Review on Metabolism and Dosimetry of Tritium

Tae Young Kong*, Hee Geun Kim, Woo Tae Jeong, Seok Tae Kim
Korea Electric Power Research Institute, 103-16 Munji-dong, Yuseong-gu, Daejeon, Korea
**Corresponding author: eagertae@kepri.re.kr*

1. Introduction

This paper aims to review the current knowledge of physical and chemical characteristics and biological transport process associated with tritium metabolism, especially for tritiated water (HTO) and elemental tritium (HT). The summary of the in vivo behavior of tritium is also provided taking into account dosimetry and radiological risk assessment.

2. Physical and Chemical Characteristics

Tritium (^{3}H or T) is a radioactive isotope of hydrogen which occurs from both natural and manufactured processes. Its half-life is 12.3 y, decaying to helium while emitting a low beta energy particle. Because these beta particles released during tritium decay cannot penetrate the outer layer of dead skin cells due to their small range in tissue of less than 1 ㎛, tritium has no external hazard [1]. Various types of chemical compounds of tritium can occur by many different biological processes. When tritium is combined with water, tritiated water (HTO) can be formed. Most of tritium in the environment exists as HTO, a major contributing factor to human exposure. In addition to HTO, hydrogen gas (HT) is also one of the interest chemical compounds for dosimetry since the conversion of HT into HTO can occur through various processes [2]. Conversion of HT to HTO has two important routes: 1) oxidation in soil attributable to micro-organisms, 2) oxidation in humans attributable to bacteria within the large intestine [3]. However, studies have shown that the conversion rate of HT to HTO is extremely low both in environment and in human body. On the other hand, tritium in HTO may exchange with hydrogen atoms and become organically bound tritium (OBT). OBT has its own particular metabolism that may result in inhomogeneous distributions of tritium within the body and individual organs. In most organic compounds, OBT can easily exchange with hydrogen in the body water pool and will have the same metabolism and distribution as for HTO. Tritium may also exchange with hydrogen in carbon-hydrogen bonds and this OBT is difficult to remove.

3. Metabolic Models of Tritium

Tritium can enter the body in the form of many different chemical compounds. In general, two chemical forms of tritium (HTO and OBT) contribute the most of the radiation exposure to the body. Because HTO plays the dominant role in most metabolic processes of tritium, the accuracy of the risk assessment from exposure to tritium is mostly dependent on the accuracy of HTO dosimetry.

3.1 HTO metabolism

A compartmental model for HTO metabolism was described by Dunford and Johnson (Fig.1) [5]. In this model, the characteristic of the retention of total body water and the characteristic of OBT are two main components. For purposes of estimating radiation dose, the retention of all forms of OBT compounds is appropriately described by assuming tow compartments with different mean lives and uniform distribution throughout soft tissues.

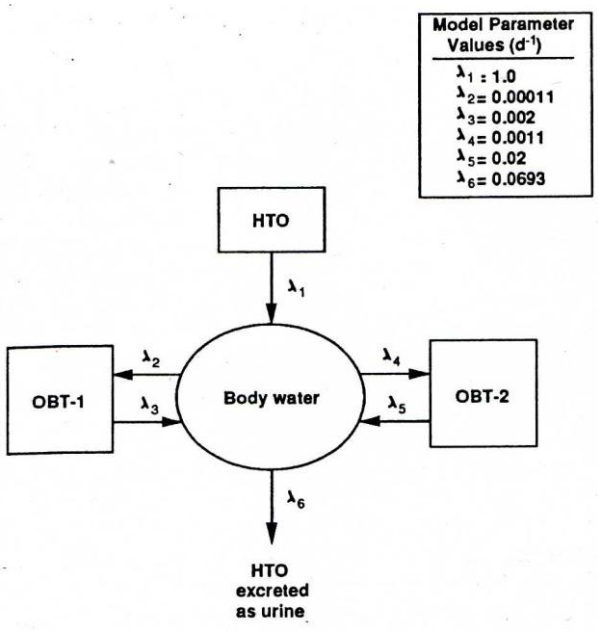

Fig. 1 HTO compartmental model [5]

3.2 HT metabolism

A compartmental model for HT was described by Peterman (Fig. 2) [6,7]. This model coupled to the HTO model. This model was used to analyze the results from a human volunteer study and it was found that the effective dose from inhaled HT consisted of two major contributions which have approximately same amount. The average equivalent dose form the dose to the lung from HT contained in inhaled air was found to be basically the same as the average equivalent dose from HTO formed by oxidative processes after HT gas

exposure. However, this contribution is ignored in the ICRP model since the limit on exposure to HTO is more than four orders of magnitude less than that for elemental tritium (HT) and in most cases in practice exposure to HTO will be the limiting factor.

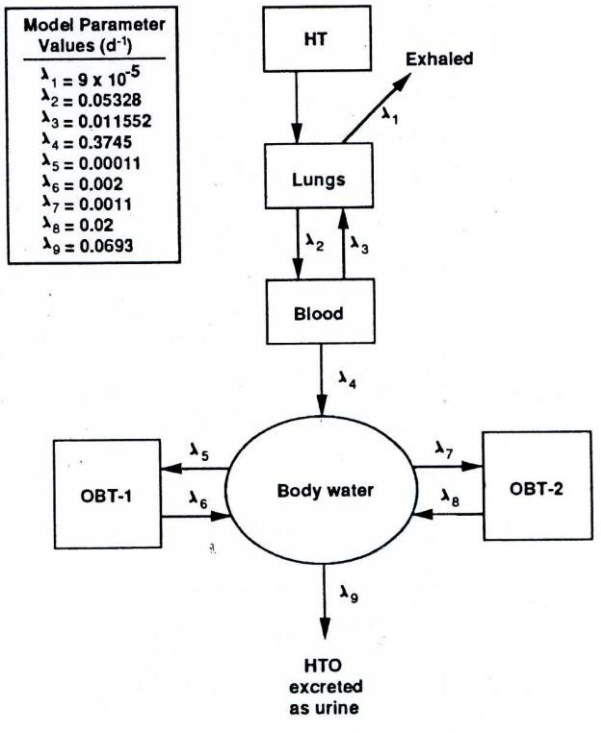

Fig. 2 Inhaled HT compartmental model [6,7]

3.3 OBT metabolism

In terms of OBT from foodstuffs, Etnier proposed a four compartment model that is based on hydrogen balance within the human body [8]. The four compartment model enables for input of OBT directly into compartments representing tissue rather than into the body water pool. This feature should be taken to distinguish between the different OBTs. The catabolism of OBTs in foodstuff will be governed by the catabolism of the carbon compounds with tritium and it is unlikely that only four compartments will give a reasonable estimate of retention.

4. Conclusions

To help understanding of metabolism and dosimetry of tritium, this paper provides not only the physical, chemical, and biological characteristics of tritium but also the several metabolisms depending on its chemical forms. It is expected that this paper can be used to estimate the exposure by workers who involve the process of tritium removal facility (TRF).

ACKNOWLEDGEMENTS

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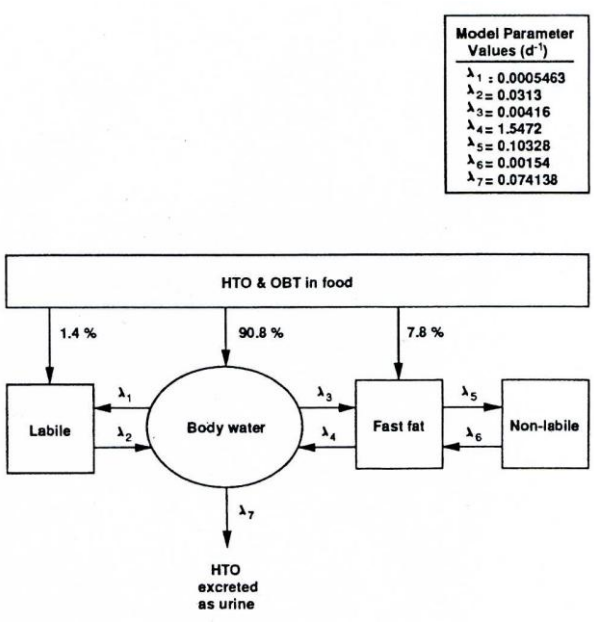

Fig. 3 OBT compartmental model [8]

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