ALARA IN EUROPEAN NUCLEAR INSTALLATIONS

Christian Lefaure[1]; John Croft[2];
Wolfgang Pfeffer[3] and Theo Zeevaert[4]

CEPN[1] - BP 48 - 92263 Fontenay-Aux-Roses Cedex - France
NRPB[2] - Chilton, Didcot - Oxon OX11 ORQ - United Kingdom
GRS[3] - Schwertnergasse 1 - 50667 Köln - Germany
SCK/CEN[4] - Boeretang 200 - 2400 Mol - Belgium

ABSTRACT

For over a decade the Commission of the European Community has sponsored research projects on the development and practical implementation of the Optimisation principle, or as it is often referred to, ALARA. These projects have given rise to a series of successful international Optimisation training courses and have provided a significant input to the periodic European Seminars on Optimisation, the last one of which took place in April 1993. This paper reviews the approaches to Optimisation that have developed within Europe and describes the areas of work in the current project. The on-going CEC research project addresses the problem of ALARA and internal exposures, and tries to define procedures for ALARA implementation, taking account of the perception of the hazard as well as the levels of probability of exposure. The relationships between ALARA and work management, and ALARA and decommissioning of installations appear to be other fruitful research areas. Finally this paper introduces some software for using ALARA decision aiding techniques and databases containing feed back experience developed in Europe.

INTRODUCTION

Since the publication of ICRP 22 [1] and ICRP 26 [2] in 1973 and 1977 respectively, the understanding and practical implementation of the concept of Optimisation of Radiation Protection has developed considerably in Europe. This past progress can be split into three periods. The first period, lasting up to 1982 was mainly focused on theoretical aspects and an evaluation of possible quantitative decision aiding techniques, with most emphasis being placed on cost effectiveness and cost benefit analysis. The second period from 1982 to 1987 was mainly devoted to the development of a structured approach to optimisation, the ALARA Procedure, within which decision aiding techniques, if required, could be used. The period also saw many case studies being carried out in a wide variety of installations in relation to both design and operational problems, but predominantly a posteriori. The third period from 1988 onwards has seen the development of more structured approaches and "tools", which together with an a priori predictive approach are being integrated into operational radiological protection programmes. This evolution can be traced through the proceedings of the four European Seminars on Optimisation [3,4,5,6], the last of which was in Luxembourg in April 1993.

Staff from CEPN, France, and NRPB, United Kingdom, have been working on the practical implementation of ALARA for a number of years and some of the results of this work have been published in a book [7]. Much of this has been financially supported by the Commission of the European Community (CEC) within joint research projects. In 1993 two other organisations, SCK/CEN from Belgium and GRS from Germany joined the European research project on radiation protection optimisation in installations. During the last four years CEPN and NRPB have also been heavily involved in running training courses on optimisation. One of the strengths of these events has been the input provided by lecturers from utilities in the UK, France and Sweden who have experience in implementing ALARA in the nuclear industry. Another strength has been the wealth of practical experience that the participants themselves, from a range of countries and different backgrounds, have been able to bring to these courses. Many of the perspectives on optimisation of radiological protection in Europe given in this paper have developed out of these research and training programmes.

I - EUROPEAN ALARA PROGRAMMES: 1994 STATE OF THE ART

We have always taken the ALARA principle to apply to both individual and collective exposures. The principle as now stated in ICRP60[8] explicitly covered this but also emphasised the need to focus on individual exposures. To satisfy this principle it is clear that one should not just pursue control of individual doses relative to limits or targets; one has to implement an ALARA approach i.e. an a priori management of both individual and collective exposures. This means that radiation protection has to be integrated into the global management of organisations. The ALARA approach may then be characterised with some key words such as "prediction, efficiency, and equity ".

In most of our countries management of the radiological risk is now a feature of the operational and maintenance phases of nuclear installations through implementation of the so called ALARA Programme. The programme fits with the three phases of any project (see figure 1): setting dosimetric objectives during the preparation phase, following up the dose results during operation and analysing the feed back to improve the next operation.

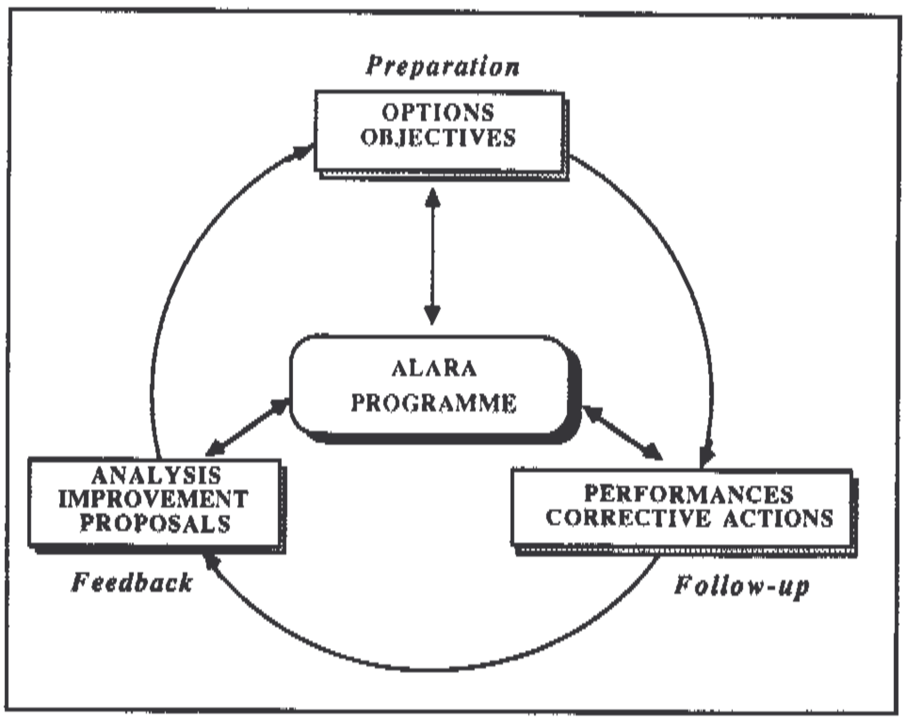

Figure 1. ALARA Programme and phases of any operation, outage or year

The main characteristics of such programmes are the commitment of all the "actors" from the regulators to the workers, the appropriateness of the decisional structures to ALARA implementation and the use of adapted "tools" such as the monetary value of the manSv (often referred to as the alpha value). The first part of this presentation does not aim to provide an exhaustive description of the European situation but will address some specific points of interest within the European context.

Regulatory Arrangements

The ALARA principle has been progressively incorporated into most European national regulations (see table 1) [9], where in most cases it appears as a top level general requirement or objective. Major exceptions are Germany and Portugal where the regulations still require the minimisation of doses i.e. as low as possible.

Table 1. ALARA and National regulations in Europe

Countries	Date and reference text	Wording of optimisation
Belgium	Royal Decree, 25/04/1987	
Ireland	Statutory Instruments 43, 1991	
Luxembourg	Grand-ducal Regulation, 29/10/1990	"...as low as reasonably possible"
Netherlands	Decree, 10/09/1986	
Spain	Royal Decree 53/1992, 24/01/1992	
Denmark	Regulation 383, 1986	"as low as reasonably achievable"
United Kingdom	Regulations 1985	"restrict so far as reasonably practicable"
Greece	Decree, 19/07/1991	"as low as reasonably achievable technological feasibilities, results of cost-benefit analysis and in general every other social and economic factor being taken into account"
Germany	Ordinance, 30/06/1989	"...as low as possible, taking due account of the state of the art and paying attention to the merits of each individual case"
France	Decree, 02/10/1986 modified 1988 and Decree, 28/04/1975 modified 1988 (occupational radiation protection)	"...as low as reasonably possible"
Italy	President Decree, 13/02/1964, never revised	"...to reduce workers exposures, taking into account good current practice"
Portugal	Regulatory-Decree 9/90, 19/04/1990	"...as low as possible"

Different views exist in the various countries on the extent to which this requirement should be expanded into precise prescriptive regulations. Both the form of the ALARA principle in national regulations, and the will of the Authorities to enforce its implementation appear to have a very important impact on the radiological protection culture in the different countries and on organisations' and individuals' perceptions of what ALARA means. This point has repeatedly emerged from the CEC courses on optimisation. In countries like France and Belgium the Authorities tend not to intervene, while in Sweden or Spain the Authorities require any utility to provide collective or individual dose predictions per important job, discuss with the utility the possible protection actions to optimise the exposures, and check the results against the predictions. In the United Kingdom, the authorities use the general regulatory requirement to underpin improvements they require, and also specify levels of individual dose, which if exceeded, require the employer to carry out an investigation to determine if appropriate action had been taken to keep doses as lows as reasonably practicable. Another important point is the extent to which the ALARA requirement has been tested in a court of law. At present ALARA requirements have been addressed in the law courts of two European countries. The first is the UK, where `reasonably achievable' is replaced by "reasonably practicable", a term that has been used for many decades in a wide variety of safety legislation. As a result there are case precedents that can be used in a court of law, and several convictions in respect of failure to meet the ALARA requirement have been recorded [10, 11]. The second country is France where, in 1993, for the first time [12], a court convicted a manager on the grounds of not meeting the ALARA principle. This case is currently the subject of an appeal.

Management Commitment, Workers Motivation and Training

It is now obvious that real success in the application of ALARA demands that organisations take a more positive role than only responding to regulatory pressure [13, 14]. A strong management commitment, through for example Corporate Codes of Practice, is as fundamental as the commitment of individuals at all levels within the organisation. It is therefore important for each organisation, to ensure that ALARA is totally inserted within its culture as a "way of thinking", through its various components such as training, information, communications and incentives. At this point it would be appropriate to identify questions that, as yet, have not received a consensus view in Europe. Do rewards and incentive schemes have a role to play in optimisation, and if so in what form ? Are there problems associated with the use of such schemes, and if so what are the solutions to these problems ?

Contractors Involvement

For Light Water Reactors, more than 80% [15] of the collective dose is received by contractors' employees, and it is therefore impossible to achieve ALARA without effective and efficient cooperation from the contractors. As a result more and more frequently' European utilities are introducing ALARA oriented requirements into contractual arrangements e.g., dose prediction, dosimetric goals, radiation protection feedback reports etc. They also analyse the contractor's proposals concerning the development of "tools" and process modifications with respect to dose savings and their corporate value of the man sievert. In Sweden, at Vattenfall, the corporate man sievert value is specified in the contract; it is then mandatory for the utility to accept any contractor's proposal which leads to dose savings costing less than this man sievert value.

The standard of radiation protection shown by contractors is increasingly becoming an important part of their ability to compete and win contracts. This is to be welcomed, however it is not without problems. For example the retention of intellectual property rights by contractors for their expertise in processes and the development of specialised "tools", can inhibit the dissemination of feed back experience.

Organisational Structures

A key element of management's contribution to ALARA is having an organisational structure capable of ensuring that ALARA is implemented. Whilst many different approaches are no doubt possible, it is worth considering two distinct approaches which have each been shown in Europe to be capable of applying ALARA in the workplace.

In the first approach, ALARA is accepted as an integral part of the overall radiological protection programme, and normal existing management structures are sufficient. The operational (or project) management team carries the formal responsibility for all aspects of safety, and the established culture of the organisation naturally extends this to encompass ALARA. In such cases the existing Health Physics organisation is likely to be effectively integrated into the overall management framework and to carry significant influence. This type of arrangement is, for example, the situation generally pertaining in the UK, Sweden and Finland.

A second approach is to create specific ALARA structures to provide an effective focus for pursuing ALARA. This could for example involve a special management ALARA Committee, with objectives such as setting targets (e.g., collective dose goals), taking strategic decisions on the impact of radiological protection actions on costs and production, and arbitrating in conflicts between designers, health physicists, engineers and operators. This committee could be supported by the appointment of a specified individual as ALARA Coordinator with responsibilities for the implementation of all aspects of the ALARA programme during the operation. This type of approach has been used with considerable success in some parts of the French, Spanish and Belgian nuclear industries. Nevertheless this leads to the following question. Is the use of ALARA structures only a temporary step on the way to integrating ALARA into the overall radiation protection programme and structure, or can both approaches complement each other? Irrespective of which approach is taken, the involvement of Health Physicists in the early stages of projects is strongly advocated. This can be justified in pure business terms in that it maximises the effectiveness of the investment of effort.

Adapted "Tools" and Procedures

Whilst ALARA success is mainly due to "Attitude", the use of adapted specific "tools" and procedures can be very helpful. In line with any ALARA programme these "tools" and procedures have to correspond to different functions dealing with the three phases of any operation (see figures 2 & 3). Most of these "tools" such as decision aiding techniques, particularly cost benefit analysis (CBA), or pre-job and post-job ALARA reviews together with corresponding check-lists, are now in current use, both in Europe and America. Special attention will be paid here to the "ALARA procedure", the status and levels of alpha values in the different European countries, the analytical "tools" and, finally, networks for exchanges of feedback experiences between utilities.

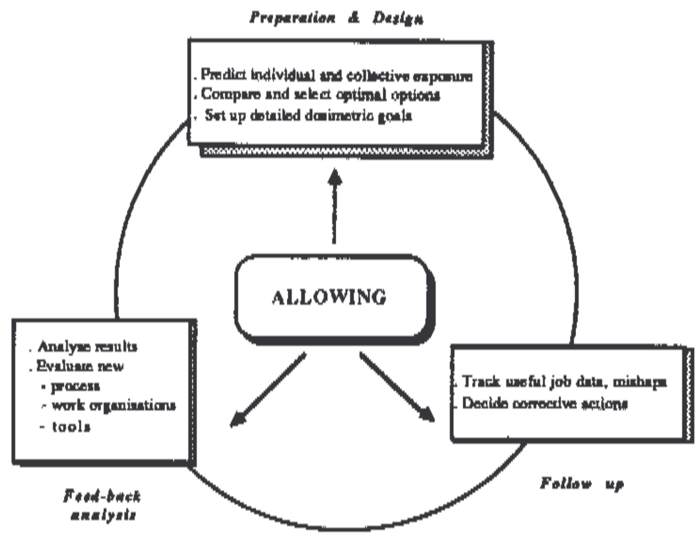

Figure 2. Functions of ALARA "tools" with regard to the phases of operations

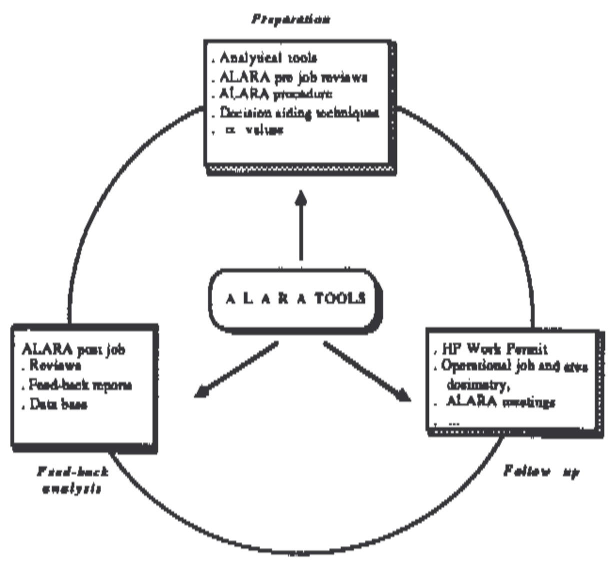

Figure 3. ALARA "tools" and phases of operations

The ALARA Procedure

So that ALARA decisions can be made in a systematic fashion, the ALARA Procedure was developed, and subsequently incorporated into ICRP publication 55 [16] on Optimisation. Its function is to provide a way of structuring and standardising judgements. It is stressed that this is only a schematic representation of a logical approach to clear decision-making, and as such it is also a representation of what many experienced health physicists already do in practice.

The keys steps in the ALARA Procedure [7] are as follows: to define the problem fully at the outset, setting boundaries to the analysis; to identify alternative courses of action (options) and the important factors in terms of doses and costs; to quantify, where necessary; and to make some comparison of the options identified. At this point a quantitative decision-aiding technique may be of use, but that will depend on the problem. Sensitivity analysis may or may not be required depending on the nature of the problem. The product of the Procedure is the ALARA result. However, this may not be the same as the final decision, because the decision-maker quite legitimately may conclude that other factors not directly considered in the analysis are also important and need to be taken into account. However, the procedure should ensure that all the radiological protection factors that are considered important are explicitly included in the study. This helps to make decision-making, and the rationale behind final preferences, more transparent.

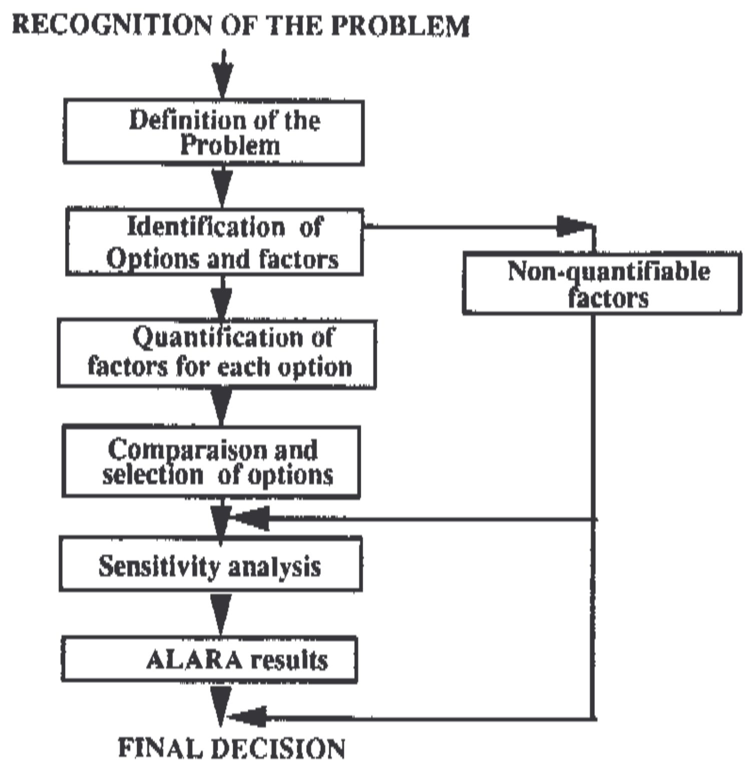

Figure 4. The ALARA Procedure steps

Alpha Value Status in European Countries

In order to assess what are reasonably achievable radiation protection options from an economic point of view a monetary valuation of unit collective dose (the cost of the man sievert) is obviously essential. This is often referred to as the 'alpha' value and has been addressed in many ICRP publications [1,8,17,18]. In the European countries, there are many different man sievert values corresponding to different rationales.

In a few countries, such as the UK and the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), national organisations have recommended values of the man sievert. For example in 1991 the radiation protection authorities of the Nordic countries recommended [19] value equivalent to approximately US $ 100k per man sievert. This single value was deemed suitable for all radiological situations and types of exposure ie, public and occupational in the nuclear, medical and industrial fields. In the UK, the NRPB, using its previous model [20], has recommended a base line value of £ 10k (US $ 15k) per man sievert together with a set of values for different radiological situations [21]. For example for occupational exposure the NRPB has taken into account the average annual levels of individual exposure of a few millisievert and using a multiplier to integrate the aversion to risk, recommended a minimum value of £ 50k (US $ 75k) per man sievert.

In the countries with recommended values, as well as in other countries, many utilities have set up their own corporate alpha values. It is noticeable that these corporate values have generally been several times higher than the nationally recommended ones. Some utilities have adopted a value covering all doses ranges. An example is the case of British Nuclear Fuels in the UK where a £ 100k (US $ 150k) per man sievert was used for a long term refurbishment project [22]. Another case is that of Vattenfall in Sweden, where a baseline value of SEK 4000k (US $ 700k) per man sievert [23] is used internally and contractually ie, if for a particular operation; a contractor proposes a radiological protection improvement costing less than this value, Vattenfall is contractually obliged to implement that improvement. In France, Electricite de France (EdF) has adopted a set of values rather than a single value. The valuations adopted are based on a model developed by CEPN [24]. There are five values ranging from FF 100k (US $ 18k) per man sievert for individuals with annual doses lower than 1 mSv to FF 15 000 k (US $ 2 700 k) per man sievert value for individuals with annual doses between 30 and 50 mSv.

What is clear from the above is that national and corporate values of the man sievert are now common and well founded. Variations in values are to be expected and they reflect the factors folded in, the social and economic pressures and available resources, together with the dose distributions pertinent to the defined exposed population they are applied to.

Analytical Softwares

In order to facilitate its use, particularly by non specialists, most of the ALARA procedure steps may be formalised in a computerised way. One example is DOSIANA [25] which was developed to assess and analyse predicted doses, as well as real dosimetric data. More recently a user friendly software to carry out cost effectiveness/cost benefit analysis (OPTI-RP) has been developed by CEPN and NRPB within the CEC joint project. This uses `ACCESS' under `Windows' , can accommodate both single and sets of alpha values, can accommodate temporal distributions of costs and can cope with a great number of options. It is totally independent of both national and computer contexts and will be available by the end of 1994 in two versions: one in English and one in French.

Feed back Databases and Networks

Both the utilities and authorities in Europe have put considerable effort into improving feedback exchanges between all the "actors" in the nuclear field in order to achieve as quickly as possible the necessary input to the ALARA management of the radiological risk. For about ten years, the Commission of the European Communities has set up a data base and an annual European meeting of utilities'representatives, in order to facilitate exchanges of feed-back experience in the radiation protection field and to analyse the evolution and levels of collective doses and individual doses distributions. In 1992, the European countries became part of the OECD-NEA Information System on Occupational Exposure (ISOE). By 1994 all 112 European light water reactors are participating to the ISOE system, providing it both with statistical data and job related informations (good practices, radiation protection problems) and using it as an operational network to ask questions, and speed up feed back experience retrieval.

II - ON GOING RESEARCH

Despite advances in the practical implementation of ALARA, there is still significant potential for improvement. In this part of the paper we will address four topic areas that are the focus for on going research, namely work management, decommissioning, internal exposures and potential exposures.

ALARA and work management

The application of the ALARA principle to occupational exposure implies the adoption of an analytical approach in order to identify the relevant factors contributing to individual and collective exposures. In Europe over the last two decades much has been done to reduce the ambient dose rates. However there is considerable evidence that much remains to be done to reduce the duration of exposure and the number of exposed workers required to carry out particular tasks. All procedures and actions which can influence these last two factors come under the heading of 'Work Management' [26].

In a recent study, CEPN has looked at three different categories of "work management factors": those linked to working conditions (ergonomics of work areas, protective suits...), those characterising the operators (qualification, experience level, motivation...), and those directly dependent on the organisation of operations (tasks planning, general preparation of work...). In order to quantify the impact of different working condition parameters, a detailed survey was carried out in five French nuclear power plants, and was supplemented by a literature review on the influence of "hostile" environments on working conditions. Also tests were carried out to quantify the impact of various types of protective suits used in French nuclear installations on a variety of types of work. All these factors have been included in a model aimed at quantifying the effectiveness of protection actions, from both dosimetric and economic points of views. The main results of this study will be presented during this workshop [27].

The direct impact of the approach to organising operations is more difficult to quantify. Nevertheless, some studies on causes of mishaps occurring during outage maintenance jobs in French NPPs has shown that up to 30% of the doses from mishaps can be attributed to organisation problems (planning, scheduling ...). A study of the organisation of outages in 4 different nuclear power plants from various countries has confirmed [28] the importance of commitment and motivation toward the ALARA principle. Also it highlighted the value of the total integration of radiation protection criteria in the overall outage process, from planning stage to feed back experience, through both effective co-ordination and collaboration of all groups involved in the outage, and an effective use of well documented feed back data bases for jobs, doses, dose rates, mishaps etc.

ALARA and Decommissioning

ALARA thinking is well on the way to pervading many aspects of the operational and maintenance phases in the life of nuclear installations. The extension of this approach to the whole life of an installation, although perceived as essential is not as well developed in Europe. During the next few decades, many nuclear facilities will be decommissioned and possibly dismantled. Decommissioning and dismantling operations have their own specific problems, differing in various aspects from normal maintenance operations in nuclear reactors. As a consequence radiological protection optimisation with respect to decommissioning/dismantling is an area warranting further attention in various aspects.

These aspects are mainly related to:

- the decommissioning strategy;
- the decommissioning methodology;
- the dismantling operations;
- the management of the radioactive waste generated during the decommissioning.

The decommissioning strategy defines the major milestones in the decommissioning process as a function of time. Conventional endpoints are:

- evacuation of free activity and confinement of that remaining;
- dismantling of the most contaminated structures and confinement in a reduced volume;
- evacuation of all radioactive materials and complete restoration of the site.

Economical, technical and radiological arguments feed into decisions on the scale and timing of each step. The economic and radiological attributes relate to the costs and doses associated with survey, maintenance and finally the dismantling operations. Also economic benefits, e.g. from the restoration of the site, and radiological risks from uncontrolled intrusion and from degradation of barriers as well as radiological impacts of waste management options play a role. The values of these attributes depend strongly on time, and consideration has to be given to the capitalisation of monetary provisions, to the degradation of equipment and the loss of human know-how with time. SCK/CEN is currently examining the variation with time of the relevant attributes involved in ALARA decision making concerning the decommissioning strategy. Important trade-offs playing a role in the decision-making, have been identified eg:

- the use of a telemetric monitoring system (exposure during the installation) versus local survey (exposure during monitoring);
- decontamination prior to dismantling (doses during the decontamination) versus no prior decontamination (higher doses during dismantling);
- the costs, doses and equipment reliability related to the use of robots.

Dismantling can be broken down into the major tasks of isolation, cutting, transport, interim storage and clean up. A serious lack of experience is evident, particularly with respect to the technological aspects and radiological protection factors of cutting operations. As a consequence a data base collecting experience from dismantling operations, is considered as a very valuable aid for future optimisation analyses. SCK/CEN has developed a draft-structure for such a data base and has demonstrated its applicability with respect to dismantling operations at its BR-3 reactor. In routine maintenance activities, external gamma exposure is the major radiological attribute, however in dismantling operations, skin doses, internal contamination and waste generation (quality and quantity) are also important and can often dominate the decisionmaking. With respect to waste generation it should be noted that the decommissioning of an installation produces approximately as much radioactive waste as the amount generated during the total operational life of the installation. Therefore it is recommended that decommissioning and subsequent waste management be considered as a whole in the optimisation process, resolving conflicts between the nature of the waste generated by the best decommissioning option and the requirements on radioactive waste related to the best waste handling and storage option.

ALARA and Intake

Much of the thinking in optimisation has tended to focus on external exposure. Although the principle of optimisation clearly applies to all forms of exposure, it is often found in practice that internal exposure is treated in a very different manner to that for external exposure; with the approach being nearer to minimisation. This stems from two principal factors.

Firstly unlike external exposure it is often quite difficult to predict the levels of intake and hence the doses; because so many variables come into play. The problem is compounded by the difficulties encountered for many radionuclides in accurately measuring intakes that have occurred. This is further exacerbated for low ALI radionuclides, principally those of the actinides, as almost any measurable intake gives rise to a significant fraction of the dose limit. Thus we are often faced with the trade off of the certainty of increased external exposures, of the order of a few mSv per task due to loss of efficiency and manipulative skills from wearing protective clothing against the potential, albeit often less frequently than once in a decade, to receive an ALI or so if protection measures or procedures fail. Secondly feedback from the CEC training courses indicates that workforces appear to be significantly more averse to receiving an intake giving a committed effective dose of say 1 mSv, than for the same equivalent dose from external irradiation.

Often the costs of protecting against intakes are significantly greater than for comparable external irradiation protection measures. Thus the same resources if applied to external exposure would be more efficient in reducing the overall risks. To develop thinking in this area guidance is being prepared by NRPB which takes the basic structured approach of the ALARA Procedure and addresses the special considerations that apply to internal exposures e.g.. the exposure pathways, the protection options available, trade-offs between chronic routine exposures and probabilistic exposures, quantification of costs and intakes etc. Once the draft guidance has been completed, case studies will be carried out for a variety of uses e.g.. large scale handling of Low Specific Activity material, radiochemical laboratory design, work in nuclear power plants, decommissioning work, use of glove boxes, etc.

From discussion sessions at the 4th European Seminar [6] and the CEC Training Courses it appears that workforce perceptions and management decisions are based almost entirely on worst case predictions with inherent large pessimistic assumptions. Therefore improvements in applying ALARA will be dependent on stimulating better measurement regimes or means of assessing intakes.

ALARA and Potential Exposure

One of the major changes brought about by ICRP 60 [8] was the introduction of an explicit reference to potential exposures in the system of radiological protection. Subsequently, ICRP 64 [29] (and an imminent INSAG publication) have provided the conceptual basis for this topic. Any situation involving potential exposure will present a range of scenarios, each being characterised by a distribution of individual exposures, a collective exposure and a probability of occurrence. This topic will be further addressed during this workshop [30].

Theoretically the optimisation process will apply to situations where potential individual exposures above the normal operational dose limits might be encountered. Indeed one may have to consider deterministic effects (albeit with a very low probability) as well as stochastic effects. The optimisation process will require the ability to compare options where it will be possible to modify the distribution(s) of individual exposures for one or several scenarios and consequently the number and types of expected effects and/or to modify the probabilities of occurrence of the scenarios. To address this, firstly there will be a need to develop a means of weighting the different types of effects into a kind of unique index of harm in order to be able to compare the consequences of the different options independently of their probabilities. It will then be necessary to develop other tools to take into account the perception or utility of probability-consequences pairs and of their modification. Then and only then will it be possible to introduce optimisation of potential exposure in a structured way within a decision making process. It has also to be pointed out that regulators may need to define the boundaries of any optimisation process dealing with potential exposure.

It seems likely that the increased emphasis on potential exposures, will push managements into more explicit consideration of probabilistic events, which in its own right may lead to operational improvements. The development of thinking in this area may also have an impact on the previously mentioned problem area of ALARA and intakes.

CONCLUSION

The last few years have seen the spread and establishment of an ALARA culture within many European countries and organisations. This is reflected in organisational arrangements; attitudes of workforces, managements and regulators; databases for accessing past experience and most importantly work efficiency coupled with lower dose distributions. A number of papers at this meeting provide examples.

However it needs to be noted that to date the principal focus has been routine operations involving mainly external exposure. There is still an ongoing need to develop thinking in respect of the special problems posed by decommissioning and work involving intakes and potential exposures.

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Authors' Biographies

Christian Lefaure, born in 1946, Ph.D. in Economics, was successively Assistant Professor at Paris University, researcher at the French Ministry of Finance and industrial economist. Since 1981 he works at the Centre d'Etudes pour l'Evaluation de la Protection dans le domaine Nucléaire (CEPN France), where he is Project Leader in charge of studies dealing with ALARA and nuclear facilities. He is currently coordinator of the European joint research program "ALARA in installations" with the participation of NRPB (UK), GRS (FRG), SCK/CEN (B). Since 1992 he is also Head of the European Technical Centre for the International System on Occupational Exposure (ISOE) of the OECD NEA.

Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire
BP 48
92263 Fontenay-Aux-Roses Cedex - France
Phone: 46 54 74 67
Fax: 46 57 62 58

John Croft is currently Head of the Southern Centre of National Radiological Protection Board (NRPB) in the UK. He has been involved in Optimisation work across a wide spectrum of uses of ionising radiations, presented many papers at seminars on Optimisation, acted as consultant to IAEA on the subject and co-authored a book "ALARA from theory towards practice". Much of this work has been done under the auspices of CEC joint research projects, particularly with CEPN France. He has also acted as consultant to IAEA in Post Accident reviews of four fatal radiation accidents.

National Radiological Protection Board
Chilton, Didcot
Oxon OX11 ORQ - United Kingdom
Phone: 235 831 600
Fax: 235 833 891

Wolfgang Pfeffer, born in 1945, has a doctor's degree in nuclear physics. He joined the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) in Köln, Germany in 1979, working in the field of emergency preparedness of NPPs and radiation protection of occupationally exposed personnel in NPPs. Since 1989 he is the head of the Applied Radiation Protection-Group in GRS. The group is working on topics in the field of off-site emergency preparedness and radiation protection of workers. In this context the group works as a consultant for the Federal Authorities.

Gesellschaft für Anlagen und Reaktorsicherheit
Schwertnergasse 1
50667 Köln 1 - Germany
Phone: 221 206 8296
Fax: 221 206 8442

Theo Zeevaert, born in 1946, civil engineer (University of Leuven, 1969) has been working for fifteen years in the Department of Radiation Control and Safety at SCK/CEN in Mol. Since five years he is working in the Radiation Protection Research Unit, where he is project leader in the field of radiological optimisation and for validation and development of impact assessment models in the biosphere. In the framework of radiological optimisation, he is involved in the implementation of ALARA principles in the CEC project concerning the dismantling of the BR3 reactor at SCK/CEN and has elaborated impact assessment methodology for nuclear site restoration, on behalf of the CEC.

SCK/CEN
Boeretang 200
2400 Mol - Belgium
Phone: 14 33 2868
Fax: 14 32 1056