MODEL VALIDATION : THE USE OF HUMAN MEASUREMENT DATA

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ABSTRACT

Measurement of radionuclides in individuals provides the most direct method of evaluating the results of modelling procedures used to estimate the uptake and distribution of radionuclides in humans, for both environmental and occupational exposure. This paper describes recent and on-going comparisons of human measurements with model predictions and considers the benefits and difficulties associated with this approach to model validation.

INTRODUCTION

One method which can be adopted to establish the adequacy of the results of modelling procedures used to estimate radionuclide uptake by individuals, is to compare predicted radionuclide contents with measurement data obtained for the population under examination. This paper summarises two studies where such comparisons have been undertaken. In the first, measurement data for inhabitants of Seascale, a village close to the UK Sellafield nuclear reprocessing plant, were compared with model predictions based on methodology utilised to assess the risks of radiation-induced leukaemia and other cancers in children and young persons living in the village[1]. A second study is also in progress to compare plutonium concentrations measured in individuals resulting from atmospheric weapons testing with predicted values based on current ICRP models.

SEASCALE COMPARISON

Human measurement data for the Seascale population are available in the form of radionuclide concentrations in tissues taken at autopsy (plutonium-239+240 and caesium-137), measurements of plutonium in fetal tissues and whole body radiocaesium measurements. The assessment methodology used to determine the radionuclide uptake, and thereby the internal doses received by the inhabitants of the village, was based on estimations of the annual inhalation and ingestion intakes of a range of radionuclides, in association with the most recent dosimetric and biokinetic models. These calculated intakes were derived, as far as possible, from direct measurements of radionuclides in environmental materials, air concentration measurements and habit data. Where measurement data were insufficient, intakes were estimated using a combination of discharge data and environmental transfer models.

The comparison of measured and predicted whole body radiocaesium levels for the period 1957 - 1989 is given in Figure 1 and shows that the radiocaesium contents of individuals are generally in good agreement with the mean radiocaesium contents measured in groups of subjects prior to 1969. The overestimation in whole-body contents for the late 1970s and 1980s is probably due to the pessimistic assumption that all fish consumed by the Seascale residents was locally caught: consumption of foodstuffs of marine origin providing a large contribution to the radiation dose received during these years. An increase in both predicted and measured values can be observed for 1986, the year of the Chernobyl accident.

The autopsy data detailed in Table 1 suggests that the modelling procedure tends to overestimate radionuclide concentrations in the skeleton and liver, but leads to underestimates of the concentrations of plutonium-239+240 in the lung. The reason for this discrepancy is unclear but, may be due to the assumption made in the modelling procedure that the absorption from lung to blood of all inhaled plutonium compounds could be characterised as Type M (moderate absorption rate) as defined in the current ICRP Human Respiratory Tract Model[2]. In reality, it is more likely that the inhaled plutonium would have behaviour intermediate between Type M and Type S (slow absorption rate), which would result in a greater retention in the lung and lower concentrations in the liver and skeleton. The default absorption parameters for Type M material were used in the modelling procedure since this is the more cautious assumption with regard to dose to the red bone marrow, the tissue thought to be at risk when considering leukaemia induction. Table 1 also shows a comparison of concentrations of plutonium-239+240 predicted for the fetus at full term, with measurements in fetuses following termination. All measurements were below the limit of detection of the technique, giving considerable support to the conclusion that uptake of plutonium is unlikely to have been significantly underestimated in the modelling procedure.

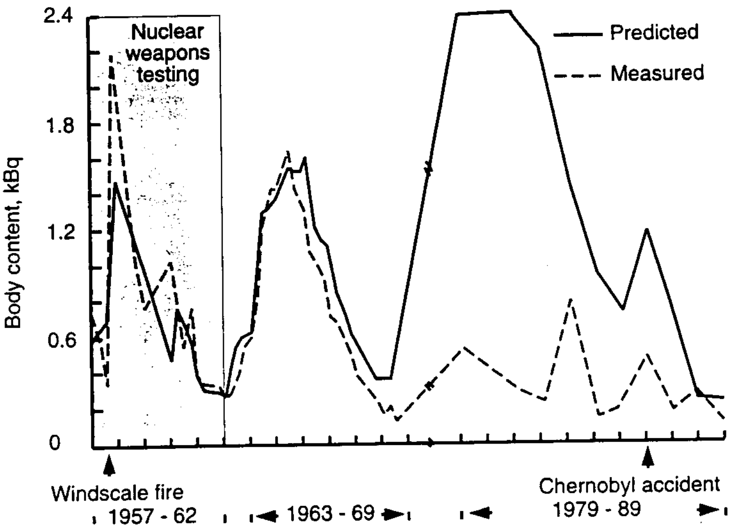

Figure 1: Measured and predicted radiocaesium body contents for 1957-89

	Skeleton		Liver		Lung		Fetus	
Radionuclide concentration	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured*	Predicted
$^{239}Pu + ^{240}Pu$ (mBq kg^{-1})	7	153	68	342	12	2	AND <1.5	0.1
^{137}Cs (Bq kg^{-1})	-	-	4	11	-	-	-	-

* AND = Activity not detected, followed by the 95% detection activity

Table 1: Comparison of mean measured with predicted radionuclide concentrations in autopsy and fetal tissues

WEAPONS FALLOUT COMPARISON

Worldwide autopsy measurements of plutonium-239+240 have been collated and median activity concentrations determined on a yearly basis for each location where data are available. In the cases examined, intakes of these radionuclides has arisen from atmospheric weapons testing and not from occupational exposure. Using an adapted version of NRPB's LUDEP (Lung Dose Evaluation Program)[3], which implements the new Respiratory Tract Model[2] and uses the new ICRP biokinetic model for plutonium, coupled with estimations of plutonium intake, activity concentrations for lung, liver, skeleton, lymph node and kidney were predicted. Annual intakes of inhaled fallout plutonium-239+240 were estimated using air concentration measurements of these radionuclides where possible. In the absence of these data, estimations were based on strontium or caesium air concentration measurements by utilising the radionuclide ratios, measurements made at similar latitudes or modelled data. Inhalation of plutonium was the only route of intake considered, this being the predominant exposure pathway.

Two sets of predicted values were calculated based on i) Type S and ii) Type M parameters. The comparison undertaken for one organ, lung, is illustrated in Figure 2. Taken with preliminary comparisons for the other organs, the results indicate that absorption of plutonium from lung to blood lies between Type S and M parameters. This study does appear to suggest that there is reasonable agreement between measured and predicted concentrations, given the inherent uncertainties in the process.

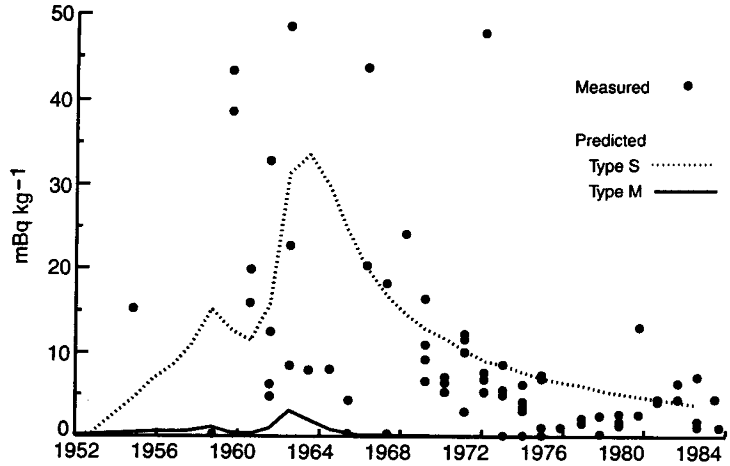

Figure 2: Measured and predicted plutonium lung concentrations

CONCLUSIONS

Human measurement data have been shown to be a valuable source of information to substantiate the data and methods used in model predictions. The Seascale comparison has shown that modelling procedures used to determine the radiation doses tend not to underestimate radionuclide intakes and deposition, and often overestimate them. Preliminary results of the weapons fallout study appear to indicate reasonable agreement between measured and predicted concentrations.

The benefits of using human measurement data for model validation are immediately obvious: it is only measurements of individuals which provide direct evidence of the level of radionuclide uptake by a population. There are disadvantages associated with this approach however, since in order to provide a reliable estimation of the radionuclide uptake by a population it is necessary to have a large number of measurements to ensure that the distribution of radionuclide uptake by the population has been adequately represented. Human data are by their very nature scarce and therefore for the purposes of these comparative studies, the measured radionuclide contents of studied individuals have been assumed to be representative of the population under investigation.

REFERENCES

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