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ASSESSMENT OF WHOLE-BODY RETENTION TO WORKER AFTER ACCIDENTAL INHALATION OF ^{192}Ir

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ABSTRACT

The ICRP Publication 78 gives graphs of predicted values of measures quantities (body content) as a function of time following a single intake by inhalation but no data are given about ^{192}Ir. Whole-body retention is assessed for one worker who accidentally inhaled particles containing ^{192}Ir. A special monitoring was carried out with a 8x4 and 3x3 NaI(Tl) detectors at *In Vivo* Monitoring Laboratory of IPEN/CNEN-SP. The initial measurement has indicated retention of (22.15 ± 0.98) kBq after approximately 19 h from the incident. Comprehensive whole-body measurement data to one year are available for this individual. Measurement uncertainties enable the χ^2_0 value to be calculated. This value is used to determine whether the predictions of the model used to fit the data is consistent with the data. Whole body (WB) and extrathoracic (ET) measurements were assumed to be distributed exponentially and lognormally.

1. INTRODUTION

In July 2007, an incident occurred inside a radioactive source production operated at Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP), which resulted in internal contamination of one worker with particles containing ^{192}Ir.

A special whole body and extrathoracic counting showed that the worker was contaminated with ^{192}Ir. The measurements were made in the *In Vivo* Monitoring Laboratory (LMIV) of IPEN. The counting system used for measuring high-energy gamma emitters comprises two thallium-activated sodium iodide [NaI(Tl)] detectors. The measurements system was calibrated with an anthropomorphic phantom (Alderson Research Labs.) to take account of photon absorption in the tissues.

The ICRP Publication 78 [1] gives graphs of predicted values of measures quantities (body content) as a function of time following a single intake by inhalation but no data are given about ^{192}Ir. The data set for the incident provides a good opportunity to explore the biokinetic of this radionuclide. Furthermore, the follow up time for whole body measurements was sufficient to fitting the data. The data used in this assessment include 16 whole body and extrathoracic measurements over 1 y. No information is available on the physical or chemical form of the inhaled material. Davis et al. [2] presented a guideline for the assessment of intakes to workers followed accidental inhalation of radionuclides.

Following Marsh et al. [3], fits to the data were judged to be adequate if:

- the probability is greater than 5 % that the theoretical chi-squared distribution (χ^2) is less than the calculated chi-squared distribution (χ^2_0), that is $p > 0{,}05$. In other words the fit is adequate at the 5 % level of significance.

- the fit displayed graphically looks reasonable to the eye.

Additionally, the expected value for the reduced chi-square (χ^2_{red}) is 1 (unity) in the case that the data are described by the model with given statistical uncertainties. If the reduced chi-square is near 1.0 this usually means that it appears to have a good fit to the model [4].

2. ASSESSMENT OF CASE

2.1. Specific Route and Pattern of Intake

The case history indicates that an acute intake by inhalation occurred at a known time, namely 12 July 2007 at 3:30 pm.

2.2. Process Data

The initial measurement has indicated retention of (22.15 ± 0.98) kBq after approximately 19 h from the incident. Measurement uncertainties enable the χ^2_0 value to be calculated. This value is used to determine whether the predictions of the model used to fit the data is consistent with the data. Table 1 gives the χ^2_0, χ^2_{red} values and *p*-value. Whole body (WB) and extrathoracic (ET) measurements were assumed to be distributed exponentially and lognormally as specified in ICRP Publication 30 [5] and suggested by Marsh et al. [3], respectively. The fits to the whole body and extrathoracic data using these distributions are shown in Fig. 1 and 2, respectively.

Table 1. Goodness of fit parameters

Model	χ^2_0[a]	χ^2_{red}	*p*-value (%)[b]
Exponential WB	8.103	1.35	23
Exponential ET	2.596	0.43	86
Lognormal WB	3.893	0.65	69
Lognormal	1.431	0.24	96

a. The theoretical chi-squared distribution, χ^2, is equal to the number of degrees of freedom, which for simplicity is assumed to be one less than the number of data points, i.e. 7 - 1 = 6.
b. The *p*-value is the probability that χ^2 is greater than χ^2_0 for 6 degrees of freedom.

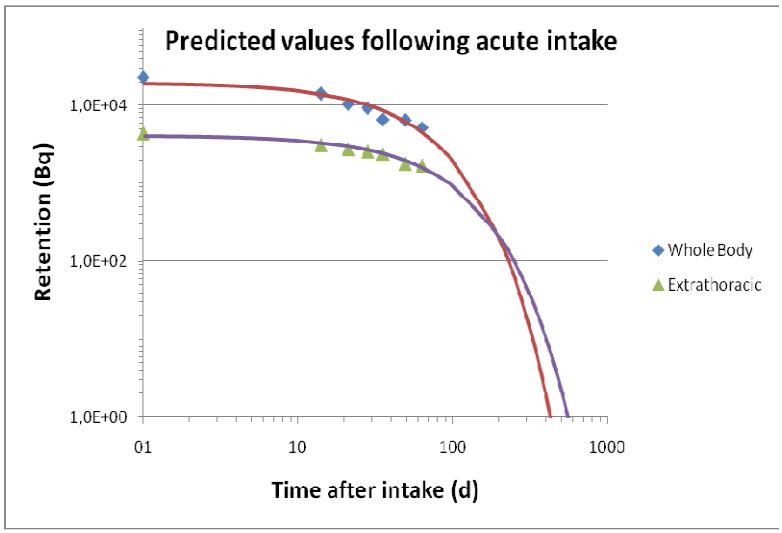

Figure 1. Fit to whole body and extrathoracic retention assuming an exponential model.

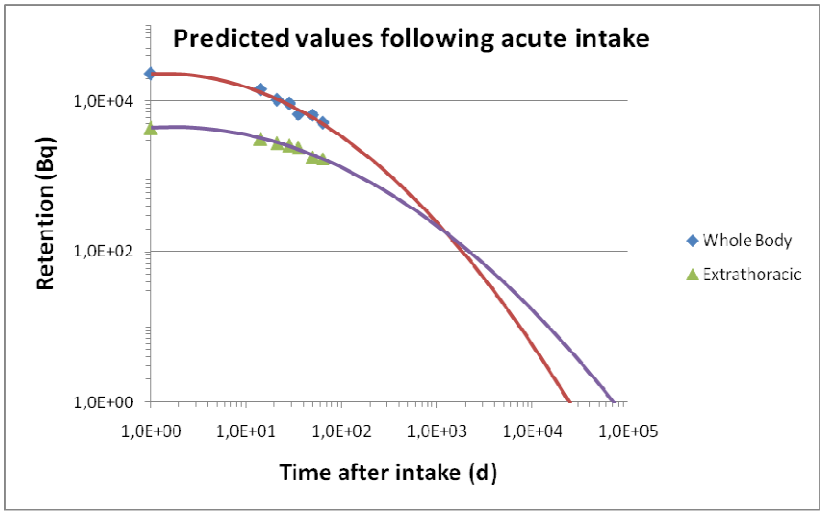

Figure 2. Fit to whole body and extrathoracic retention assuming a lognormal model.

Fits were improved by eye (Fig. 1 and 2) and the χ^2_0 remained small with the correspondent p-value significantly greater than 5 % (Table 1). Both exponential and lognormal models appear to well fit between 1 and 100 d, but other data are not.

The last measurement made 439 days after the incident results values below the lower limit of detection (<LLD). Only the exponential model predicts this result. Fig. 2 shows that the lognormal fit overestimates measured values at time points greater than 100 d.

Bailey at al. [6] predicted a similar lung retention intermediate between soluble (Type F) and relatively soluble (Type M) materials.

3. CONCLUSIONS

Fig. 1 and 2 compare the fits to each of the models exponential and lognormal. The best fit to case studied gives less retention at late times. Table 1 compares the goodness of fit parameters.

The biokinetic behavior in the case described here agrees with the ICRP assumptions. Whole body retention has been assessment up to about a year after inhalation. The results show that whole body and extrathoracic retention over this time typically follows an exponential function, having half-times of about 30 and 50 d, respectively.

The data set for this incident is important because a worker was exposed to ^{192}Ir and the whole body measurements were carried out over a period of 1 y. Because this data set is so comprehensive other retention cases should be compared with that found here. In this way it may possible to propose improvements to the biokinetic of this radionuclide.

REFERENCES

1. International Commission on Radiological Protection, "Individual Monitoring for Internal Exposure of Workers", *Annals of ICRP*, **Vol. 27** (1997).
2. K. Davis, J. W. Marsh, M. Gerondal, M. R. Bailey, B. Le Guen, "Assessment of Intakes and Doses to Workers Followed for 15 Years After Accidental Inhalation of ^{60}Co", *Health Physics*, **Vol. 92**, pp. 332-344 (2007).
3. J. W. Marsh, M. R. Bailey, A. A. Birchall, "A Step-by-step Procedure to Aid the Assessment of Intakes and Doses from Measurement Data", *Radiation Protection Dosimetry*, **Vol. 114**, pp. 491-508 (2005).
4. J. R. Taylor, *An Introduction to Error Analysis*, University Science Books, Sausalito, USA (1997).
5. International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers, Part I", *Annals of ICRP*, **Vol. 2** (1979).
6. M. R. Bailey, R. A. Guilmette, N. S. Jarvis, M. Roy, "Practical Application of the New ICRP Human Respiratory Tract Model", *Radiation Protection Dosimetry*, **Vol. 79**, pp. 17-22 (1998).