20 Years of ALARA Management, Research and Development at the Belgian Nuclear Research Centre SCK•CEN

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Abstract

The Belgian Nuclear Research Centre SCK•CEN performs research and offers services in the domains of nuclear safety and radiation protection. It operates major large facilities such as research reactors and hot laboratories, it develops innovative nuclear infrastructures and decommissions and dismantles old facilities. After a reorganisation in 1991, an enhanced safety management was implemented, including a systematic ALARA approach.
Staff was trained in the ALARA approach. A case study was developed: the dismantling of BR3, the first PWR reactor at the European continent. An ALARA management system including an ALARA-committee, an ALARA-procedure and an ALARA database was put into place, taking into account the complex mixture of routine tasks linked to the operation of larger facilities, and many unique, innovative tasks characteristic of a research environment.
To support the ALARA policy, a dedicated tool called "VISIPLAN 3D ALARA planning tool" to assess doses prior to an operation in a radiation environment was developed. Technological developments such as improved electronic dosimeters were implemented. Conceptual work has led to a holistic approach of radiation protection, nuclear and industrial safety, including waste management and cultural aspects. At present, an extension towards enhancing an adequate security culture is being made.
The design of a new research reactor MYRRHA creates a new challenge for our ALARA approach. Due attention must be given to dose reducing measures already embedded in the design. The experience gained in radiation protection in the past 20 years at the research centres is a valuable asset in the design process.

Keywords: ALARA management, ALARA tools, ALARA in dismantling, ALARA in design

1. Introduction

The Belgian Nuclear Research Centre SCK•CEN, www.sckcen.be , was created in the fifties to support the introduction of nuclear electricity production in Belgium. Several research reactors were constructed and a range of laboratories was designed and commissioned: hot laboratories for post-irradiation examination of nuclear fuels and materials, for radiochemical analyses, waste management and research, medical isotope production, radiation protection research including radioecology and radiobiology etc. In the seventies, when the first Belgian nuclear reactors in Doel and Tihange were connected to the grid, the need for nuclear research diminished and an exercise of diversification was started (energy in general, studies of materials in a non-nuclear context etc.). The isotope production was handed over to a subsidiary company located elsewhere. At the end of the eighties, it was decided to diminish the activities, leading to an important reduction in staff. The BR3 reactor, the first PWR nuclear power reactor on the European continent, was shut-down. The operational waste department was transferred to another company (Belgoprocess), and the non-nuclear activities were moved from the SCK•CEN to a newly created Flemish institute (VITO) in 1991. In parallel, a new management was nominated, a new organisation was put into place and many young people were recruited to fill the gaps in the organisation. This exercise included also a re-enforcement of the Health and Safety department. This resulted into the development of important efforts for education and training, initially mainly of in-house staff, later also for other nuclear actors feeling the need. The need to strengthen the management of radiation protection and ALARA was also identified and put into operation.

2. Implementation of an ALARA policy

2.1. Preparation

At the end of the eighties, at the moment ALARA management became an issue (e.g. Radiation Protection 44, 1988), SCK•CEN was in reorganisation, not actively introducing it within the organisation. From 1991 on however, efforts were made to implement an ALARA policy at the

SCK•CEN. This took the following steps: i) decision by the management; ii) nomination of staff at the Health Physics Department to get specific training and to follow-up international guidance and developments; iii) selection of key persons in each facility and provide an adequate training; iv) campaigns of information and dissemination of information; v) formal approval of the ALARA procedure. CEPN, the 'Centre d'Etude sur l'Evaluation de la Protection dans le domaine Nucléaire', (France, www.cepn.asso.fr), was strongly involved in the training of the staff and in the dissemination efforts (CEPN, 1992), and also supported the first real case studies on site. Exchange was established with the Doel nuclear power plant (Segers, 1991). The book "ALARA from Theory towards Practice" (Stokell et al., 1991) was a valuable reference document used frequently and in all major facilities. Simultaneously, a constraint of 10 mSv maximal annual individual dose was approved.

2.2. ALARA Procedure

This paragraph shows the present status of ALARA at SCK•CEN. A particularity for a research centre is the large variety of facilities and projects, generating a large diversity of circumstances. This leads to many unique operations, though the maintenance of the major facilities also includes a number of routine tasks. Further information can be found in (Antoine 2007; Antoine 2010).

2.2.1. Scope

The ALARA procedure is applicable for all works involving a risk of external exposure or contamination.

2.2.2. The actors involved

The *applicant* is the person responsible for the execution of some particular project or task involving a risk of contamination or exposure.
The *Local ALARA Coordinator* is a person nominated within each major facility of the SCK•CEN, who performs the following tasks:

- Assistance to the applicants in correctly applying the procedure;
- Introduction of the ALARA demand in the ALARA database, launching the application officially;
- Follow-up of the outcome;
- Contact person with the Health Physics Department.

The *Radiation Control Agent* belongs to the Health Physics Department. This person provides the necessary data (radiation and contamination maps etc.) in the preparation stage, supervises the work if levels are high, and makes sure the right steps are followed and followed-up afterwards.
The *SCK•CEN ALARA Coordinator* is a high level staff member of the Health Physics Department, who is responsible for the analysis of the ALARA procedures submitted, and who gives the final approval to launch the work. He also reports results to the management of SCK•CEN, the Committee for Prevention and Protection at Work (a committee composed of employers and employees, the latter being appointed after social elections involving the trade unions), and the supervision authorities. For complex procedures, supplementary approvals by the authorities may be needed, e.g. if the operations involve modifications to the installations etc.
In the major facilities, a *Local ALARA committee* may be meeting, playing a role mainly in the preparation stage (defining the options, the planning etc.). It is composed of the major actors: the applicant, the radiation control agent, the local ALARA Coordinator and supplementary staff if considered useful.
At the level of SCK•CEN, the *ALARA Committee* meets monthly. It is composed of high level representatives of various departments: the Safety department, the Health Physics unit, the Medical Service, the head of the Waste Management Department, the Local ALARA Coordinators. The SCK•CEN ALARA coordinator acts as a secretary, and the meeting reports are distributed up to the top management of SCK•CEN.
Its roles are:

- The follow-up of on-going and past 'ALARA procedures';
- Advice and exchange and feedback of experience;
- Approval in case of larger doses involved (see below);
- Discussion of practical issues (waste, dosimetry, database development).

2.2.3. The major steps in the procedure

The ALARA procedure foresees the use of three forms:

Form A is used in case the operation it covers is to be executed for the first time (or is a unique operation). It has to be supplemented by a detailed working procedure for the particular operation. The first part contains the dose estimates, the number of staff involved, the indication of non-radiological risks, data on waste generation and management etc. and is filled-in by the local ALARA Committee. The second part contains the remarks and conditions to be respected during execution (e.g. use of protective equipment, need for supervision by a Radiation Control Agent etc.)

Form B is a simplified version for operations that have been performed in the past without operational difficulties and without serious underestimations of the dose. Its objective is to make sure the operational and radiation environments have not changed in a negative sense, e.g. due to a change in radiation levels at the spot or the mounting of other equipment in the time lapse between previous and present execution.

Form C is used for the follow-up of the doses, based on electronic personal dosimeters, their parameters of importance, and the feedback of experience.

For dose estimations *below 0,5 man.mSv of collective dose*, and if the operation is executed for the first time (form A), an approval for execution by the SCK•CEN ALARA coordinator is needed; if it is a repetition of previous operations (form B), a check of form C is made, and the operation may be executed immediately.

For dose estimations between 0,5 and 5 *man.mSv of collective dose*, whether it is a first execution or not, the approval always has to be at the level of the ALARA coordinator at the level of SCK•CEN.

If the dose estimations trespass *5 man.mSv of collective dose and/or a maximal individual of 1 mSv of individual dose* is at stake, the approval by the ALARA committee is necessary.

Of course, depending on other risks present, whether industrial (fire, toxic products, …) or nuclear (interventions changing the facilities, or nuclear materials) or environmental (waste generation), other authorisations may be needed as well, either in-house or at the level of authorities.

2.3. Development and evolution

2.3.1. Improvements as regards dosimetry

Within SCK•CEN, the legal dosimetry is based upon TLD dosimeters. They show all the requirements imposed as regards stability, sensitivity, reproducibility, linearity as a function of energy, dose range etc. but they do not allow direct read-out nor provide alerting possibilities.

At the moment the ALARA became an organisational process, only electrostatic dosimeters were available, allowing direct read-out; yet, they were certainly not very reliable (very sensitive to shock), they did not allow to generate alerts and the dose records were made on paper, limiting future use for analysis. A major improvement was the introduction of electronic dosimeters for major projects from 1992 on, the test case being the BR3 dismantling project, solving the major issues of dose follow-up: alerting to assist reducing the doses during operations (as radiation fields may drastically change from one spot to another in the facilities), and to have at least a daily overview of individual doses.

In 2002, a new system was implemented, first stand-alone in the various facilities, and from 2003 on all systems were linked. This approach allows:

- Coupling authorisations in the ALARA procedure to tasks in the electronic personal dosimeter system allow defining dose constraints per task, combining the doses incurred with predictions etc. Tasks not being approved yet in the ALARA-procedure do not get a dosimeter task number, and as such do not allow starting the operations.
- The coupling of the various systems allows keeping daily track of all individual doses of all staff, also the ones working in several facilities.
- The coupling of the system to other systems allows limiting access to controlled areas for staff or subcontractors not having the adequate training, medical control, assessment of internal contamination,….

2.3.2. ALARA Database

The decision was made to develop an electronic tool to support the ALARA procedure; at present, the

tool is programmed in Access®. It allows managing the ALARA-process electronically: authorisations, follow-up, dose records etc. The main advantage of electronic management is the guarantee that anyone involved has access to the most recent information and to identical versions; furthermore, delays are avoided: no forms have to circulate between several parties located in different buildings.
The Database also allows performing statistical analyses comparing tasks, doses, dose predictions, etc. Feedback to the staff, the ALARA Committee and reporting to the management, the committee for prevention and protection at work and the authorities is very convenient.

2.3.3. Non-radiological risks

For many operations, the radiation risks are but one of the inherent risks. Very often other risks are present. Heavy loads (shielding, use of containers), working at height or in closed environments (e.g. in dismantling projects) are part of daily experience. On rare occasions, other risks show up, such as the presence of asbestos (dismantling of old loops operating at high temperature).
The introduction of the ALARA procedure and the ALARA database also allow better identifying these risks on beforehand, supporting their prevention in a systematic way and following-up the outcome via the feedback foreseen on form C.

2.4. Major benefits

The formal introduction about 20 years ago of an ALARA policy, with supporting tools as explained above, has led to a considerable improvement of the protection against ionising radiation.

- Awareness was raised at all levels (workers, responsible of carrying out, management,...) of the importance of adequate management of the doses.
- Proposals to reduce the doses are debated inside the local ALARA committee, stimulating creativity, accountability and knowledge about practical radiation protection issues.
- The development of an ALARA database has enabled to centralise all information about ALARA, leading to a consistent approach within all facilities of SCK•CEN and for all types of tasks.
- The circulation of information concerning ALARA was strongly improved (among others via reports ALARA Committee).

3. A few illustrations

3.1. A major test-case: ALARA in the dismantling and decommissioning of the BR3 reactor

This paper is limited to some illustrations of the ALARA procedure; in the past, several papers and presentations have been made on the subject. We refer to (Antoine et al., 2009), (Govaerts and Zeevaert, 1993), (Massaut et al., 2002). This illustration deals a mixed risk case: radiation and asbestos.
The context:
The BR3 reactor was the first PWR (pressurised water reactor) in Western Europe and also the first one being decommissioned. Within the framework of the European five-year programme for research and technological development for the decommissioning of nuclear installations, BR3 was chosen, next to three other European installations, as a pilot project for the demonstration of the decommissioning of PWR plants. A second objective of this programme was to address the issue of the implementation of the ALARA principle in decommissioning operations.
The problem:
As required by the Belgian regulations the welfare on the workplace has to be guaranteed, including quality of the air. In this case, thermal insulation was present containing asbestos. This compound is a proven initiator of lung cancer, and air strict concentration limits have been set by law. During the BR3 decommissioning project, measurements indicated that this limit was reached on some workplaces located in controlled areas. Actions were undertaken in order to remove asbestos. The removal of asbestos is to be performed under stringent conditions fixed in Belgian legislation; only accredited companies are allowed proceeding to such removal operations. The main challenge faced with was to optimize the whole process, bearing in mind both requirements: radiation protection and asbestos.

Methodology:
The Health Physics department, in close co-operation with the BR3 management, decided:

- to invite the external company for a visit to the workplace and to inform them on the radiation protection measures to be followed by all workers in controlled areas;
- to require a detailed procedure describing the removal operations as well as the protective measures against the risk of asbestos;
- to develop, in addition to the daily monitoring of the workers, special monitoring of internal contamination of the external workforce; this was done for psychological reasons but also to detect, a potential internal contamination from asbestos;
- to inform all Belgian regulatory authorities concerned by radiological and non-radiological protection of workers – about this methodology.

Main results:
Due to this approach involving both the external workers and the BR3 workers, it has been possible:

- to reduce the number of required working days from 50 to 35;
- to reduce the number of external workers required for the removal operations;
- to avoid any air contamination with asbestos;
- to remove twice as much insulation material than planned.

As a consequence, the total collective dose for the whole operation was a factor 4.5 lower than the expected dose (19.2 man.mSv instead of 88.9 man.mSv).
Lessons learned:
Many valuable lessons have been collected during this removal project: examples are:

- Optimization doesn't prevent to comply with other requirements concerning other industrial risks; on the contrary, an ALARA approach contributes to a higher level of awareness and individual commitment to safety;
- An open minded approach with respect to all regulatory requirements and with adequate interactions with all authorities allows time-, dose- and cost savings;
- In such yards, time has to be made available for the initial information of external workforce and different ways of behaving have to be kept in mind;
- Detailed procedures need to be discussed between all the involved stakeholders and operators;
- Flexibility has to be allowed in order to cope with the technical, human and regulatory requirements.

3.2. A decontamination procedure of an experimental loop in the BR2 materials testing reactor

Context:
The BR2 reactor is a material testing reactor used for the production of medical isotopes, for the doping of high quality Si, for testing the behaviour of reactor materials and fuels etc. One of the major experimental loops within the BR2 reactor is the so-called Callisto loop. This loop simulates PWR temperature, pressure and water conditions, and allows the irradiation of materials for use in reactors in very high neutron fluxes for qualification and for prediction of their behaviour.
The problem:
The Callisto loop was installed in the early '90s, and due to deposition of activated materials at various positions, the dose rate around the loop has been rising throughout its operation. This had a negative impact on the dose to the workforce performing the maintenance of major components of this loop. The maintenance and inspection activities in the so-called Sub Pile Room (underneath the BR2 reactor and containing the major components of the loop such as the primary pumps) lead to a collective dose of 18.34 man.mSv in 2008.
Methodology:
As a topic within the periodic safety review of the BR2 facility, it was decided to investigate the possibility to decontaminate the loop. Decontamination has the advantage of reducing forthcoming exposures if further maintenance operations are performed. It has the disadvantage that the operation itself leads to exposure of the people performing it, to radiochemical wastes and maybe to damage to the loop if a sub-optimal chemical cocktail is used or if technical problems occur during the decontamination. After some test experiments, it was decided to proceed with the decontamination that was performed in 2011. Actors were: in-house staff specialised in this domain, in co-operation with the BR2 staff and the Health Physics department.

Main results:

- The decontamination of a major part of the Callisto loop lead to a collective dose of 5.5 man.mSv, with a maximal individual dose of around 0.8 mSv. (One part of the loop was not decontaminated because of some uncertainty of chemical compatibility between these components and the cocktail optimal to decontaminate the other parts);
- The operation took place without incidents (neither radiological nor chemical);
- The dose estimations were very comparable to the real doses;
- Predictions made indicate that in future in service inspections will lead to doses 4-5 times lower than in the past.

Lessons learned:

Many valuable lessons have been collected during this project: examples are:

- Optimisation includes an adequate balance between process control (sampling and subsequent radio-activity analysis), dose and effectiveness of the operations: very frequent sampling allows adjusting technical parameters adequately, yet leads to higher doses (due to the more frequent interventions and sample manipulations).
- An adequate cooperation between specialists (in decontamination in this case), operators within the facilities and the Health Physics department leads to reliable dose predictions and to successful elaboration of complex processes avoiding incidents. Involvement of all stakeholders and operators is vital.
- Optimisation includes the balance between a gain in dose reduction on the one hand, and the risk of future operational difficulties that might lead in their turn to higher doses. That's why a part of the loop has not been decontaminated.

<u>Remark</u>: Major decontamination operations have been adopted during the BR3 decontamination process as well, at the level of the primary circuit (Klein and Valenduc, 2002).

4. Development of tools: VISIPLAN 3D-ALARA planning tool

During the decommissioning of the BR3 reactor a need was identified for a tool to support the ALARA-analyst in the evaluation of dose reducing options. In order to perform a good ALARA-study for a planned work, information has to be gathered concerning the site geometry, the distribution of the sources, the work planning, the shielding options, the costs,... All these aspects have to be considered and integrated to arrive at an adequate ALARA-decision. The information has to be organised, structured and analysed to determine the best approach for the planned work. Evaluating the potential effectiveness of the dose reduction options is a large and time consuming part of the work. The need to dispose of a fast 3D - calculation tool became apparent due to the geometrical complexity and the distribution of source in the BR3 decommissioning work environment.

Therefore SCK•CEN started with the development of the VISIPLAN 3D-ALARA planning tool to assist the ALARA analyst in the ALARA pre-job studies, in the dose calculations but also in the communication between the stakeholders during the ALARA process (Vermeersch and Van Bosstraeten, 1998), (Vermeersch, 2003), (Vermeersch, 2004). The tool is based on a point-kernel dose calculation in a 3D environment with build-up correction. Dose accounts can be evaluated for different work scenarios investigated in the ALARA process taking into account the worker position, work duration and subsequent geometry and source distribution changes.
Its capabilities were proven in the decommissioning of the BR3 reactor especially in the optimisation of the work under the operating deck. Scenarios could not only be assessed in a shorter time; the communication of the results was also facilitated by the 3D representation. Soon external interest for the use of the VISIPLAN grew in the field of decommissioning and resulted in the creation of commercially available software. The field of application was extended to ALARA in routine operation and design of new installations and experiments. The use of VISIPLAN has stimulated a more rigorous implementation of ALARA and has facilitated the communication with stakeholders.

5. ALARA in Research

5.1. Support of policy by Research activities

Though working in a research centre leads on the one hand to complications due to the large variety of applications (routine versus experiments; very innovative experiments in old installations; design of prototypes versus dismantling), it also allows reflection on both the conceptual and managerial levels, as well as on practical implementation. In this paragraph, we briefly mention some examples of study subjects that have been tackled in the past without detailing them, just to stimulate the reader to be creative and open minded. Applications in the medical domain or legal aspects have been studied as well, but are not explained here.

5.1.1. The value of the man.Sievert

In the nineties, a lot of attention was paid to formal decision making based on cost-benefit analysis or cost-effectiveness analysis. Some references are (Lefaure et al., 1993), (Lefaure, 1995). Our centre has contributed in the clarification of conditions for application, the costs to include or not in the assessment etc. as published in (Hardeman et al., 1998).

5.1.2. Extending the scope

The scope of application was extended from external exposure in an occupational context to non-radiological risks (EAN 2000), management of radioactive waste as a contributing factor (conceptually, waste generation may lead to a transfer of professional exposure to long term public exposure), and potential exposures as aspects of a major refurbishment operation in the BR2 research reactor. The preparatory stage is given in (Hardeman, 1993).

5.1.3. Emergency conditions

The intervention levels applicable for early countermeasures in emergency conditions have been generically optimised in the nineties (ICRP 63), (IAEA SS 109); though some of the visions have been recently modified/superseded, the exercise of generic optimisation remains valid. Our centre has contributed in assessing whether higher intervention levels were justified and could be optimised for particular actors, such as people active in industrial facilities in the vicinity of a major nuclear power station in accidental conditions (Pauwels et al., 1999).
Further research has been performed in the domain of the selection of management options, using much more advanced mathematical methodologies besides the cost benefit analysis, and including methodologies for stakeholder involvement. This work has been published a.o. in (Turcanu 2007), (Turcanu et al., 2010).

5.2. Future developments

At present, much effort is made in supporting the integration of optimisation of the radiation protection risk from a cultural approach, not only focussing on optimisation, but also taking into account justification, and human and organisational factors. The management of culture is furthermore broader than radiation protection culture: it also needs attention to nuclear safety culture, safety culture with regards to non-nuclear related risks and environmental impact, security culture and safeguards culture. Reflections are still on-going and not yet to full maturity. Yet we refer to (Hardeman and Vermeersch, 2009) and (SSRAOC 2012) for further information.

6. ALARA in design

Nuclear safety plays a major role in the design and construction of new installations such as Myrrha, the new research reactor currently in design at the SCK•CEN. In the past occupational radiation protection and ALARA were addressed to a lesser extent in the design phase. However, it is clear from experience feedback that occupational radiation protection (ORP) and ALARA need to be included from the beginning in the design in order to avoid doses due to a bad design or architecture of the installation (OECD 2010).
Design and architectural changes in order to reduce dose can become very expensive once the design is fixed or the facility is under construction. Therefore we included ORP and ALARA from the beginning in the Myrrha design process, and anticipate exposure situations in all phases of the life cycle of the installation. The design will be regularly reviewed by an ALARA review committee in order to give feedback on the design. The review will be based on past experience in construction, operation and decommissioning, and on the critical evaluation of the different manipulations leading to exposure situations that are to be performed in the future installation. This calls for a multidisciplinary approach in which radiation exposure is seen as one of the risks among others.

7. Conclusions

The present paper has given an overview of the major evolutions in ALARA management at the level of the Belgian Nuclear Research Centre SCK•CEN, illustrated from a managerial, an implementation and a conceptual point of view. It is obvious that optimisation is and remains a vital cornerstone of risk and dose management in a nuclear setting, though the scope is and has to be widened:

- Including other risks (non-nuclear industrial risks, environmental risks, security issues, safeguards issues);
- Including cultural issues, taking into consideration organisational and human factors;
- Using advanced tools for risk prediction (such as VISIPLAN for radiation related issues; other methodologies for more complex problems);
- Including stakeholder involvement processes, communication issues.

A research centre is a good environment to explore the possibilities and needs and to test methodologies and tools, as it is a rapidly changing environment, tackling many issues from dismantling to design of innovation.

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