INTERPRETATION OF INTERNAL DOSE CALCULATIONS FOR DOSE RECORD KEEPING

J A B GIBSON, R K BULL, M MARSHALL AND J W SMITH
Environmental & Medical Sciences Division, Harwell Laboratory of the UKAEA
Oxon, OX11 ORA, UK

INTRODUCTION

Persons working with radionuclides are exposed to external and internal sources of radiation. The fundamental concept of adding the dose equivalent from both types of source, devised in ICRP26[1] is embodied in the UK regulations produced by the Health & Safety Executive in regulations[2] and a code of practice[3]. The measurement of external radiation is well established[4] through the use of film or thermoluminescent dosemeters. Internal dose assessment presents many more problems.

The techniques of whole (or partial) body monitoring are inadequate for most actinides, eg ^{239}Pu, at the annual level of intake (ALI)[5] and detection in urine and faeces at $\leq$0.1 ALI is only possible in the first few days after intake: sampling of the aerosol in the breathing zone is therefore important. Rapid variation in the concentration of aerosols and radioactive gases can be observed over distances of less than 1 m[6]. Thus it is important to place any collector of aerosols (a personal air sampler; PAS) as close to the face as possible; usually on the upper chest. The derived air concentration (DAC)[5] for some actinides, eg ^{239}Pu, is such that there are only a few particles per m^3 to detect and these particles will be randomly distributed in time and space. As the activity per particle usually follows a lognormal distribution, the activity collected on filter samplers will have a wide statistical spread. Other radionuclides do not necessarily present such problems and uranium detection by a PAS is probably the most sensitive and accurate method of dose assessment.

This paper will present the models used to provide dose estimates from personal air sampling, nose swabs, whole (and partial) body monitoring, excretion analysis; followed by an example. Also included are an outline of the proposed methods of dose record keeping and an initiative through Eurados-Cendos to improve the dose assessment.

MODEL DEVELOPMENT FOR ASSESSING INTERNAL RADIOACTIVITY

The model used at Harwell is essentially that described in ICRP30[5] by combining the lung, gut and other organs models. Each compartment is represented by a first order differential equation. There is no indication of excretion from organs, other than the gut, so the model includes a choice of excretion to urine or faeces from each organ. The excretion model for some radionuclides, such as ^{239}Pu, are presented in ICRP10[7] and 10A[8] as multiparameter function unrelated to particular organs and so the model output has been fitted to the function by adding additional compartments with appropriate input & output constants. The model has been programmed in two forms:

(a) a completely analytical solution for one pass through the system;
(b) numerical form for either one pass or the recycling of material as occurs with iodine.

(It should be noted that the ICRP30[5] model is designed for dose estimation and not as a representation of metabolism including excretion and a better model is required.)

The input to the body can be via lungs, with variable particle size, mouth or injection into the blood. The output from both programs is both tabular and graphical and gives the activity in individual organs and sums of organ contents, for assessing nose swabs and body monitoring measurements; and excretion in urine and faeces: all information as a function of time. Over the first few days it is important to integrate the excretion over the day rather than take the average organ content times the excretion constant because some of the latter are of the order of 0.25 d.

ANALYSIS OF A URANIUM AND THORIUM CASE

This is an example of a chronic exposure at various times throughout 1986, and the case is used for illustrative purposes to demonstrate the approach used. A personal air sampler (PAS) is used for all operations which involve uranium fuel fabrication. Urine samples are taken at approximately quarterly intervals but because the intake is a chronic one it is not possible to interpret the urine data directly in terms of intake. Thus for comparison purposes, the excretion rate in urine has been calculated from the PAS data and is as follows:

Date	Bioassay Measured mBq	PAS(Y) Calculated mBq	Ratio PAS/BIO (Y)	PAS(W) Calculated mBq	Ratio PAS/BIO (W)
27.01.86	-	0.0	-	0.32	-
17.02.86	22	0.4	0.02	11.65	0.53
12.05.86	67	4.3	0.06	116.3	1.74
11.08.86	-	1.3	-	26.2	1.31
3.11.86	-	5.0	0.07	121.9	1.74
8.12.86	254	94.7	0.37	2446.	9.62

There is probably a mixture of class Y and W material[5] but since the ALIs differ by a factor of 15 and the urinary excretion per unit intake is approximately 25 times higher for class W than Y, a small amount of class W material can change the urinary excretion rate dramatically.

Taking the conservative assumption of class Y, the resulting total intake for 1986 is shown below

Limit Nuclide	Intake Bq	ALI %	CDE mSv	CI	Organ
Non-Stochastic					
Nat U	705	35	176	0.35	Lungs
Th	2.6	0.5	2.4	0.005	Lungs
Total		36	179	0.36	Lungs
Nat U	705	0	0	0	Bone Surface
Th	2.6	2.6	13	0.026	Bone Surface
Total		2.6	13	0.03	Bone Surface
Stochastic					
Nat U	705	35	17.6	0.35	Whole Body
Th	2.6	1.3	0.7	0.01	Whole Body
Total		36	18	0.36	Whole Body

It is interesting to note that the organs for the non-stochastic limits are different for uranium and thorium. Thorium contributes a small dose to the lungs but there is no contribution to the bone surfaces from uranium. Also noteworthy is the similarity between compliance indices for non-stochastic and stochastic doses.

DOSE RECORD KEEPING

The assessment of dose equivalent or more commonly compliance index is entered on to the person's record. Compliance intake is defined for stochastic, CI(s), and non-stochastic intakes, CI(NS) as:

$$CI(S) = \frac{\text{Intake in Bq}}{\text{ALI (Stochastic) in Bq}} \quad \text{and} \quad CI(NS) = \frac{\text{Intake in Bq}}{\text{ALI (organ) in Bq}}$$

The non-stochastic compliance index may be needed for several organs if the person is exposed to several radionuclides and/or external radiation. If a person exceeds a total CI(S) or CI(NS) in a year of 0.30 then the exposure(s) is investigated by management to ascertain whether doses are being kept as low as reasonably practicable (ALARP). There are facilities within the regulations to allow an adjustment of the internal dose as more information on excretion becomes available.

The dose record for an individual is already on computer but a new data base, Harwell Approved Dosimetry Services (HADES)[9], is being established to provide on line information to Health Physicists to enable them to maintain day to day dose control. Information from film dosemeters and personal air samplers (PASs) is already stored in machine readable form and bioassay data will soon be available on the control computer. (Body monitor measurements are only made as part of an assessment.) Measurements are at or below the threshold of measurement or a CI <0.05. Results from PASs or bioassay measurements are handled automatically and compared to check if they come from the same person over the same time period. If there is an indication of a significant intake eg PAS > 100 DAC.h, then a detailed dose assessment is made based upon all data available.

HADES is used to combine all external and internal dose data into regular reports for the Health Physicist and other reports for the Central Index for Dose Information (CIDI) held by the UK National Radiological Protection Board[10]. This confidential index starts with a Registration Report to notify CIDI of monitoring for an individual; an Entry Report is returned from CIDI to provide any previous history on that individual; the Annual Return provides summarised doses and classification of the individual to CIDI within 3 months of the end of the year; a Termination Record notifies CIDI that the individual has left employment and gives details of doses received. It is hoped that HADES will be fully operational by mid 1988.

EUROPEAN INITIATIVE TO IMPROVE INTERNAL DOSE ASSESSMENTS

Eurados-Cendos, whose objectives are to coordinate dosimetry research programmes in the EEC through exchanges both within Europe and outside, instituted committee 6 on the Assessment of Internal Dose to prepare guidance on the interpretation of monitoring data relating to internal exposures of radiation workers and the implementation of ICRP recommendations on this topic within Europe. The committee drawn at present from the Federal Republic of Germany, France and the UK has set up a programme of work to: devise more

realistic models for excretion; improve interpretation of air sampling, in-vivo monitoring and bioassay data; examine autopsy data in relation to intake; ensure cross-frontier compatibility of dose records; provide for information exchange on the limited number of cases that arise in the nuclear industry in Europe. It is recognised that existing information is sparse and any improvement in knowledge of internal dosimetry and metabolism will assist European Dosimetry Laboratories in the rapid assessment of cases and so improve dose estimates to limit exposure to individuals.

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