Simple Internal Exposure Measurement for Tritium by Expiratory Water Trapping Method Using Water Bubbler.

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1. ABSTRACT

The Tritium Process Laboratory (TPL) is the first facility which uses tritium over 1 gram (1g=3.58×10^{14} Bq) in the fusion research of Japan. Main objections of the TPL are to study basic engineering technology of tritium processing in the fusion fuel cycle and to develop tritium safety systems. Therefore, the few grams of tritium is handled in TPL. Internal exposure is more important than external exposure for the exposure control such as tritium treated facilities. In TPL, the internal exposure inspection is carried out by a simple internal exposure measurement method for tritium using expiratory water trapping apparatus with a water bubbler. The method is applied for workers who have a possibility to intake the tritium with their work. All the workers must also undergo the internal exposure inspection every month period.

Generally method for measuring amount of tritium in the urine is used to evaluate the internal exposure. But a pre-processing equipment of urine is needed in this method. The expiratory water trapping apparatus only collect the expiratory water by the water bubbler. Therefore, the tritium internal dose is evaluated using expiratory water trapping apparatus in TPL.

However, the fluctuation of collection efficiency of the apparatus before remodeling was about 40-90%. The collection efficiency is an important coefficient to evaluate the dose. The factor of fluctuation of the collection efficiency is that all of the tritiated water of the water bubbler in the apparatus can’t be poured in the vial. Then, the apparatus was remodeled in order to collect the residual tritium in the apparatus. As the result, the collection efficiency increased about 85-96% with small fluctuation after the remodeling.

2. Evaluation of internal exposure using expiratory water trapping method

Simple internal exposure measurement for tritium by expiratory water trapping method using water bubbler is used in TPL. The procedure is, (1) the worker blows his expiration into the expiratory water trapping apparatus, (2) the expiratory water is collected mainly into the water bubbler, (3) the collected expiratory water is measured by the liquid scintillation counter, (4) the tritium internal dose would be evaluated.

Ingested tritium water is assumed to be completely and instantaneously absorbed from the gastrointestinal tract and to mix rapidly with the total body water so that, at all times following ingestion, the concentration in sweat, sputum, urine, blood, insensible perspiration and expired water vapor is same. And, it is assumed that this tritiated water is instantaneously distributed uniformly among all the soft tissues of the body\(^{(1)}\). Actually, the tritium concentration in the body is uniform after about two hours.\(^{(2)}\)

From the tritium concentration of the expiratory water, effective dose equivalent by the intake of tritium is evaluated according to following equation.

\[
Di = \frac{Ec \times 42000 \times 1.7 \times 10^{-5}}{0.38 \times Cf}
\]

Where Di : Effective dose equivalent by the tritium(\(\mu\)Sv)  
Ec : Amount of tritium of expiratory water into the 10000cm\(^3\) expiration recovered by the expiratory water trapping apparatus.(Bq)  
Cf : Collection efficiency of the expiratory water trapping apparatus.  
0.38: Amount of expiratory water into the 10000cm\(^3\) expiration.(g)  
42000 : The mass of the water which the reference man possesses for the whole-body.(g)  
1.7×10^{-5} : Effective dose equivalent conversion factor from the unit intake of the tritium.\(^{(3)}\)

\((\mu\text{Sv}/\text{Bq})\)

The experimental value of the collection efficiency using the same type of apparatus was 0.66 (maximum),\(^{(4)}\) though the specification of collection efficiency of the expiratory water trapping apparatus is 0.92. There is large difference in the collection efficiencies. Since the efficiency is very important for estimating the dose, the difference of two data is large problem. Therefore, it is necessary to investigate the cause of the fluctuation of the collection efficiency, and to remodel the apparatus to stabilize the collection efficiency.

3. Outline of the expiratory water trapping apparatus.

The outline of the expiratory water trapping apparatus is shown in Fig.1. The main component of the apparatus consists of vial drive section, expiratory water trapping part (water bubbler), water supply pump,
liquid scintillator supply pump, flowmeter and control unit.

Fig. 1. Outline of the expiratory water trapping apparatus.

The procedure is, (1) the distilled water (5ml) is poured into the water bubbler, (2) a worker breathes out into the apparatus using the mouthpiece, (3) the expiration passes through the water bubbler, and the expiratory water is trapped there. (4) it’s expiratory water trapped in the water bobbler is poured into the vial, (5) liquid scintillator is added into the vial. After that (6) the water bubbler is washed two times by the distilled water to remove the residual tritium. These procedure is carried out automatically.

4. Fluctuation of the collection efficiency
4-1 Collection efficiency before the remodeling.

Fig. 2 shows the outline of saturated water vapor generation equipment, which can made the tritiated water vapor of uniform concentration. This equipment has been composed of tritiated water vapor generator, gas washing bottle drying air with silica gel, temperature and humidity measurement section, air circulation pump, tritiated water vapor storage section with air bag.
Fig. 2. Outline of the saturated water vapor generation equipment.

First, the air is circulated in order to drop the humidity to near 0% by the A-loop. Next, the dry air is moisturized by the tritiated water vapor generator using B-loop, until the humidity in the loop become near 100%. After that, the air into the air bag is run through the expiratory water trapping apparatus using the C-line. The flow rate is 3000cm³/min. The collection efficiency is calculated by the ratio between the total quantity of tritium run through the apparatus and the tritium quantity collected by the apparatus.

\[
\text{CF} = \left( \frac{V_t}{T_i} \right) \times 100
\]

Where  
\( \text{CF} \): Collection efficiency.\(^{\text{\%}} \)  
\( V_t \): Tritium quantity collected by the apparatus.\(^{\text{(Bq)}} \)  
\( T_i \): Total quantity of tritium run through the apparatus.\(^{\text{(Bq)}} \)

Where, \( T_i \) is calculated.

\[
T_i = BW_c \times D \times 10000 \times 10^{-6}
\]

Where  
\( BW_c \): Tritium concentration in tritiated water vapor generator.\(^{\text{(Bq/g)}} \)  
\( D \): Saturated water vapor density.\(^{\text{(g/m³)}} \)  
10000 : Quantity of tritiated water vapor run through the apparatus.\(^{\text{(cm³)}} \)  
10^{-6} : Unit conversion.\(^{\text{(m³/cm³)}} \)

4-2 Measurement of the residual tritium in the expiratory water trapping apparatus.

As well as the collection efficiency measurement in 4-1 before the remodeling, tritiated water vapor (10000cm³) runs through the expiratory water trapping apparatus by the C-line (the flow rate is 3000cm³/min.), and the tritiated water vapor is collected in the apparatus. Then, the tritiated water is poured into the vial, and measured by the liquid scintillation counter. To measure the residual tritium in the bubbler, the bubbler washing water is also collected and measured.
4-3 Collection efficiency of the apparatus before the remodeling

Fig. 3 shows the fluctuation of the collection efficiency of the apparatus before the remodeling. The collection efficiencies fluctuate from 41-85%. The tritium quantity proportion of bubbling water, first and second bubbler washing water and total in the water bubbler are shown in Table 1. 17-37% of tritiated water was contained in the first washing water of bubbler. And, 6-20% was residual in the second washing water. 41-85% was contained in the bubbling water (sample), so about 95% of total tritium quantity was collected in the water bubbler. Only 5% of total is stained at the other part of the apparatus and the air passed through the water bubbler. The measurement was carried out by changing temperature, humidity for examining the effect of humidity and temperature. The correlation between humidity and temperature could not be observed.

![Fluctuation of the collection efficiency of the apparatus before the remodeling.](image)

Table 1. Tritium quantity proportion of bubbling water, first and second bubbler washing water and total in the water bubbler.

<table>
<thead>
<tr>
<th></th>
<th>Bubbling water (sample) (%)</th>
<th>First bubbler washing water (%)</th>
<th>Second bubbler washing water (%)</th>
<th>Total in the water bubbler (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>41.3-85.2</td>
<td>17.3-36.9</td>
<td>6.5-20.1</td>
<td>90.4-99.7</td>
</tr>
</tbody>
</table>

5. Collection efficiency after the remodeling

5-1 Outline of the apparatus after the remodeling

After the remodeling, the air pump is added shown in Fig. 1. The procedure is same as section 3 until number (4). After that, the following procedures are added, (4′) the residual tritiated sampling water in the water bubbler is blown up by using the air pump, (4′′) the washing water (5ml) is poured in the water bubbler, and (4′′′) the washing water is poured in the vial.

5-2 Collection efficiency measurement after the remodeling

The standard water vapor generation equipment is same as 4-1 for the measurement of the collection efficiency after the remodeling. 10000cm³ tritiated water vapor is run through the expiratory water trapping apparatus by the C-line, and the tritiated water vapor is collected into the water bubbler. After that the bubbler water and first washing water are collected in the vial.

5-3 Collection efficiency after the remodeling

The collection efficiency after the remodeling is shown in Fig. 4. The collection efficiencies after the remodeling were about 85-96%, average about 88%, and the fluctuation was less than before the remodeling. From the results of 4-3, about 95% of collection efficiency is expected. But actual collection efficiency was about 88% in average. The reason is why the vial volume is 20ml, and the sampling water (5ml) and liquid scintillator (10ml) is poured in the vial, so the washing water is limited to 5ml. The correlation between humidity and temperature could not be observed as well as before the remodeling.
6. CONCLUSION

The expiratory water trapping apparatus method is useful to measure the tritium internal exposure for workers. The average of the collection efficiency of the expiratory water trapping apparatus after the remodeling increased about 88%, and it would be able to be used at the collection efficiency 85% in the practical use. And, the fluctuation of the collection efficiency also decreased, and it would be possible to evaluate more accurately the dose of the tritium at practical radiation monitoring. The investigation of the effect of flow rate of expiration is needed, because the flow rate is difference for each worker.

7. REFERENCES

1) ICRP Publication 30, Limits for Intakes of Radionuclides by Workers Part1, Pergamon Press, Oxford(1979)
2) E.A.Pinson, et al , Physiology and toxicology of tritium in man, J.Appl.Physiol.10(1957)