DEVELOPMENT OF GUIDELINES FOR INCORPORATION MONITORING PROGRAMS

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1. INTRODUCTION

Federal regulations for radiation protection in Austria (1) require routine checks to be made on occupationally exposed persons if there is a risk of incorporation of radionuclides. No detailed requirements of a practicable routine program of bioassay, however, are given for such a surveillance. It was therefore necessary to develop a special monitoring program for each radionuclide taking into account single, recurrent and continous intakes.

2. PERFORMANCE AND RESULTS OF MONITORING PROGRAM

2.1 Control examinations of workers preparing organic compounds labelled with carbon 14

Various organic substances are synthesized in our center routinely for labelling with carbon 14. The employees are therefore controlled by urinanalysis and the results of a one year's period are shown graphically in fig. 1. Discussing the obtained values in fig. 1, it can be noticed that mainly three higher incorporations must have occurred. An overall estimation based on the mean of incorporated activity gave an amount of $5{,}2.10^{7}$Bq carbon 14 yielding a whole body dose of 10 mSv and a dose commitment of 16 mSv for the bone. If the amount of activity handled is related to the incorporated quantity it gives a ratio about $1{:}10^{-5}$.

2.2 Control examinations of workers preparing organic compounds labelled with tritium

In another laboratory also organic compounds are labelled with tritium. One person processed 1,85 to $3{,}70.10^{11}$Bq of tritium in the form of T_2 or HTO. The type of handling varied from storage to complex wet-handling techniques involving the danger of spilling liquids and the use of radioactive compounds with high vapor pressure. The results of these examinations are presented in Fig. 2.
If one assumes a constant tritium concentration in urine at the level of the arithmetic mean of all measurements which is 14,4 Bq/ml this would lead to an estimated average dose of 720 µSv for the period mentioned.
If the data presented in fig. 2 are interpreted as results of a recurrent intake, a maximum dose of 4,5 mSv and minimum dose of 400 µSv may have been accumulated over the control period of nearly 2 years.

Evidently, the difference between the extreme values increases with a longer time period between every two samplings. Therefore it is reasonable to use a sampling period not exceeding three times the biological half-life, i.e. one month for tritium.

2.3 Excretion analysis for ^{90}Sr

The handling of radioactive waste - including the gathering sorting and conditioning - involves a certain incorporation risk for the employees.
All people therefore engaged with radioactive waste were routinely surveyed by quarterly urinanalysis (3).
Generally ^{90}Sr-values between 0,2 and 0,02 Bq/l were registered. Higher ^{90}Sr-contents over 0,8 Bq/l ^{90}Sr in urine were only caused by two persons, who incorporated ^{90}Sr during an incident. They were afterwards examined for three month and the observed excretion curves were in good agreement with the biological half-lives cited by ICRP (4).
For the most unfavourable case, a body burden of 592 Bq ^{90}Sr, deposited in the bones, was calculated and a resulting dose commitment of 6 mSv had to be expected.
For comparison, the urine samples of 21 different persons, who were working in inactive areas, were analysed too and the mean value of 32 determinations was 0,031 $\pm$ 0,013 Bq/l
If intakes of the global fallout are included and a variation of the calcium content between 100 - 400 mg Ca per liter urine is taken also into account (5), a possible ^{90}Sr-content of $7{,}8.10^{-3}$ to $7{,}8.10^{-2}$ Bq/l results.
If possible, individual differences in metabolism, feeding habits etc. are considered a ^{90}Sr incorporation above fallout level should be assumed with certainty, only if the ^{90}Sr concentration exceeds 0,2 Bq/l of urine.

2.4 Control examinations of workers in the nuclear fuel section

From technicians engaged in the analysis of fuel elements containing natural uranium regularly an urine sample is taken and the isolated uranium determined by fluorometry (6, 7).
If ^{233}U or enriched uranium can be present, the urine sample must be examined by alphaspectrometry. Datas are given in table 1.

2.5 Excretion analysis for plutonium

The investigation level for ^{239}Pu lies at 1,48 Bq (3), causing a dose commitment of 15 mSv for the bones throughout the following fifty years. If no further incorporation occur a yearly dose of 0,3 mSv will result. If the critical level is set at 3 mSv per year and a steady state is assumed an activity of 3.10^{-2} Bq of ^{239}Pu will

be excreted per day and can be detected easily by monthly urine analysis as shown in table 1.

2.6 Monitoring of ^{99}Mo and ^{99m}Tc

In our center daily several Curies of ^{99m}Tc for medical applications are delivered to hospitals in Vienna. The effective half-life of 1,8 for ^{99}Mo and 0,2 days for ^{99m}Tc make an evaluation of the urine analysis rather difficult but can be best interpreted as a form of continous intake. Results of a survey performed by a body-counter shows a ratio between the handled and incorporated activity of $1:10^{-7}$.

2.7 Monitoring of iodine 131

Various labelling procedures in the $7,8.10^{9}$ Bq range with ^{131}I made a monitoring necessary. The survey was being made with the special incorporation monitor of our institute which has already been described.
Correlation between handled and incorporated activity gives a ratio of $1:10^{-7}$.

2.8 Monitoring of iridium 192

In one section on the isotope production, ^{192}Ir-sources are prepared routinely under strict precautions. In the monitoring interval about $1,5.10^{14}$ Bq of ^{192}Ir were processed and the employees surveyed by whole body counting. The ratio of handled and incorporated activity was $1:10^{-12}$

3. GUIDELINES FOR THE DEVELOPMENT OF SURVEY PROGRAMES

The described cases show clearly that despite of various precautions incorporations of radioactive substances can not be completly avoided.
It was also demonstrated that the risk of incorporation varies with the amount, the chemical form, the toxicity and the way of handling of the used radioactive substances Generally before setting up a survey program two main questions arise:
-above what activity level incorporation monitoring is necessary
-what time intervals must be chosen to insure an effective monitoring.

For the answer of these questions we have defined firstly a so called "handling factor".

$$H_f = \frac{A.I_f.100}{M_1} \qquad (a)$$

A = activtiy /Bq/; H_f = handling factor; I_f = incorporation risk factor; M_1 = monitoring level (= 1 % of the maximum permissible body burden of radionuclides of the tox.class 1 (1) and 10% for all other radionuclides /Bq/).

From the handling ways described in the foregoing chapter, the following in table 2 listed incorporation risk factors could be derived.

TABLE 2: Incorporation risk facotrs (I_f)

Physical state	way of handling: routine	with special precautions	incidents
gaseous and dusty material	10^{-5}	10^{-7}	10^{-3}-10^{-2}
liquids	10^{-7}	10^{-9}	10^{-5}-10^{-3}
solids	10^{-10}	10^{-12}	10^{-8}

If the calculated handling factor is $H_f \geqslant 1$, regular monitoring procedures are necessary.
The corresponding time intervals should be defined in such a manner that a single intake in the magnitude of the fixed monitoring level in the most unfavourable case that is at the beginning of the monitoring interval can be determined safely. For fixing the time intervals the following formula is proposed:

$$M_1 . Y(\Delta t) \leqslant 2\ D_1 \qquad (b)$$

M_1 = monitoring level see formula (a)
Y = value of the excretion function for the time interval Δt
Δt = time interval between two samplings
D_1 = detection limit for the radionuclide

By using the proposed formulas "a" and "b" a special monitoring program for each radionuclide can be set up. Further datas can be found in table 2.

4. LITERATURE

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TABLE 1: GUIDELINES FOR THE PERFORMANCE OF PERSONAL MONITORING

Radio-nucl.	Detection limit (Bq/l)	Monitoring level (Bq)	Dose Commitm. for monitoring level (mSv)	Concentration in Urine (Bq/d) Normal (Bq/l)	after 30days	after 60days	after 90days	after 180days	Recommended interval sampling
^{3}H	74	$3,7.10^{6}$	0,17 Whole B.	185-370	$3,2.10^{4}$	$4,03.10^{3}$	518	-	1 month
^{14}C	74	$1,1.10^{6}$	0,22-0,33 W.B.	-	170	74	-	-	1 month
^{90}Sr	$3,7.10^{-3}$	$7,40.10^{2}$	7,8 Whole Body	$7,8.10^{-2}$	1,0	0,44	0,26	0,11	3 months
^{131}I	$7,4.10^{-3}$	$2,6.10^{3}$	1,16(Thyroid)	-	-	-	-	-	1 month
Unat	0,3(µg/l)	1,5 mg	-	0,3(µg/l) 50 µg permanent					14 days
233/234 Uran	$1,85.10^{-3}$/ 24 h	18,5	0,8	$1,1.10^{-2}$	$4,0.10^{-3}$	$2,82.10^{-3}$			12 months
^{239}Pu	$7,4.10^{-4}$	14,8	2,85 Whole Body	2.10^{-3}	$2,37.10^{-3}$ permanent				1 month

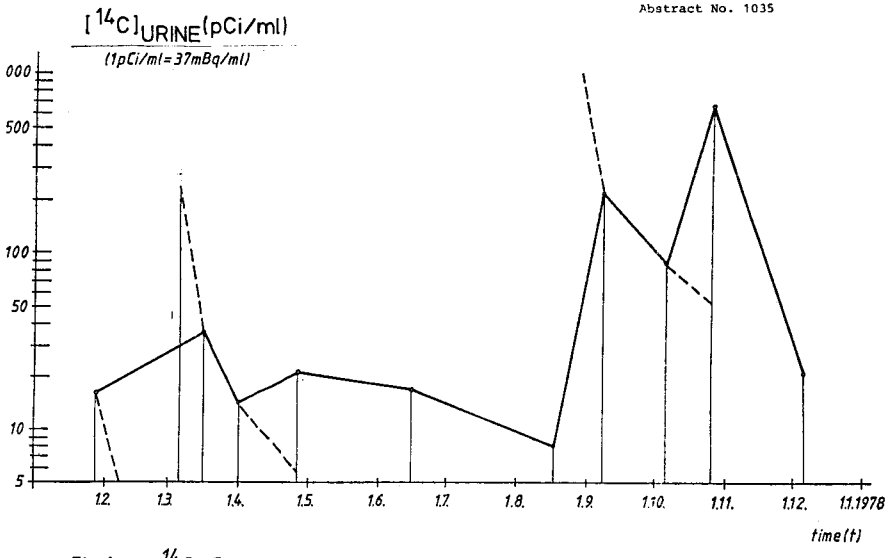

Fig.1 ^{14}C Concentration in urine after labelling work

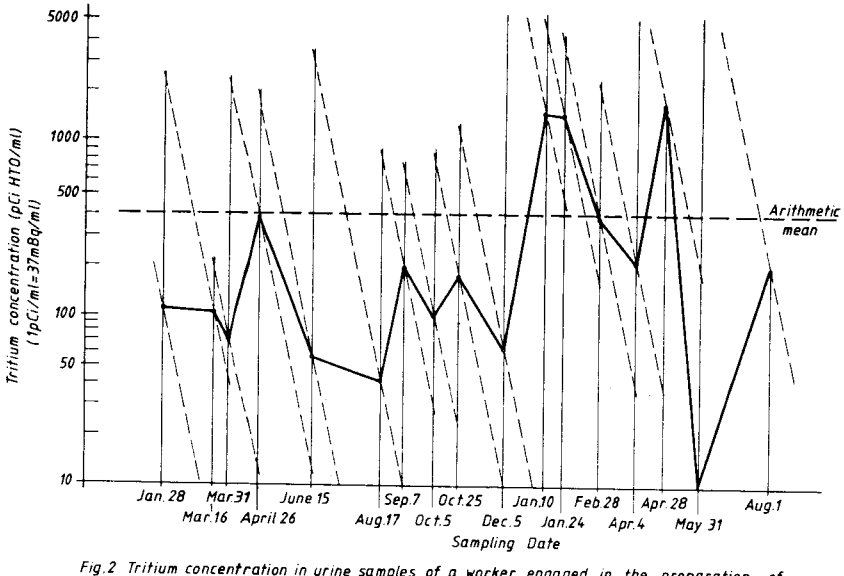

Fig.2 Tritium concentration in urine samples of a worker engaged in the preparation of tritium-labeled organic compounds