**Frequently Asked Questions on ALARA…**

…optimization of doses for occupational exposure

IAEA consultancy meeting

4th and 5th of March 2010

## Foreword

*Radiation protection specialists often state that they have to answer questions from the workers, employers and other interested parties from all sectors that work with radioactivity on the subjects of "why do we have to implement ALARA?" and "what can we do to implement it properly?" This list of frequently asked questions (FAQs) intends to provide information to these specialists so that they can answer quickly and correctly the most frequently asked questions.*

*The first version of the FAQs was written in French and was issued in 2002 by the French Atomic Energy Commission. This revised version is the result of the work of an IAEA consultancy meeting held in March 2010 for reviewing, updating and extending the scope of the first version.*

*It turns out that the document also can provide useful information directly to the workers, employers and other interested parties. In order to facilitate the search for information, a list of questions is available at the beginning of the document, and an index with keywords is available at the end.*

*There are three distribution formats for the FAQ document:*

- A paper version that will be made available in three languages (English, French and Spanish);
- The web version on the IAEA "ORPNET" site in English;
- A CD version containing also the references mentioned in the text

*For those who want to go more in depth, a bibliography is added at the end, and links on the web version are provided within each answer. The links go directly to material provided by international organisations (regulations and recommendations) or provided by the end users (practical examples).*

*The document intends to be a living document, and will incorporate the feedback from the readers of both the printed document and the web version on the existing questions and answers as well as on new questions to be answered.*

*The IAEA would also like to acknowledge the kind permission of the European Commission Research Directorate-General and Ms. Pamela Stockell for us to use the ALARA drawings and cartoons which help us to grasp the underlying concepts so well.*

CONTENTS

# PART 1: INTRODUCTION

## 1. Why ALARA?

### 1. What does ALARA stand for?

ALARA is the acronym standing for 'As Low As Reasonably Achievable', used to define the principle underlying optimization of radiation protection: radiation exposure must be kept as low as reasonably achievable, taking economic and social factors into account.

### 2. Why implement an ALARA approach?

In order to reduce the risk for occupationally exposed workers, it is mandatory to implement optimization i.e. ALARA to comply with both international and national regulations.
See, for example, ICRP Recommendation 103, Paragraph 203, the Preamble and Section 2.24 of the International Basic Safety Standards (BSS) **(IAEA Safety Series 115. 1996)**.

**ICRP 103 (2007):**
*The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should be kept as low as reasonably achievable, taking into account economic and societal factors.*

***International BSS (1996)*** *www-pub.iaea.org/MTCD/publications/PDF/ss-115-web/start.pdf*
Preamble
*Radiation sources and installations should be provided with the best available protection and safety measures under the prevailing circumstances, so that the magnitudes and likelihood of exposures and the numbers of individuals exposed be as low as reasonably achievable, economic and social factors being taken into account, and the doses they deliver and the risk they entail be constrained (i.e. protection and safety should be optimized);*
*Paragraph 2.24.*
*In relation to exposures from any particular source within a practice, except for therapeutic medical exposures, protection and safety shall be optimized in order that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposures all be kept as low as reasonably achievable, economic and social factors being taken into account, within the restriction that the doses to individuals delivered by the source be subject to dose constraints.*

### 3. How is ALARA integrated into national regulations?

National requirements will vary from country to country, but will contain requirements on optimisation and on how to achieve ALARA. Management should be prepared to answer: how can the licensees demonstrate that they are complying with the national regulations on ALARA.

# PART 2: SCIENTIFIC AND REGULATORY BACKGROUND

## 2. The radiation protection system

### 4. What is the UNSCEAR?

UNSCEAR (http://www.unscear.org/) is the United Nations' Scientific Committee on the Effects of Atomic Radiation, which carries out a 4-yearly review on exposure and scientific knowledge regarding the health effects of ionizing radiation. The ICRP uses the UNSCEAR data (among others) to formulate its recommendations.

### 5. What is the ICRP?

This is the International Commission on Radiological Protection. (http://www.icrp.org/) This Non-Governmental Organization issues recommendations regarding the management of radiation risks, based on scientific data.

### 6. What are the three principles of the radiation protection system recommended by the ICRP?

These principles are:

- Justification of practices,
- Optimization of radiation protection, (ALARA)
- Limiting individual exposure.

### 7. What is the link between the ICRP and the national regulations?

Some countries derive their regulations directly from the ICRP recommendations, others through the IAEA BSS or other national guidelines – but all regulations include an ALARA requirement.

### 8. What does "justification" mean?

Any human activity that results in exposure, for example a planned exposure situation or existing exposure situation will be considered "justified" if the expected advantages of this activity to an individual or to society outweigh the disadvantages related to the radiation-induced effects on health.

### 9. Who decides whether a planned exposure situation is justified or not?

In most cases, declaring a planned exposure situation justified is the result of a social and political decision at a national level. It is occasionally implicit: in every country in the world, the use of ionizing radiation for the purposes of medical diagnosis is seen as justified and is not questioned. Sometimes, its use is challenged and debated: this is the case of nuclear power production.
In the medical field, there are two additional levels of justification:

- Generic justification of a procedure resulting from a decision by the professional medical body, made by comparing the procedure with possible alternatives.

- Justification of every treatment procedure for which the medical practitioner is responsible, depending on the characteristics of the patient.

Up until the end of the 20th century, there were only a few human activities that were expressly defined as unjustified under certain national regulations. Examples are the use of radioactive materials in lightning conductors, sources in children's toys and cosmetics, etc. At the end of the 1990s, many countries published comprehensive lists of unjustified activities and have established very clear regulatory procedures for deciding whether or not a new practice is justified, or even for re-examining the justification for existing practices at regular intervals.

More details on this question can be found at:
EAN Workshop No.10: "Justification and optimisation in radiation protection: which one is first?" M. Bourguignon (DGSNR)
*link (*http://www.eu-alara.net/index.php?option=content&task=view&id=62*)*
EAN newsletter November 2006: "The implementation of the European Directives 96/29 and 97/43".
*Link :* http://www.eu-alara.net/index.php?option=com_content&task=view&id=119&Itemid=53

**10. Can an unjustified practice be optimized?**

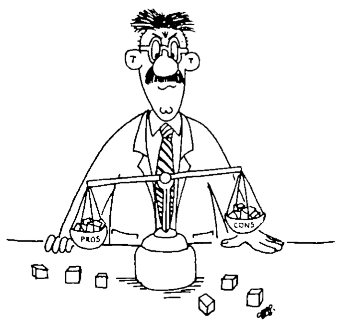
By definition, an unjustified practice must not be implemented; so optimizing it is not applicable.

**11. What is the difference between "ALARA" and "optimization of radiation protection"?**

The two terms are perfectly synonymous in ICRP and IAEA documents. They are used interchangeably without distinction.

**12. What are the objectives pursued through optimization of radiation protection?**

The First objective is to achieve an appropriate balance between the efficient use of protection resources and the risks associated with radiation exposure.




*The balancing of advantages (benefits) and disadvantages (detriments) is implicit in everybody's way of thinking when making a decision.*

The second objective is to ensure equity*:*

- Ensuring that any risk is evenly and acceptably distributed (equity regarding dose distribution among populations), and making it a priority to reduce the highest individual levels of exposure (equity in individual dose distribution).
- In the case of a nuclear, industrial or medical licensee that subcontracts workers, equity implies the equal treatment of its own workers together with those from the subcontractor companies.

**13. What is the role of the whole body individual dose limit (effective dose)?**

Complying with the effective dose limit not only ensures that the risk of developing radiation-induced cancer is kept at an acceptable level, but also ensures that the individual will not develop deterministic effects *(see also Q 14 and Q15).*

**14. Why has the ICRP set the dose limit for workers at 100 mSv over 5 years?**

The ICRP considers that workers exposed to ionizing radiation throughout their entire working lives should not be at any greater risk than the risks met by workers in the safest industries. To achieve this objective, the dose limit for workers proposed by the ICRP, since its publication 60 in 1990, was established as 100 mSv over 5 years (i.e. an average of 20 mSv per year). However many national regulations establish an annual effective dose of 20 mSv.

**15. Why did the ICRP 2007 recommendations, publication number 103 propose specific dose limits for the eye lens and skin (and, more especially, for the extremities) rather than contenting itself with a whole body dose limit?**

In most cases, if the annual effective dose limit (whole body dose) were to be reached following irradiation to a single organ, the dose to the organ would be significantly lower than the threshold at which deterministic effects for that organ would appear.
However, applying the same logic to the skin or to the eye lens shows that respecting the whole body effective dose limit is **not** sufficient to avoid the appearance of skin erythema or cataracts, etc. It was therefore necessary to propose specific dose limits to these parts of the body to ensure that people exposed will not develop deterministic effects to these organs: 500 mSv for the skin and the extremities, and 150 mSv for the eye lens for occupationally exposed workers.

**16. What is the relationship between dose limits and ALARA?**

Whilst dose limits establish a clear regulatory requirement, not exceeding the dose limits is not enough, the residual doses have to be maintained ALARA

# 3. Health effects of ionizing radiation

**17. What is a deterministic effect?**

A deterministic effect is a health effect that requires a specific level of exposure to ionizing radiation before it can occur, but this level is not exactly the same for all people; it also depends on the individual's radiosensitivity.
For example, a dose to the eye lens of 2 Gy is the minimum dose, which will produce a radiation-induced cataract over a short period of time. This means that the most highly

radiosensitive people will develop a cataract if they receive a dose of 2 Gy to the eye lens. However, above 10 Gy, everyone will develop a cataract.

**18. What is a stochastic effect?**

This is a health effect, for example cancer, which randomly occurs following exposure to ionizing radiation, with the probability of occurrence being proportional to the dose. When many individuals are exposed to ionizing radiation, there is no way of predicting who will develop cancer, nor of knowing whether or not a person who is suffering from cancer developed it due to ionizing radiation.

**19. Is there any scientific proof that stochastic effects can be caused by exposure to low doses?**

Yes, for exposures above 100 mSv received within a very short period (less than 2 days).
No, for exposure below 100 mSv. However, as a precautionary approach, it is considered that any dose may give rise to a stochastic effect. It is assumed that there is a linear (straight line slope) relationship between dose and stochastic effects.

**20. Is scientific knowledge in this field progressing?**

Yes. There is an on-going significant body of work to review epidemiological data of exposed populations (see UNSCEAR http://www.unscear.org/ *and also BEIR VII http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/beir_vii_final.pdf*). Between the 1960s and the present date, the dose which represents the "detection limit" for stochastic heath effects has been reduced by a factor of 10.

**21. Is receiving a dose within a very short period of time the same as receiving the same dose accumulated over a long period?**

No. It is thought that at low doses the probability of developing a radiation-induced cancer for a dose accumulated over a long period ("chronic exposure") is half that for the same dose received within a very short period. ("acute exposure").

**22. What is the probability of developing cancer or any serious hereditary effects?**

The table below groups together the probability coefficients defined by the ICRP in Publication 103 (2007) for stochastic effects at low doses:

| | **Cancer** | **Serious hereditary effects** | **Total** |
|---|---|---|---|
| Workers | $4.1 \times 10^{-2}\ Sv^{-1}$ | $0.1 \times 10^{-2}\ Sv^{-1}$ | $4.2 \times 10^{-2}\ Sv^{-1}$ |
| General public | $5.5 \times 10^{-2}\ Sv^{-1}$ | $0.2 \times 10^{-2}\ Sv^{-1}$ | $5.7 \times 10^{-2}\ Sv^{-1}$ |

These are average coefficients. In reality, the situation is more complex since probability coefficients vary according to age, sex and the population group in question, among other factors.

# 4. Absorbed dose, equivalent dose and effective dose

**23. What are the differences between these different dose quantities and their significance?**

The basic quantity is the **Absorbed Dose**. This is a measure of the amount of energy, measured in Joules (J) deposited in an organ of mass given in kilograms (kg). **The unit of Absorbed Dose is the Gray (Gy),** which equals 1 J/kg. For most types of radiation commonly encountered, e.g. X-rays, gamma-rays and beta particles, the absorbed dose is primarily the amount of energy absorbed by the organ that is relevant to organ damage as seen in deterministic effects. Thus the unit of Absorbed dose (Gy) is used in such circumstances.

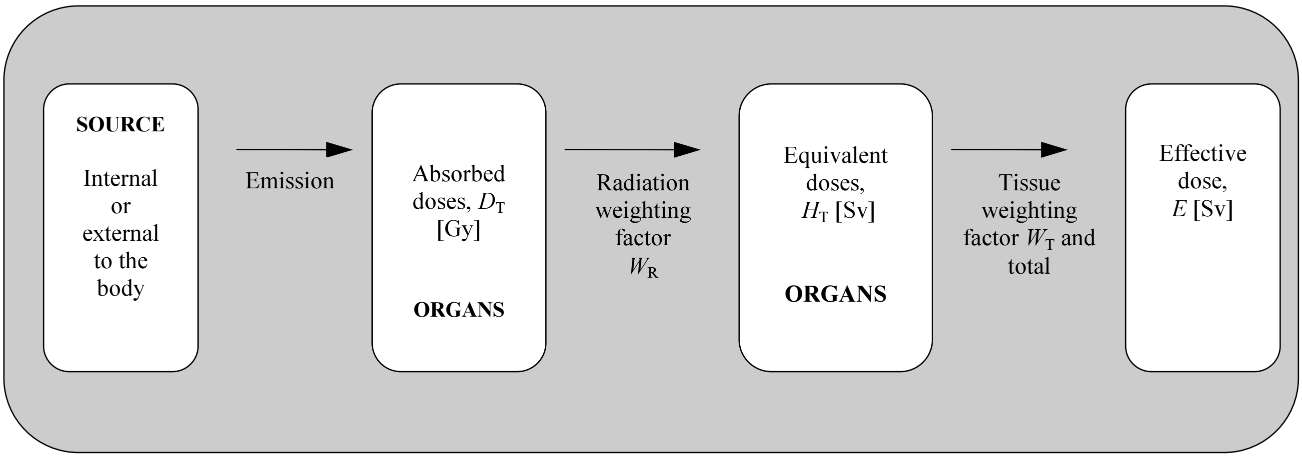
However there are some types of radiation, e.g. neutrons, protons and alpha particles, that because of the way they deposit their energy, cause more damage (up to a factor of 20) per unit of Absorbed Dose. To take this into account, another quantity is required, **the Equivalent Dose in Sievert (Sv).** This is equal to the Absorbed Dose multiplied by a radiation weighting factor, $W_R$, (see table below).

The Equivalent Dose is used to measure the doses in particular organs. However this does not allow one to compare the risks of stochastic effects (see question 18) associated with say the exposure of a small area of the body with exposure of the whole of the body. Here one also has to take into account the facts that:

- some tissues are more sensitive than others to the effects of radiation exposure, and
- different Equivalent Doses in different organs may often occur.

These factors are taken into account by using a mathematical model that assigns a tissue weighting factor, $W_T$ (see table below), to the organs of the body; and requires the products of the Equivalent Doses and Tissue weighting factors to be summed across the body. The result is then called **the Effective Dose, also with the unit of the Sievert (Sv)**

The relationship between these dose quantities is shown in the diagram below.




The values of $w_R$ (no unit) depend on the type of radiation and are given in the table below (the greater the value of $w_R$, the more harmful the radiation).

| Type of radiation | Value of $w_R$ |
|---|---|
| X-rays | 1 |
| $\gamma$ rays | 1 |
| $\beta$ particles | 1 |
| Neutrons | 2.5 to 20 (continuous curve depending on radiation energy) |
| Charged protons and pions | 2 |
| $\alpha$ particles | 20 |

*(source :ICRP 103, Annals of the ICRP, Volume 37, p 272)*

$w_T$ is the "tissue-weighting factor" representing the radiosensitivity of the exposed tissue or organ, T, (no unit).

| Tissue or organ | Tissue-weighting factor, $W_T$ |
|---|---|
| Bone marrow (red) | 0.12 |
| Colon | 0.12 |
| Lung | 0.12 |
| Stomach | 0.12 |
| Breast | 0.12 |
| Gonads | 0.08 |
| Bladder | 0.04 |
| Liver | 0.04 |
| Esophagus | 0.04 |
| Thyroid | 0.04 |
| Skin | 0.01 |
| Bone surface | 0.01 |
| Salivary gland | 0.01 |
| Brain | 0.01 |
| Sum of remainder tissues or organs | 0.12 |

*The sum of $w_T$ is equal to 1 (source: ICRP 103, Annals of the ICRP, Volume 37, pp1-332, 2007)*

**24. What is a collective dose?**

Given that the relation between dose and effect is linear (a person that receives an effective dose twice as great as that received by another person will be twice as likely to develop a radiation-induced stochastic effect), calculating the sum of individual doses is meaningful: it means we can determine a total dose known as the "collective dose", which corresponds to what is known as the health detriment, equal to the sum of individual probabilities of developing a stochastic effect.

The collective dose is expressed in terms of man.Sievert (man.Sv).

# PART 3: WHAT CAN WE DO TO IMPLEMENT ALARA PROPERLY

## 5. When should an ALARA approach be implemented?

### 25. From what levels of individual and collective doses should we begin to apply the ALARA approach?

The ALARA approach should be implemented regardless of individual and collective dose levels, although resources for any ALARA study to identify dose reduction options should be adapted to the expected level of doses received.

For example, for a job where the collective dose is a few man.μSv, common sense should prevail and normal good practices in the area of radiation protection should be implemented. The workers involved, thanks to an effective safety culture including radiation protection and the workers professionalism, should apply good practices to ensure they receive the lowest possible dose.


*Significant reductions in dose can be achieved by common sense ALARA and a minimum of effort.*

At the other end of the scale there may be situations involving collective doses of hundreds of man.mSv and where individual doses may exceed 10 or even 15 mSv per year. These may be found in the case of renovating or dismantling a facility in the nuclear, industrial, medical or research sectors, or during the operation of certain interventional radiology workstations, etc., In such cases an ALARA study would be appropriate, and this study might involve several man-weeks or man-months of effort.

**26. Who draws up the formal procedures for the ALARA approach?**

The ALARA approach represents the commitment of the various stakeholders to ALARA. To achieve the ALARA approach, the licensee in compliance with national regulations and the licensee's internal regulations should establish specific procedures. The ALARA approach should also take into account conventional safety considerations.
These procedures must take into account the operating conditions, available resources and the culture of radiation protection specific to the licensee or to the site. They must be known by the authorities and workers and discussed with these partners within the framework of radiation protection and labor regulations in force in the country in question.

**27. Are there different levels of sophistication of the procedures according to different levels of individual or collective dose?**

The ALARA approach applies regardless of the level of exposure. Nonetheless, the time-scale and the sophistication of the procedures should be aligned with the type and quantities of individual and collective doses at the site. Dosimetric criteria (individual and/or collective dose levels and/or dose rate and/or the frequency of a task, etc.) are often taken into account in deciding on how formalize the procedures.

**28. Is it worthwhile to implement ALARA for the workers exposed to radon and for those working in NORM industries?**

Yes, according to ICRP 103 and the new BSS it is clear that ALARA should be applied to all these workers in the same manner as for the other workers from the nuclear, medical and research areas.

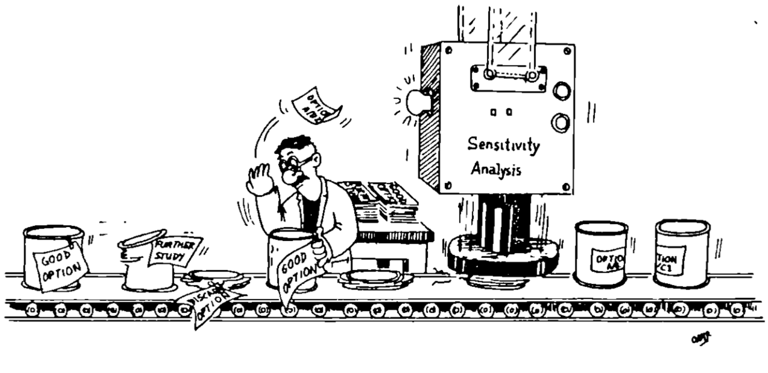
# 6. What is an ALARA study?

**29. What are the different steps in an ALARA study?**

*An ALARA approach may indentify the need for an ALARA study of a specific situation. The study may include the following steps (see also European Commission "ALARA from theory to practice", report EUR 13796, 1991)*
*Link:*
*http://cordis.europa.eu/search/index.cfm?fuseaction=lib.document&DOC_LANG_ID=EN&DOC_ID=7918222&pid=0&q=531E0BB3B70C4C1704BB68C1269AB9E5&type=sim:*

- Define the problem,
- Make a preliminary analysis of the type and level of doses,
- Define the radiation protection options,
- Quantify, where possible, the impact of these options in terms of cost, dose, time, etc. For some factors a qualitative assessment may be necessary
- Compare the options,
- Make a sensitivity analysis,
- Select and implement an optimized solution.

**30. Is it important to make a sensitivity analysis as part of an ALARA study?**




*One aim of sensitivity analysis is to test the "robustness" of the results.*

Yes: to test how robust the results are in light of possible variations in the scenarios implemented. This problem can be tackled in two ways:

- Either by providing realistic margins for variation in each scenario (dose rates, length of exposure, costs, the reference monetary value of the man.Sievert, etc.),
- Or by asking what the maximum variation is for each scenario that will ensure that the solution implemented remains optimal.

# 7. What is an ALARA dose objective?

**31. What is an ALARA dose objective?**

A dose objective is called an "ALARA" dose objective when it is the result of an ALARA study (see also question 29): i.e. it is derived from a well-supported choice from among the possible radiation protection alternatives and options for a set of tasks or all the operations for a given site, workstation, workshop, laboratory, or healthcare department (collective and individual doses). There may be an initial major ALARA study followed for subsequent tasks/years with refinements of the ALARA dose objective on the basis of experience and feedback.

It represents a level of dose that should be attainable. It is important that there is an ongoing comparison with what is achieved in practice and that feedback is provided for subsequent review of the acceptability of the ALARA dose objectives.

# 8. What is dose constraint?

**32. Is a dose constraint a dose limit?**

No, the dose limit is an annual individual dose established by the national regulatory agency above which workers should not be exposed. A dose constraint is an annual individual dose lower than the dose limit, and is established by the ongoing, iterative process of optimization.

Exceeding a dose constraint should not represent a regulatory infraction, but could result in the implementation of follow-up actions.

For occupational exposure, a dose constraint serves as an upper boundary for the range of options in optimization. A protection strategy is planned so that doses do not exceed the applicable dose constraint. After the exposures have occurred, the dose constraint may be used as a benchmark when assessing the suitability of the optimized protection strategy that has been implemented and for making adjustments as considered necessary. In certain situations, radiation exposure may not be the only or dominant workplace risk and the setting of dose constraints should be seen as part of a total risk management regime.

### 33. How are dose constraints established?

Annual dose constraints between 1–20 mSv should be used for occupational exposures. Dose constraints for a specific planned exposure situation should be decided on a case-by-case basis. A process of generic optimisation that takes into account national or regional attributes may establish the specific value for the constraint and preferences together, where appropriate, with a consideration of international guidance and good practices in similar work places.

In large industries, dose constraints may be set up by the management and appear as a managerial tool; in other industries or in the medical and research sectors, they may be proposed by the regulatory bodies in negotiation with the concerned stakeholders.

It must also be realised that dose constraints do not represent a demarcation between 'safe' and 'dangerous' or reflect a step change in the associated health risk for individuals.

## 9. Is ALARA implementation achieved by….?

### 34. Does setting dose objectives achieve the implementation of the ALARA approach?

*It all depends on what is meant by the word "objective":*

- If the objective reflects a simple predicted dose, entailing no optimization, that is not the same thing as implementing ALARA (see also Questions 29 and 31);
- If the objective, in terms of collective or individual doses, is determined by a licensee purely as a matter of policy with regard to everyone that works at its sites, this rather implies objectives related to a "continuous improvement approach" than objectives resulting from application of the ALARA approach.
- If the objective complies with the definition given in Question 31, then it is **PART** of an ALARA approach.

### 35. Does setting dose constraints achieve the implementation of the ALARA approach?

Not necessarily. For example, applying a dose constraint of 0.5 mSv/day does not mean that optimization has been implemented.
This type of dose constraint is often estimated on the basis of the regulatory limits or of "managerial policy" objectives applied by the licensee. It is related to a system of limiting and managing individual exposure, not to optimization, although it must be factored into optimization. Optimization must not result in non-compliance with these constraints

**36. Does predicting doses achieve the implementation of the ALARA approach?**

If all that has been done is to predict the individual and collective doses, without examining any possible radiation protection alternatives and options, i.e. without optimizing radiation protection, then the ALARA approach has not been fully implemented.

**37. Does using a real time dosimetry system achieve the implementation of the ALARA approach?**

No, but it is a tool; a very useful tool, to monitor what is being achieved.

Some dosimetry systems only provide data on individual doses over a standard period. This is often necessary for regulatory purposes on controlling individual doses. However in an ALARA approach, it is essential to be able to relate the doses measured with the tasks performed, and the place where they are performed etc. The objective here is to be able to answer the following questions: Where, When, How, and by Whom, are the doses being received? This often requires a real time dosimetry system.

**38. Does systematically not putting the same workers to work at sites with the highest doses achieve the implementation of the ALARA approach?**

No. ALARA does require personnel management, enabling the different workers to be assigned to different tasks in a fair and equitable manner, but that is not enough for an ALARA approach, since it does not entail a study aimed at reducing the total collective dose.
Integrating fair treatment in the ALARA approach entails a study on ways to reduce **collective** and individual exposure, aimed primarily at the highest levels of exposure. This approach implies choosing radiation protection options.

**39. Does area classification achieve the implementation of the ALARA approach?**

Drawing up an area classification is an essential and required component of any effective radiation protection process, but it is not a component of the ALARA approach. Area classification is used in determining the training, information and monitoring requirements that should be taken. The classification of an area depends on the risks of exposure likely to be encountered by certain workers in the area in question. The international BSS confers responsibility for defining these levels of risk to the national authorities. European Directive No. 96/29 links area classification directly to the possibility of exceeding the effective dose of 1 mSv in a year (limit for the public) or 1/10 of the equivalent dose limit for workers (Article 18, Section 1). Area classification is part of a process of "limitation". Area classification absolutely does not provide any guarantee to the individual who works in a zone that his risk of exposure is kept as low as reasonably achievable, according to the amount of time spent in the zone and the nature of the work performed, etc.

# 10. How is ALARA implemented?

**40. How should an ALARA approach be implemented in a facility where there is not one main routine work but a number of diverse and low-dose tasks?**

In a case such as this, it is possible to try and group together similar or repetitive tasks, in order to plan common radiation protection measures. If some tasks can indeed be grouped together, and if the dose thereby becomes more significant, a formal ALARA study, as described in question 29, may be implemented. When this is not the case, common sense, radiation protection culture and good practices must prevail.

**41. How should ALARA be implemented for a task which does not involve high doses but which has to be performed repeatedly?**

In this case, a generic ALARA study can be drawn up for the task. This study must be revised at regular intervals with feedback from experience. This is in particular the case in many medical applications.

**42. How should ALARA be implemented when the risk is from contamination?**

There are two possibilities

- The potential for intake of radioactive material is significant and likely to result in committed effective doses at much higher levels than the doses limits; e.g in some nuclear power sector operations. The procedure that should be followed in such cases is to reduce as far as possible any probability of such internal exposure occurring. .
- Secondly, there are situations in which possible internal contamination is expected on a routine basis (use or production of naturally occurring radioactive materials, such as phosphate, thorium and mineral sands, handling uranium during the upstream stages of the nuclear cycle, or exposure to tritium, etc.). In such situations, workers are subject to internal exposure in a more or less continuous (chronic) manner and, apart from a few exceptions, the doses are lower than the dose limits. In such cases, the ALARA principle must be applied.

More details on this question can be found at: (see “summary and recommendations” of 3rd EAN Workshop Neuherberg, Germany, 1999 on "Managing Internal Exposures" http://www.eu-alara.net/index.php?option=content&task=view&id=55)

**43. Might there need to be a trade off between internal and external exposures?**

Yes, in a few cases. This situation can arise where there is the potential for the presence of relatively low levels of contamination in an environment where high dose rates exist, but in which work has to be carried out. Here measures used to reduce doses from one exposure route may cause the other to increase. An ALARA study needs to be carried out and a judgment made on which is the optimum approach.

**44. How should the ALARA approach be implemented in the case of doses received to the extremities?**

This question involves examining what is meant by the concept of optimization when dealing with doses received to the extremities. To reply to this question, we need to look at the deterministic effects as well as at the stochastic effects.

An optimization procedure does not apply for deterministic effects as they are seen only above a certain threshold dose, and this threshold dose should be avoided in all cases. .

In the case of stochastic effects, optimization can be implemented by focusing on the risk of cancer, which can only be estimated on the basis of the “whole body” effective dose. Doses received to the extremities therefore have to be aligned with the whole body doses. This is achieved by applying well-established calculation rules that take into account the radiosensitivity of each organ or tissue, in this case, of the skin.

For example:

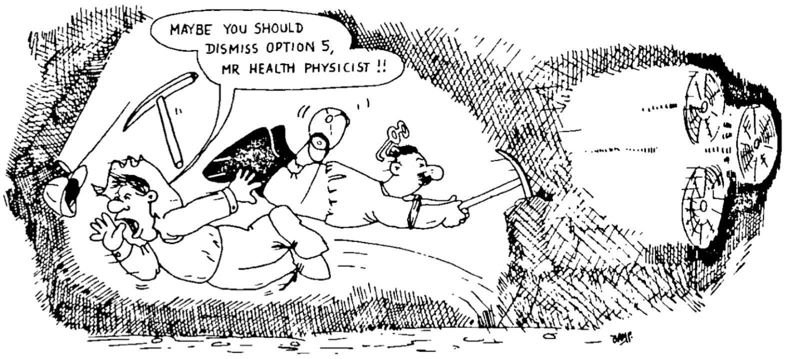
Supposing that an individual receives a dose of 500 mSv to the extremities (dose limit to the extremities). Given the weighting factor ($w_T$) for the skin of 0.01, and the fact the hands account for only 5% of total skin surface (therefore, no dose is received by 95% of the skin), the 500 mSv delivered to the extremities represents a whole body effective dose of [(500 x 0.05) + (0 x 0.95)] x 0.01 = 0.25 mSv. Thus, even if a worker reaches the dose limit to the extremities every year for 5 years, the corresponding total effective dose will only be 1.25 mSv, which is well below the 100 mSv in 5 years effective dose limit.
In reality, doses received to the hands are usually much lower than the 500 mSv per year dose limit, but the ALARA approach may still be applied.

**45. Why are the regulatory processes different for occupational radiation exposures and non-radiation risks?**

The reason can be found looking back over the last century. After the First World War, ILO was established in 1919 to promote decent treatment of working people. Most countries have set up Labour Ministries or their equivalent and have regulations covering all occupational conditions. However, after the Second World War and the atomic bomb, the IAEA was set up as the world's "Atoms for Peace" organization in 1957 within the United Nations organization. Adapting the ICRP recommendations (see Questions 6 and 7), the IAEA issues the international Basic Safety Standards for ionizing radiation. Since then, most countries have set up specific regulatory bodies dealing with nuclear safety and radiation protection. Therefore in most countries occupational radiation risk is regulated through specific regulations. However both at the international and national levels it is expected that both regulations and work places should be harmonized in terms of occupational risk management.

**46. How can a balance be found between radiation risks and non-radiation risks within the framework of the ALARA approach?**

This is a very real problem. At the moment, there is no general risk scale that can be used to compare stochastic and deterministic risks, threshold and non-threshold risks, immediate risks, delayed risks, radiation and non-radiation risks. However, radiation risks should not be given priority over other types of risk (conventional accidents, for example). International organizations (IAEA, ILO and the WHO) recommend implementing a general and coherent risk management approach.
In practice, in places where there exist both radiation risk and other risks one has to take care of avoiding conflicts and reinforce coherence, complementarities and synergies between different risk management. This implies interactions between all the concerned stakeholders including health physicists staff and other occupational health specialists), as well as an exchange of principles and good practices.




*The levels of dose and the financial costs may not be the only relevant factors - Example of ventilation measures in a uranium mine.*

More details on this question can be found in:
All presentations from EAN Workshop Antwerp, Belgium, November 2000 on "Management of Occupational Radiological and Non-radiological Risks: Lessons to be Learned", (http://www.eu-alara.net/index.php?option=content&task=view&id=56)
Presentations from EAN 10th Workshop, Prague, Czech Republic, 2006 on "Experience and new Developments in implementing ALARA" in particular session 2, http://www.eu-alara.net/index.php?option=content&task=view&id=62

# 11. ALARA and design, dismantling phases

### 47. Should ALARA be applied from the design stage?

Yes, the ALARA approach should be applied from the design stage (for a facility, refurbishment, maintenance, dismantling, etc.) since, on the one hand, the earlier it is implemented, the more freedom you have and the lower the cost (it is easier to change something on paper than once construction work has been completed) On the other hand, the earlier ALARA is implemented, the more can be done regarding radioactive sources and dose rates.

### 48. What can be done to ensure that the ALARA approach is implemented from the design stage?

One has to include radiation protection as one of the main criteria in the design process, and therefore it is essential to:

- Study feedback on radiation protection carried out for similar facilities or for similar tasks,
- Analyze the alternatives (or various scenarios), taking account of radiation protection measures,
- Set optimized dose objectives.

### 49. Are there any specific points to bear in mind when applying ALARA to dismantling a facility?

Yes, some of which are problematic insofar as radiation protection is concerned, especially in the case of the oldest facilities. For example, dismantling involves a significant increase in the degree of uncertainty regarding the radiation conditions that may be encountered at the

various stages of the dismantling, especially when very little is known about any modifications that may have been made to the facility in relation to the available plans; or when nothing is known, or is no longer known, about the sources or their composition.
On positive side, there is a possibility of making use of the decay law, as there is much more time to perform all the tasks required than is the case for facilities that are still in operation, together with the possibility of removing the most hazardous sources as work progresses.
All these specific characteristics confirm the need for a predictive ALARA approach, which includes scenarios that integrate sensitivity analyses while taking account the fact that hypothetical situations may vary considerably. Such analyses must be much more detailed than is the case for facilities in operation and must answer the question, “What will we do if…”

**50. How should we take timescales into account in determining optimized objectives for dismantling projects?**

As in the case of facilities in operation, the optimized objectives will be collective and individual dose objectives. It is crucial not to make use of the fact that there is more time available to artificially reduce the annual doses. The objectives must therefore be overall objectives covering the entire dismantling project (or each technical stage), and only then should they be set with regard to target dates.

**51. Can a dismantling strategy be modified solely for the purposes of radiation protection?**

Of course, and this has happened many times. Some strategies would result in exposures in excess of the limits or produce dose profiles that are not at all reasonable. It is recommended that every eventuality be planned for, rather than waiting for a strategy to be underway before becoming aware that it has to be stopped for reasons related to radiation protection. Experience has shown that it is much less expensive to be well prepared in advance.

**52. How important is the maintenance of the collective knowledge of a facility?**

Often there are differences between the original specifications or detailed plans for a facility and how the facility is actually built. Often this is due to the building process identifying practical difficulties and overcoming them with minor modifications. Similarly over the life-time of a facility much can change in its physical structure, fittings, services and how the facility is used. It is important that plans are accurately updated and logs maintained of maintenance, what operations have been undertaken in the facility, successful approaches, lessons learned and the range of radionuclides that have been used.

This knowledge base is particularly important in taking an ALARA approach to routine maintenance work, refurbishment, rarely carried out operations and decommissioning. The knowledge of those that have been involved with the facility needs to be captured in an accessible form and where appropriate included in training. In some older facilities this enlightened approach to maintaining a collective knowledge base may have only recently started. Here it may be necessary to introduce processes to capture knowledge from long serving staff and those leaving / retiring or even by contracting former staff members.

**53. What is the best way to motivate{XE “Facility shutdown and motivation”}{XE “Motivation”} workers to take the ALARA approach on board when “their” facility is to be shut down?**

In this case, it is important to remind them that they remain responsible for preparing for dismantling. The facility must be clean so that dismantling can take place in the best possible conditions. In many cases the groundwork for the motivation to take this professional approach, will need to have been made during the preceding years of normal operation, with an ALARA approach as integral part of the attitude of management and workers.

# 12. ALARA and good practices

**54. What is the difference between implementing good practices and an ALARA approach?**

- Extensive knowledge of the company’s radiation protection culture helps in implementing certain common practices, which can be termed “good practices” (e.g.: systematic deployment of radiation protection measures at hot spots). It may nonetheless be useful to carry out analysis from time to time in order to verify that these good practices are optimised. The results of that study should then be very clearly explained to all involved stakeholders.
- Options for which the benefits in terms of limiting *both* doses and costs are immediately obvious will also be considered as good practices to be integrated as part of the optimized solution.

# 13. Commitment on the part of various stakeholders

**55. Who is legally responsible for implementing an ALARA approach?**

At nuclear, industrial or medical facilities, implementation of the ALARA principle is primarily the responsibility of the licensee, who is required to implement, through management, all that is “reasonably” possible to ensure that contracted or subcontracted workers benefit from the best working conditions The employer in some cases may have the primary responsibility when he is sub-contracted to do work for the licensee The contract will define the respective roles played by the two parties in implementing ALARA. Thus, there is a level at which responsibility is shared between the employer, the plant manager and the holder of the operating license for the source take responsibility for general ALARA coordination.

**56. Who should be responsible for an ALARA approach?**

The management of the facility has the overall responsibility. This involves clearly identifying and delegating responsibilities together with the necessary resources to implement the ALARA approach. Those individuals with these responsibilities may call for advice, expert appraisal and, whenever it seems useful and necessary, assistance from all types of specialists and also from the “subcontractors” involved.

**57. Should only the Radiation Protection specialists perform the ALARA approach?**

Certainly not, the ALARA approach is a “team project” that requires the know-how, participation and commitment of all concerned, including the operating team, maintenance, planners, designers, contractors, radiation protection officers and workers.


*'Brainstorming' - where relevant experts sit together and write down their ideas for factors and options.*

**58. Should those involved in the process of purchasing services and equipment be integrated into the ALARA approach?**

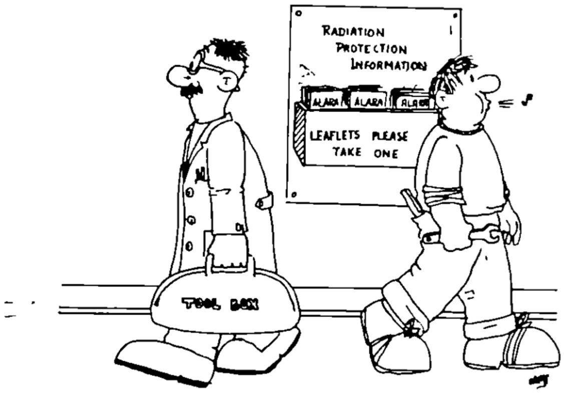
Where they can have an impact: Yes. They should be immersed in the ALARA culture to ensure that they do not systematically choose to work with the “lowest bidder” service providers, but rather with the “lowest responsible bidders”, who will have incorporated ALARA in their bid proposals and in their good practices (examples of this can be found in the contracting of industrial radiographers to carry out work on different facilities; *5th EAN Workshop on "Industrial Radiography: Improvements in Radiation Protection, in particular session 3" Rome, Italy, October 2001*
Link *http://www.eu-alara.net/index.php?option=content&task=view&id=57*

**59. Is a specific structure needed to implement ALARA?**

Generally speaking, no, as long as Management has a clear, pro-active policy. Nonetheless, special meetings should be planned, attended by radiation protection specialists, the operation or maintenance manager, the project manager and the contractors, whenever it is necessary to officially define specific procedures for implementing ALARA. In some cases, especially when the type and level of collective and individual doses makes it necessary, as in the nuclear industry, it may be advantageous to set up an ALARA decision-making committee headed by the plant manager or the head of department, or his/her deputy.

**60. How can the “ALARA culture and commitment” be sustained in the long term?**

It is necessary to organize regular reminders to demonstrate to all those involved the progress made from one year to the next, any new problems that may have arisen recently and to show them how their suggestions for improvement have been taken into account. To this end, internal training may be organized and staff may be sent to external training courses on ALARA culture and commitment.




*Making educational leaflets available to the workforce is not enough.*

## 14. How should a licensee take into account service providers' workers in an ALARA approach?

**61. Is it necessary to have access to the *dose* records of subcontracted workers that occasionally work on a task?**

Yes, to ensure that the regulatory dose limits are not exceeded during the task in question. The corollary to such knowledge is, naturally, the fact of having drawn up an optimized prediction of the collective dose and of the individual dose distribution for the task.
This requirement is specified very clearly in the International BSS:
"Registrants or licensees shall, as a precondition for engagement of workers who are not their employees, obtain from the employers, including self-employed individuals, the previous occupational exposure history of such workers and other information as may be necessary to provide protection and safety in compliance with the Standards." (BSS Appendix 1; 1.6; 1996)

**62. As a part of optimization, should the dose records of workers who work on a task on a one-off basis at a licensee's site be taken into account?**

No. Of course, knowing their dose history is fundamental to ensure that the task will not mean they will exceed a dose limit, but this is not at all the case for optimizing the dose received during the task. This would be tantamount to making other licensees unaccountable.

**63. Does ensuring that subcontractors' workers do not exceed the annual dose limit satisfy the requirements of the ALARA approach?**

No, no more than for the licensee's own workers. This would only mean complying with the dose limits rather than the correct procedure of reducing the doses to levels as low as reasonably achievable.

# 15. ALARA tools

**64. What are the main tools that are essential for the ALARA approach?**

- Risk assessments for each new piece of work and a pro-active predictive approach
- Operational monitoring (individual and workplace),
- Feedback databases,
- Plant layouts with surveys of dose rates and contamination at workstations,
- ALARA check lists,
- Task related Radiation Work Permits (RWP),
- Simple codes for calculating dose rates.

**65. What are the additional tools that are useful for the ALARA approach in more complex situations?**

- More complex codes for calculating dose rates,
- Analytical codes for calculating doses, including 3D modeling of the installation
- The monetary value of the man.Sievert,

**66. How can use of ALARA tools be promoted?**

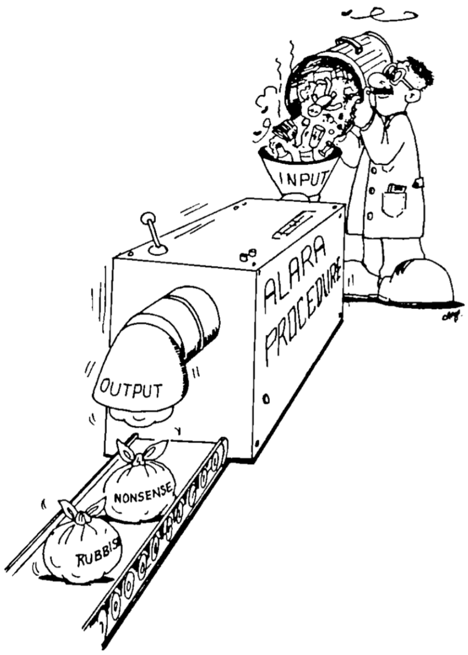
- By spreading a culture of radiation protection as widely as possible,
- Through effective information sharing on good practices, through international and national symposia and networks, and inside the facilities themselves,
- Through management leadership,
- By providing support for radiation protection officers, etc.

**67. What information should be recorded during tasks to perform ALARA studies?**

The information recorded must provide answers to the following questions:

| **Questions** | **Examples of answers from the nuclear sector** |
|---|---|
| Who receives the doses? | List of professions of all the workers, and dose records per profession. |
| When and how are the doses received? | Daily dose records, a coding system for activities and records of any unforeseen event. |
| Where are the doses received? | Appropriate area classification where doses and dose rates are recorded, |
| For how long? | Collection of exposure times for each individual, for each task and for each area. |

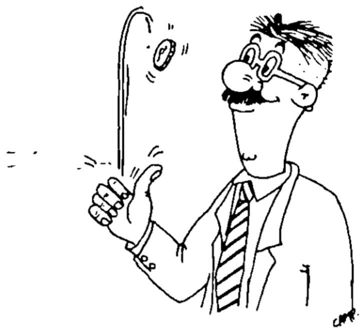
If all the above-mentioned information is known, it should be possible to cross-check and analyze it after the task in question has been completed.
This information may be gathered by hand (on paper) or by using computer systems.
In all cases, the amount of detail required in the information to be gathered must be aligned with the stakes i.e. types and levels of doses (see Question 27).




*The quality of the results will ultimately depend on the quality of the database.*

**68. Are there any decision-aiding tools for implementing ALARA?**

Yes. There are decision-aiding methods, such as the cost-effectiveness method and the cost-benefit method. There are also “multi-criteria” methods (for more details, see the Commission of the European Communities report, “ALARA from theory towards practice”, EUR 13796 EN and ICRP 55 published in 1989, “Optimization and decision-making in radiological protection”. Annals of ICRP 20). Drawing on feedback from the last few decades, the ICRP analyzed the most useful methods in an appendix to its recent document, “The optimisation of radiological protection: Broadening the process”, Annals of the ICRP, Volume 36, Issue 3, Pages 89 – 104, 2007.



# 16. ALARA and taking account of exposure times

**69. Is it enough to use nominal working hours in implementing an ALARA approach?**

No. Multiplying a dose rate at the workstation by the nominal working hours (8 hours of work a day, for example) is likely to result in significantly overestimating the predicted dose. This

arises from the fact that of the nominal working hours includes breaks, movement outside the area and, in some sectors, the time taken to put on and take off protective clothing.
For every job then, the actual Exposed working hours (EWH) should be estimated.

**70. What is the exposure correction coefficient?**

During a task, a worker does not spend all his time at a specific point of the workstation where the dose rate at the workstation is estimated. While still exposed, he moves to and from this point. Feedback shows that the product (dose rate times the exposure time) often overestimates the actual dose.
In a predictive study, it is, therefore, often justifiable to multiply the product (dose rate times the exposure time) by an exposure correction coefficient. For example, a coefficient of 0.7 has been found to be appropriate for a range of tasks in nuclear facilities).

# 17. ALARA and decision aiding techniques

**71. Depending on the type of data included in the cost-benefit study (or cost-effectiveness study), is there not a risk of drawing the most convenient conclusions?**

As with any study, the results depend to a large extent on the assumptions taken. It is the role of the different players (radiation protection officers, the manager and subcontractor, etc.) to mutually challenge each other's assumptions. The fact that the issue has been raised a number of times shows that a sensitivity analysis is essential to test the robustness of the results.

**72. Should the cost of the ALARA study be included in the cost of the protection actions?**

No, because implementing ALARA is a regulatory requirement: the law must be applied regardless of the cost. This cost is therefore part of the total cost of radiation protection at a site and cannot be charged against a specific ALARA study.
However, the cost of the study must be in line with the level of doses: thus, taking several man-months to carry out an ALARA study for a non-repetitive project of a few man.µSv would be totally unreasonable!


*It is important that the effort devoted to the ALARA study should be proportional to the costs of implementation and the potential dose savings.*

## 18. A special tool: - the monetary value of the man.Sievert

**73. What is meant by "the monetary value of the man.Sievert"?**

To facilitate the practical implementation of the ALARA principle, the International Commission for Radiological Protection (ICRP) has, since 1973 (Publication No.22) up to the last recommendations ("The optimisation of radiological protection: Broadening the process", Annals of the ICRP, Volume 36, Issue 3, 2007), proposed interfacing costs related to radiation protection options with the benefits in terms of reducing exposure. To do this, it suggested using an analysis in which the benefit or efficiency are given a monetary value, using a reference monetary value for the unit of avoided dose: the monetary value of the man.Sv.
Allocating a monetary value to the health benefits of radiation protection measures, or, in other words, the choice of a reference monetary value for the collective dose unit reflects how much the company is prepared to pay to avoid any radiation-induced effects on health.
The monetary value of the man.Sv helps in decision making on:

- Reducing the level of collective exposure.
- Reducing the distribution of individual exposures.
- Reducing the dose *dispersion* by making it a priority to reduce the highest levels of individual exposure.

**74. Is it possible to implement ALARA without a system defining the monetary value of the man.Sievert?**

Yes. It depends on the type and quantity of doses and the amount of money required to optimize them. If a significant dose reduction is achieved for a modest sum, there is no need to apply the monetary value of the man.Sv. In some situations, quantitative information may not be available (or needed) on all the factors and as a result a qualitative decision must be made. However, in all cases, the basis on which the decision was made should be recorded so the future reviews of the achievement of ALARA can assess its continued effectiveness.

### 75. Are there different types of monetary value of the man.Sievert?

**Yes, there are two types of values:**

- Those recommended by some regulatory bodies at national level, such as in Canada, Czech Republic, Finland, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States.
- Those which are used as a managerial tool at over three-quarters of the nuclear facilities in the world.

The values recommended by the regulatory bodies are generally to the order of tens or a few hundreds of US $ per man.mSv (as of the beginning of the first decade of the 21$^{st}$ century), while the facilities' managerial values are one order of magnitude higher: they often range between one thousand and three thousand US $ per man.mSv (ISOE ETC Information sheet 18 and 34)
Link: *http://www.isoe-network.net/index.php?option=com_docman&task=cat_view&gid=120&Itemid=125&limitstart=24*.

### 76. Are these monetary values of the man.Sv often used in the nuclear field?

In all countries, the use, by nuclear facilities, of the monetary value of the man.Sievert is mainly limited to important decisions both in terms of budget and (or) impact on the operation and safety of the plant. A formalized use of the monetary value of the man.Sv appears then, except for a few users, not to be part of day-to-day life.
More information is available in an ISOE ETC survey published in 2006 as Information Sheet Number 34 link (*http://www.isoe-network.net/index.php?option=com_docman&task=cat_view&gid=120&Itemid=125&limitstart=12*).

### 77. Is it possible to define a specific system for the monetary value of the man.Sievert to address the problem of doses to the extremities?

No, this would not be relevant (see Question 44, as regards to optimization of doses to the extremities).

### 78. How is the problem of subcontractor workers dealt with in terms of the monetary value of the man.Sv?

If we use the monetary value of the man.Sv, this value should be the same for all workers, both utility and subcontracted workers.

# INDEX

PLEASE NOTE: the numbers following each word, are not page numbers, **they are the numbers of the questions!**

## List of Participants to the consultancy meeting

"Frequently asked Questions on ALARA"
IAEA 4th and 5th of March 2010.

| | |
|---|---|
| T. de Bruyne ( France) | Chairman |
| J. Croft (UK) | |
| G. Massera (Argentina) | |
| M. Paganini Fioratti (Italy) | |

*IAEA Staff;*

| | |
|---|---|
| R. Czarwinski | |
| J. Hunt | Scientific Secretary |
| R. Cruz Suarez | |
| C. Lefaure (IAEA consultant) | |

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