BIOKINETICS OF INTERNAL EMITTERS AND ANNUAL LIMITS ON INTAKE*

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1 Objectives

The Radiation Protection Ordinance of the Federal Republic of Germany (Strahlenschutzverordnung 1976) in its present form is essentially based on ICRP Publication 2 (1960). Additional knowledge acquired since that time in regard to radiation effects and biokinetics of radionuclides has been included in ICRP Publication 30 (1979). These recommendations were passed by the Council of the European Communities in the form of an EC-Guideline (EG-Richtlinie 1980). This guideline represents the basis for the Federal Ministry of the Interior, BMI, for a revision of the Radiation Protection Ordinance in the Federal Republic of Germany. For occupationally exposed persons the annual limit of 0.05 Sv effective dose equivalent will be adopted, but the annual dose limit for non-stochastic effects of 0.5 or 0.3 Sv be substituted by organ dose limits of 0.5 Sv (extremities and skin), 0.05 Sv (gonads and uterus) and 0.15 Sv (other organs), the latter being referred to as BMI dose limitation system.

Secondary limits ALI (annual limit on intake) and DAC (derived air concentration) being relevant for practical radiation protection, essentially depend on the biokinetic data of the radionuclide compound in addition to the physical properties of the radionuclide and the dose limitation system. Since it is difficult for the reader of ICRP Publication 2 (1960), sometimes also of ICRP Publication 30 (1979), to trace the selection of biokinetic data used therein, a research project was initiated within the scope of which own proposals of biokinetic data for 32 elements were derived from available literature and compared with those contained in ICRP Publication 30 (1979) for the purpose of examining the reproducibility of the values used therein and the sensitivity of the ALI in regard to variations of biokinetic data.

2 Methods

Initially, data available from literature on uptake to blood, inhalation class, distribution and retention were compiled and tabulated. They were scored as to their suitability for absorbed dose calculations. From this, own proposals for biokinetic data were derived and compared with those in ICRP Publication 30 (1979). For both sets of data the ALI was calculated and evaluated for 263 radionuclides.

3 Results

3.1 Biokinetic data

In regard to their conformity, the results may be assigned to 3 classes as shown in Table 1 for uptake to blood f_1, inhalation class, fractional distribution F and biological half-life T(biol).

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Table 1 – Comparison of own proposed biokinetic data for 32 elements with data used in ICRP Publication 30 (1979)

Quantity	Identical	Slightly modified (factor < 2)	Significantly modified (factor ≥ 2)
Uptake to blood f_1	77 %	5 %	18 %
Inhalation class	76 %		24 %
Fractional distribution F	22 %	22 %	56 %
Biological half-life T(biol)	30 %	35 %	35 %

Accordingly, our proposed values for fractional distribution and half-lives differ in about 75 % of cases either slightly (factor < 2) or significantly (factor ≥ 2) from those values in ICRP Publication 30 (1979); for uptake to blood f_1 and inhalation class this proportion is approximately 25 %.

3.2 Annual limit on intake (ALI)

Results from calculations of the ALI can be described by the ratio

$$R = \frac{\text{ALI (own proposed biokinetic data)}}{\text{ALI (ICRP biokinetic data)}}$$

In Table 2 the relative frequencies of R for values lower and greater than 1 are summarized.

Table 2 – Relative frequencies of R for values lower and greater than 1

Range of R values	Frequency of R values in dose limitation systems according to ICRP / EG		BMI	
	Oral Intake	Inhalation	Oral Intake	Inhalation
$0.99 \leq R \leq 1.01$	62 %	51 %	69 %	58 %
$R > 1.01$	16 %	30 %	16 %	27 %
$R < 0.99$	22 %	19 %	15 %	15 %

Table 3 shows the cumulative distribution of R values within given ranges.

Table 3 – Cumulative distribution of R values

Range of R around 1, characterized by factors as given below	Frequency of R values in dose limitation systems according to ICRP / EG		BMI	
	Oral Intake	Inhalation	Oral Intake	Inhalation
< 1.5	83 %	82 %	81 %	78 %
< 2	89 %	87 %	85 %	84 %
< 3	91 %	91 %	90 %	89 %
≥ 3	9 %	9 %	10 %	11 %

From 263 radionuclides examined the following values of the geometric mean of R were derived (see Table 4).

Table 4 – Geometric mean of R values in both dose limitation systems

Route of intake	Geometric mean of R values in dose limitation systems according to ICRP / EG	BMI
Oral intake	1.08	1.09
Inhalation	1.25	1.28

Accordingly, the ALI values calculated on the basis of biokinetic data from ICRP Publication 30 (1979) on the average are more restrictive than those calculated on the basis of our own proposed biokinetic data. One of the reasons for this result may be seen in the frequently quite conservative ICRP estimates of the long-term retention component which, in many cases, could not be substantiated by us from the available literature.

In spite of – from an overall view – relatively few changes of ALI when substituting ICRP biokinetic data by own proposed data, there are some chemical forms of radioisotopes of the following elements for which the ALI values, calculated from these two sets of data, differ by a factor of 3 or more:

Co, Hg, In, Ni, Np, Se, Te, Zr

As a more detailed analysis of these data shows, essentially the following reasons apply for the described differences in the two sets of ALI values:

- the compounds with $R > 3$ are particularly those for which the above mentioned, quite conservative long-term retention values used in ICRP Publication 30 (1979) cannot be easily substantiated from the available literature;
- for compounds with $R \leqslant 1/3$ our proposed biokinetic data are frequently more differentiated with higher organ uptakes than those given in ICRP Publication 30 (1979).

4 Discussion

These investigations not only confirm the relative insensitivity of the ALI values that may be expected for the concept of effective dose equivalent in respect to modified biokinetic data. Although in the BMI dose limitation system the effective dose equivalent limit is the determining factor in only a few cases (in approximately 10 % compared to approximately 75 % in the ICRP/EG dose limitation system for the 263 radionuclides considered here), the ALI in both dose limitation systems reacts comparatively insensitive to modifying the biokinetic data, particularly for changes of uptake to blood.

One explanation may be that for oral intake the GI-tract frequently represents the limiting organ, so that the biokinetic data for the remaining organs are practically without relevance, and thus a change of the fractional absorption from 10^{-4} to 10^{-1} with a corresponding portion of the administered activity in the GI-tract of 99,9 % or 90 %, respectively, only results in a 10 % change of ALI, as long as the GI-tract remains the limiting organ.

5 Conclusions

The biokinetic and dosimetric models used in ICRP Publication 30 (1979) are so complex that the effect of modified biokinetic data on the ALI values can hardly be predicted and thus in most cases require a detailed calculation. At the Institute for Radiation Hygiene of the Federal Health Office, the required programs and data files, which were developed and implemented within the scope of the above mentioned research project, are available.

In view of the variability and the scarce knowledge on biokinetic data this relative insensitivity of ALI values, even within the BMI dose limiation system, in respect to modifying the biokinetic data used is quite remarkable. On account of this relative insensitivity together with a now given possibility for rapid calculation of ALI values also for modified biokinetic data, future discussions and problems in this field may be dealt with more easily.

6 References

EG-Richtlinie
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Strahlenschutzverordnung
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