ON THE STATISTICAL MEANING OF ENVIRONMENTAL MODELS USED IN DERIVING INTERVENTION REFERENCE LEVELS

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ABSTRACT

A stochastic simulation of the (forage, cow milk, thyroid) exposure pathway shows, for a given peak concentration of ^{131}I in cow milk following an acute contamination, a lognormal distribution of the 60 days committed thyroid equivalent dose, with a geometric standard deviation of 2. The statistical variability of the values predicted by environmental models should thus be taken into account for a sound optimization of radiological protection in an emergency situation.

INTRODUCTION

Some important steps are required for environmental modelling (1) in the decisional process of banning milk consumption following an environmental contamination by a radionuclide (e.g. ^{131}I). Usually the adopted model is based on a set of coupled, distinguishable compartments, e.g. anatomical regions, metabolic phases, environmental segments, etc. Analytical solutions for the first order differential equations describing such a system are available but, as the model becomes more complex (but perhaps no more realistic for a given circumstance), numerical methods must be used. If information on the system is incomplete or inaccurate a detailed model is not warranted. The model structure and the form of the equations should be carefully tested and perhaps revised.

MODELLING THE (FORAGE, COW MILK, THYROID) EXPOSURE PATHWAY

Some complex models have been developed for this pathway, with up to twelve or more compartments inferred from the detailed iodine metabolism in cow and in man. The application in a given circumstance of a such very elaborate model, attractive by itself, seems to be justified only when accompanied by accurate and carefully verified values of the input parameters, owing to uncertainty in model predictions associated with uncertainty in the values of each new parameter included. The simplest model which can be acceptably validated is deemed thus more suitable than a more complex model. As an example (Figure 1) the simplified model simulating the (forage, cow milk, thyroid) exposure pathway can be used for estimating, in an emergency situation, the committed equivalent dose in thyroid starting from the measured peak concentration of ^{131}I in cow milk. The transfer constants in the model are simply related (proportional) to the "exposure parameters" listed in Table 1, which are easy to be measured or estimated in a given exposure circumstance. In the cow model the transfer parameters between the compartments A and B, which should not be given a metabolic or anatomical meaning, have been adjusted to simulate the experimental time behavior of ^{131}I concentration in milk after a single intake, with a peak value between the second and the third day.

If the model adequately represents the situation being assessed, uncertainty analysis by stochastic simulation can be very useful to estimate the uncertainty in the model predictions and to rank the input parameters which more influence them. As a first approximation their values can be inferred from published data, usually in the form of a range into which the actual values distribute themselves as a random sample from an unknown population. An estimated frequency distribution of the values of the relevant parameters should be used to produce a frequency distribution of the model results, to be used together with the "deterministic" results computed from the values assumed for the parameters. Therefore numerical values predicted by the model should be processed as statistical values from an unknown distribution.

PRELIMINARY RESULTS AND CONCLUSIONS

For an effective reduction of the exposure consequences a decision about cow milk banning should be adopted early (within the first two or three days) after the beginning of environmental contamination by ^{131}I. The thyroid equivalent dose **H(60)** committed over 60 days by the exposed adult member of the public consuming the milk can be computed as

$$H(60) = k_o * IA(60) = k_o * C(peak) * G(peak,60)$$

where **IA(60)** is integrated activity of ^{131}I in thyroid over 60 days, **C(peak)** is the measured peak concentration, **G(peak,60)** is a factor to be evaluated by means of the model of Figure 1 and k_o is a suitable factor related to the "exposure parameters" of the model and to specific dosimetric aspects of thyroid irradiation by ^{131}I, as the value of the thyroid mass (Table 1). Owing to the propagation rules of statistics through multiplicative chain models the resulting values of **H(60)**, for a given value of **C(peak)**, could be assumed to follow a probability distribution function related to the statistical distributions of the input parameters, i.e.

$$var(H(60)) = var(k_o) + var(G(peak,60)).$$

The variance of k_o and **G(peak,60)** has been estimated by a Monte Carlo simulation of the model in Figure 1, solving the associated differential equation system by means of a microcomputer program (2). In each simulation run (up to 200) the values of the input parameters are sorted from their statistical distribution around published values (Table 1)(3), assuming a correlation between some parameters (e.g. feeding habits and milk production) for avoiding a full random, unrealistic sorting, which could produce an unacceptably wide range of predictions. For the transfer constants describing the iodine metabolism in the cow a uniform distribution in the range from 85% to 115% of the input values has been inferred on metabolic grounds to reproduce the observed geometric variance in the forage-milk transfer factor (SGD = 1.2).

Table 1
Standard geometric deviation (SGD) (3) for the model parameters

Weathering half-time for forage	1.4
Forage intake by the cow	2.0
Milk production rate by the cow	1.6
Cow milk intake	1.2
Biological half-time in thyroid	1.8
Iodine uptake by thyroid	1.4
Thyroid mass	1.6

Preliminary results for the probability distribution of the ratio of **H(60)** to the deterministic value (Figure 2) suggest a SGD value of about 2, with a value aroud 8 for the ratio of the 95th percentile to the 50th percentile (mediane). A comparison with previous simulations (2) for ^{137}Cs in cow milk and beef shows the effect of the short radioactive halftime of ^{131}I in reducing the variability of predicted committed equivalent doses. A lognormal distribution (SGD around 1.5) has also been found for the ratio between the ^{131}I peak concentration and the first day value, when sound results of environmental monitoring begin to be available.

The significative rank correlation found between **H(60)** and "exposure parameters" requires moreover circumstance specific values to be used for the feeding habits and milk consumption rate to avoid biased and misleading results. No such a strong correlation exists with the parameters in the cow model: widespread use of a generic model seems to be justified.

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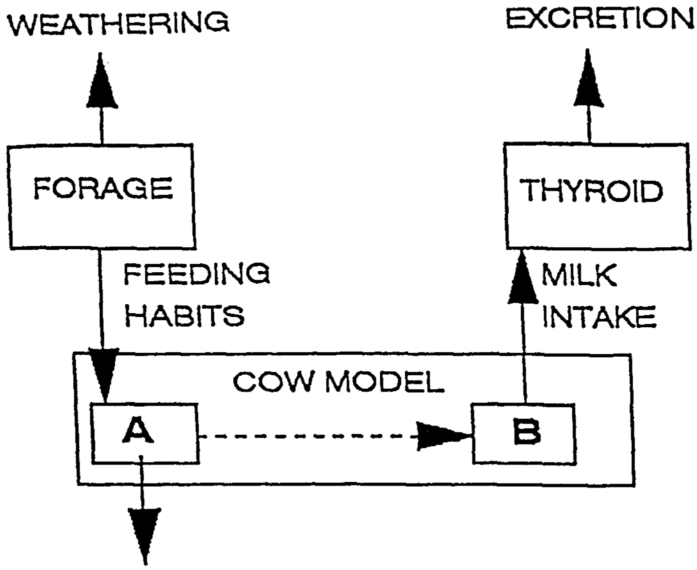

Fig.1 Simplified model of the (forage, cow milk, thyroid) exposure pathway.

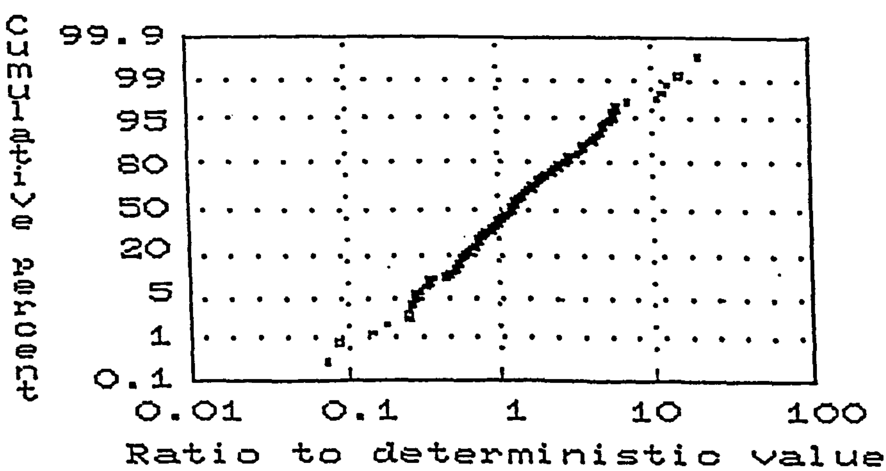

Fig.2 Monte Carlo distribution of the ratios to the deterministic value of the 60 days thyroid committed equivalent dose by ^{131}I in cow milk.