PERCUTANEOUS ABSORPTION OF TRITIATED OIL AND DOSIMETRIC CONCERNS

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ABSTRACT

Tritiated oil deposited on the skin provides an intake route for organically bound tritium (OBT) and tritiated water (HTO). The kinetics of tritium excretion in the urine of hairless rats exposed to tritiated vacuum-pump oil have shown a much shorter effective time constant for OBT, compared to HTO. However, the detection of long-term tritium activity in urine indicates that there is also long-term retention in the body. This is attributed to metabolism and assimilation of tritiated compounds into the body.

INTRODUCTION

Tritium has been measured in pump oils within the vacuum pump reservoirs in tritium handling facilities [1]. A high-performance vacuum pump operating in the tritium handling facilities can retain significant amounts of tritium activity in oil and lubricants [2]. Tritium activities in the pump oils from a D-T neutron generator facility are being detected and reported as a possible source of internal contamination during maintenance of the pump systems [3].

Tritium contamination of vacuum-pump oil can result in radiation-induced polymerization of the oil. Thermal degradation and tritium radiolysis of pump fluids are considered to be critical factors in generating specific tritiated impurities. Also, tritium gas in the oil may convert to tritiated water by the catalytic effect of the emitted β-rays. This conversion becomes an important factor in contamination evaluation.

The absorption of tritium through the skin has long been recognized as a possible route of intake. Our earlier study on the skin-contact exposure to tritium-gas-contaminated metal surfaces has increased the awareness of the radiological consequences of such tritium exposures [4]. To enable improved assessment of the risk from skin contaminated with tritiated oil, the urinary excretion of tritium following the skin-contact exposure of hairless rats has been investigated. The analysis of urinary excretion of tritium is performed to evaluate the possible radiological consequences from this mode of contamination.

EXPERIMENTAL PROCEDURE

Tritiated oil was prepared by the Chemical Engineering Branch at Chalk River Laboratories. The tritium content of the oil was 31± 1 $mCi \cdot g^{-1}$ (1.2×10^3 $MBq \cdot g^{-1}$). To prevent abrasion to the skin, six-month old male hairless rats (Sprague-Dawley:hy.hy) were used. The contaminated oil (28 MBq in 0.05 mL) was applied against the dorsal skin (4 cm^2) to expose the animal percutaneously. The application was short (less than a minute), but the oil remained on the skin. Urine samples were collected before exposure to provide

background specimens, and were subsequently collected at regular intervals to determine HTO and OBT rates of excretion.

RESULTS AND DISCUSSION

The application of contaminated oil on the skin does not represent an acute exposure, as a thin film of contaminated oil on the skin was detected in the post-exposure examinations (within 24 h). This situation may represent a continuing exposure for the period in which a gradient of the contaminated oil exists across the skin.

Tritium in pump oil has been identified as existing in two distinct chemical states: one is tritiated organic impurities or nonexchangeable tritium (95%), and the other is tritiated water (5%).

Tritiated water in the oil should behave similarly to HTO from skin exposed to HTO vapour [5]. Thus HTO absorbed through the skin from contaminated oil should distribute uniformly throughout the body, and be excreted with a dominant single time constant. However, the urinary excretion of HTO from contaminated animals was best fit in terms of two exponentials: a fast- and a long-term component (Fig. 1). The fast component of HTO excretion was represented with an average half-life of about 3.3 ± 0.4 days (Table I). This half-life value is identical to the value of clearing component observed after skin exposure to HTO, suggesting that the HTO excreted in this component originated predominantly from the oil. The presence of a second component with half-lives of 25.5 ± 3.5 days was attributed to the fact that the turnover of HTO in the body is initially influenced by rapid absorption of tritium through the skin as tritiated water with subsequent excretion in the same form, followed by the delayed excretion of HTO as a result of catabolism of stored OBT in the body.

TABLE I Urinary Excretion of Tritium ($MBq \cdot d^{-1}$) and Biological Half-Lives (days). Values are mean of four independent animal experiments (n=4), and the standard deviation (S.D.) for each value is in parentheses.

Component	$U_{0,1}$	$U_{0,2}$	$U_{0,3}$	$T_{0,1}$	$T_{0,2}$	$T_{0,3}$
HTO	2.7E-02 (1.5E-02)	2.0E-05 (4.7E-06)		3.3 (0.4)	25.5 (4.0)	
OBT	9.0E-02 (4.5E-02)	6.1E-04 (3.0E-04)	1.3E-05 (4.1E-06)	1.0 (0.1)	5.4 (0.6)	31.4 (1.9)

A significant amount of OBT was also observed in urine (Fig. 1). The excretion of OBT elevated sharply and reached a maximum at 12 h. The OBT excretion in urine was analyzed in terms of three exponentials: fast-, medium- and long-term components. As shown in Table I, a much faster OBT (compared to HTO) clearing was noticed with a half-life of 1.0 ± 0.1 day. The slower

components were represented with 5.4 ± 0.6 days and 31.4 ± 1.9 days of half-lives. The amount of OBT excreted in the urine during the experimental period (for 112 days) accounted for about 75% of the total tritium excreted, whereas HTO concentration ranged between 20% and 30%.

The urinary concentrations and kinetics of tritium not only reflect the degree of percutaneous absorption of tritiated oil, but also exhibit a function of the distribution and elimination characteristics of the tritium in the body. The majority of tritium (~80%) is cleared in the urine in very early periods post-exposure (within five days). However, that fact does not account for the total applied activity on the skin. The excretion of total tritium in urine accounts only for 1% of the applied activity. The unaccountability of a large portion of tritium in urine suggests that a significant portion of tritium has: (i) been retained in the body, (ii) been lost through exhalation, (iii) been evolved from the skin, or (iv) may never have entered the body. The last seems most likely; however, the estimation and accountability of such large portions of tritium are prerequisites in developing a proper metabolic understanding.

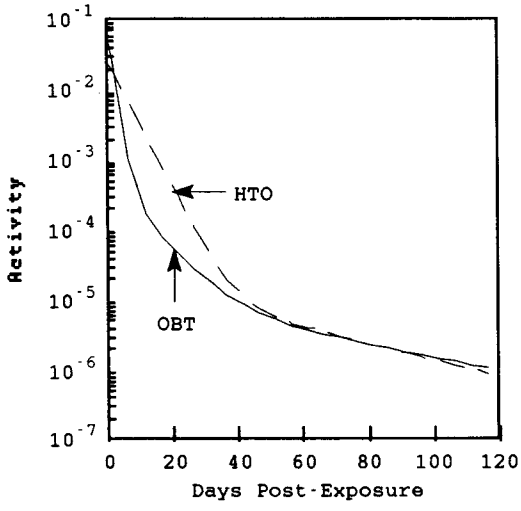

Figure 1. Urinary excretion ($MBq.d^{-1}$) of tritium following skin-contact exposure to tritiated oil.

The skin forms a complex barrier to external contaminants. The knowledge of the skin penetration of tritium contaminants is important. In predicting the rate at which tritiated contaminants penetrate the skin, it is necessary to consider the fundamental physiology of the skin and relate this to the possible rate-limiting steps in the permeation process. It would be useful to learn quantitatively the absorption and retention of tritium in

skin. It is thought that tritium diffuses passively in all its forms across the skin. This assumption is necessary if a simple mathematical representation of the experimental results is required for dosimetric interpretations.

Comparing the current data with our earlier work on tritium-gas-contaminated metal surfaces [4], it is apparent that the mode of contamination from two different sources results in similar tritium excretion kinetics in urine. Such observations support (but do not prove) the notion that tritium contamination from metal surfaces is due to the transfer of tritium impurities that originated external to the body and are then assimilated into the body.

CONCLUSION

It is apparent that skin-contact exposure to tritiated oil results in HTO uptake and OBT accumulation in the body. The accumulation of OBT at the point of contact in the skin and in various tissues influences the kinetics of tritium excretion in urine. The long-term retention of tritium in the body can contribute to doses to the skin and other tissues. It is therefore important to illustrate the significance of long-term retention of tritium in the body and its influence on dosimetry.

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