ALARA AND WORK MANAGEMENT

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ABSTRACT

At the request of Electricité de France (EDF) and Framatome, the Nuclear Protection Evaluation Centre (CEPN) developed a three-year research project, between 1991 and 1993, to evaluate the impact of various work management factors that can influence occupational exposures in nuclear power plants (NPPs) and to assess the effectiveness of protective actions implemented to reduce them.

Three different categories of factors have been delineated: those linked to working conditions (such as ergonomic of work areas and protective suits), those characterizing the operators (qualification, experience level, motivation, etc.), and the factors directly dependent on the operation's organization (tasks planning, general preparation of works, etc.). In order to quantify the impact of these factors, a detailed survey was carried out in five French NPPs, focusing on three types of operations: primary valves maintenance, decontamination of reactor cavity, and specialized maintenance operations on the steam generator. This survey was augmented by a literature review on the influence of "hostile" environment on working conditions. Finally, a specific study was performed in order to quantify the impact of various types of protective suits used in French nuclear installations according to the type of work to be done. All of these factors have been included in a model aiming at quantifying the effectiveness of protection actions, both from dosimetric and economic point of views.

INTRODUCTION

The application of the ALARA principle to the management of occupational exposure implies to adopt an analytical approach in order to identify the relevant factors contributing to the formation of individual and collective exposures. Within these factors, all procedures and actions which can influence the duration of exposure and the number of exposed workers come under the heading of "Work Management."[1]

Within the framework of their ALARA programs, EDF (Electricité de France) and FRAMATOME have initiated a pluri-annual research project conducted by the CEPN (Nuclear Protection Evaluation Centre), in order to delineate the various factors related to work management which can influence occupational exposures and to evaluate the effectiveness of possible protection actions influencing these factors.

Different categories of factors have been delineated. A quantification of the impact of some working conditions have been done. Finally, all of these factors have been included in a model aiming at quantifying the effectiveness of protection actions, both from dosimetric and economic point of views.[2]

RELEVANT WORK MANAGEMENT FACTORS

The objective of applying optimization of radiation protection by the way of work management is mainly to reduce the time spent in radioactive areas and the number of workers exposed. While analyzing the total exposed time resulting from any maintenance operation, it appears that it can be split into two main parts: the "productive" and the "non-productive" time. The productive exposed time can be defined as the time which is technically necessary in order to complete the task, given the state of the technology and the set of working conditions. The non-productive exposed time usually results of mishaps due to a bad training of workers, malfunctioning of tools, etc.

Various factors having direct or indirect impacts on the productive exposed time have been identified. They can be grouped together into three main categories:

1) Working conditions

- Individual protection
- Collective protection
- Noise, light, thermal conditions, etc.
- Dimension of the working area
- Ambient dose rate
- Adaptation of tools
- Video or audio links
- Shift work conditions

2) Worker characteristics

- Qualification
  - Radiation protection education
  - Specific specialty related training
  - Specific task related training
- Experience
  - Individual experience
  - Transfer of experience between teams
- Motivation
  - Individual motivation
  - Management commitment

3) Work organization

- Scheduling of tasks
- Preparation of working areas
- Preparation of equipments
- Level of information of the workers

A modification of one or several working condition factors will have a direct impact on the productivity of workers and then influence directly the productive exposed time. The factors characterizing the operators will modify the productive exposed time and mainly the nonproductive one, which is usually due to a bad knowledge of working areas and tasks to be performed. The general work organization will particularly affect the nonproductive exposed time.

The above factors may be quantified by first creating for each factor a scale of values describing different possible situations. The second step is the quantification of the impact on productivity and doses of moving from one situation to a "better" one, either for one factor or for a combination of factors. This quantification would result in determining time modification coefficients corresponding to the previous scales of values. It is then possible to predict the impact on exposure time of any action improving the situation.

ESTIMATION OF IMPACT OF FACTORS

Impact of Protective Suits

In order to assess the impact of protective suits, a specific study on mock-up was performed.[3] Three different mock-ups were used to take account of the effect of ergonomic parameters like the level of effort, the need for precision or the task duration.

- The first mock-up was a steam generator channel head where a maintenance spider (20 kg) had to be installed and removed. This represented a heavy and precise work of short duration in a very congested area.

- The second mock-up was a "big" valve (12-inch) where the workers had to unscrew, remove, and screw 12 nuts (of 0,9 kg each). It was a heavy work, not very precise, in a less congested area with a long duration.

- The third mock-up was a "small" valve (2-inch) modelizing a long precise work in a congested area. The workers had to remove, place, and adjust two limit switches.

Eight clothing situations have been selected, representing protective suits of both French nuclear power plants and nuclear industry:

Suit 1 : 1 cotton coverall and 1 set of cotton gloves = "Reference"

Suit 2 : 2 cotton coveralls, 2 sets of rubber gloves, 1 respirator, 1 cotton hood

Suit 3 : 2 cotton coveralls, 1 rubber overall suit, 3 sets of rubber gloves, 1 air supplied respirator, 1 cotton hood

Suit 4 : 2 cotton coveralls, 1 rubber coverall, 3 sets of rubber gloves, 1 respirator, 1 cotton hood

Suit 5 : 1 cotton coverall, 1 rubber coverall, 1 set of cotton gloves, 1 set of rubber gloves, 1 air supplied hood

Suit 6 : 1 cotton coverall, 1 air supplied overall suit, 1 set of cotton gloves

Suit 7 : 2 cotton coveralls, 1 air supplied overall suit, 3 sets of rubber gloves, 1 air supplied respirator

Suit 8 : 1 cotton coverall, 1 air supplied overall suit, 1 set of cotton gloves (this suit has only been used for the steam generator mock-up)

Nine workers were timed on each mock-up, with every suits. Then, an average percentage of time difference was calculated for each mock-up and each suit, with the first suit always used as the reference.

The main results of this study are presented in Table 1.

Table 1. Impact of protective suits on exposed time

	Case 1: - Permanent concentration - Precision work - Heavy effort - Duration <2 mns - Very restricted workspace - Uncomfortable posture	Case 2: - Permanent concentration - Precision work - Heavy/light effort - Duration < 10 mns - Restricted workspace - Uncomfortable posture	Case 3: - Nonpermanent concentration - "Non precision" work - Heavy effort - duration <10 mns - Not much work space - Comfortable posture
Non ventilated cotton clothing			
Clothing 2: Cotton coverall + mask	34% (±17)	34% (±14)	19% (±14)
Non ventilated impervious clothing			
Clothing 3: Non ventilated Chadoc + ventilated mask	34% (±19)	65% (±20)	21% (±13)
Clothing 4: Impervious clothing + mask	29% (±8)	46% (±18)	25% (±13)
Clothing 5: Impervious clothing + ventilated hood	28% (±12)	27% (±16)	22% (±10)
Air-fed pressurized clothing			
Clothing 6: Air-fed pressurized Mururoa	30% (±11)	42 (±24)	8% (±4)
Clothing 7: Air-fed pressurized Chadoc + ventilated mask	51% (±12)	57% (±25)	16% (±14)
Clothing 8: Shrunken air-fed pressurized Mururoa	21% (±12)		

Dose Rates as a Working Condition Factor

Usually, the impact of dose rates is taken into account when workers have to perform a job in high ambiences. In this case, it is well known that the stress resulting from the dose rates can influence the productivity of workers. For such operations, the workers should perform a specific training to lower the potential effect of dose rates on the technical performance of the operation.

The analysis of feedback data concerning some specialized maintenance operation has pointed out another effect of dose rates which could be called the "lax" effect: when the same operation is performed in various radiological conditions, the lower is the ambient dose rate, the longer the time is spent to perform the job.

For example, the analysis of the collective exposure associated with the machining of Residual Heat Removal System heat exchangers performed on 17 French units between 1984 and 1988 by nearly the same team, revealed clearly this type of behavior. The trend of the collective dose without any reference to the associated dose rate, shows that an asymptote is reached starting from the eighth operation and the collective dose is nearly equal to 50 man-mSv for the last seven operations. However, the various operations have been performed in different ambient dose rates.. In order to make a true comparison of the exposure associated with the operations, the collective dose has to be related to the same value of ambient dose rate. It can then be seen that the "normalized" total doses of the last seven operations vary widely (see Figure 1).

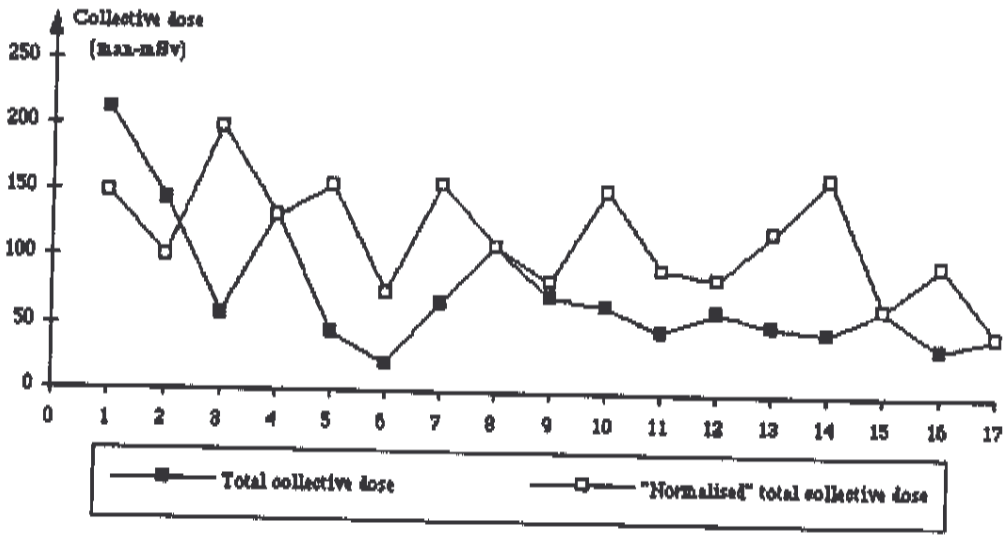

Figure 1. Evolution of the collective dose for the machining of RHR exchangers

The comparison between the "normalized" total collective dose (which in fact represents the level of exposed time) with the level of ambient dose rate reveals an inverse relationship between the level of dose rate and the exposed working time. This is shown on Figure 2, especially for the last operations when the workers are "used" to receive a collective dose of 50 man-mSv. As long as they have not reached the 50 man-mSv level, they are not really concerned by the level of exposure, considering they still have some "dose credit".

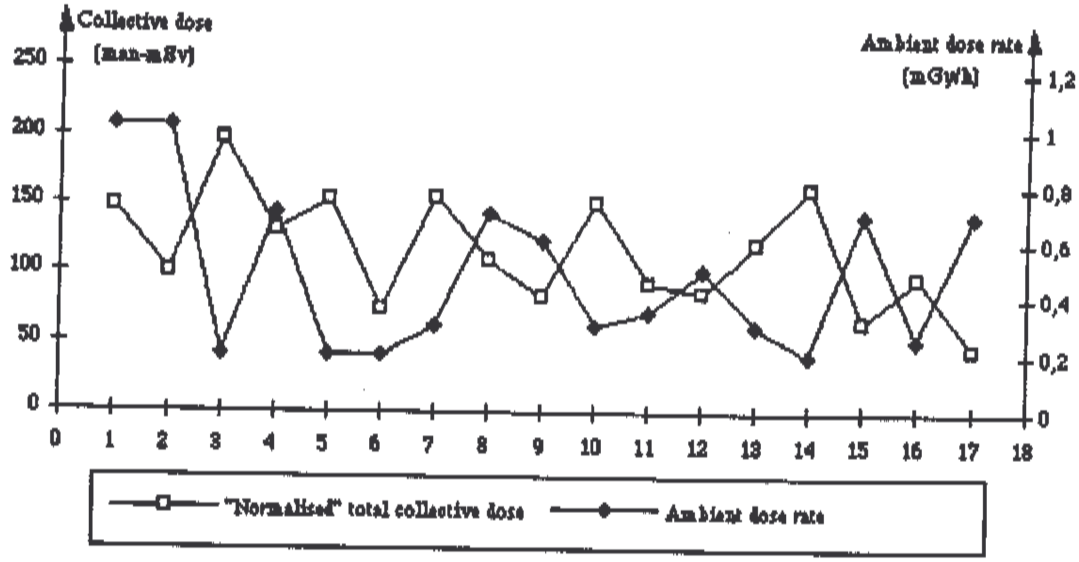

Figure 2. Evolution of the "normalized" total collective dose and the ambient dose rates for the machining of RHR exchangers

This type of result demonstrates the need for adequate estimates of collective doses before each job taking into account the actual ambient dose rate, and for a proper information of workers and health physicists before starting the work.

Other Factors

In order to quantify the impact of the above listed factors, a review of the literature was performed. It allowed to estimate the impact of the modification of some working conditions on exposed time. These results have been complemented by a survey carried out in five French nuclear power plants and focused on three types of operations: primary circuit valves maintenance, decontamination of reactor cavity and some specialized maintenance operations. Eighty persons (workers, foremen, health physicists, planners, etc.) have been interviewed about their perception concerning the impact of working conditions on the exposed work time, and on the main causes of mishaps.

As far as the ergonomic literature is concerned, most studies are focused on the potential "physiological" impact of working condition factors on workers. Very few deal with the impact of these factors on productive time. Table 2 presents a summary of both literature and survey results.

Table 2. Impact of working conditions factors on exposed time

Working conditions	Literature and survey
Training	- Savings between 30 % and 40 % in exposed time
Light	- 20 % of exposed time can be saved by good lighting of working areas.
Audio links	- 20% of exposed time can be saved (decontamination of reactor cavity).
Working space	- Not very congested area: increase up to 20 % of exposed time. - Highly congested area: increase up to 40 % of exposed time.

The "Benefits" of ALARA Programs

After the discovery of cracks on some reactor vessel head penetrations in 1991, it was decided to inspect and, if necessary, repair part of the 900 MW and 1300 MW units' vessel heads in France. Because of the urgency of the situation, and in the absence of feed back experience in this domain, the first operations didn't benefit from a good preparation. This situation leads to an "abnormal" number of mishaps. The application of a specific ALARA program for these post-incidental jobs started by the beginning of 1992. Given the number of involved units, and the great haste of operations, the degree of integration of ALARA procedures differed largely from one operation to another. The analysis of the average percentage of mishap dose for the same operations as a function of the degree of integration of ALARA at the different stages of the preparation, follow up, and feed back experience analysis, shows a direct link between these two factors (see Table 3).

Table 3. Average percentage of mishaps for 22 jobs on reactor vessel heads

Degree of integration of ALARA programs	Average percentage of dose due to mishaps (min-max)
No application of a structured ALARA procedure.	70 % (50 - 80)
No specific ALARA preparation, but application of the ALARA procedure during the operation.	40 % (30 - 50)
ALARA preparation and follow up, but no full technical control of the operation.	30 % (15 - 40)
ALARA preparation and follow up, and use of feed back data from previous operations.	10 % (0 - 30)

At the beginning of 1993, EDF estimated that 5 man-Sv had been saved on the vessel head operations by implementation of ALARA programs.

CONCLUSION

The integration of ALARA within work management procedures is obtained by analyzing precisely the operations from the angle of their associated exposed time. The latter is influenced as much by good general organization of tasks (including planning, preparation of working areas, etc.), as by some specific actions improving working conditions. We have seen here some quantification of factors in terms of their direct impact on time of exposure. The direct impact of general organization is more difficult to quantify. Nevertheless, some studies on causes of mishaps occurring during outage maintenance jobs in French nuclear power plants have shown that up to 30% of mishaps' dose can be attributed to organization problems (planning, scheduling...).[4] A study of outage organization in four different nuclear power plant from various countries has then been performed. It allowed to highlight some "good practices" favoring the implementation of ALARA programs.[5] The main conclusion can be summarized in six points :

- Integration of radiation protection criterion in the overall outage process, from planning stage to feed back experience.
- Management commitment.
- Effective coordination and collaboration of all sections concerned by the outage.
- Important decision making power of health physicists.
- Feed back data bases for jobs, doses, dose rates...
- Motivation and commitment of all actors towards ALARA principles.

REFERENCES

1. **Work Management to Reduce Occupational Doses**, Proceedings of an NEA Workshop, Paris, 4-6 February 1992.

2. Schieber C., **Optimization de la radioprotection et organization du travail**, Rapport CEPN R-227, To be published in May 1994.

3. Schieber C., **Equipements de protection individuelle en milieu nucléaire : impact sur les temps d'exposition** Rapport CEPN R-226, To be published in May 1994.

4. Schieber C., **ALARA and Work Management**, Radiation Exposure Management Seminar, Pittsburgh, September 1994.

5. Margerie H. et al., **ALARA and the Organization of Outages in Nuclear Power Plants: an Intentional Perspective**, IRPA Regional Congress, Portsmouth, June 1994.

Author Biography

Caroline Schieber has been a researcher for four years in the Nuclear Protection Evaluation Centre (CEPN) in France. she has been working mainly on the implementation of ALARA programs on nuclear power plants through work management actions and in the definition of a system of reference monetary values for the unit of collective dose. She has a masters in economics.

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