Summary and Recommendations of the 3rd European ALARA Network Workshop on "Managing Internal Exposure" Neuherberg, Germany, November 1999

Predictable and accidental internal exposures

Within the Western European radiological protection culture an approach often advocated is to minimise internal exposure in all situations. However the Workshop identified that there are two main categories of situations and that these are amenable to different approaches.

The first type of situation involves "predictable internal exposures". Such exposure situations are often encountered in the front end of the fuel cycle (mining, uranium refinement, fuel fabrication…) as well as in the industries using Naturally Occurring Radioactive Materials (NORMs), and in some aspects of decommissioning. In all these situations, the exposure whilst not continuous does occur with a reasonably predictable pattern and the air contamination is often the result of the worker's own activities. The estimated doses are, with few exceptions, lower than the dose limits, but can reach a significant fraction of it "Doses are typically in the range 0-5 mSv, and in some cases, 10 mSv or more. Where doses are high, the internal component is the dominant exposure pathway" (Hipkins, Shaw). In many such situations an approach that minimised dose from internal exposure might result in excessive costs or an increase in external exposure that exceeded the savings in dose from internal exposure. In such situations the ALARA principle can be applied to controlling the doses and therefore must be applied.

The second type of situation covers "accidental internal exposures" or "probabilistic internal exposures". These exposure situations correspond to work activities which, if no preventative measures are taken, could result in significant internal exposure. The probability of such exposure is often low but, if intakes do occur, the dose limit could be exceeded. The tendency then is to apply a broad "cautionary principle" approach and seek to eliminate exposures via both engineering methods (containment…) and the use of personal protective equipment. "The design should remove the worker from the hazard by appropriate engineered reliable barriers. The use of appropriate technology, remote operation and maintenance should provide an operating system where human intrusion is minimised." (Simister). In such situations, the main objective is the minimisation of the probability of occurrence of the accident.

Lack of statistics

From the papers presented and the discussion sessions it was clear that within Europe for internal exposure there is little data on the numbers of workers concerned (even to an order of magnitude) as well as on their internal doses distribution. As may be seen in Table 1, internal exposures are not always included into the national statistics regarding occupational exposure and, even in those countries where they are included into these statistics, the data are far from being exhaustive, particularly for the industries related to NORMs.

Table 1. Integration of individual internal dose assessment into national occupational exposure statistics

Country	Internal Doses included into national statistics
Belgium	No
France	No
Finland	Yes
Germany	Not yet
Italy	No
The Netherlands	Yes
Norway	Yes
Spain	Yes
Sweden	Yes
UK	Yes

Recommendation 1

The meeting identified that there was limited data, at the national regulatory body level, on the number of workers exposed to intakes and the profile of the dose received. It is recommended that the Commission and the regulatory bodies pursue efforts to improve the data. Of particular concern is the area related to doses from the use of NORMs.

Impact of dose assessment complexity on inconsistencies and difficulties to manage and communicate

Unlike in external exposure, it is often difficult to predict the levels of intake and hence the doses associated with internal exposure, because many variables come into play. The problem is compounded by the difficulties encountered in accurately measuring the actual intakes of many isotopes. Over the years, research has improved our understanding of physical and biological characteristics of internal exposure and the accuracy of the pulmonary, digestive, biokinetic and irradiation models. However, progress in these fields is still needed and the Workshop gave the opportunity to different stakeholders to present their point of views on the necessary improvements.

A number of internal dosimetry specialists provided presentations covering inter-comparison exercises (e.g. 3rd EULEP/EURADOS European Inter-comparison, IAEA surveys of inter-comparisons) showing that the assessment methods used vary largely from one country to another and even from one utility to another. Large variations in the intake and dose assessment results were observed, essentially due to the variety of the different biokinetic models and software tools used. Misinterpretation of instructions (i.e. the exposure scenario) and inconsistencies between dose factors and models used (new -old or old - new) were also put in evidence. "Internal dose inter-comparisons (mSv) reveal commonly larger differences in the results than measurements inter-comparisons (Bq). Depending on the case, the differences vary from a factor ten to several thousands." (Beyer, Dalheimer). "As a result, the mixed use of different models and dose factors can lead to results which are not scientifically based and also lead to greater inconsistencies." (Cruz Suarez, Gustafsson). These specialists concluded that there is a strong need for harmonisation of the evaluation procedures especially for the radionuclides with high radiotoxicity.

These uncertainties in the dosimetry results bring into question their utility in the practical management of the hazards. In the discussions, managers from different industries clearly expressed their needs. They are looking to have at their disposal measurement tools and standardised methods of interpretation corresponding to a good compromise between accuracy of the dose assessment and the ease of the use of monitoring and results. Therefore they require from the researchers that "they recognise operational radiological protection services as customers, and aim for as simple and transparent models as possible" (Britcher). They also consider as fundamental the participation of the persons to be protected in the management of their doses and the trust of these individuals into the dose monitoring and assessment systems. Hence there is a requirement that follow up procedures be as simple and as easy as possible to understand by the workers. They also advise to communicate with the workers in terms of mSv rather than Bq, in order to allow the workers to put into perspective the external and internal risks. "Don´t speak about becquerels…. Tell a person, that an internal dose is so much in mSv and that it has the same effect as an equally large external dose." (Sundell)

Recommendation 2

The assessment of internal exposure often involves a wide range of parameters, which can lead to complex mechanisms to assess doses. These complexities provide problems for the communicating of dose information to the workforce and others, and in the ongoing management of doses. Thus there is a judgement to be made between the scientific accuracy and the ease of assessment/operational usefulness of the data. Where doses are not a significant fraction of the dose limit the meeting was strongly of the opinion that the ease of assessment should be the dominant factor in determining approved dosimetry, with more complex measurement protocols only being invoked for higher doses. This recommendation is mainly directed to regulatory bodies and monitoring laboratories.

Needed qualities of measurement methods to implement ALARA

When, three decades ago, the process of implementing ALARA for external exposure was just starting, the use of film badge dosimeters, or even TLDs, could not provide in most cases answers to the questions: when, where and how were the doses received? Without this information it was thus difficult to answer the question "What could be done reasonably to reduce individual and collective exposures? " Since then, much has been done in order to assess and follow up as realistically as possible the external doses per job, task, category of workers etc. Several generations of electronic dosimeters have been developed, feed back experience computerised data bases have been set up, ALARA programmes have been elaborated and implemented…

Concerning internal exposure, one fundamental question raised during the Workshop was then:

"Have we adapted tools and strategies to provide answers to the "when, where, how and what" questions for "predictable" internal exposures?" (Lefaure)

In other words, are the tools available for the assessment of individual and collective internal doses, enough realistic, sensitive and analytical to allow the identification of the main sources of exposure and the selection of the optimal protection options, for individual dose levels by far lower than annual limits? To achieve this, are the measurement intervals shorter than the task duration?

As far as bioassays are concerned, it was clear from the Workshop that they cannot (and are unlikely ever to be) able to provide operational monitoring for "predictable exposure situations". For many reasons (cost, burden of work, worker acceptability…), even when they are performed regularly, their frequencies are not less than monthly intervals. Very often, the incorporation time profile of the worker between two measurements is not known and this may result in significant uncertainties on the dose assessment. In many situations, measurements below the detection limit could be compatible with annual doses equal or higher to the annual dose limit; this has been illustrated in the case of natural Uranium processing or Ra 226 arising from insoluble sulfates in oil and gas facilities, where the results of yearly lung counting correspond respectively to 50 mSv (Degrange) or 400 mSv (Van Weers). For these reasons, the bioassays are not useful to set up any operational internal dosimetry system for "predictable doses". However, even for that type of exposure situations, the bioassays remain very useful to assess the dose after an incident or accident.

Several presentations from sectors as different as radio-pharmaceutics, nuclear or phosphorus industries (Ardissimo, Bricher, Degrange, Erkens, …) have then shown that air samplers are much more adequate for providing an operational dosimetry than bioassays. The Static Air Samplers (SAS) allow a daily follow-up of the "sources" but do not allow any analysis of the contribution of individual tasks to the overall exposure, nor an operational assessment of the workers exposure. Personal Air Samplers (PAS) are the only method, which in theory provide that capability, particularly as in many cases the intake is directly due to the workers activities; i.e. the workers activities produce particles in suspension at the workers breathing zone. Representatives of Sorin Biomedica, British Nuclear Fuel (BNFL), Comurhex Uranium refinement plant and Termphos phosphorus production plant have particularly pointed out this point.

The adequacy of the different measurement methods to optimisation is summarised in Table 2 from Degrange

Table 2. Adequacy of measurement methods to optimisation (Degrange)

	Air sampling				**Bioassays**	
	Collective	Individual			Urinary excreta	Lung retention
		5 L/h	120 L/h			
Measurement periodicity	1day	5 days	5 days	1 day	30 days	180 days
Sources	Good	Average	Average	Average		
Tasks	Average	Good	Good	Very Good		
Operators	Insufficient	Good	Good	Very Good	Average	Very insufficient

The characteristics of the available SAS and PAS devices that are used up to now still raise many problems when optimisation of radiological protection is the objective.

Through a survey of many studies performed in different sectors, Witschger has shown that the ratio between PAS and SAS measurements may reach several orders of magnitude (see Figure 1)

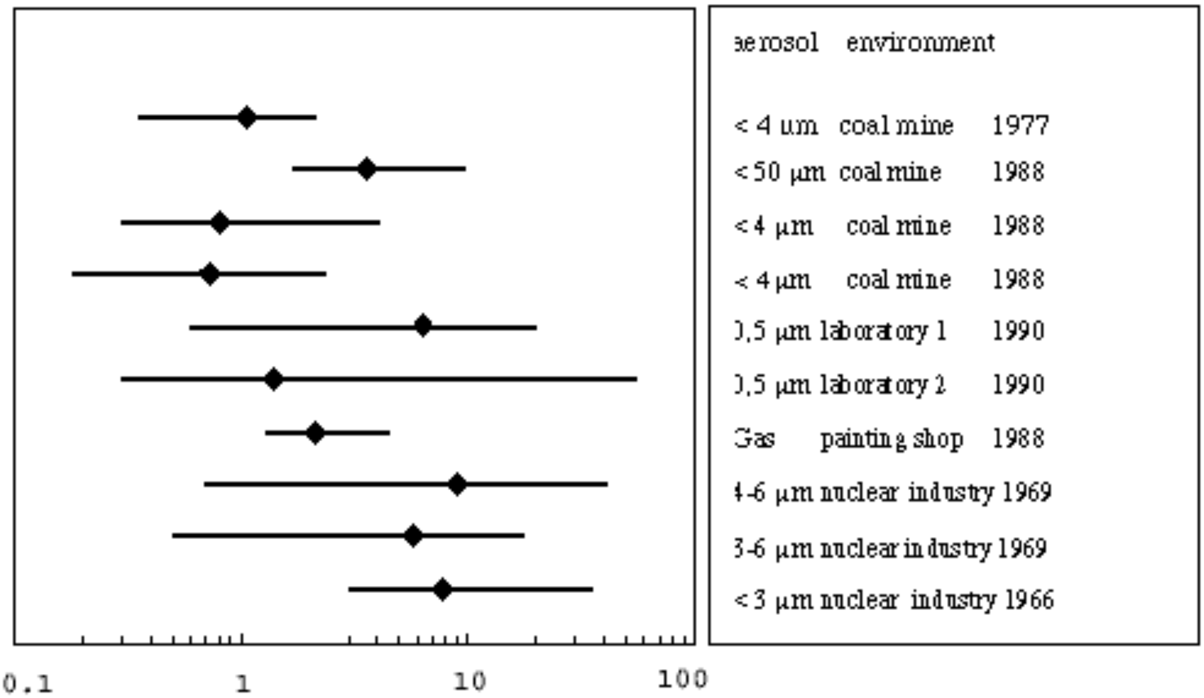

Figure 1: Ratios of personal measurement / static concentration measurement (Witschger)

In many circumstances it has been seen that SAS greatly underestimate doses. This is always the case when the dose is only due to the worker activity. Personal air sampling is then the only measurement method whose results might be close to the actual inhaled air concentration. However, when the air sampling rate is too low, when the particle size is high and when the radiotoxicity of compounds is important, the representativeness of the air sample in the PAS may be insufficient: a single particle may "disrupt work and home life for nothing"(Britcher). So even though the personal sampling measurement is usually considered much more representative of the aerosol in the breathing zone than the static sampling measurement, "the personal sampling may(still) be inaccurate and imprecise"(Witschger). Some new PAS sample the air at a high rate close to the breathing zone, but they are quite heavy (one kilo or more). Those problems explain that the unpopularity in most situations of the PAS among the workforce is not only due to the inconvenience of their use during the work, but also to the lack of trust and confidence in their results.

Therefore there is much to be done to select or develop adequate personal air sampling tools and to find monitoring strategies appropriate to the optimisation of radiological protection and acceptability from the workforce.

Recommendation 3

Not withstanding the above recommendation, there is a need to pursue efforts to improve the quality and accuracy of internal dose monitoring techniques (particularly personnel air sampler) to fit with the specifications needed for analytical task dosimetry. The meeting recommend to the Commission and regulatory bodies, that they support research in that area.

Where PAS are used as part of the implementation of the ALARA programme, the organisations that use them have developed strategies to ensure the acceptability of the measurement regimes by the workforce. Very often, PAS are only used during specific campaigns, when needed "for analytical purpose" (Sorin Biomedica) (Comurhex). However a few utilities have set up more formalised strategies, as illustrated by the figure 2 from BNFL, where PAS are sometimes routinely used.

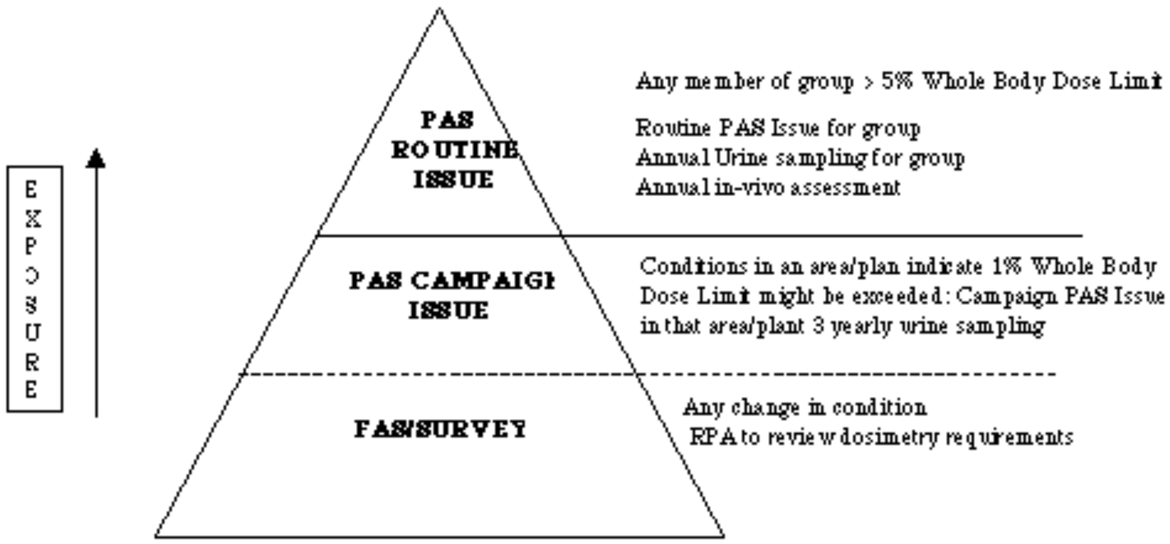

Figure 2: BNFL Sellafield internal dosimetry monitoring Programme (Britcher)

ALARA implementation case studies

Less than ten percent of the presentations provided examples where the use of both PAS and SAS were used as input to a real analytical ALARA approach. One example was from Sorin Biomedica who has been able to select through such an analysis protection actions to efficiently reduce the predictable internal doses. In another case, Termphos used the monetary value of the man Sievert to check the cost efficiency of options. In these and other cases, the efficiency of the approach relied heavily on the involvement of both managers and workers. Some utilities have even set up what should be called an ALARA programme targeted at internal exposure. For example, Nycomed (alpha foil production for detectors) has had such a programme running since 1994. It has three major components: training and awareness of the workers, design and modifications of the workplaces and a global work management. This has resulted in a reduction of the collective dose from 57 to 19 mSv/year and the maximum individual internal dose from 9 to 2.6 mSv/year.

These examples demonstrated that implementing ALARA in the case of predictable internal exposures is possible and efficient. However, in most cases, ALARA is not applied even when it might be possible. It is thus necessary to demonstrate its potential through more case studies, in order to describe generic procedures and tools that will take into account the specificity of the ALARA approach applied to internal exposure.

Recommendation 4

The workshop identified parallels with the development of the application of ALARA for external exposure in the 1980's and in particular the need for case studies on the application of ALARA for internal exposure. These may involve both retrospective studies to identify important points in previous decisions as well as predictive case studies. They should cover the whole range of exposure scenarios e.g. NORM, nuclear fuel cycle, medicine, source production and transport... The meeting recommended that the Commission and regulatory bodies support such research.

Recommendation 5

The meeting noted that whilst the commitment, attitude and awareness necessary to implement ALARA, was now commonly in place for external exposure, the same could not be said for internal exposure. A number of case studies showed the positive impact of management explicitly committing themselves to applying ALARA to internal exposure, and the meeting urged all stakeholders, but particularly management, to adopt this approach.

Conclusion

Many strategies have been proposed for the assessment and the follow-up of occupational internal doses, but these strategies have, in most cases, essentially dealt with respecting dose limits. The situation is hence quite similar with the development of the application of ALARA for external exposure in the 1980's. The participants to the Workshop expressed their hope that their recommendations will help to expedite the spread of an ALARA culture and to have adequate ALARA tools for internal exposure.

Recommendation 6

The meeting concluded that the Workshop had been successful in providing feedback between specialists in internal dosimetry, between operators and between the two groups. However the meeting also identified the need for ongoing exchanges. Therefore it is recommended that the Commission and regulatory bodies support the establishment of networking arrangements in this area.