and an overview of the work packages (cost items) and working groups (a kind of cost item definition) considered in the EC DB COST were received.

The information received was compared and compiled into one list, presenting a draft for a single and a standardised list of cost categories and related definitions, similarly to what was done for the decommissioning cost item definitions.

4.7 Report on proposed standard list of decommissioning cost items

It is intended to produce a document describing the history, the scope, and the implementation of the co-ordinated action to develop a standardised list of decommissioning cost items and cost groups, including their respective definitions.

It should be a comprehensive document trying to give a first answer to the detailed comments, questions and remarks received during the last few years, and containing underlying principles reviewed for consistency by the participating organisations.

5. Conclusions

The European Commission (EC), the International Atomic Energy Agency (IAEA), and the OECD/Nuclear Energy Agency (NEA) have ongoing activities addressing various aspects of decommissioning and decommissioning costs. Based on these concurrent activities and common objectives, and acknowledging the advantages of standardised cost item definitions, the three organisations agreed to carry out a co-ordinated action to establish a standardised list of cost items and related definitions for decommissioning projects. Such a standardised list should mainly facilitate communication, promote uniformity, and avoid inconsistency or contradiction of results or conclusions of cost evaluations for decommissioning projects.

The co-ordinated action required identification, definition, harmonisation and verification of general and specific decommissioning activities and relating cost items.

Lists of decommissioning cost items and related definitions were received from each partner in the project, and their harmonisation was carried out taking into account the underlying principles of the different organisations.

During the entire co-ordinated action, good progress was made in all tasks defined, thanks to the effective support the co-ordinated action received from the three organisations, and in particular thanks to the high effectiveness of the project co-ordinator (Belgoprocess). Links have been forged with other relevant projects and with other organisations that are interested to contribute to the general objectives of the programme.

During the co-ordinated action, the initiative also obtained a growing interest from a lot of other organisations/companies involved in decommissioning all over the world.

It is agreed to publish an interim technical document containing the standardised list of cost items and their definitions in the first half of 1999. Although it is hoped that the standardised list will be widely accepted and used, it is recognised that at this stage the list has achieved approval in theory only and should be further evaluated in practice. It is therefore proposed that this list is viewed as an interim version, to be broadly distributed, discussed and used, and to be finalised, most effectively in a work shop format, after approximately three years. At that point, a more definitive and more broadly tested and supported list will be issued as a report.

6. References

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[3] EUROPEAN COUNCIL DECISION 94/268/EURATOM of April 1994, Official Journal No. 115 of May 6, 1994.

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THE REGULATOR'S VIEWPOINT: WHO REGULATES, WHAT ROLES, WHAT MECHANISMS

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Ladies and Gentlemen,

My given topic seems at first sight to be rather straightforward and simple to deal with. However, I must confess that more than ten years' experience has brought new shades of grey into an area which at the time seemed almost black and white.

I would first like to deal with nuclear waste management programs, the licensing of these programs and the authorities.

For any observer it strikes as extremely natural and self-evident that you cannot just stipulate that a nuclear producer is responsible for the necessary nuclear waste management and that's it.

One way or the other you have to connect the authorities to that process. And usually they are the very same authorities who are responsible for nuclear safety and who else would they be.

I think, overall, you can find a whole range of control and supervision systems, depending on the degree of public involvement in the nuclear waste programs. It is rather natural that, as the means available to the public authorities develop, they tend to dwell deeper and deeper into the programs, even if they are still formally run by the nuclear producers.

This development means that a core expertise of these authorities is nuclear waste management, which also means that these should be the only people outside the producers themselves to be able to calculate and assess the cost of the measures, whether those of the past or the future. If you let these people to do the licensing and regulating as well, then you have a wholesome package in the right hands, I think.

And then comes the question of how to provide in advance for the financing of these nuclear waste management programs – a system that is. Such a system could, in principle, be an internal or external one. An internal system in its purest form would be to regulate that the nuclear producer should set aside money in its balance sheets for the purpose of nuclear waste management. The next step, perhaps, would be to enhance the system by requiring securities that correspond to the primary obligation.

Thinking one step further, you might come up with the notion that, firstly, you cannot trust the nuclear producer to live up to its obligations under all commercial and technical circumstances and, secondly, how does all this look from the perspective of the public who, as the case may be, eye nuclear power production suspiciously.

Then you have the external option in mind. The people in the Ministry of Finance would naturally suggest a solution where a special tax should be introduced or rather a special charge if that sounds better. Whatever the name the yield would flow directly to the state budget and yes, when in the distant future that money would be needed, it's available in the same coffers. At this stage it is quite natural for the producer to say that such a system is all right as long as the state would assume responsibility for the future cost of nuclear waste management.

If, however, this is not desirable, the next idea should be to turn to an external fund which is not based on direct State financing.

There is again a host of various options available.

If the ultimate goal of the funding system would just be a high profit, you could, for example, appoint a private financial institution to manage such a fund. This could be a bank, an insurance company, an investment fund or what-have-you. This could be a simple and easy way out of the problem. It has, however, its drawbacks. For example, you may want some public participation in managing the fund; there is always a risk of mismanagement of the funds and the usual commercial risks. Furthermore, the cost of such management could be high. And finally, that money would not be available at all for the nuclear producer itself.

It could also turn out that the nuclear producer thinks that he could use the funds in a sufficiently efficient way in his own business. In that case it is conceivable that at least part of the funds can be re-appointed to the use of such producer, with the necessary securities furnished to the actual body responsible for the Fund.

This is where the above-mentioned thought-process led to in Finland. After reaching this conclusion, one of the main problems was to decide what kind of body was needed to manage the funds. Consequently, it was decided that a public body would be sufficient in managing the funds taking into account that a major share of the funds (75%) would be lent back to the Finnish producers on a fixed administrative interest.

After further consideration it was decided that such a body would have to be separate from the regulating and licensing authorities whose task would have to be to assess the amount of money needed at any given time. It is also my impression that it was deemed absolutely necessary to keep these two functions independent of each other so as not to raise doubts of a single body managing and investing the funds and simultaneously deciding upon the need for further obligations by the producers. At the same time, one wanted to keep these two functions sufficiently close to each other to guarantee exchange of information, compatibility of future planning, budget forecasts etc.

Because any direct dependence on the state budget was to be avoided and the Ministry of Trade and Industry was the seat of the licensing and regulating authority, it was decided to create a new legal person (The State Nuclear Waste Management Fund) adjacent to the Ministry and subject to its control and supervision. The added advantage would of course be the savings accumulated by using the existing resources in personnel and facilities.

The Roles in the Finnish System

The Fund shall collect, hold and invest in a secure way the funds needed for future management of nuclear waste. In spite of this the nuclear power producers are responsible for all nuclear waste management and all its costs until the waste is in a final repository on a permanent basis.

At the outset it was determined that to pay for the costs of the actual nuclear waste management measures out of the Fund would be too cumbersome and complicated. Therefore it was decided to keep the Fund as high as required in case the nuclear producers were to omit their obligations, so as to be able to finance these measures if need be. Therefore the Finnish Fund essentially works as a security for the society.

It is the duty of the Ministry to check the status of each producer's nuclear waste management program thoroughly at least once a year in order to determine which parts and actual measures are left for the future. An essential part of the check-up is to evaluate the total costs of these measures at that date. The result of this process is a resolution of the Ministry whereby the yearly Fund Target for any individual producer is determined. After this it is the duty of the Fund to calculate whether the relevant Fund Holding (past contributions with accumulated share of the profits) is adequate to meet the Fund Target. If not adequate, the producer shall have to pay a Fund Contribution. In case of a surplus, the producer is entitled to be refunded.

This system may appear as elaborate, but it does away with the need to speculate with long – term cost and value of money fluctuation and a system of discounting. It also calls for continuous surveillance of technical progress and price development by the relevant authorities.

The question also arises how to deal with large, one-time investments such as decommissioning the nuclear power plant itself, construction of the final repository and other large facilities. You may then choose to take that money into the fund at one stroke and let the company solve the problem of dividing this burden between their past, present and future clients. Another solution would be to gather the money in step with the operational lifetime of the power plant. In that case you have to obtain some guarantee for the society for the share that remains unfunded. In Finland, the main reason for choosing this alternative was the aim to distribute these costs evenly to all the power plant's customers.

In order to achieve this, a calculation scheme was designed, where the lifetime energy production of nuclear power plant was taken as a reference for accumulation of funds. To be on the safe side, 25 years was chosen as the theoretical operational lifetime in this calculation. As a basis for the accumulation rate, the load factor was set at 75%. Consequently, an average load factor higher than that will lead to a respectively faster accumulation of money in the Fund. The unfunded share, diminishing at a respectively faster rate, must be covered by supplying the Ministry of Trade and Industry securities.

In Finland, contrary to some other countries, every possible stage of nuclear waste management and all kinds of nuclear waste are covered by this funding system, though it is clear that for instance the day-to day operations concerning low and medium level waste play only a minor role in the system in terms of money. I would like to mention that future costs of the relevant government bodies for their work in supervising and controlling the nuclear waste management programmes are also included in the system.

In determining the role of the nuclear producers the question also was raised whether the producers should have a role in managing the funds to be gathered. The answer was to give them the right to borrow at most 75% of their current fund holding and for good balance make the producers themselves responsible to compensate for any loss of the Fund. As part of this political compromise, it was decided that the Finnish State would have the right to borrow the remaining 25% of the fund holdings. The same interest-rate applies to both types of loans. At present the interest-rate is roughly EURIBOR-12 months.

I would like to conclude by saying that the system adopted in Finland has worked remarkably well and there doesn't seem to be pressure anywhere toward any fundamental changes. The system is cost efficient, dependable and not too cumbersome as soon as the routines are established. At present the Fund covers 85% of the total future cost of nuclear waste management and we look forward to reaching 100% in a few years' time.

SESSION 6

HUMAN FACTORS AND ORGANISATIONAL ISSUES

FINDINGS OF THE CSNI WORKSHOP

Nuclear Power Plant Transition from Operation into Decommissioning: Human Factors and Organisational Considerations

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Background

The Senior Expert Group of the Committee on the Safety of Nuclear Installations (CSNI) proposed work on the human factors (HF) aspects of the transition from operation into decommissioning. A meeting in Sweden was held to define the agenda. A workshop was proposed to Principal Working Group 1 (PWG1) of CSNI. The timing was very appropriate since the workshop could be held in conjunction with the Joint NEA/IAEA/EC workshop on The Regulatory Aspects of Decommissioning.

A workshop on these issues was proposed because organisational aspects are fundamental to any successful decommissioning process. Organisations must provide support for the management of change during the transition from operations to decommissioning. In addition, they must assure that resource and competence needs are appropriately specified, that uncertainty is minimised and staff morale is maintained. Furthermore, many new technical challenges must be met. The organisation often has to address all these challenges with little guidance or experience and with reduced resources.

Below is a summary of the presentation made at the Joint NEA/IAEA/EC workshop on The Regulatory Aspects of Decommissioning which describes the workshop on human factors and organisational considerations. The organising committee is currently preparing a report on the outcomes of the workshop for CSNI/PWG1.

The aim of the workshop was to identify and discuss issues related to the impact of organisational aspects on decommissioning. Professionals from regulatory agencies, utilities, and research organisations from 11 countries participated; a total of 23 people attended the workshop. The workshop began with the presentation of papers and then moved into genuine workshop sessions in which small groups of participants "brainstormed" concerns and presented them to the entire workshop group. The organising committee distilled these concerns into eight key issues. Finally, the small groups explored these eight key issues in detail and presented the results of their discussions to the entire group. The key issues were:

1. The impact of delaying dismantling of decommissioned nuclear power plants;
2. The use and control of contractors during decommissioning and dismantling of nuclear power plants;
3. Sustaining safety culture and morale during the transition from operation into decommissioning;
4. Identifying key organisational functions and management skills that are critical during the transition;
5. Reconciling regulatory and government policies and demands regarding decommissioning;

6. Sustaining organisational memory and obtaining and retaining staff competence during decommissioning;
7. Decommissioning multi-unit sites when one unit continues to operate;
8. Developing an experience feedback system on organisational and human factor aspects of decommissioning.

Findings and Outputs

The feedback from the workshop participants was positive regarding the value of the workshop papers and discussions as well as for the need for more work on organisational and human factor issues during decommissioning. It was recognised that organisational demands during decommissioning differ from the organisational demands during operations. Several areas were identified for further consideration. Selected findings are presented here. Additional findings and more detailed discussion will be included in the report to CSNI/PWG1.

Key findings

Significant variation across plants, utilities, and regulators

There is significant variation in the reasons for final shutdown across plants and this variation has a significant impact on the organisational and human factor issues that arise during decommissioning for both utilities and regulators. Some utilities may not be ready to implement decommissioning activities under certain circumstances, such as a rapid, unexpected decision for "premature" shutdown. Similarly, some regulators may not be well prepared to regulate and provide oversight of the decommissioning process because of limited prior experience with this issue. This variation has an impact on the organisational and human factor issues, which need to be addressed during planning for and carrying out decommissioning. Early planning is critical.

The risk profile changes

The risk profile of the plant changes when moving from operations to decommissioning: from high hazard with low probability to lower hazard with higher probability. The protection to avoid irradiation and contamination of workers is also a greater risk during some phases of decommissioning than during normal operations. In addition, the risk perception of the workforce-- including management, workers, and contractors--may underestimate or be unaware of some hazards because of assumptions of minimal risk at shut down plants and limited experience with decommissioning activities.

Capturing and retaining competence

The capture and retention of competence which may be needed during the decommissioning process is critical. An analysis of decommissioning tasks in order to identify competence needs is an important first step. The retention of key personnel in order to assure both the availability of skill competence and plant-specific knowledge is necessary. Strategies to assure this retention need to be developed and implemented early. In addition, project management skills are in high demand during decommissioning. Retaining critical staff over the extended period of the full decommissioning process is a particularly difficult problem.

Obtaining information on organisational aspects of decommissioning experience

Gathering decommissioning experience is very important but may be difficult because there are few incentives for utilities to share experience. For example, those gaining the experience are leaving the industry and contractors performing decommissioning may consider their experience “proprietary”. In addition, there is less experience than during operations - each activity is done only once or a few times at each plant. International links are needed to assure that both good practices and problems are shared. Programs for sharing experience have thus far mainly focused on technical methods and issues during decommissioning. An emphasis on organisational and human factors aspects is also needed for a full understanding of issues and strategies for successful decommissioning, which manages safely the transition period, minimises irradiation and contamination of workers, and respects the work storage and transport rules. This type of experience feedback is important so that lessons learned can improve the process of decommissioning in the future.

Regulatory Oversight

Regulator and government oversight of decommissioning needs a clear and consistent regulatory strategy. A number of agencies – such as environmental, health, safety (radiological and industrial) and transportation - have oversight responsibilities for different aspects of decommissioning. It is important to have a clear policy prioritising safety and environmental goals.

Contractors

The extensive use of contractors creates significant issues during decommissioning. An increased reliance on contractors, and, in particular, contractors without nuclear experience, is common during decommissioning. While the nuclear safety responsibility remains with the licensee, with fewer personnel, the licensee may have difficulty maintaining oversight of and expertise to assess contractor performance. The licensee needs to retain:

- an “intelligent customer” capability (i.e. the internal capacity to identify problems and the need for work, and to evaluate the contractor’s abilities and quality of work)
- sufficient control and supervision of contractors.

Contractors need to be integrated into the licensee culture, especially a nuclear safety culture. Long-term partnering arrangements may be desirable. The ALARA practices have to be promoted to reduce contractors’ doses.

Safety culture and motivation

The perception of risk among the management and the staff may degrade. There is a period of increased uncertainty at the plants that can lead to poor management and low employee morale. There is an increased need for clear and open communication across all areas of the plant. Motivation is a key element for the management of change. The changed mission of the facility needs to be clarified, including new roles and responsibilities, and impacts on the job security of the workforce.

Organisational functions

While no specific organisational structure is necessarily "the best", it is important to have a dedicated decommissioning team that has sufficient resources and direct access to top management. The organisational structure needs to accommodate the use of contractors and recognise that new contractors, unfamiliar with the nuclear industry, may be used. There are significant changes in the demands on the organisation and the resources available to meet these demands. The organisation needs to continue to assure that it adequately provides resources to support functions such as quality assurance, training, and personnel acquisition and retention. Experience feedback is important for defining necessary functions.

The Way Forward

Given these findings the workshop participants and the committee agreed that it is important to continue to examine these issues. The first step will be to further analyse the workshop outputs and to prepare the report to CSNI/PWG1. In addition, recommendations will be given for further consideration.

SESSION 7

CONCLUSIONS AND CLOSURE

PANEL DISCUSSION: CONCLUSIONS AND CLOSURE

The last session of the workshop was a panel discussion on the most significant issues that had been raised. The members of the panel were:

- Yukka Laaksonen, STUK, Finland, (Workshop Chairman)
- Giuseppe Grossi, ANPA, Italy, (Workshop Co-Chairmen)
- Greta Dicus, NRC, United States
- Pedro Carboneras, ENRESA, Spain
- Luis Valencia, Forschungszentrum Karlsruhe GmbH, Germany

To begin the panel discussion, the Chairman presented draft summary points based on notes taken by Rapporteurs at each session. Each member of the panel was invited to comment on these summary points, as well as to note additional points not previously covered. The floor was then opened to questions and discussion.

The following is a summary, organised by session, of the discussions and conclusions resulting from this Panel Discussion. Summaries of sessions 1 and 2 are presented together.

Sessions 1: Setting the Scene,
Sessions 2: The Current Situation

Conclusions

- World statistics indicate a rapid increase in nuclear power plants undergoing decommissioning. Several plants are being decommissioned earlier than expected for economic or political reasons, but not because of safety concerns. An opposite trend to early decommissioning is life extension, which is being considered for a number of facilities.
- Decisions concerning decommissioning strategies – for example immediate versus deferred decommissioning, waste disposal options, recycling options, etc., – are influenced by numerous factors. The relative weights of these factors vary from country to country
- The level and type of regulation of decommissioning activities tends to vary from country to country. The degree to which it is necessary to have a consistent international approach to the regulation of decommissioning should be further explored.
- In some countries the strategy of recycling and reusing the materials from decommissioning is preferred for economic and sustainability reasons, while in others waste disposal and replacement with new raw materials is intended.

Discussion

Thus far, decisions to decommission nuclear power plants have been made mainly on economic and political grounds. Optimisation considerations include balancing the benefits of radioactive decay against the loss, with time, of “original” knowledge of the site. In some cases economic considerations may be overriding. One example is where a nuclear power plant is located at a multi-plant site. It may be more practical and economic to wait until all the units at a multi-plant site are ready for decommissioning. The availability of suitable disposal facilities is also an important factor influencing strategies for decommissioning.

In some countries it is philosophically and practically important to consider the recycling of material as part of the decommissioning strategy. However, it has been found in other countries that the savings through recycling or reuse of material coming from the decommissioning of a plant are very small when compared to the overall decommissioning costs. In these cases there is little incentive to recycle material and, taking account of possible public acceptance aspects, direct disposal is preferred.

In a regulatory sense, decommissioning is relatively new. Although some countries have had comprehensive decommissioning regulations in place for many years, this is the exception rather than the rule. For example, regulations regarding the clearance of materials from regulatory control, specifically as applied to materials from decommissioning, are under development in most European countries in order to comply with the latest EU directives. Rule making in this area is also currently in progress in the United States. Internationally, the IAEA, together with the NEA and several other international organisations, is developing guidance on exclusion, exemption and clearance. These efforts attest to the current relevance of these issues and the level of interest both nationally and internationally, by regulators, waste handling organisations and operators alike. While it is clear that international harmonisation is necessary in areas such as exemption levels, it is not clear to what degree it is necessary to have such international harmonisation in other regulatory areas, such as the licensing process, or criteria/approach for the approval of submitted decommissioning strategies.

Session 3a: Management of Radioactive Waste from Decommissioning

Conclusions

- Strategies for the management of radioactive wastes from decommissioning vary significantly from country to country, and are influenced by the availability of interim and final storage facilities.
- The time schedules and costs of decommissioning are strongly affected by the availability of waste disposal routes and/or storage facilities.
- The radiological criteria for the release of materials from regulatory control have a major impact on waste management plans and their costs.

Discussion

Decommissioning and waste management are closely linked. Waste management aspects must be considered during the planning and performance of decommissioning activities. A close co-ordination between decommissioners, waste management organisations and regulators is highly desirable.

Radioactive waste volume reduction, in this context largely meaning avoiding the mixing of clean and contaminated waste streams, should always be considered during the decommissioning process. Direct disposal of waste is very expensive in most countries. A balance between spending on volume reduction and on direct disposal must be sought.

Session 3b: Exemption, Clearance and Authorised Release

Conclusions

- It is generally recognised that international consensus is needed on the radiological criteria for releasing materials from decommissioning from regulatory control.
- Further guidance is needed on the interpretation and application of the concepts of exemption, clearance, and authorised release. Besides guidance on risk and dose levels, internationally accepted practical numerical values are needed for the nuclide-specific activity concentrations derived from the dose criteria. The technical means for verifying compliance with the criteria need to be further developed.
- Lacking clear international consensus, decisions to release materials for unrestricted use in some countries have been made individually, based on the regulatory analysis of submitted proposals. Decisions generally take international recommendations into account (particularly the individual dose criterion of 10 µSv/year).
- An appropriate international regulatory approach is needed for controlling exposures to Naturally Occurring Radioactive Material (NORM). The approach adopted must be coherent, in terms of its risk basis, with that being adopted for man-made nuclides originating from the nuclear industry.
- The practice of recycling metal scrap from the nuclear industry may not be acceptable to all concerned parties. Representatives of concerned groups – for example, the regulators, the recyclers, the steel industry and the public – should be more closely involved in the process of developing clearance standards. The problem of "orphan" sealed sources appearing in metal scrap is a separate issue from recycling and should be treated independently.

Discussion

There was broad agreement that international consensus is needed for the concepts of clearance, exemption and exclusion, as well as for certain aspects of their practical application. In particular, in order to release materials from regulatory control, dose criteria must be translated, through models, into allowed specific activities (Bq/g and/or Bq/cm^2) which can be assessed at the point of release. The models used to determine these clearance levels are thus very important and they should be developed in a transparent, internationally co-ordinated and accepted fashion.

In addition, practical guidance is necessary in terms of how large volumes of materials can be certified to meet clearance criteria. This includes a discussion of both the physical methods which are acceptable, and the regulatory process which is necessary.

Care is needed with the terms that are used when describing clearance levels. Very often, clearance levels are considered as "limits", when what is really meant is "reference value" or "level".

Since cleared materials are free to be transported internationally, the international guidance on clearance levels should be consistent with, and not restricted by, the international regulations for the transport of radioactive materials.

Representatives of the steel and aluminium producing industries have indicated their desire to have a 'clean product' and indicated their industry's sensitivity to any public perception that "contamination" with radioactive materials might have occurred.

The scrap metal industry considers the control of large radioactive sealed sources to be a serious problem. There may be cases where the portal monitors, at the entries of scrap yards, do not detect a source which is shielded by surrounding material. This could lead to the source being included in scrap processing, causing the contamination of large amounts of metal.

Session 4: Management of Site Decommissioning

Conclusions

- There is a need for effective (clear and realistic) regulations which facilitate, rather than hinder, the decommissioning process. This includes criteria for the release of sites and facilities from regulatory control which is not in contradiction to criteria for the release of materials.

- There is no consensus on the most appropriate type of legislation or regulations for decommissioning, that is, whether or not it should address the whole or only a part of the decommissioning process or whether it should be generic or site/facility specific.

- There must be a clear definition of when decommissioning begins and what is considered as the transition phase. No matter how the phases are defined, the licensing process must continue during all phases and responsibilities must be clearly defined.

- The need for keeping the memory of the facility history and radiological conditions is important for safe and cost effective decommissioning.

Discussion

Radiological criteria are needed for the release of sites and facilities from regulatory control. The criteria will likely differ from those used for the clearance of materials because the dose assessment scenarios and modelling require different considerations. In the case of the release of facilities, which would imply the release of materials from those facilities, criteria should be consistent with those for the release of materials for unrestricted use, and with transportation regulations for radioactive materials.

In order to demonstrate appropriately compliance with regulatory requirements a good site characterisation is needed, especially for sites where operations were terminated at some time in the past.

Technology is available for decommissioning nuclear facilities. Most improvements currently being made are based on reducing radiation dose to workers and reducing costs. There may be a need for having international meetings to facilitate the dissemination of information concerning these technologies.

Session 5: Liability and Financial Issues

Conclusions

- Factors that cause major differences in costs have been identified through international comparisons. The factors are real and depend on country/facility specific circumstances.

- A major step has been taken, by a joint task group (NEA, IAEA and EC), towards standardised cost calculations through the preparation of a draft guide. This guide presents a standard list of terminology, especially on cost items.

- The approach for financing decommissioning and other waste management activities is still undefined in many countries, while others have adequate arrangements in place. Issues to be considered include:
  - determining if the decommissioning fund should be controlled by an internal (power producer) or external (government, private financial institution) organisation;
  - preparing a schedule for accumulation of the funds;
  - choosing securities that correspond to the obligation;
  - specifying the characteristics for fund management (reasonable costs, healthy interest, high security).

Discussion

The total decommissioning cost is a moving target and must be re-evaluated periodically to ensure that proper funding is available when needed. In particular, the development of an internationally standardised costing system is seen as a very positive step, not only allowing costs to be compared in a valid way, but also providing decommissioning projects with a tool for use in retrospective, current account and prospective costing analyses.

Accurate costing is essential to ensure that appropriate funding is available for decommissioning, and that these funds are collected during the operating period of the plant. Although many questions remain open in the area of financing, it is clear that the strategy followed for decommissioning will have an influence on the collection and dispensing of these funds. For example, the timing of the dismantling work will influence not only when the funds should be available, but also how they should be invested in terms of liquidity. The financial security of such funds is also a consideration which might influence these issues, with investments at higher interest rates requiring less initial capital, but being generally less secure.

Session 6: Human Factors and Organisational Issues

Conclusions

- There must be a competent organisation available for all steps of decommissioning. Deferred dismantling may cause major problems if nuclear infrastructure is lost, especially in countries with small nuclear programmes.

- There is a need for a dedicated decommissioning group in the licensee's organisation. The change of the mission from operation to decommissioning must be well clarified. The project organisation must be goal orientated and focused on decommissioning rather than on the continuation of the operating organisation
- When contractors are used during the decommissioning activities the licensee should have sufficient competent personnel to understand, own and use the plant safety case, to act as an intelligent customer for work by contractors, ensure enough control and supervision and make informed judgements of contractor's work.
- Decommissioning experiences should be shared and this provides an important role for international organisations.

Discussion

This session focused on human-factors and safety considerations during the period from the time the decision to shut down has been taken, until the disposition of the plant's fuel has been finalised. This includes such issues as the morale of plant personnel and the loss of competence, particularly over what may be long periods of safe storage before final decommissioning for site free-release. A two-day workshop on this issue had been held immediately prior to the decommissioning workshop to discuss areas of concern and areas which merit further research. Its results were summarised by one paper during this session, which formed the basis for subsequent workshop discussions and conclusions.

The local community should be informed of the process and the status of the project. Other organisations that are interested in the decommissioning activities should also be kept informed.

The decommissioning team should be primarily composed of individuals who understand the concepts and principles of decommissioning. It was suggested that the team should be supplemented with a few (3–5) operational individuals who can provide facility history and system operating experience. If a team is composed of mainly operations personnel, they might tend to perform their duties following an operational way of thinking. This can be time consuming and very costly.

ANNEX 1

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5	Lamberto MATTEOCCI	Patrick VANKERCKHOVEN
6	Gabriele Del NERO	Patrick VANKERCKHOVEN
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ANNEX 3

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