Application of the ALARA principle to the design of new nuclear laboratories, and to the definition of safety options for dismantling operations, with regard to the radiation protection objectives

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1 - INTRODUCTION

Prior to being authorized to construct, to operate or to dismantle a nuclear installation, all operators have to demonstrate that the safety and protection regulatory obligations are satisfied. In the radiation protection field, this means in particular, that the three following principles has been implemented: **justification of a practice, radiation protection optimization** and **dose limitation**, according to the ALARA[1] principle [1].

This paper intends to present, in a first part, the general rules for applying the ALARA principle to the design of a new nuclear laboratory and in a second part, the methodology recommended by different organizations to define the safety options for dismantling operations, as far as radiation protection objectives are concerned.

2 - APPLICATION OF THE ALARA PRINCIPLE TO THE DESIGN OF NEW NUCLEAR PLANTS

2.1- Regulatory obligations

Optimization is a regulatory obligation, as recommended by the following organizations, and implemented by national laws.

◆ **The European Directive 96-29 (EURATOM), specifies, in its article 17 [2]:**

> *« Operational protection of exposed workers shall be based in particular on the following principles (...):*
>
> *a) prior evaluation to identify the nature and magnitude of the radiological risk to exposed workers and implementation of the optimization of radiation protection in all working conditions;*
>
> *b) implementation of control measures and monitoring relating to the different areas and working conditions including, where necessary, individual monitoring ».*

◆ **The International Commission on Radiological Protection (ICRP) [3]** recommends, in its publications 26 (1977) and 60 (1990), that the ALARA principle be considered as an analytical process allowing the reduction of the exposure doses, by using simultaneously the three following considerations.

• **Justification** *of any practice:* No practice involving exposure to ionizing radiation can be allowed unless the benefit is sufficient, compared to its radiological detriment.

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(1) ALARA, which is an english acronym meaning « As Low as Reasonably Achievable », is a predictive and evolutionary procedure, applicable for the definition of the efficiency of the radiation protection, namely for quantifying protection actions, dose monitoring and dose management, in order to maintain the individual and collective exposure of the workers and the general public as low as reasonably possible, taking into account technical, economic, juridical, social, public and environmental policy considerations. This approach applies to fixed shieldings intended to reduce external exposures as well as to the means intended to reduce internal exposures and to the radioactive discharges to the environment.

• **Optimization** *of the radiation protection*: For each source associated to a practice, the level of individual exposure, the number of persons exposed, as well as the probability to become exposures shall be maintained as low as reasonably possible, taking into account economical and social considerations. This procedure shall be implemented under the condition to restrict individual doses (dose constraints) or taking into account the risk caused to individuals in case of potential exposure (risk constraints), in order to limit the inequity between individuals.

• **Limitation** *of doses:* People exposure resulting as a consequence of a practice shall be limited. These dose limitations shall ensure that no individuals shall be exposed to an unacceptable radiological hazard during normal conditions of work.

As a result of these obligations, nuclear operators have to define radiological objectives, in terms of dose limits, lower than the regulatory limits, according to the risk acceptance concept (see figure 1).

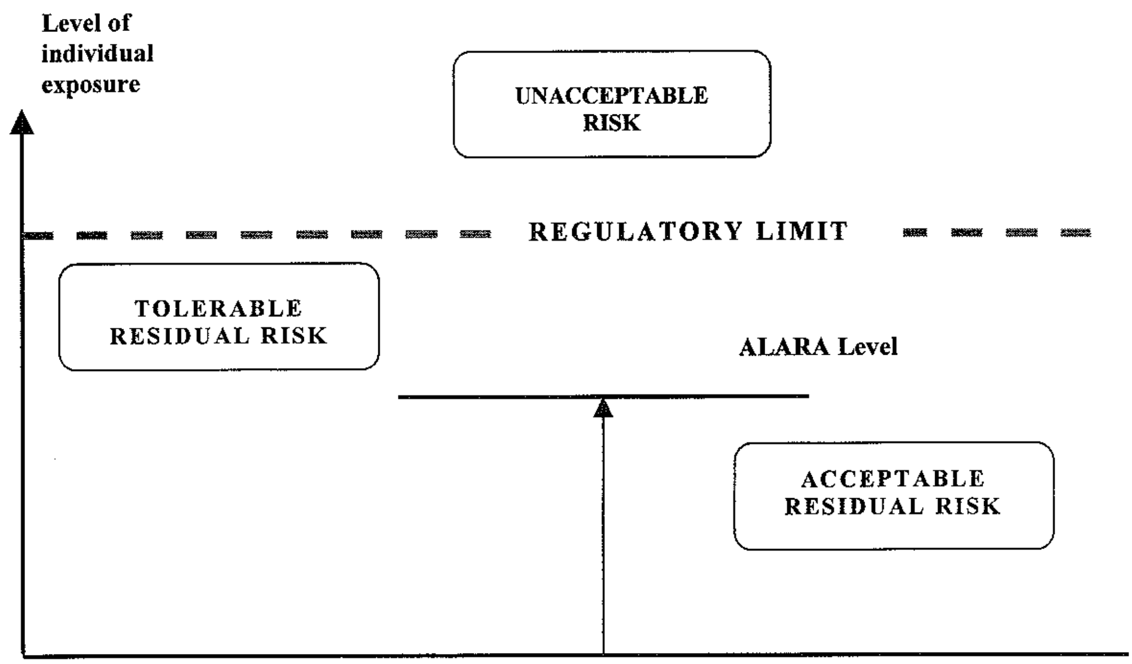

Figure 1 - The risk acceptance model

2.2- Practical considerations

◆ **ALARA program architecture**

ALARA is an approach allowing to manage and to control doses. The principle of optimization is generally achieved using a cost-benefit analysis. The architecture of the this cost-benefit analysis methodology, includes the following steps (see also figure 2 here below) [4]:

- ❑ Identification and examination of the problems to solve.
- ❑ Setting up of radiological objectives (in terms of individual and collective doses, namely).
- ❑ Identification of the different radiological options: For that purpose, a quantitative and/or qualitative evaluation of the different options through a set of performance criteria is done.
- ❑ Grading and comparison of the options, according to their qualitative or quantitative performances. For this comparison, a sensitivity analysis can be carried out, using technical tools such as dose evaluation computer codes, monetary value of the man.Sievert [5], experience feedback or other decision helping methods.
- ❑ Selection of the final solution.

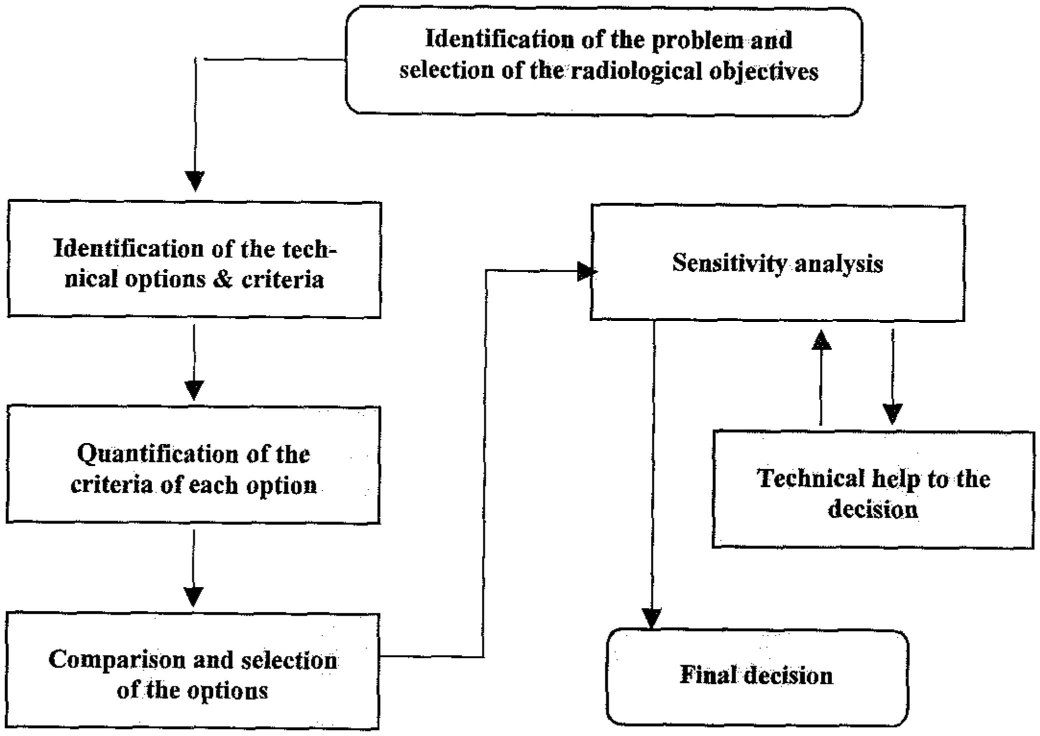

Figure 2- Implementation of the ALARA procedure

◆ **How is the ALARA procedure implemented ?**

The ALARA procedure is an iterative process, which includes three phases: a **preparation phase**, a **realization phase** and an **experience feedback phase**. Figures 3 and 4 here enclosed show how this ALARA program is implemented and which operational tools can be used in each phase [6].

In practically, the otimization procedure is realized by achieving an **operational design review**[2], which consists in a systematic pre- and post work review that ensures that ALARA controls are planed, evaluated, implemented where reasonable, and documented.

Optimization includes in this approach ALARA measures, dose saving, and intangible variables such as workers concerns, administrative concerns, ... During operations, the combination of design features and administrative control procedures guaranties that the chosen radiological objectives are met.

Design reviews can be done based on systematic procedure or upon the demand. In order to facilitate the process, and to demonstrate that a real optimization design review program has been performed, the following solutions can be recommended:

- ***Split in a chronological manner*** the whole work to be done into single operations, and associate to each one a predictive dosimetry,
- ***Identify each « critical» phase***, *from* the radiological point of view,
- ***Use appropriate means*** to maintain the exposures during theses phases as low as reasonably achievable (optimization).

Remark: *(2) An ALARA design review is a systematic review of the design, construction and decommissioning of equipment/facilities to ensure that ALARA considerations are evaluated, incorporated if reasonable, and documented for modifications to existing and new facilities that involve the potential for exposure to ionizing radiation.*

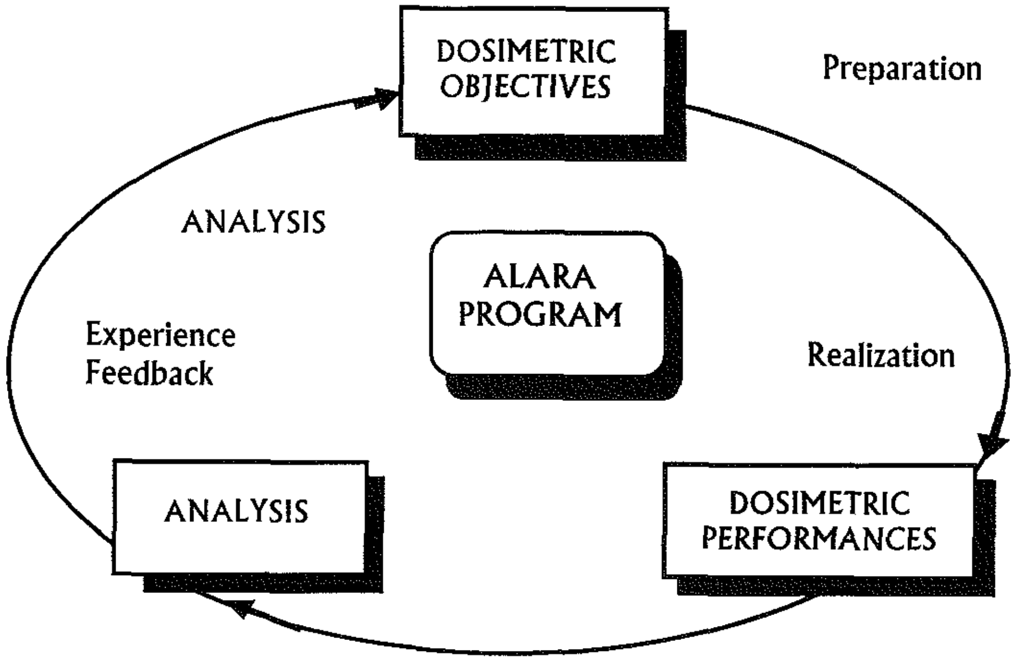

Figure 3 - Methodology for the implementation of the ALARA program

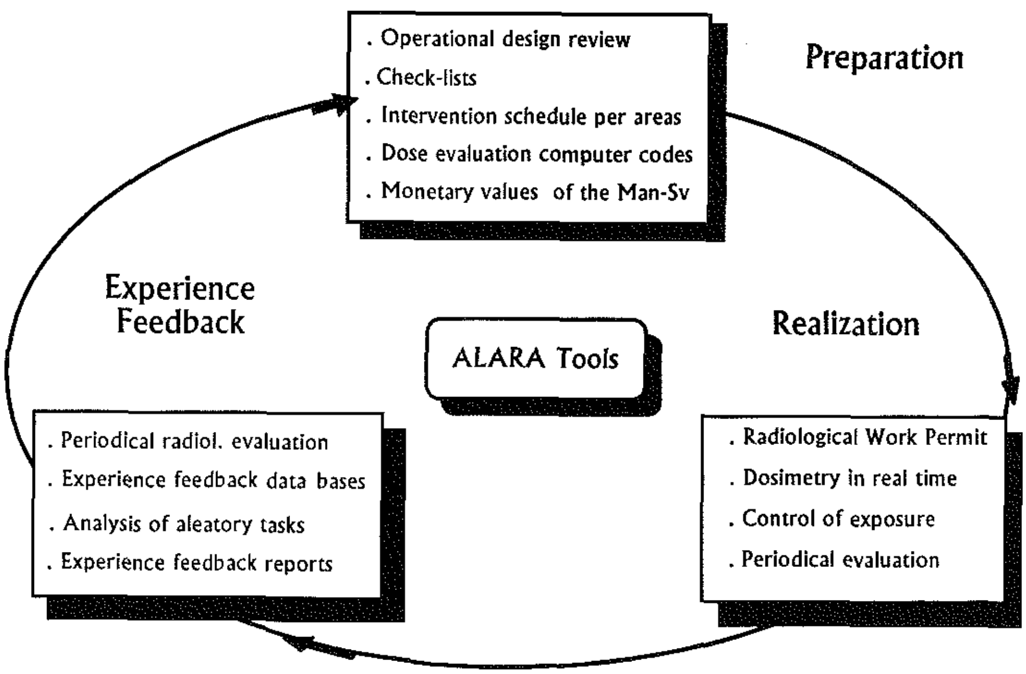

Figure 4 - ALARA tools and operational procedure

◆ **When shall the ALARA program be implemented ?**

In some countries (USA namely, US/DOE), the following statements have been proposed [7]. An ALARA operational design review is performed for any of the following:

- *Non routine jobs or operations* in which individuals receive a dose higher than **1 mSv** or where there is uncertainty in the predictive dose.
- *Routine jobs or operations* in which an individual may receive more than **3 mSv** or where doses might be significative.
- *Any job or operation* in which the collective dose is expected to exceeds the facility limit.
- *Any job or operation* in which the airborne levels may potentially exceed **10% of the DAC** (Derived Air Concentration).

◆ **Recall of collective dose**

The collective dose is defined as follows:

Duration of the intervention

Ambient dose rate → d **Number of operators** → n

Collective dose ⇨ $$S = d \, . \, t \, . \, n$$

During the implementation stage, when a reference situation has been established, the operator shall check that all exposure levels are optimized. Especially, he should ensure that no protection actions of lower cost could be defined, which could reduce exposures as low as reasonably achievable. Each action allowing exposure reduction is called an **option.**

Criteria are associated **to each option.** These criteria are generally of two types:

❑ <u>Doses</u> : the collective dose associated to the option
the collective doses associated to the various job specialities
the distribution of individual doses

❑ <u>Costs</u> : the costs associated to the radiological options
investment costs
operating costs

In the present situation, reducing exposure means acting on each component of the collective dose (ambient dose rates, intervention duration and number of workers), as for example defined here after (see also figure 5 here enclosed):

➧ Actions allowing to reduce the **ambient dose rates:**

- Protection actions : individual protection equipment
  collective protective means
- Reduction of the source: reduction, modification
  transfer, decontamination

> ***Attention:***
>
> *1 - **Individual doses**: Optimization applies to each operator and worker.*
>
> *2 - **Number of operators**: Optimization does not consist in reducing individual doses by multiplying the number of operators; it should also have an impact on the collective dose.*
>
> *3 - « **Reasonably possible** »: Optimization consists in selecting the best working conditions, according to the technical criteria, the work organization of the available solutions.*

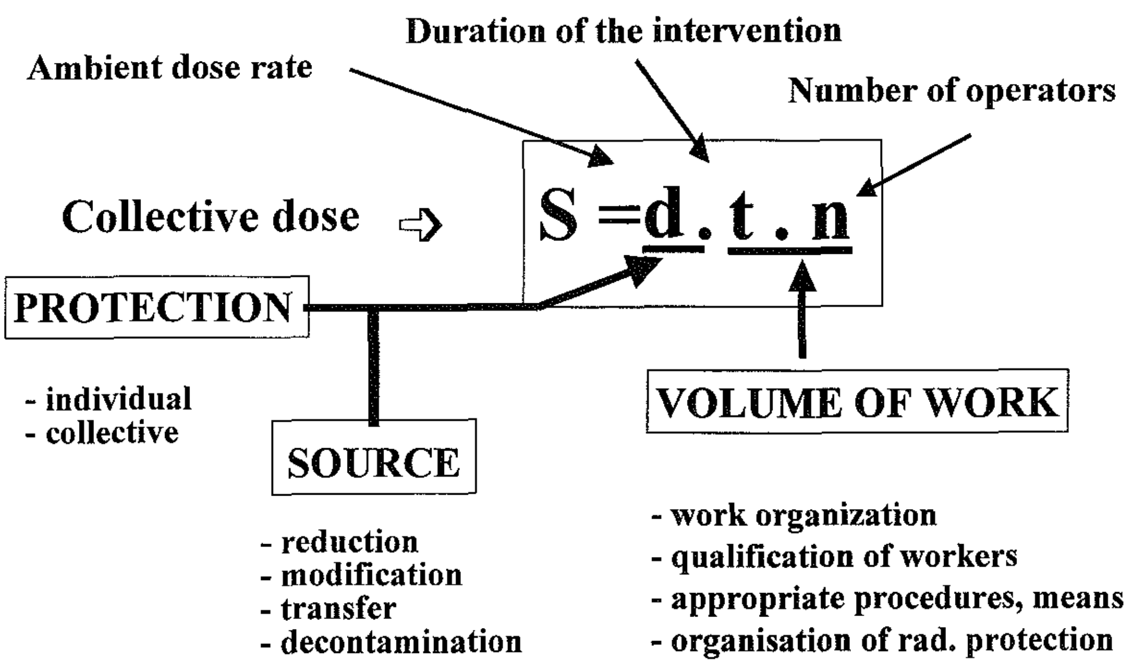

Figure 5 - Way of acting on the volume of work

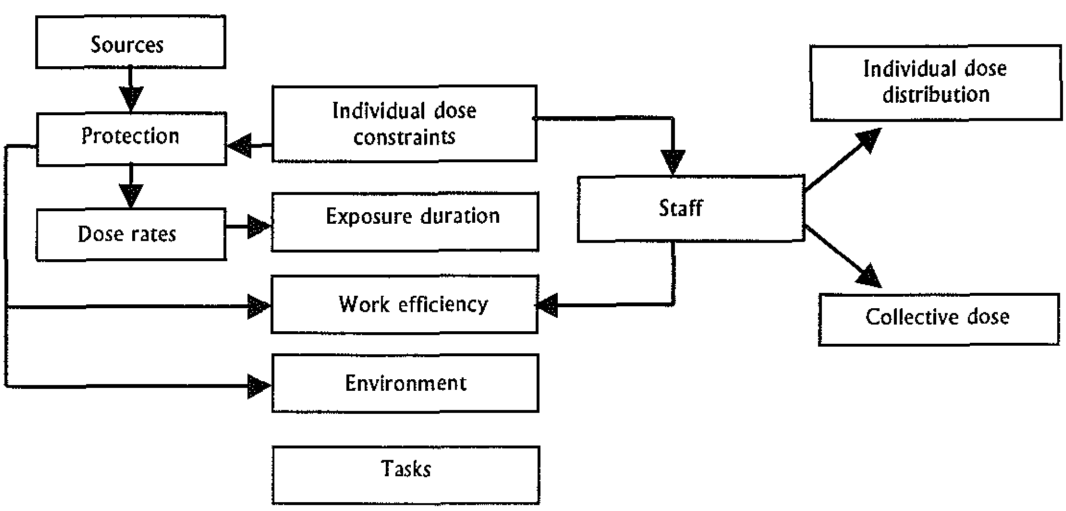

Figure 6 - ALARA Optimization procedure

➡ Actions allowing to reduce the **duration of the interventions (or the volume of work[2]):**

- Work organization : qualification of workers
  appropriate procedures
  organization of the radiation protection
  control of doses, use of experience feedback

Previous figure 6 explains the general architecture of the procedure allowing the optimization of the volume of work.

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(3) Volume of work = special concept used for defining the product [Duration of operation x Number of workers]

3 – APPLICATION OF THE ALARA PRINCIPLE TO DISMANTLING OPERATION

3.1 – General guidance

For dismantling operations the following rules can be applied:

◆ Individual as well as collective doses shall be considered.

◆ Radiological objectives shall be set up by nuclear operators, according to the state of the residual surface contamination and/or the ambient external exposure level (dose equivalent rate) inside the buildings, rooms and equipment to be dismantled.

● The type and the quality of the implementation of the ALARA procedure shall be adapted to the amount of dose involved (called radiological importance).

The enclosed tables 1 and 2 provide an example of guidance which can be used by the nuclear operator when implementing the ALARA procedure for dismantling operations. The key point of this method is to associate to each category of radiological challenge (low level risk, medium level risk and significant risk) the minimal obligations imposed to the nuclear operator: number of options to compare, performance criteria to take into account, use or not of technical helps for option evaluation, taking into account experience feedback, ...

◆ Criteria to consider for the design review.

The criteria to be taken into account and compared for the choice of the optimal options are:

- possible of elimination of hot spots or use of radiation shielding,
- consideration of the duration of each individual task,
- impact of each individual task to the next one,
- number of operators concerned,
- availability of workers according to their skill and social benefit,
- summation of doses with respect to the total radiological dose credit,
- nature and quantity of waste produced, capability of evacuation,
- ratio « financial cost/dosimetric cost », according to the reference monetary value of the man.Sievert in the considered dosimetric range.

3.2 – Application to the dismantling of a heavy water gas cooled research reactor

The methodology used in this example by CEA, is based on the main following considerations [8]:

◆ **Work organization**

Operations are divided into tasks called individual work units. Tasks are classified into categories, according to the level of ambient dose (see table here below).

For each task, sub-contractor companies have been requested by CEA to demonstrate before starting the work, how the radiological optimization will be achieved, according to the following rules:

- **Tasks of category 1 and 2.** Three alternative scenarios shall be considered, with the associated cost and predictive dosimetry. Selection is done on the basis of a multi-criteria method. This procedure is called *« specific operating mode ».*
- **Tasks of category 3 and 4**. Optimization has to be done using one single scenario. Radiological options and predictive dosimetry shall be provided. This procedure is called *« standard operating mode ».*

Category of task	Airborne contamination within the working area	Dose rate within the working area
1	80 to 4000 DAC	2 to 100 mSv/h
2	1 to 80 DAC	25 µSv/h to 2 mSv/h
3	0,3 to 1 DAC	7,5 to 25 µSv/h
4	< 0,3 DAC	< 7,5 µSv/h

◆ **Radiological objectives**

They should meet the following:

- A **collective dose of 2 man.Sv** or less for the whole work.
- An **annual individual dose** for the most exposed worker ≤ **10 mSv** (including internal and external exposure)
- The CEA has requested all sub-contractors to meet a lower annual dose limit **(5 mSv/year)** in order to implement more carefully the ALARA optimization process. This second limit as called the dose constraint.

3.3 – Conclusion

For dismantling operations, the radiological objectives taken into account in the previous example, can be considered as realistic, compared to the level of the predictive exposure (less than 10 mSv/year) and the potential for unforeseen difficulties during this type of work.

CEA decision to impose a dose limit of 5 mSv/year to all sub-contracting companies meets the third ALARA obligation (dose limitation) and represents a good contribution to the implementation of the ALARA process.

4 – REFERENCES

[1] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, IAEA, Vienna, 1996.

[2] Official Journal of the European Communities - European Directive 96-29/Euratom, 13 May 1996.

[3] Recommendations of the International Commission on Radiological Protection, ICRP Publications 26 and 60, Annals of the ICRP, Pergamon Press, Oxford (1987), (1991).

[4] A. OUDIZ and al, *Une approche pragmatique de l'optimisation*, Journées SFRP, La Rochelle, 9-10 juin 1998, France.

[5] Rapport CEPN N° 254, Valeurs monétaires de l'Homme-Sievert, du concept à la pratique, résultats d'une enquête internationale, C. LEFAURE, Septembre 1998.

[6} C. SCHIEBER and al, *Les principaux aspects de l'intégration de la gestion du risque radiologique dans le management global de l'entreprise,* Journée de sensibilisation à la démarche ALARA, INSTN Saclay, 14 Octobre 1998, France.

[7] DOE Standard, *Applying of the Alara Process for Radiation Protection of the Public and Environmental Compliance with 10 CFR Part 834 and DOE 5400.5 ALARA Program Requirements*, Volume 1, Discussion, DOE-STD-ALARA1draft, Washington, 20585, April 1997.

[8] Note Technique SMA/RAD/NT/98/0032, *Optimisation en matière de radioprotection lors du déclassement du réacteur de recherche du Site des Monts d'Arrêe*, France.

Table 1 - Operational approach recommended for dismantling operations, depending on the radiological challenge

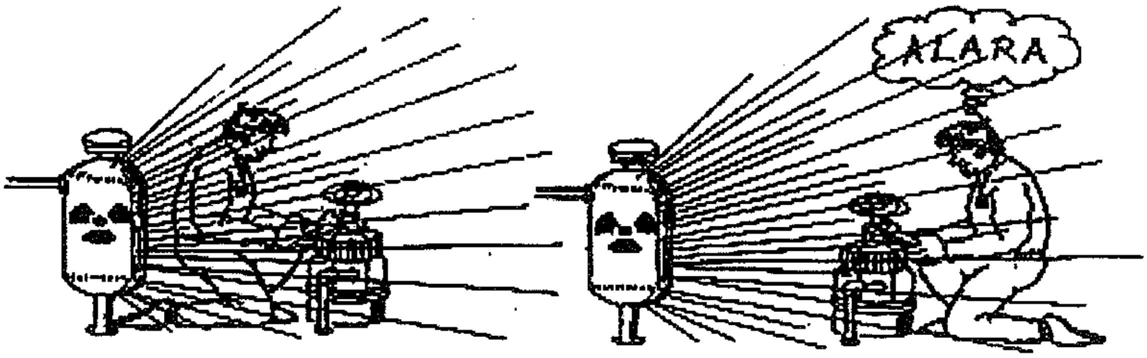
Process implemented by the nuclear operator	High challenge (Significant radiological risk)	Medium challenge (medium radiological risk)	Low challenge (low radiological risk)
Planning of the operations and dosimetry predictions	yes	yes	yes
Radiological objectives	yes	yes	yes
Number of options to compare	many	many	2 or 3
Performance criteria to take into account: - cost if the different options - indirect benefit	yes yes	no necessary no necessary	no no
Options evaluation and selection: - qualitative comparison - use of a tool to help to the decision	yes, if sufficient yes, if helpful for the nuclear operator	in general, sufficient no	in all cases, sufficient no
Experience feedback	elaborate	yes	yes

Table 2 - Proposal for a classification and definition of radiological challenges for dismantling operations

	Collective dose (Man.mSv)	Mean individual dose (mSv)	Mean individual dose / 2 (over the duration of a single operation, per month) (mSv)	Example
Significant radiological risk	> some tens	> 1	> 1	10 mSv over 3 month $\left(\frac{10}{2x3} = \frac{5}{3} \right)$
Medium radiological risk	> some tens	> 1	1	12 mSv over 9 month $\left(\frac{12}{2x9} = \frac{2}{3} \right)$
Medium radiological risk	any	< 1	> 1	1 mSv over 0,25 month $\left(\frac{1}{2x0{,}25} = 2 \right)$
Medium radiological risk	< some tens	1	> 1	> 1
Low radiological risk	any	< 1	< 1	1 mSv over one month $\left(\frac{1}{2x1} = 0{,}5 \right)$

ALARA

ALARA : a good feeling .....



But ..... not always optimization