SOME EXPERIENCE WITH THE RECENT DEVELOPMENT OF STANDARDS IN RADIATION PROTECTION

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Abstract

Conceptual issues in Radiation protection are today subject of a development being faster and more complex than some years ago. Scientific progress has to be incorporated into standards and legislative issues, but the time schedule is becoming tighter than before. This is because developments take place by different bodies, under different constraints and also in different administrative levels and dimensions. This lead to a situation that additional interactions takes place and issues of practicability have to be taken into account, disregarding irrational political issues. Some major issues in 1990 recommendation are not yet implemented and not properly used. Another issue is that standards for different exposures are not discriminating between different potential of dose reduction, but execute all in the same manner. As the discrepancy between conceptual and practical issues becomes more diverging than before, some more effort is needed to develop links between different types of standards (as recommendations and technical standards). In the present paper, the recent development for some modes of exposure is discussed considering issues as interaction of different types of standards, use of different dose quantities, hierarchy of limits.

1. General

Radiation Protection Standards are developed by different organisations. As the objective of the different bodies is different, the results are not necessary the same. This lead eventually to some potential of misinterpretations and difficulties in application. Standards have the objective to prove uniform conditions, but the term “uniformity” is considered different in different standards, and this in turn might lead to difficulties.
As the names of the committees imply, the area covered by the different organisations is different. This in turn lead to the different approaches in objectives and hence in terminology, and requirement in accuracy. Meetings try to make-believe harmonisation (as Florence 02), but the process of harmonization is not fully developed. Therefore, the following approaches have to be brought in line for rules in radiation protection (see figure 1 next page)

2. Development of Standards

2.1 Scientific basis:

Data on deterministic effects are well proved /IC 91/, data on stochastic radiation effects include still some uncertainties / Pi 01, Sa 01, Ca 01/. These informations provide the biological basis of radiation protection, and the data from the original investigations are further evaluated by bodies as UNSCEAR /UN 00, UN 01/. The original data lead numbers in risk factors, but indicate also a substantial uncertainty (see e.g. http://www.rerf.jp/)

2.2. Recommendations

The **International Commission on Radiological Protection** (ICRP) prepares recommendations /IC 91/ based upon the scientific data, and provides the conceptual basis, e.g. by proposing key issues as justification, optimization and application of limits as well as numbers as dose limits. New recommendations are to be expected in the near future. / Cl 02/.

Fig. 1: Radiation standards: approaches and requirements /Ts 02/

Scientific approach	**Legislative approach**	**technical approach**
Original research papers *RERF, epidemiological investigations* ⇓ Scientific Committees UNSCEAR, BEIR ⇓ International Commissions ICRP, ICRU ⇓ è	} } } € } } }	} } } €
International Organisations Basic Safety Standards of IAEA,WHO,ILO,NEA,PAHO	**International Directives EU** ⇓ **National Legislation :** **Radiation Protection Law** **Ordinance**	**International:** • **CEN** • **CENELEC** • **ISO** ⇓ **National :** • **ÖNORM** • **DIN**
To be consistent with requirement in radiation protection	*To be consistent with legal requirements and national constraints*	*To be consistent with general requirement of technical standards*

The **International Commission on Radiation Unit and Measurements** (ICRU) defines Quantities and Units [IU 93] as operational quantities (e.g. ambient equivalent dose H*(d)). As the ICRP defined also some quantities (as limit quantities as effective dose E), there is still some confusion between the application in different standards (see below).

2.3 Standards of International Organizations

The Basic Safety Standards of International Organizations /BS 96/ are based upon ICRP and ICRU, are focused only to radiation protection issues in depth, but are general in formal issues and apply not directly in some counties as EU members.

2.4 Legal approach

The Standards of the European Commission [EU 96a, EU 97] are also dealing with radiation protection, but have to be in line with formal general requirements. Translation in numerous languages lead to additional problems, and some terms are not very practicable [1]. National legislation has to take into account additional constraints, where e.g. they tend to be very "cautious" to lower certain figures in general.

2.5 Technical approach

The following national and international organisations issue technical standards in radiation protection/Gr 02/:

a) European Committee for Standardization: CEN (www.cenorm.be)
CEN/TC 114 Safety of machinery
Safety of machinery - Ionising radiation

b) European Committee for Electrotechnical Standardization:
CENELEC (www.cenelec.be) mainly medical field, X-ray

c) International Organization for Standardization: ISO (www.iso.ch)
ISO/TC 85 Nuclear Energy (SC2 Radiation Protection).
ISO has more than 200 Technical Committees, their scope ranging from TC 127: Earth moving machinery to TC 191: Animal (mammal) traps

d) International Electrotechnical Committee: IEC (www.iec.ch)
IEC/TC 45 Nuclear instrumentation (SC45B Radiation Protection Instrumentation)
IEC/TC 62 Electrical equipment in medical practice

e) On a national level, organisations as DIN and ÖNORM are producing standards in close relation to international standards

f) In addition, standards are also available for transport of radioactive material within the frasmework of "Safe Transport of dangerous goods" issued by international organisations, also applying different constraints and terminology

3. Examples

Some examples are presented below to show the relation between different standards.

a. Language

Radiation protection standards have the task to convert the findings gained in scientific investigations (including cautions conclusions, expressing uncertainty of finding, requiring further investigations, etc) into clearly defined and executable rules, which in turn can be set

[1] e.g. the definition of „Ionizing radiation". A more appropriate definition can be found in the International BSS/IA 96/

into force by legislative means ad which are executable by people unaware of the scientific background.
The phrases are therefore different, the examples below perhaps a little overdone to show the conversion of a scientific statement to a paragraph in a legal document:

- *Scientific:* The information available at present suggests that there is some evidence that a dose of less than 1 mGy might not lead to the detectable deleterious effects.
- *Recommendation:* It might be advisable to keep the dose in general below 1 mGy.
- *Legal*: The dose must not exceed 1 mGy.

Interpretation is therefore occasionally difficult, and the accuracy of the number is much lower than it looks.

b. Quantities and Units

There are different kinds of quantities, which are defined in order to fulfil specific requirements. In particular, the "new quantities" created many years ago are still not yet implemented. A few examples related to the dose are shown in brief in Table 1:

	Example	**Unit**	**Properties**
Basic Quantities (ICRU)	Absorbed dose D	J/kg, Gray [Gy]	generally applicable physical quantity not measurable directly
Limiting quantità (ICRP)	Effective dose E	Sievert[Sv]	for stochastic effects only not measurable directly
Operational quantitatives (ICRP)	Ambient equivalent dose H*(10)	Sievert[Sv]	Conservative approach of E Measuring quantity
Quality factor (ICRU)	Q	1	based on LET
Radiation weighting factor (ICRP)	w_T	1	based on biological effects
Special quantities	Dose area product Committed dose	[$Gy.m^2$]	medical radiography Integrated dose

It has to be stated that international recommendations and standards are not excessively clear in these issues.

Some confusion can be demonstrated by the use of different kinds of quantities in limitation of dose:
Based upon ICRP, the BSS and the EU-guideline define for members of the public:

- The estimated average doses to the relevant critical group of members of the public shall not exceed the following limit of 1 mSv/a, effective dose. This implies that the dose clearly refers to persons.
- In technical Standards, however (DIN 6814,) a term "Ortsdosis" (dose at a certain site) is coined and defined as: Equivalent dose, ***measured*** at a certain site (DIN 6814)". This quantity is adopted in ÖN S 5212 /ÖN 02/ and used as limiting quantity to prove compliance with limits. The Austrian Radiation Protection ordinance will probably also follow the procedure. The development is adopted from the period where no distinction between operational and limiting quantities was made. Also used since

many years, the quantity used is no primary limit (annual dose) but a derived limit (dose per week)

The development is not in line with /EU 96/, because the effective dose is used correctly as limiting quantity, comprising of external exposure, and internal exposure by inhalation and ingestion. Technical standards, however, use an operational quantity as limiting quantity. This leads to the situation that

- a figure to be measured (by definition retrospective) is used for design of protective measures of an installation
- a dose of a individual is changed to a dose at a certain site, which in turn is biasing optimisation (see 2.3 below)

Technical standards do therefore apply quantities in another sense then initially intended.

c) Biasing Optimization

Primary standards require, as one of the key issues, optimisation of protection. This requirement is one of the most misunderstood issues and the procedure is often not straightforward. Optimisation is therefore difficult to execute as authorities are usually in charge of radiation protection only and not responsible for general safety and hence for possible non-radiological hazards. For the same reason, it happens that technical standards incorporate an additional bias by straightforward procedures leading to over-conservative approaches.

An example of such procedure is shown below for the limitation of the dose of a member of the population by medical X-ray equipment.

As a limiting quantity, the dose at site under consideration is taken instead of dose of an individual (as shown in 2.2)

In design, parameters are set by standards leading to bias of optimisation by numerous "cautious" assumtions

a) design assumptions:

- Design high voltage based upon equipment characteristics rather than on medical requirements (e.g. a tube potential of 150 kV have to be taken in any case even when investigations have to be done with 85 kV. The use of then potential of 150 kV would lead to useless images and is in contradiction to other EU guidelines as /EU 96b/
- operational parameters are checked without taking into account their sensitivity (e.g. a increase of the workload for a factor of two requires an additional layer of 0,1 mm lead for the primary beam at 150 kV, but a change of the tube potential from 75 kV to 100 kV requires an additional layer of 0,7 mm lead. Both layers are required for the same shielding effect.
- distribution of scattered radiation assumed as homogenous, maximum scattering factor chosen over-conservative for a factor of two
- anode angle (and hence spectrum) not taken into account
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b) testing and operational assumptions

- equipment to be operated at maximum high voltage (never used in normal operation)
- required accuracy do not take into account of sensitive and nonsensitive parameters

- small field size taken as to be representative
- Due to design constraints mentioned above, the dose at the site of interest will never numerically identical with the design figure. But it is still assumed that a single person remains their full lifetime on the considered point, e.g. at the outer wall of the ordination.

d) Dependence of acceptable uncertainty of assessment of a number in relation to a limit to the used quantity

International standards do not consider the question to prove compliance with limits, which can be done by modelling (prospective approach) and by measurement (retrospective approach). Both approaches include some bias (see above) but include also some uncertainties. However, the uncertainty of the limit is zero by definition, even when the number is expressed in one representative digit (e.g. 1 mSv/a), but the number must not exceeded (see 2.1). When the compliance with the limit has to be proved by measurements of dose or activity, the result includes both a number and an uncertainty. e.g $A \pm \Delta A(1\sigma)$. Some work was done, which can be found in Austrian Standards ÖN 5250 and ÖN5255 /ÖN 02/ how the total uncertainty can be set in Relation with the limit. The hierarchy of the limits lead to different acceptable requirements in uncertainty / see Ts 02 and 2.5/

e) Hierarchy of Limits

There is a clear hierarchy of limits, as well described in /IA 86/ where the following distinction is made:

- Primary limits
- Secondary limits
- Derived limits
- Authorized limits
- Operational limits

This hierarchy seems of formal nature only and has apparently no consequences in most cases. However, one application is important where this hierarchy not actually taken into account. This is when compliance with the limit is to be proved by measurements (see /2.4/). As only the primary limit is a value not to be exceeded, the question of the relation of the result and his uncertainty with the limit has to be discussed. In all other cases, the (lower than primary) limit is related with the primary limit by a model, e.g.

$$\text{dose [}\mu\text{Sv]} = \text{dose rate[}\mu\text{Sv/h]. time [h]}$$

If this model is applied to prove the dose limit (e.g. the annual dose, being a primary limit) by accurate assessment of the derived limit: dose rate [µSv/h], or dose per week, the uncertainty of the result is governed, following the well known law of error propagation, by the larger uncertainty of the components of the product. Improvement of the uncertainty of one factor (the dose rate) will have very little influence to the total uncertainty when the uncertainty of the predicted time [h] is not known, and may range from 1 hour or 8766 h per year. To adopt a residence time of more then 8766 h per year is over- conservative, but even to take a full year is biasing optimisation. These facts imply that improvement of the uncertainty of the dose rate measurement will not improve the uncertainty of the annual dose at all.

f) Potential of dose reduction

Recently, standards included additional pathways, but they do not distinguish in procedures, assessment and required accuracy between the associated potential of dose reduction. The following table shows the main characteristics:

Source	Dose	dose range	potential of dose reduction
Radon	High	Large	High
cosmic radiation in airplanes	Medium	Small	Low
terrestrial external exposure	Low	Low	No
medical	High	large	*)

+) new techniques (CT, IR) are associated with a high dose, but justified by high diagnostic and therapeutic benefits

4. Conclusions

The development in different standards is occasionally not consistent with the conceptual basis of radiological protection:

1) For administrative reasons, primary quantities are replaced by secondary or derived quantities because of easier assessment and monitoring. The compliance with primary quantities is often replaced by compliance with derived quantities
2) Requirement for the accuracy of the assessment of other than primary quantities (dose per week, activity concentration) are enhanced although contributing parameters (occupancy time, consumption) include large uncertainties by definition
3) Limitations are often expressed in terms of derived quantities just for easier assessment. This has no conceptual basis in the dose range of stochastic effects.
4) It is not distinguished between limiting and operational quantities
5) As the development of standards consumes too much time, a new generation of radiation protection standards is to be expected before the previous step is executed.
6) Harmonization of standards is a need in order to make progress in radiation protection practically executable in the future

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