DOSIMETRY INDEX: A USEFUL CONCEPT IN OPERATIONAL RADIATION PROTECTION

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INTRODUCTION

The aim of dose assessment, including dosimetry measurements in operational radiation protection is to provide information which is needed:

- to demonstrate that individual dose equivalents are in compliance both with the ALARA approach as well as with dose limits
- to signalize and elucidate trends in exposure levels in different working conditions and radiological practices
- to organize and manage effective and efficient routine and operational monitoring programs.

In conditions of uniform external exposure to penetrating radiation, the dose assessments in terms of dose equivalent to total body will be adequate since dose limitation for total body is determant.

However, in working conditions that cause a substantial non-uniformity of exposure for different organs or tissues, it may be necessary to evaluate organ dose equivalents in comparison with respective organ dose equivalent limits.
To facilitate these evaluations we use the concept of «dosimetry index».

The quarterly dosimetry index has proven to be a useful concept to define and applicate a coherent system of classification of working conditions. Also the management of person related arrangements for radiation protection, for dosimetry and for medical supervision can effectively be based on individual index values and frequency distributions of indexes within groups of persons with the same working conditions.
In our practice, dosimetry index is also used in dose registration.
In this paper the concept and practical application of dosimetry index will be discussed.

DOSIMETRY INDEX

The operational quantity «dosimetry index» is defined as the ratio (per cent) between the value H(t) of the individual dose equivalent in a periode of time (t) and the pro rata fraction (f) of the relevant annual dose equivalent limit (H_{lim}), corresponding to that periode of time.

$$\text{Dosimetry Index} = \frac{H(t)}{f \cdot H_{lim}} \cdot 100$$

This definition fulfills the conceptual requirement that an index value shall be dimensionless.

UNIFORM EXPOSURE

In working conditions which are characterized by uniform external exposure to penetrating radiation, assessment of dosimetry index per monitoring period is based on the dose equivalent limit for total body. The values for individual dose equivalent are derived from

- Ambient dose measurements. This approach is considered satisfactory as long as dosimetry index for the monitoring period is not above 3.
- Individual dosimetry with one basic dosemeter worn at the trunk of the body. These dosemeters are calibrated to Individual Dose Equivalent as recommended by ICRU [1].
  Only in cases where dosimetry index derived so far, are significantly in excess of 30, a better assessment is made in terms effective dose equivalent using conversion functions [1,2].

NON-UNIFORM EXPOSURE

Non-uniformity of exposure for different organs, tissues or body parts can be the result of a variety of causes:

- Mixed radiation fields, different radiation quality will result in highly different pattern of energy absorption. Non-penetrating radiation effect mainly superficial tissue such as skin and eye lens. Depth dose distribution for neutrons is highly dependent on neutron energy.
- Partial external irradiation due to narrow beam configuration or due to shielding or protective clothing.
- Combination of external exposure and internal contamination, especially when internal contamination is from radionuclides that are highly concentrated in specific organs or tissue.

Dose assessment for non-uniform conditions are complicated by the fact that dose equivalents for superficial organs are non-additive and are not included in the concept of effective dose equivalent. In addition dose limits for internal organs, skin, eye lens and extremities differ from dose equivalent limits for total body and effective dose equivalent. Dosimetry index is a helpful tool in the evaluation of dosimetry measurements (or calculations) by applying the concept to each of the non-additive components.
When none of these respective index values for the monitoring period exceeds 10, no further dose evaluation or more precise assessment is made. Doses are recorded as measured. In working conditions where at least one of the non-additive dosimetry indexes in a monitoring period exceeds the value of 10, individual dosimetry will be focussed on measuring the dose equivalent (or related quantity) for related organ or tissue. In many practical situations this means that in addition to the basic individual dosemeter, other dosemeters are worn to measure exposure of skin, eye lens or extremities. In case of internal exposure, monitoring programs are organized in such a way that, where possible, intakes can be assessed in terms of committed effective dose equivalent.

In general, the highest index value is determinative for the operational radiation protection approach.

REFERENCE LEVELS

Reference levels for record keeping, investigation and intervention are related to dosimetry index. Dosimetry measurement results, corresponding to index values below 10 for the monitoring period are recorded as such, but no special attention is paid to the accuracy or validity of each result. Further investigation by radiation protection staff will only take place in those cases, where zero measurements were to be expected.
Dosimetry measurements below threshold of detection are treated as zero for dose assessment purposes, but are recorded in such a way that they can be distinguished from non-measurements.

Investigations levels and intervention levels are layed down in a monitoring program in relation to both dosimetry index per monitoring period as well as dosimetry index per quarter. Investigation levels are by no means used as derived limit. Where excess was not planned or expected it is a trigger level for radiation protection staff to evaluate the practice, operating procedures and working conditions.
Where excess was expected, investigation is aimed at confirmation that working conditions are consistent with planned practice.
Since exposure levels in normal conditions are quite different for working condition A and working condition B, numerical values for investigation levels are different also (see table 1).
Where investigation levels on a quarterly base are exceeded for working condition A, attempts are made to assess actual effective dose equivalent and/or organ dose equivalent more accurate.

TABLE 1 REFERENCE LEVELS EXPRESSED IN TERMS OF DOSIMETRY INDEX

	Monitoring period	Quarter
Investigation A	100	30
B	30	10
Intervention A	300	100
B	100	30

CLASSIFICATION

In international recommendations and national legislation reference levels for classification of working conditions or persons are related to criteria, whether individual occupational exposure during a year «might exceed» or «is unlikely to exceed» specified fraction of respective annual dose equivalent limits. For several reasons, evaluation of actual or projected dose equivalents is better be done over shorter time periods:
- In many practices (e.g. research and education) persons are not continuously involved in radiological work. Dose evaluation on a yearly base can lead to underestimation of the potential exposure.
- In general, doses are not received at constant rate (e.g. hot jobs, maintenance).
- Radiation protection management must provide necessary dose-allowance for the rest of the year to prevent conflict with ALARA-concept or annual dose limits.

DOSE DISTRIBUTION

In literature, information about dose distributions in occupational exposure is generally related to dose equivalent for total body [3]. Use of dosimetry index on quarterly base provides a mean to present distributions of potential or actual exposure for non-uniform exposure conditions. Examples for five types of

practice are given in fig. 1. In all case the highest value of non-additive indexes is determinative.
For example: in cardiac catheterization we have learned that dose equivalent to the eye lens is far out the higher in proportion to annual dose limits [4]. For comparison, collected data about medical X-ray diagnostics are presented. The same type of distribution is given for radiological research in our university. Separately the distribution is given for working conditions A in cyclotron with radionuclide production.
N.B. The number of observations for each distribution is given, expressed in number of persons•quarter.

Fig. 1 DOSE DISTRIBUTION
FOR DIFFERENT WORKING CONDITIONS

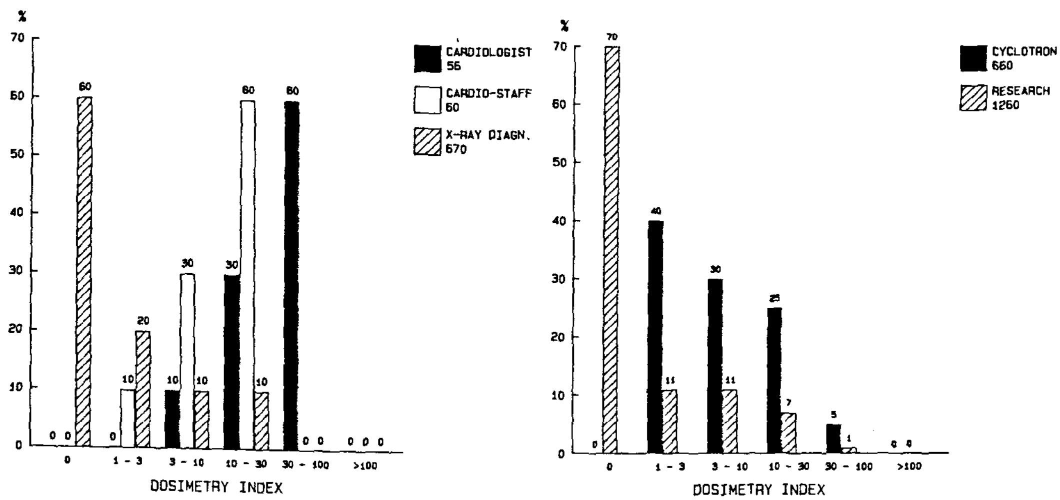
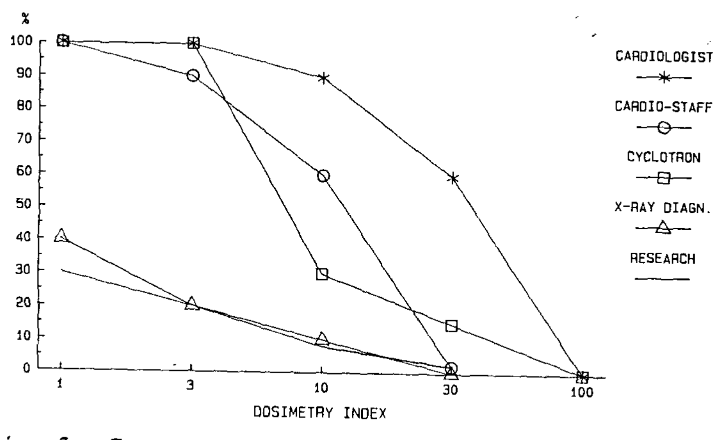


Fig. 2 PROPORTION OF WORKERS EXCEEDING
GIVEN DOSE LEVEL PER QUARTER

A useful characteristic of a dose distribution is the proportion of persons exceeding a given dose level. For the same practices this information is displayed in fig. 2. This type of information is extremely useful for planning purposes in radiation protection management.



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