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# Effect of the Changes of Respiratory Tract Model on the Uranium Bioassay Data

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## 1. Introduction

The actual retention of a material in a body tissue and excretion from a body following intake of radionuclides may be very complex. For simplicity the simple compartment models which depict the respiratory and alimentary tract, systemic behavior after absorption have been used to predict the retention and excretion. ICRP published the HRTM(Human Respiratory Tract Model) representing respiratory tract for inhalation in publication 66[1] and the model have been used to establish bioassay data. The HRTM, however, was revised based on the recent experimental data in OIR[2](Occupational Intakes of Radionuclides) draft report of ICRP. The changes of respiratory tract model are predicted to directly affect bioassay data like retention and excretion functions.

Lung retention function is especially important to internal exposure assessment for workers related to fuel manufacturing because the place could be contaminated by uranium. In addition, faecel samples are recommeded to be used for in-vitro bioassay of uranium because of very slow excretion via urine. More reliable assessments for the workers in fuel manufacturing could be achieved by recalculation of bioassay data for uranium and the comparing study using original and revised HRTM.

In this study, therefore, the lung retention and faecal excretion functions for inhalation of $UO_2$ and $U_3O_8$ were recalculated using revised HRTM and the results were compared with those of original HRTM. The effect of the changes of HRTM could be confirmed by the results of this study.

## 2. Materials and Methods

For comparing of two respiratory model, the Human Alimentary Tract Model(HATM, ICRP 100[3]) and the recent systemic model for uranium in OIR were adopted for both two cases. In this section, the changes of revised Human Respiratory Tract Model(revised HRTM) and the calculation methods are described.

### *2.1 revised Human Respiratory Tract Model*

*Deposition*

No changes are made in revised HRTM to the original HRTM of deposition model for aerosols, except for the distribution of the deposit in the ET airways between regions $ET_1$ and $ET_2$. In Publication 66 the same deposition fraction was assumed for $ET_1$ and $ET_2$ although actual deposit amount of $ET_1$ was more than $ET_2$. In OIR, however, more realistic fractional deposition in extrathoracic region is adopted because the more realistic transfer rate is available(see below). The fractional deposition changes in each region of the respiratory tract of the reference worker are given in Table 1 for aerosols of 5μm AMAD.

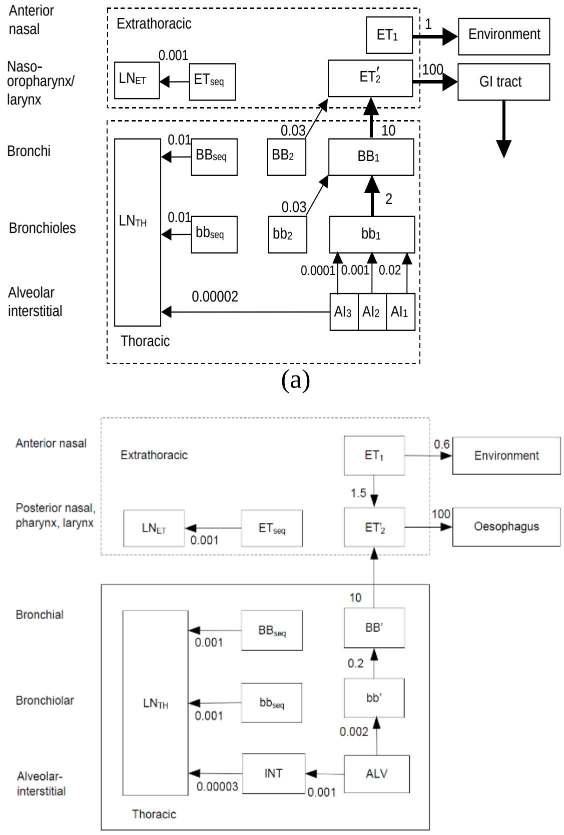
Table 1. Regional deposition of inhaled 5μm AMAD aerosols in Reference Workers

| | Deposition (%) | |
|---|---|---|
| | Original HRTM | Revised HRTM |
| $ET_1$ | 33.85 | 47.94 |
| $ET_2$ | 39.91 | 25.82 |
| BB | 1.78 | 1.78 |
| bb | 1.10 | 1.10 |
| Al | 5.32 | 5.32 |
| Total | 81.96 | 81.96 |

*Clearance: particle transport*

The original HRTM was revised for simpler and more realistic particle transport in OIR report. The important change is the transfer rate from $ET_1$ to $ET_2$. While the transfer was not allowed in original HRTM, it is assumed that material deposited in $ET_1$ is cleared at a rate of $2.1d^{-1}$ on the basis of recent data; about one-third, by nose blowing and two-thirds by transfer to $ET_2$. This change will increase systemic uptake in $ET_2$ and the alimentary tract.

In case of the slow clearance in the revised HRTM, it occurs only in the bronchiolar(bb) region. The rate from bb to BB was decreased by a factor of ten instead of omission of $BB_2$, $bb_2$ compartments. In addition, the changes of transfer rate in alveolar-interstitial region show that greater long term retention in the AI region is assumed. The original and revised compartment model representing time-dependent particle transport from each respiratory tract region is shown on Fig 1.




(a)

(b)

Fig. 1. Compartment model representing particle transport. (a) original HRTM (b) revised HRTM

*Clearance: absorption to blood*

Absorption to blood of materials deposited has been classified according to absorption speed; F, M, S. While the absorption parameter values of original HRTM were not based on experimental data, ICRP recommended the more realistic values based on recent data in revised HRTM. In OIR report, however, the material-specific parameter values are offered where sufficient information is available. For this reason, more reliable assessment could be made when the material information is kwon. The material-specific parameters were offered for $UO_2$ and $U_3O_8$ in OIR part 3 whereas ICRP 78[4] recommended type 'S' for both two compounds. In this study, the above absorption data of ICRP 78 and OIR was adopted for original HRTM and revised HRTM, respectively. The material-specific parameters in OIR are shown on Table 2.

Table 2. Absorption parameter values for inhaled uranium recommended in OIR report

| | Absorption Parameter Value | | | $f_A$ |
|---|---|---|---|---|
| materials | $f_r$ | $S_r(d^{-1})$ | $S_s(d^{-1})$ | |
| $U_3O_8$ | 0.04 | 1 | $6x10^{-4}$ | $2x10^{-4}$ |
| $UO_2$ | 0.015 | 1 | $5x10^{-4}$ | $2x10^{-4}$ |

*2.2 Calculation of lung retention and faecal excretion functions.*

The lung retention and faecal excretion functions can be calculated using the algorithm proposed by Birchall and james[5] with the transfer rate. The algorithm first transforms the rate matrix into a new matrix [A]. If $r_{ji}$ is the transfer rate from compartment i to j and $a_{ij}$ is the value of the elements of the matrix [A], respectively, then

$$a_{ij} = r_{ji},\ for\ \ i \neq j,\ \ and$$
$$a_{ij} = -\sum_{\substack{j=1 \\ j\neq i}}^{N} r_{ji} \quad (1)$$

Once the matrix [A] is formed, the amount in compartment $i$ at any subsequent time $t$ could be calculated by

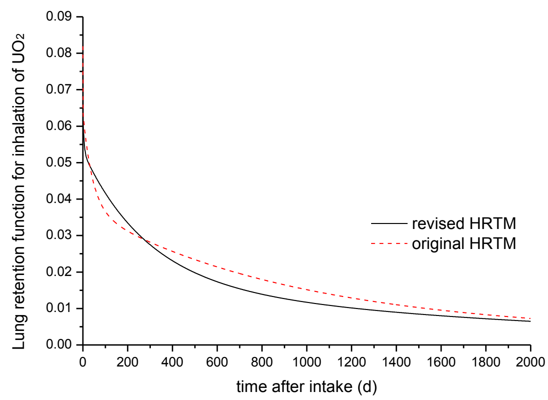
$$q_i = e^{[A]t} q_i(0) \quad (2)$$

Where $e^{[A]}$ is the exponential of the matrix $[A]$, and $q_i(0)$ is the column vector of initial amount in each compartment $i$ when the unit activity, 1Bq, is taken into the body. The lung retention and faecal excretion functions were calculated every day after intake uranium compounds using MATLAB.

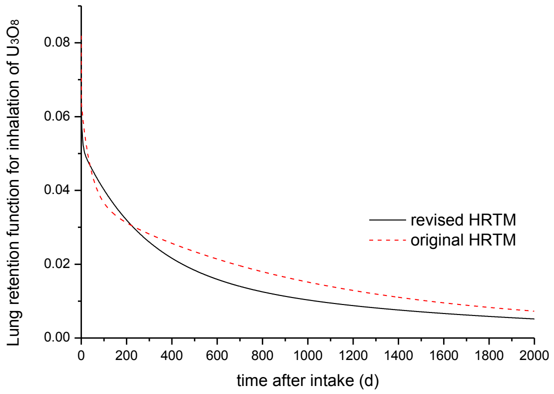
## 3. Results and Discussion

The lung retention functions for inhalation of $UO_2$ and $U_3O_8$ are shown on Fig.2. Both two cases show that the revised HRTM makes the higher retention in lung up to 1 year after intake. Since then, however, the lung retention functions of original HRTM exceed that of revised HRTM. In other words, the $UO_2$ and $U_3O_8$ in lung of revised HRTM are cleared slowly because of the slower clearance rate from bb\` to BB\` in revised HRTM. The intake amount of uranium, for this reason, could be overestimated by using the retention functions of original HRTM up to 1 year after intake.

The very long period results after 2,000 days are not shown in this report. The retention functions of revised HRTM, however, will make re-reversal that of original HRTM by longer retention in the alveolar-interstitial region.



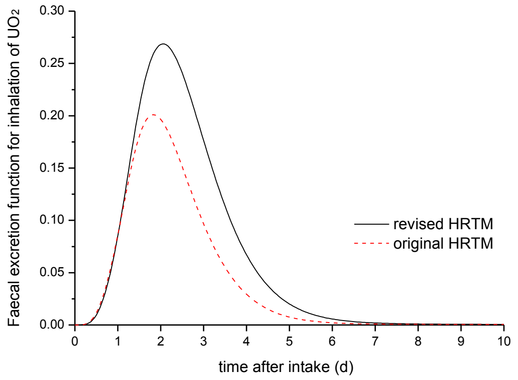

(a)



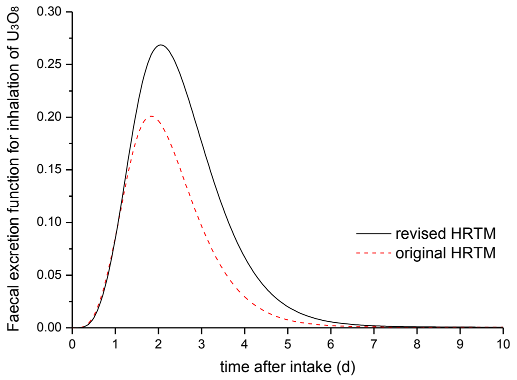

(b)

Fig. 2. Lung retention functions for inhalation.
(a) $UO_2$ (b) $U_3O_8$

In case of excretion, the more uranium inhaled is excreted via faeces when revised HRTM is used as shown on Fig. 3. This result is caused by the transfer rate from $ET_1$ to $ET_2$ which increases uptakes to the alimentary tract. Therefore, the revised HRTM is considered to also affect interpretation of measurements of radionuclides in faecal samples. In addition, the nearly same shapes of excretion functions of $UO_2$ and $U_3O_8$ show that the subtle differences of absorption parameter between the two could not have great effect on faecal excretion pattern.




(a)




(b)

Fig. 3. Faecal excretion functions for inhalation.
(a) $UO_2$ (b) $U_3O_8$

## 4. Conclusion

In this study the lung retention and faecal excretion functions for inhalation of $UO_2$ and $U_3O_8$ were calculated based on original and revised HRTM. The results show that the revised HRTM increases lung retention and uptakes to alimentary tract which cause the more faecal excretion. The results in this study confirm the effect of the changes of respiratory tract model on the uranium bioassay data although the more study is needed to apply to practical fields.

## REFERENCES

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