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RADIATION EXPOSURE MANAGEMENT

Presented at the Scientific Programme for Nuclear Safety during the 1985 IAEA General Conference in Vienna

Abstract

Radiation exposure management includes administrative control, education and training, monitoring and dose assessments and planning of work and radiation protection. The information and discussion given in the paper are based on experiences in Sweden mainly from nuclear power installations.

Keywords (chosen by the author)

Management, occupational exposure, radiation protection.

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Radiation Exposure Management

An introductory paper at the Scientific Programme for Nuclear Safety during the 1985 IAEA General Conference in Vienna.

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Introduction

Radiation exposure management involves a number of administrative and practical considerations for the purpose of protection of man. Some of the more significant parts of radiation protection in occupational exposure are presented and discussed in this paper and include administrative control, education and training, monitoring and dose assessments and planning of work and radiation protection. The information and discussion given in this paper are based on experiences in Sweden mainly from nuclear power plants.

Administrative Control

The organization of radiation protection means an assignment of duties and responsibilities, specification of technical and functional requirements and establishment of a system for supervision and control.

The responsibility of radiation protection is often borne by a radiation protection officer even though the final and legal responsibility particularly in controversial issues rests on the employer. The role of a radiation protection officer is, however, quite significant. He is the contact with responsible authorities, he implements basic requirements by authorities into specific regulations and practical applications, he plans and supervises the work and follows up the dosimetric results, incidents and accidents. His position in the organisation of the company might be essential. He must be able to make decisions based on sound radiation protection practice and principles without being overruled by those responsible for the operation. He should therefore be directly subordinated to the manager.

The dose limits set by the authority are based on ICRP recommendations and implemented by the employer as requirements specific for the working conditions. The upper limit for the effective dose equivalent for workers is 50 mSv/year. A continuous exposure of 50 mSv/year during a working life time results in an annual risk of $5 \cdot 10^{-4}$/year and a lifetime accumulated risk of death of about 1%. This does not correspond to a high level of safety. However, because of optimization and good radiation practice the actual average doses to workers are less, often much less. The significance of the limit 50 mSv/year and actual exposures is not always easily understood by employees. A large gap between the limit and the real exposure might be a reason to question the need for such a high limit. A lower limit or a reference level for specific occupations, issued by the authority, might be appropriate.

ICRP's comparison with average doses and risks has occasionally been misunderstood to mean a recommended limit of the average dose to a worker over a working lifetime, in other words a recommendation of a limit for the lifetime dose. That was not the intention of ICRP. It is also to be observed that if such a limit should be introduced it would interfere with the rights of an individual to follow the career of his choice.

Other administrative methods to improve the radiation protection are classification and marking of working areas with varying need for supervision and control, record-keeping of workplace monitoring and personnel-dosimetry results to follow up the routine working conditions and special events or doses of interest etc. All these results would be used for improvements of the radiation protection by optimization procedures. Investigation levels are used to initiate special investigations. These can be triggered by measurements or predicted doses. For instance, there might be an investigation level for the expected collective dose caused by planned work. If the predicted collective dose is higher than the investigation level the employer must report and discuss the radiation protection problem with the responsible authority. Examples of such levels of the order of 0.1 manSv exist.

A limitation of the collective dose caused by occupational exposures might be recommended. The purpose would be to get an appropriate balance between the collective doses caused by various parts of an operation or by releases and resulting public exposures. Another purpose would be to get an instrument for control of the average doses of the workers.

The management of overexposed workers should follow established administrative routines including
notification of the worker, employer, medical adviser and authorities,
assessment of doses,
investigation of circumstances causing the overexposure,
corrective action to prevent recurrence of these circumstanses,
medical followup and future employment restrictions.

The employment restrictions are handled on a case-by-case basis. If the overexposure is minor the negative social consequences of employment restriction should be given great significance. If the overexposure is major the risk of non-stochastic effects caused by continued exposure should be given serious attention.

Education and training

By education and training the workers will be made aware of the potential health hazards in their work and how these can be reduced by safe working methods and techniques. Even if the main safety should be built into the design, the importance of well educated and trained personnel should not be underestimated. Failures of the protection system can occasionally be caused by so-called "human factor", i.e. unplanned, irrational or undisciplined actions against everything learnt and regulated. This is minimized by applying good ergonomic principles in the planning of design and equipment. However, even when this has been done there are several examples of incidents or accidents caused by the human factor and some of them have led to very serious consequences.

An education and training program could also, hopefully, make the workers more aware of the limited reliability of all technical safety systems. Also here are several examples of severe accidents when there has been a failure in a safety system, e.g. when a failure of the interlock system to a gamma radiography exposure room has not been observed by the worker.

The extent and frequency of education and training depends on the type of work. For workers at nuclear power plants courses annually or every second year might be needed. They should include information on risks at work, current requirements and routines and practical radiation protection measures.

Monitoring and dose assessment

Monitoring is carried out to check the compliance with given regulations. The results of monitoring are also sometimes directly or indirectly used for dose assessment.

The external exposure of man is normally measured by a personal dosemeter. Thermoluminiscensdosemeter TLD and film dosemeters are used for external dosimetry. The film dosemeter has the advantage of preserving its information on dose and can be examined repeatedly afterwards. TLD is easier and more rapid to handle in an automatic system for dose measurements. In nuclear power plants, maintenance personnel work at several plants in a year and therefore it is essential to have a rapid and reliable system for continuous and automatic information on the accumulated dose.

The overall uncertainty in the assessed exposure for a given occupational practice may be ± 50% or more. If it is less than ± 20% it is certainly to be considered very good.

If the external exposure of man is measured by fixed monitors in a room additional uncertainties are introduced, like the varying representativity of the measured result for the real exposure of man. The representativity depends on how the worker is exposed in relation to the measured exposure. Because of these uncertainties fixed monitors are used only to supplement individual monitoring and as warning devices. They can be used alone in working places where the source is fixed and the normal exposure and potential risks of high exposures are small.

The internal exposure is mostly controlled by indirect measurements on the concentration of radionuclides in air, water or on surfaces. The compliance to given regulations is shown by comparison with derived limits associated with the primary limit (50 mSv/year) or a secondary limit like annual limit of intake (ALI) or with the authorized limit as is required by the competent authority. For this purpose it is therefore normally not necessary to assess directly any dose caused by internal radiation. In some cases biological monitoring is made including external body measurements and measurements on excreta or exhaled air. By metabolic models the activity concentrations in relevant organs or tissues of the body can be assessed and, if the time of intake is known, also the amount of intake. However, the reliability of the result is often small. In many occupations the intakes of radionuclides are very small in comparison with ALI or any authorized limit and the corresponding effective dose equivalents are also very small compared to the external doses and are therefore neglected in the dose records.

The relative number of workers subject to monitoring in various occupations and working places is not consistent in relation to the actual and potential risk of exposures. ICRP considers that in cases where it is most unlikely that annual doses will exceed three-tenths of the dose limit, individual monitoring is not necessary. However, personal dosemeters are often used also in these occupations and in general monitoring is more common than ICRP considers to be justified. The reasons are of social and personnel-political character and monitoring is often intended to confirm that the conditions are satisfactory.

These circumstances might cause special problems in calculating and analyzing the average doses to workers, because an increased number of dosemeters to unirradiated workers will decrease the average without any corresponding improvement of the radiation protection.

Another problem is the differences in the procedures used for reporting dosemeter results less than the minimum detectable level. These results are reported as zero or the minimum level of detection or something inbetween. However, it is generally agreed that the recording level below which the dose is recorded as zero should not exceed one-twentieth of the annual limit pro-rata for the monitoring period.

A third problem is the differences in the procedures used for reporting missing dosemeter results. The recorded dose is either an estimated dose or a pro-rata proportion of the annual authorized limit. This can distort the records and make any assessment of average and collective doses uncertain.

Planning of work and radiation protection

Good radiation protection practice includes well performed planning of work as regards the need of radiation protection.

This concerns the overall planning of the operation and the use of personnel as well as planning of particular work and specific tasks. By use of dosimetric data the personnel can be grouped according to different types of work corresponding to various degrees of radiation protection problems and various need of special planning and improvement of working condition. Groups of workers at nuclear power plants with higher average doses than others are e.g. health physicists, insulation personnel and mechanical repair personnel. Special attention and supervision might be needed for such groups.

A basic element in the planning of radiation protection is the principle that all exposures shall be kept as low as reasonably achivable, ALARA, which is synonymous to optimization. The optimization applies for doses below the dose limits. An important method for optimization is the differential cost-benefit analysis which requires minimizing the sum of the cost of protection and the cost of detriment. The cost of detriment in monetary units is the cost the society is willing to pay to avoid this detriment. As the detriment is proportional to the collective dose the cost of detriment is also proportional to the collective dose. Several attempts have been made to define a value of the collective dose and the values have ranged from \$ 1000 manSv^{-1} to \$ 100.000 manSv^{-1}. In Nordic countries a value of \$ 20.000 manSv^{-1} is recommended irrespective of the size of the involved individual doses. This is not always so in other countries, where the value of collective dose increases as the individual doses increase. By that the higher individual doses are given greater attention and the maximum individual risks are reduced at the expense of the lower individual risks.

The collective dose from occupational exposures is a measure of the radiation detriment caused by the practice. The collective doses can be grouped at various individual doses e.g. those from doses less than 5 mSv a^{-1}, between 5 and 15 mSv a^{-1} and exceeding 15 mSv a^{-1} thus indicating the range of individual doses by which the practice is carrying the greatest detriment. This may be used for guidance in the work of reducing the total collective dose caused by a practice.

The planning of work and radiation protection can also involve a balance between various aspects of protection and nuclear safety e.g. between occupational exposure and exposures caused by accidents.

This should not be a problem if the principles of optimization were consistently applied. However, there are conceptional difficulties in case of probabilistic events, like accidents, where the consequential detriments might be weighted by the probability that the accident will occur. It is sometimes argued that prevention of accidents are justified per se and should be made with an optimized protection of workers i.e. the two concepts should not be integrated. This might be a reasonable approach for accidents with low probabilities and large consequences because they are emotion ally a priori unaccepatable. The economical consequences of even minor accidents might also be very large and far exceed the monitory value of the occupational collective doses caused by the measures to prevent the accidents or mitigate their consequences even after weighting of their probabilities. However, in case of long-term aspects of radioactive waste disposal the problem of balancing cost of protection and hypothetical detriments is a real issue.

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