RADIOLOGICAL PROTECTION DURING THE DISMANTLING OF NUCLEAR FACILITIES

Teresa Ortiz, Oscar González
ENRESA, Emilo Vargas, 7 28043 Madrid Spain

Abstract
ENRESA is the national company in charge of radioactive waste management in Spain. The company was set up in 1984, and one of its missions is the dismantling of nuclear facilities. ENRESA has carried out the dismantling of the Vandellós 1 nuclear power plant, several research installations and a pool type experimental reactor and is currently initiating the dismantling of the José Cabrera nuclear power plant, a pressurised water reactor facility.
From the point of view of radiological protection, the dismantling of a facility presents a series of characteristics that set it aside from normal operation, such as for example the continuous variation of the type and level of the radiological and conventional risks and the fact that activities are performed on equipment and systems that have not been acted on previously. In addition, certain of the protection systems are left out of service and have to be replaced with mobile systems. It is also important to point out that many of the workers participating in dismantling projects are not accustomed to this type of work and may even not have worked before with ionising radiations.
During dismantling there is also an increase in the risk of internal incorporation of alpha emitters, which are much more restrictive and difficult to determine than beta-gamma emitters, this implying the need to increase protective measures and to establish controls to determine as soon as possible whether any such incorporation has occurred.
This article describes the radiological protection programmes implemented by ENRESA for dismantling projects and the organisation and resources available for their performance. There is also an analysis of the ALARA techniques implemented to prevent the incorporation of alpha emitters and the dispersal of contamination, as well as of the incorporation controls established. Finally, the results obtained are analysed, in terms of dose.

Key Words: dismantling nuclear power plants, radiation protection, ALARA, internal contamination.

1. INTRODUCTION

The Spanish national radioactive waste management company "Empresa Nacional de Residuos Radiactivos" (ENRESA) has dismantled the Vandellós 1 Nuclear Power Plant and the experimental reactor and other research facilities at the Centre for Energy-Related, Environmental and Technological Research (CIEMAT) and is carrying out the dismantling of José Cabrera Nuclear Power Plant.

During dismantling work various radiological protection challenges arise; application of the ALARA principle is fundamental.

The basic philosophy of the ALARA criterion is summarised in the phrase "individual doses, the number of people exposed and the probability of the occurrence of potential exposures should be kept as low as is reasonably achievable, taking into account economic and social factors" detailed in Article 4 of the "Spanish Protection against Ionising Radiation Regulations".

Application of the ALARA principle in all ENRESA projects and activities that carry a risk of radiation exposure, whatever its magnitude, is implemented by means of a formal procedure established in the "Manual for applying the ALARA principal in ENRESA projects and activities".

Given the diversity of projects and activities in this document, general guidelines are established, leaving the detailed implementation for inclusion in the programmes and procedures of each. Specific dose reductions procedures are also developed for those activities that by their importance require it, this is the case of ENRESA installations both in operation and being decommissioned.

The application of this programme is carried out by introducing recommendations during the phase of drawing up of the documentation of interest, as well as through the performance of ALARA audits during the different activities and phases of the project.

The radiological criteria (collective dose, individual dose, dose rates and levels of surface and airborne contamination) for the detailed application of the ALARA methodology to a specific task are specified in the ALARA work control and management and dose reduction and minimisation procedures.
The organization used in ENRESA to implement the ALARA criterion is based on the requirements of the Spanish Regulatory Authority (CSN) and consists of the following structures.

ALARA Commission (Managerial level):
This is an advisory body consisting of the Directors related with the operation and dismantling of the installations, together with the Heads of Departments with ALARA programme projects, and the Radiation Protection Service (RPS) heads of ENRESA.
It carries out the following activities:
- Promotes the ALARA culture throughout the organisation;
- Approves or endorses ALARA policy and dose objectives;
- Provides the financial, technical and administrative resources necessary to develop this policy and achieve the objectives.

ALARA Committee (Executive level):
This is an executive body which is formed at installations as required. It consists of the Installation management and the heads of the relevant services.
It performs the following activities:
- Proposes ALARA policy and dose objectives;
- Is regularly informed about the ALARA practices, studies and Training Programmes established;
- Regularly reviews the results obtained and takes corrective action;
- Reports to the ALARA Committee;
- Coordinates the Installation’s Organization;
- Coordinates the actions of the various groups involved;
- Participates and attends at an executive level training;
- Is called upon to verify compliance with the provisions;
- Encourages the support and motivation of all staff for ALARA policy;
- Manages the human, economic, technical and administrative resources allocated for the development of ALARA policy;
- Provides at management level, information about the development of ALARA policy.

ALARA Groups (Technical level)
They are established for specific jobs by convening a meeting of its members.
They perform the following activities:
- Propose improvements to be implemented as part of the work;
- Report to management as required;
- Coordinate specific actions with the RPS, if required;
- Analyse specific activities and plan specific jobs;
- Monitor work and analyses results, and propose the necessary improvements;
- Prepare a summary of the activities analysed including the actions taken, results obtained and conclusions.

In addition to these levels, contractors and all workers are part of ALARA policy. External companies therefore have the following responsibilities and functions:
- To promote the ALARA culture in their Organisations;
- To support and participate in the installation’s ALARA programmes;
- To plan their activities in Radiological Zones;
- To contribute all the information necessary to properly plan the work from a radiological optimisation viewpoint, to the PS;
- To assist in implementing established improvement solutions;
- To develop specific ALARA studies as required;

- To propose in their bids, ALARA principle-compliant equipment, methods and procedures;
- To provide their workers with specific information and training;
- To actively participate in established ALARA Groups (if applicable);
- To take responsibility for the above in the case of subcontractors;
- To adapt to the provisions of the legislation in force (Royal Decree 413/1997).

For their part, workers are responsible for adopting the ALARA culture at the Installation, including:

- To accept the Installation’s ALARA policy;
- To work with all of their company’s organisations and those of the owner in all aspects developed as part of this programme;
- To maintain the general radiation protection rules and precautions to be taken during the normal course of their work and in case of accident;
- To follow specific instructions regarding working methods and personal protective equipment during the operations to be performed;
- To keep their own individual doses and those of others, as low as reasonably achievable;
- To participate in planning further work and its analysis;
- To contribute to improved implementation of their work providing the suggestions and ideas developed;
- Staff belonging to the organisation and external organisations will be responsible for taking part in ALARA audits.

2. APPLICATION OF THE ALARA PRINCIPLE DURING DISMANTLING OPERATIONS

Application of the ALARA principle during dismantling operations does not involve significant change with respect to its application at other nuclear installations in operation, although in practice many differences arise. Therefore the Radiation Protection and ALARA objectives, and the basic criteria and regulatory responsibilities are the same in both cases. However, differences arise in terms of documentation and regulatory requirements, with regard to adapting the organisation and in terms of the human and material resources and the mechanisms for coordination with the rest of the organization.

There are other conditions that influence the approach and methodology for applying the ALARA principle, such as the type of installation to be dismantled, the time elapsed from shut-down, the level of decommissioning to be achieved and the remaining monitoring and protection systems and their potential use in the project.

The first requirement is the adaptation of the organisation to the project objectives, and it is necessary to implement a matrix operational system between all the services and to increase the number and diversity of the organisations involved. In addition it must be taken into account that many of the organizations and workers involved may not be used to working in radiological scenarios. It is essential to require that contractors and the entire organization fulfil their part of the responsibility in implementing the ALARA principle, providing the support required to simplify methods of analysing and evaluating alternatives, and to prioritise optimisation criteria regarding strict compliance with initial dose objectives. It will also be necessary to adapt the training objectives and requirements on radiological protection for exposed workers involved in decommissioning.

In addition, during dismantling, the physical configuration of the installation is modified which involves the loss of structural confinements, modification or elimination of effluent processing systems, radiation monitoring and auxiliary resources, and modification to accesses and passageways and the emergence of new controlled areas.

Likewise the radiological status of the installation is changed continuously, increasing in general, the radiation risk by rupturing the confinement of uncharacterised systems. The radiological zone should also be widened to incorporate the routes used for the movement and storage of materials, often located in areas initially non-radiological. Moreover, as a result of the work itself, new radiological risks arise, which were not present during operation, one of the most significant being the risk of

exposure to alpha emitters, and these risks are associated with a variation in the chemical composition of the contaminants and an increase in the size range of the particles generated by the different working techniques.
When working with this risk, the particular individual perception of this risk and the need for very strict regulatory requirements must be taken into account, as incorporation of small amounts of these alpha emitters can result in significant assigned doses. In addition, the need to use complex personal and collective protective equipment impacts the external dose that may be received, by slowing down the work. In addition it is necessary to establish protocols for the individual monitoring of workers that includes initial and periodic analysis of faeces. The result is that one of the most important ALARA objectives with respect to dismantling is to ensure that there will be no incorporation of this type.
Other risk that can be relevant, in case of dismantling of light water reactors are the presence of hot particles (discrete radioactive particles). This risk is mainly due to the essential task of cutting highly activated metallic materials (reactor internals). This should be taken into account from the very design phase and consideration should be given to the need to develop programmes and procedures for the prevention, location, characterisation, control and elimination of the problem (specific portable detectors, integral checking gate monitors on two levels), as well as to dose calculation tools. In accordance with the international recommendations, the control programmes set up should be aimed at preventing equivalent organ dose limits from being exceeded (fundamentally the skin) and at preventing the appearance of deterministic effects such as inadvertent exposure to hot particles.

2.1. Dismantling of Vandellós 1 NPP

The Vandellós 1 nuclear power plant was definitively shut down in October 1989 after 17 years of service. Located in the province of Tarragona, the plant was a French design and was the only Spanish nuclear power plant to use natural uranium as fuel, graphite as the moderator and CO_2 as the coolant. In July 1990, the Ministry of Industry and Energy definitively suspended the plant's operating permit and commissioned ENRESA to undertake its dismantling. The dismantling plan designed by ENRESA was equivalent to Decommissioning Level 2 defined by the Atomic Energy Agency and has implied the release of 80% of the plant site. The work began in March 1998 and was completed in June 2003.
The application of the ALARA programme to the dismantling of Vandellós 1 Nuclear Power Plant was based on the organisational chart previously detailed. During the dismantling work it was taken into account that ALARA is not simply a technique but a way of working which has the ultimate objective to ensure that all reasonable steps have been taken to reduce doses, by adopting a systematic approach to problems, in order to properly identify all components. This systematic approach results in the following basic steps:

- Prior recognition that the ALARA study is necessary and a clear definition of its scope;
- Identification of the ALARA factors that must be considered; separation between quantifiable and unquantifiable, and their evaluation as possible and optimal options (solutions).
- Comparison and selection of quantifiable options such as the possible application of shielding, ventilation, filters, change areas, work area sizes, exposure times, movement routes for personnel and waste, estimated doses, contamination control systems, etc.
- Comparison and selection of non-quantifiable options such as analysis of the schedules provided; analysing the adequacy of radiation monitoring systems designed with the radiation intensities envisaged; evaluating the changes, taking into account their impact on security, shielding, barriers and ventilation already existing and maintenance of doses; examining and evaluating the controls planned to monitor the doses received by workers, etc.

The ALARA programme should commence by ensuring adequate preparation and planning of the work to be carried out in the Radiological Zones. Then, there must be a mechanism to monitor, from a radiation protection point of view, implementation of this work and to ensure that the results are evaluated. Similarly, there should be feedback from the ALARA programme, so that lessons learned are incorporated into working procedures in order to reduce doses during subsequent work.

After a request to carry out a task, the ALARA area of the RPS gathers the necessary information to define the RP controls needed which could be a radiation Work Permit (PTR - *Permiso de Trabajo con Radiaciones)* or the need for an ALARA study, based on associated radiological criteria, the type of work, execution time...

If an ALARA study is requested the executor must prepare and submit this study for acceptance and approval by the RPS before the start. The scope of this study is as follows:

- Initial objective and scope of the work;
- Breakdown of activities and their duration;
- Initial radiological conditions (data supplied by the RPS);
- Operational doses (collective) anticipated;
- ALARA improvement techniques, practices and methods to be implemented.

Based on this study the corresponding ALARA Group is formed which will be maintained for at least the launch meeting, one follow-up meeting and the closing meeting. Throughout the decommissioning 93 ALARA Group meetings have been held and 19 Committee meetings. Also there were a total of 30 ALARA studies covering 74% of the collective doses received during dismantling.

It should be noted that the most significant radiological risk during this dismantling was the presence of alpha emitters in different locations and systems. For this reason, protective measures were reinforced to the maximum to minimize it. For this purpose the following ALARA techniques were implemented:

- Confinement and ventilation through use of rigid containment structures ensuring a significant level of dynamic depression and ensuring air circulation from the less contaminated areas to those more heavily contaminated. The use of transparent materials for its construction facilitated the tasks of monitoring, controlling and communication between the interior and exterior of the structure;

Rigid confined enclosure (CIEMAT)

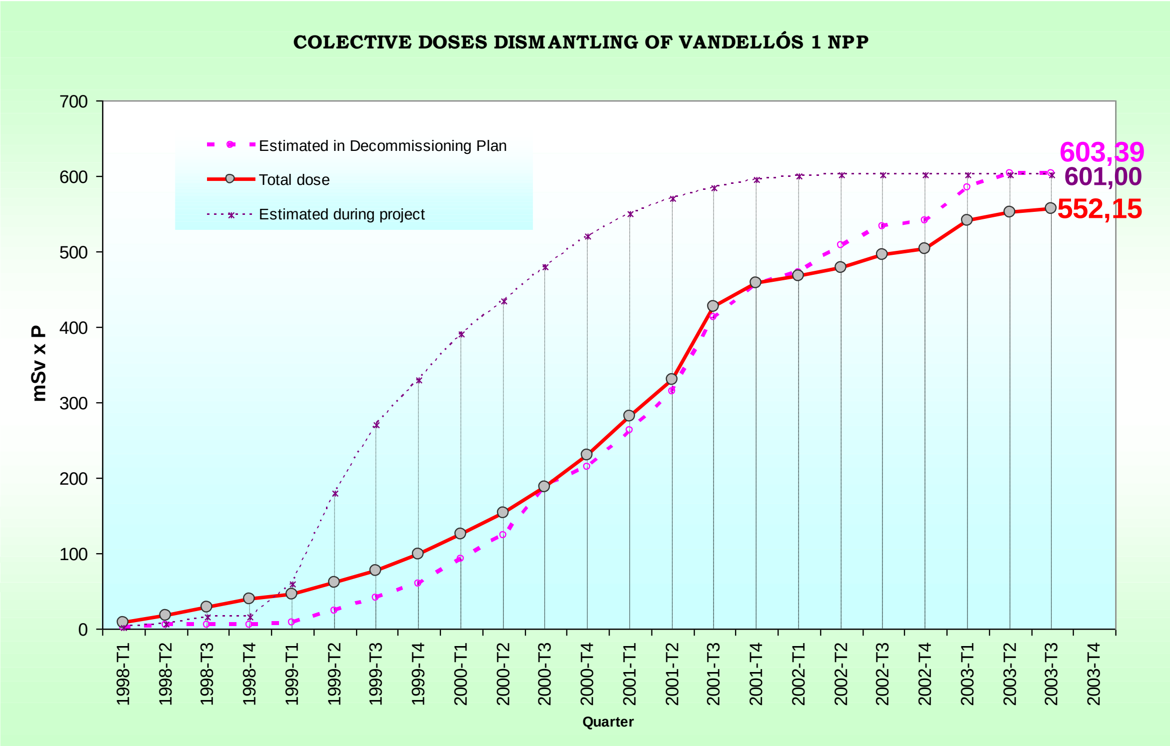
- Establishing, within the containment structure, areas adapted for loading, closing and removing waste containers and drums receiving the dismantling and secondary waste;
- Refurbishment of staff entrances and exits, with enough space to insert sequential dressing and undressing phases, with the corresponding scaling, facilitating activity in comfort and with sufficient safety. It has been shown that these are the phases with increased risk of internal contamination. In this sense it was considered imperative that individual discipline with regard to the undressing sequence was rigorous, and therefore particular attention was taken to ensure all participating employees were made aware.

Personnel exit. Previous shower and help in undressing (Vandellós 1)

- Introduction of improvements in work techniques that are likely to generate or increase the generation of surface and environmental contamination. Whereas the desirability of limiting the use of thermal rotary or thermal cutting equipment and methods was evaluated to reduce the risk of dispersion and re-suspension of contaminated aerosols, it was concluded that the use of other techniques slowed the work, with a corresponding increase in external doses, and so it was better to employ rapid methods, by trained personnel, using all appropriate protection and containment measures.
- Deployment of techniques for "in situ" leak-tight bagging of clogged filters from the portable ventilation systems, especially when used in areas with alpha contamination.
- Use of peelable paints to fix the surface contamination prior to work and to protect areas and already decontaminated.
- Use of special protective equipment to guarantee a sufficient degree of insulation in any conditions. This was semi-autonomous integrated equipment with an external air supply including mask with particle filter.
- Cold training in the use of special protective equipment and how best to undress.
- Implementation of individual monitoring protocols for exposed workers including conducting periodic analyses of faeces to evaluate the possible incorporation of alpha contaminants. These programmes were designed to establish the entry conditions for personnel (initial target) and the sampling frequencies and aims were adjusted depending on the type of work performed.
- Use of special surveillance techniques such as portable environmental pollution real-time measurement beacons, capable of alpha-beta-gamma detection, and remote control and display, in all dismantling areas susceptible to environmental pollution. The beacons were placed primarily in the areas of greatest risk of internal contamination such as transit areas, undressing areas and those used for disconnecting respiratory protective equipment within containment structures or outside them, equipped with an alarm capability in case of unexpected environmental pollution.

The application of all these measures has already resulted in a very favourable outcome in that they have doses through internal incorporation have only been assigned to 7 workers with doses well below the dose limits and with a collective dose of 24.21 mSv.p. In total, there were 771 controls on 289 workers corresponding to 61073 hxp for work with risk of internal contamination with alpha emitters.
Also the external collective dose was lower than expected as a result of the application of dose reduction techniques and the execution time. Figure 1 shows the collective dose trend and the actual doses are compared with those estimated during both the design and the actual decommissioning.

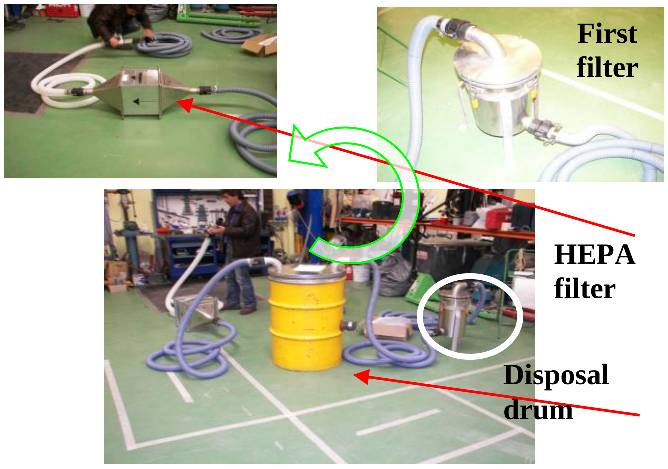
Figure 1



2.2. Dismantling of research installations

Several experimental facilities have been dismantled by ENRESA in CIEMAT, located in the University City in Madrid. These installations included: an experimental research reactor, type pool, of 3 thermal MW, stopped in 1984 and without nuclear fuel; a liquid low and intermediate radioactive waste conditioning plant; an experimental plant of spent nuclear fuel reprocessing, stopped in 1971; a medium and high activity radioactive liquid waste storage facility.
Implementation of the ALARA criterion and the established SPR organization has been the same as in the dismantling of Vandellós 1, applying the lessons learned of this project. In any case some this project had some special features such as the following: higher dose rate and alpha airborne contamination risk in the majority of the task; greater dispersion of contamination in the operational phase and in not known points; little information about the initial construction project and its subsequent amendments.
Also in this case the most significant radiological risk was the presence of alpha For this reason, protective measures were reinforced to the maximum to minimize it and the following ALARA techniques were improved:

– Use of special equipment for the removal and pre-conditioning of active liquids and the use of breathing equipment and systems for the filtering of contaminated dust, guaranteeing confinement of the particles and preventing subsequent risks of exposure to internal contamination.

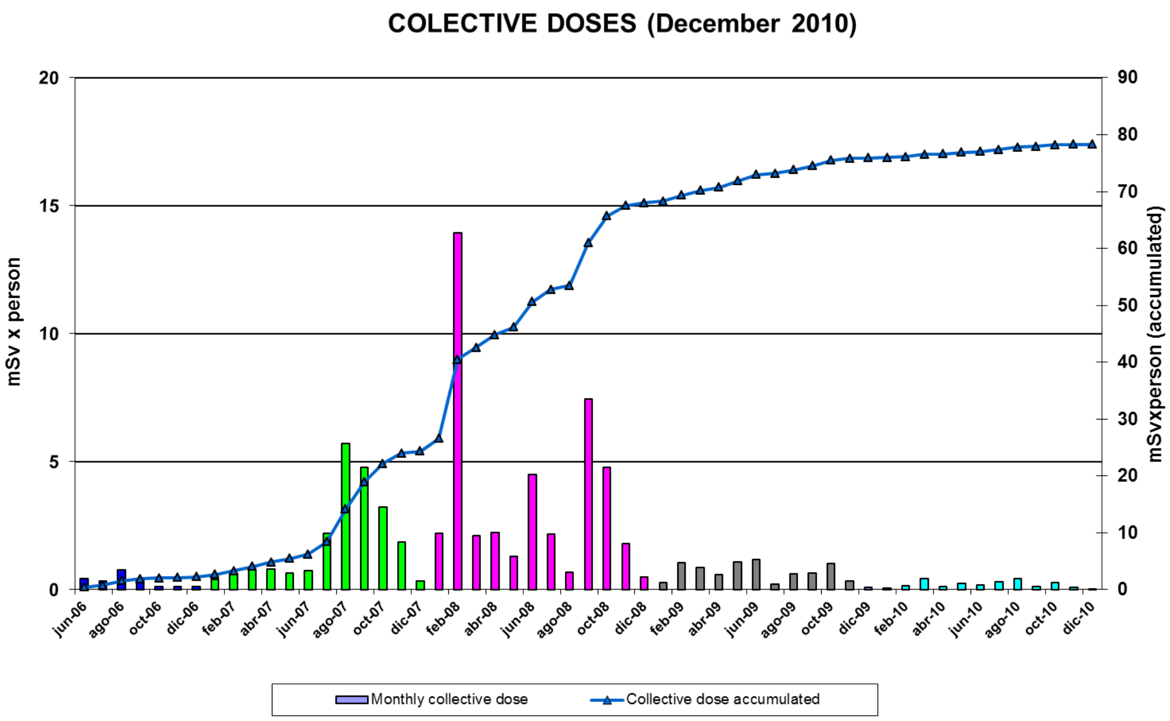


Confined system to removing active liquids

– Removal of liquids remaining in the bottom of tanks using venturi suction systems transferring the liquid and sludges directly to a confined drum, in which the air extracted passes through a HEPA filter before being vented, and the use of a similar system for the removal of highly contaminated dust, replacing the drum with a system equipped either with a sleeve filter or a cartridge filter in a plastic case (disposable without the need for handling) and a final HEPA stage, both easily disassembled and replaced, has proven to be much safer than the normal practice of using vacuum cleaners, the operation of which may pose considerable risks.

The results in terms of doses have been very favourable. The collective external doses (78 mSv.p) have been much lower than those estimated in the project. Internal doses have only been assigned to 1 worker with a dose of 1.71 mSv, well below the dose limits. In total, there were 165 controls on 107 workers. Figure 2 shows the monthly collective dose during the dismantling together the accumulated doses.

Figure 2



2.3. Dismantling of José Cabrera NPP

The nuclear power plant “Jose´Cabrera” is a first-generation Westinghouse PWR plant, which was in operation between 1970 and 1996. The decommissioning objective is Level 3, which means complete elimination of the installation and restoration of the site for other uses.
Once the plant had been shut-down and the fuel completely removed, the primary and recirculation system and the systems connected to it were chemically decontaminated (Nitrox-DfD). The result was acceptable in the recirculation system and deficient in other systems. In this condition the dismantling was undertaken, that, from the radiation protection point of view, has a number of specific characteristics resulting from several circumstances as is described below:

- **From the design:** It is a NPP whit an old structural design that provides few facilities to the radiological optimization of the decommissioning work:
  - Poor structural shielding;
  - Interior space for machinery, storage, stockpiling, confined enclosures, etc., very limited;
  - Containment with very restricted accessibility for equipment, machinery and people;
  - Fixed environmental radiological monitoring systems inadequate for decommissioning.

Racks removal (José Cabrera)

- **From the scope of the dismantling operations:** The decommissioning project, including segmentation of the major primary circuit components: vessel, recirculation piping, main pump, steam generator and pressurizer, which had to be segmented in-situ and fully packaged in the same place to be transport to the storage facility.
  The vessel internals and specific in-core instrumentation are special waste, not acceptable (because of activity levels) at the low and intermediate radioactive waste storage facility, and therefore it had to be packaged in special containers, similar to those used for spent fuel. This packaging requires mechanical segmentation, under water and must be of a size appropriate for the internals which mostly have very high levels of activation and, as result, of dose rates.
  The expected existence of localised areas in large reinforced concrete structures, internally contaminated by fluid penetration, requires the use of large-scale cutting and demolition techniques (diamond wire and saw, thermal lance, striking and cutting machines) the use of which must be compatible with the operation of controlled ventilation and the maintenance the environmental activity levels required.
- **From the regulatory requirements:** The need to comply with the norm ISO-17873 (2004), determined by the regulatory body, obliges the implementation of a series of extremely stringent requirements, both with regard to the design of fixed ventilation systems, portable ventilation and filtration units, and the depressions required in buildings, areas, and temporary confined enclosures.
  These represented a series of challenges and significant concerns for the practical implementation of Radiological Protection during this dismantling, including:

- Combining the use of high performance cutting and demolition methods (mechanical, thermal, abrasive, etc.) with comprehensive control of containment, handling, filtration and removal of any environmental contamination generated;
- Development and application of ALARA methods of analysis and evaluation of alternative ways of working in which it is necessary to compare radically limiting the risk resulting from environmental contamination by increasing external exposures, and vice versa;
- Choosing and configuring instrumentation for sampling, measurement and control of beta-alpha environmental contamination levels in real-time or delayed, so that they comply with the sensitivity levels specifically required for the project;
- Implementing operating procedures to prevent, detect and characterise the Hot Particles from activation which will be generated during segmentation (under water) of the internals, highly activated, from the reactor. Also for waste handling and safe management methods for the difficult-to-handle type of activated debris, chips and metal fragments;
- Converting retraining programmes for technicians and workers using awareness-raising methods and training to safely address the specific challenges described.

3. CONCLUSIONS

- The application of the ALARA principle to the dismantling of installations does not differ in its basic principles to the form used for operational installations, although in practice many differences arise.
- Decommissioning of the nuclear plants require the adaptation of the radiation protection programmes established during normal operations. This adaptation extends from documentary aspects, to increased human and technical resources and the reorientation of operational practices.
- The ALARA principle should be taken into account from the time the work is planned and all involved should participate in its implementation.
- Regardless of the external radiation risk level which may exist in the installation, close attention must be paid to the risk of internal contamination which will be greatly increased compared to normal operation, by the very work of dismantling, by taking out of service ventilation and confinement systems, and by the employment of equipment and components that have never been used.
- The presence of hot particles must be also taking into account in this kind of dismantlings.