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STUDIES ON THE BIOLOGICAL HALF-LIVES OF TRITIUM RELEASED AT WOLSONG NUCLEAR POWER PLANTS

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Abstract - The one of important parameter involved in the calculation of internal radiation dose to the human body is the biological half-life of the radionuclide. The biological half-life is population specific and may differ from one population group to another. So the effective half-life of tritium exposure based on urinal bioassay measurement of Wolsong Nuclear Power Plants was investigated and studied.

INTRODUCTION

The major internal hazard in CANDU reactor environments is tritium oxide (HTO) and low levels are prevalent chronically in many workers. HTO vapour is rapidly and efficiently absorbed from the air by inhalation and through the skin in a ratio assumed to be 2 to 1[1]. It is also efficiently absorbed through the skin from contact with liquids and contaminated surfaces. HTO is distributed in body water throughout soft tissue, and is eliminated with a nominal half-time of 10 days. In addition a very small fraction is incorporated in non-exchangeable form (Organic Bound Tritium: OBT) and eliminated with a much longer half-time [2]. Tritium is a very weak, pure beta emitter (E max = 18.6 KeV). So that detection is possible only in excretion samples. For the same reason, however, its presence within living tissue is required to effect damage.

The occupational doses from tritium exposures in the operation of the CANDU Reactors can account for as much as 30% of total radiation doses. The doses from tritium at Wolsong NPPs have been maintained below 1 man-Sv per year, ranging between 0.2 and 0.8 man-Sv per year. The management of tritium doses arising from the HTO exposures is a key element of the radiation protection from at Wolsong NPPs [3]. As a part of the improvement of dosimetry program in Wolsong NPPs the data on effective half-life of tritium was investigated and calculated.

BIOLOGICAL CHARACTERISTICS OF TRITIUM

Because of the short range of tritium beta rays, the radionuclide does not constitute an external radiation hazard. The reason is that human skin is composed of the epidermis, 20 - 100 ㎛ thick, and the dermis, 1 - 3 mm thick. The target cells for skin cancers and skin damage of other types are present at the basal layer of the epidermis and in the dermis; thus electrons emitted form tritium outside of the body could never reach in these radiosensitive targets.

Bremsstrahlung produced by tritium can penetrate the skin and travel a few millimeters in tissue since these radiation have a few

thousand times the range of tritium beta-rays.

The skin irradiation from this source is negligible compared with irradiation from tritium beta-rays in the body since a small fraction of the beta particles emitted by tritium in the body produce bremsstrahlung. The resulting dose is estimated to be only about 0.001% of the dose from the beta particles. In other words, radiation emitted from tritium can only inflict damage on humans when tritium is present inside the body.

This also implies that the means of tritium in bioassay samples (e.g., urine, blood or water vapour from the exhaled air).

A general summary of some of the biological characteristics of tritium is listed in Table 1. However, as mentioned above, the most abundant chemical form of tritium is HTO in the CANDU environment, and its metabolism and dosimetry are discussed later in this document.

Table 1. Biological characteristics of tritium

Properties	Value
Effective half-life(human)	
First component	10d
Second component	40d
Quality factor	1.0

METABOLIC MODEL FOR HTO INTAKES

Knowledge of the average tritium distribution in time and space (in body water and soft tissues) is a prerequisite for dosimetry. Once inside the body, the HTO diffuses freely and rapidly across the membranes of the soft tissue, equilibrating throughout the total body water pool. Tritiated water is distributed in the intracellular and extracellular body water; consequently, tritium retention in the body follows the biokinetics of body water. The concentration in urine, about 2 hours post-exposure usually after an initial voiding, is expected to be the same as in the other body fluids.

The standardization of tritium dosimetry is based on the calculation of soft tissue dose resulting from HTO that is assumed to be uniformly distributed throughout the soft tissues of the body. ICRP 56(1989) recommends that one should assume that the assumption be made that internalized HTO is completely and instantaneously absorbed and mixed rapidly with the total body water [4]. Accordingly, at all times, the concentration in urine and body fluids (e.g., sweat, sputum, blood, insensible and exhaled water vapor) is assumed to be in equilibrium with the body water. The uniform concentration of tritium in the body after HTO intakes results in the radiation dose being uniformly distributed amongst all tissues of the body.

A compartmental model for tritium metabolism, retention and excretion after HTO intakes is illustrated in Figure 1. Two main components are included-one characteristic of the retention of total body water and the other characteristics of OBT. Many bio-organic molecules fall under the term, OBT. The fate of most of the OBT after HTO intakes is dependent primarily on the carbon metabolism of the human body. For purposes of estimating radiation dose, the retention of all forms of OBT compounds can be adequately described by assuming two compartments with different mean lives and uniform distribution throughout soft tissues. These compartments are not related to physical structures or compounds, but, rather, are given to represent general differences in carbon-tritium bonding and turnover rates.

In this model, the rate constants for the transfer of tritium between compartments are denoted by λ These parameters are measured by studying the retention and loss of tritium in human subjects. Some of these parameters can be determined directly from the retention curves for tritium in the body.

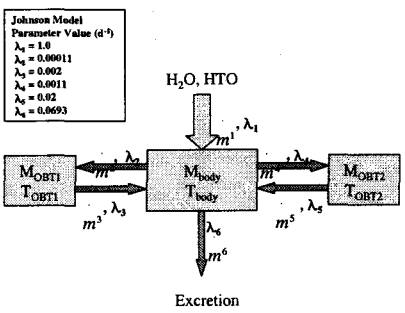

Fig 1. Balance model for water and tritium intake.

At the steady state, the water intake is;

$$\frac{\partial M_{OBT1}}{\partial t} = \dot{m}_2 - \dot{m}_3 = 0 \quad (1)$$

$$\frac{\partial M_{OBT2}}{\partial t} = \dot{m}_4 - \dot{m}_5 = 0 \quad (2)$$

$$\frac{\partial M_{body}}{\partial t} = \dot{m}_1 - \dot{m}_6 + \dot{m}_3 - \dot{m}_4 + \dot{m}_5 - \dot{m}_4 = \dot{m}_1 - \dot{m}_6 = 0 \quad (3)$$

M_x = water volume in each compartment(kg)

$\dot{m}_x$ = transfer rate (kg/day)

The tritium balance in the body is;

$$\frac{\partial T_{OBT1}}{\partial t} = \dot{m}_2 \frac{T_{bw}}{M_{bw}} - \dot{m}_3 \frac{T_{OBT1}}{M_{OBT1}} = 0 \quad (4)$$

$$\frac{\partial T_{OBT2}}{\partial t} = \dot{m}_4 \frac{T_{bw}}{M_{bw}} - \dot{m}_5 \frac{T_{OBT2}}{M_{OBT2}} = 0 \quad (5)$$

$$\frac{\partial T_{body}}{\partial t} = -\dot{m}_2 \frac{T_{bw}}{M_{bw}} + \dot{m}_3 \frac{T_{OBT1}}{M_{OBT1}} - \dot{m}_4 \frac{T_{bw}}{M_{bw}} + \dot{m}_5 \frac{T_{OBT2}}{M_{OBT2}} - \dot{m}_6 \frac{T_{bw}}{M_{bw}} = 0 \quad (6)$$

where, T x = the activity of tritium in each compartment (Bq)

Also, the transfer constants are;

$$\lambda_2 = \frac{\dot{m}_2}{M_{bw}}, \quad \lambda_3 = \frac{\dot{m}_3}{M_{OBT1}}, \quad \lambda_4 = \frac{\dot{m}_4}{M_{bw}},$$

$$\lambda_5 = \frac{\dot{m}_5}{M_{OBT2}}, \quad \lambda_6 = \frac{\dot{m}_6}{M_{bw}} \quad (7)$$

RESULTS AND DISCUSSION

Based on the urinal bioassay results, the initial and final concentration of workers were measured [5].

The biological half-life for tritium was obtained as 7.43 day, in comparison to 10 days reported for ICRP Reference Man [6]. It is interesting to note that the biological half-life is shorter than those reported for the ICRP Reference Man. Based on the relatively shorter biological half-life of the tritium, the radiation dose per unit intake of tritium to the Korean population may be lower than for ICRP Reference Man.

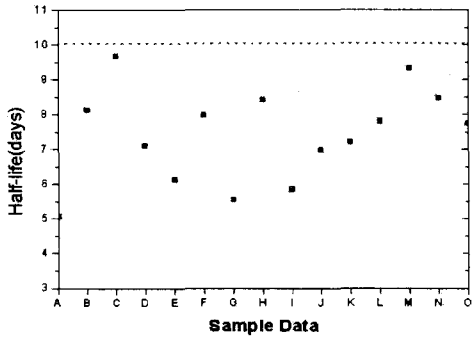

Fig 2. Half-life of HTO based on urine bioassay result of Wolsong NPPs workers.

Table 2. Measurement data used in this study

No	Sample	Weight (kg)	Duration of Observation (Days)	Number of Measurement	Initial Concentration (MBq/l)	Final Concentration (MBq/l)
1	A	68	16	8	5.39	0.540
2	B	69	36	13	9.24	0.463
3	C	90	40	10	8.57	0.477
4	D	63	18	7	3.31	0.585
5	E	73	17	9	3.50	0.500
6	F	60	21	5	3.31	0.540
7	G	62	16	5	3.20	0.429
8	H	68	23	6	2.34	0.518
9	I	67	12	4	4.29	0.108
10	J	60	26	9	6.90	0.551
11	K	64	32	11	5.68	0.259
12	L	72	13	8	2.19	0.681
13	M	74	27	6	4.08	0.566
14	N	60	19	6	2.86	0.592
15	O	63	29	6	6.63	0.459

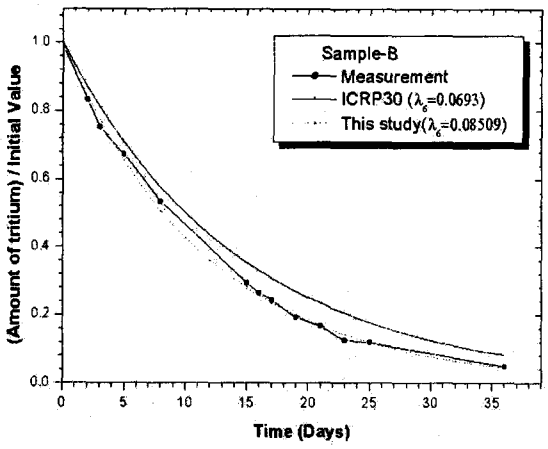

Fig. 3. Retention rate of HTO for ICRP-30 and fitted measurement (Sample-B).

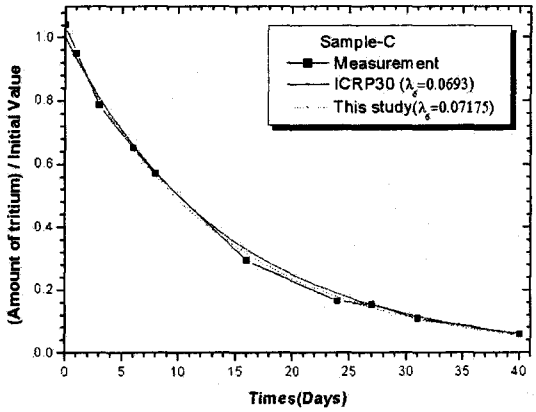

Fig. 4. Retention rate of HTO for ICRP-30 and fitted measurement (Sample-C)

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