INDOS - AN INTERNAL RADIATION DOSIMETRY ASSESSMENT COMPUTER CODE

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INTRODUCTION

Bioassay is the final quality control procedure that is used to assure adequate protection of workers from internal radiation exposures. Intake retention functions, which give the expected fraction of an intake in a bioassay compartment, are needed for the proper design and conduct of bioassay programs, including the interpretation of bioassay data in terms of estimated intakes and internal radiation doses. In cases of accidental exposures, estimated intakes can be compared to either regulatory intake limits or the ICRP Publication 30 Annual Limits on Intakes (ALIs). The quotient of an estimated intake of a radioelement by its stochastic based ALI value when multiplied by 0.05 Sv gives an estimate of the whole body committed effective dose equivalent. This dose assessment of bioassay data can be used to identify those exposures that require further investigation from those that do not require such action and expenditure of time and resources.

This paper describes the main features of a bioassay/internal dosimetry IBM PC computer code called INDOS, which provides a rapid and efficient way of calculating values for intake retention functions and estimating intakes from bioassay data, including a complete documentation of all input and output data used in each individual exposure case. The derivation of the intake retention functions is outlined in a companion paper. Examples of the input and output from actual exposure cases are shown in the poster session for this paper. A demonstration diskette, which allows evaluation of essentially all features of the actual INDOS software, is available from the authors upon request.

INTAKE RETENTION FUNCTIONS

As shown by Equation 1 and Figure 1 of our companion paper, intake retention functions for all in vivo and in vitro bioassay compartments are obtained by application of a single catenary kinetics equation to a multicompartmental model that describes the metabolism of radioelements from intake to excretion. For a single acute intake, functions are expressed by sums of exponentials with constant coefficients, including the function for an accumulated excretion compartment. The coefficients of the exponentials are independent of the decay constant λ of the radioelement; so, they also apply to the intake retention function for the stable element. Replacement functions for the exponentials provide an efficient way of calculating the values for other types of intake retention functions that are described

in INDOS. For example, the exponential exp(-kt) in each term of the radioelement accumulated urine function, which gives the fraction of a single acute intake that is expected to be present in the accumulated urine compartment, is replaced by

$$\left[e^{-(k-\lambda)t} - e^{-(k-\lambda)(t-\Delta t)}\right] e^{-\lambda t}$$

to obtain the incremental urine function, which gives the fraction of a single acute intake expected to be present at time t in an incremental sample of urine that is collected from $(t-\Delta t)$ to time t after the intake, where:

$k = K+\lambda$ = total removal rate constant, which is shown to be calculated by the sum of the compartment's total biological removal rate constant K and the radioelement's decay constant λ.

PROGRAM DESCRIPTIONS

All of the programs in INDOS allow the user to input metabolic parameter values different from the standard ICRP Publication 30 values for the respiratory tract, GI tract, and systemic compartments. When more specific models and parameter values have shown to provide greater accuracy, their use will provide a better estimation of intakes and internal radiation doses than can be obtained from standard ICRP 30 models. Default values are provided for parameter values associated with the ICRP 30 respiratory and GI tract models and inhalation compound classes.

The programs in the INDOS software include:

1. Program INT: This program estimates an intake from one or more bioassay measurements of a radioelement. The user specifies the intake conditions and other pertinent data. Based upon one of three selected assumptions regarding the variance of the bioassay data, the program then performs a best fit to the data to obtain an estimate of the intake, exposure, and associated dosimetry. This includes the estimated exposure in units of MPC-hours or DAC-hours and the committed effective dose equivalent. All or part of the input data, including default values, can be stored on a disk or printed with the output to document the models and parameter values that were used.

2. Program DIL: This program generates tables of Derived Investiation Levels (DILs) for in vivo and/or in vitro bioassay compartments of interest. The user specifies the intake that corresponds to the specified investigation level (e.g., an intake of 0.02 ALI, which corresponds to an exposure of 40 DAC-hours) and inputs other pertinent data. The program then calculates the activity of the specified

radioelement that is expected to be present in particular bioassay compartments at various chosen times after a single acute intake or after the onset of a specified continuous intake interval. One can use such tables, for example, to screen those routine bioassay measurements that may require further investigation. By selecting that monitoring frequency and those procedures that have sufficient sensitivity and accuracy for the detection of a DIL value, a routine bioassay program can be designed to help ensure that significant intakes are detected, recorded, and properly investigated.

3. Program IRF: This program generates tables of Intake Retention Fractions (IRFs) for in vivo and/or in vitro bioassay compartments of interest. The input for this program is similar to that of Program DIL. The program calculates the fraction of an intake expected to be present in particular bioassay compartments at various chosen times after a single acute intake or after the onset of a specified continuous intake interval. One can use such a table, for example, to make a preliminary estimate of an intake from a single bioassay measurement of a radioelement by dividing the measurement by the IRF value given in the table for the radioelement and bioassay compartment of interest.

4. Program NOD: This program generates tables of values for the Number of Disintegrations that are expected to occur over a chosen time interval in various in vivo compartments of interest due to an acute intake specified by the user. Such a table can be used, for example, to calculate individual organ doses over any time interval after an intake, including the 50 year standard interval that is used for the calculation of committed doses and the associated ALIs. Estimated doses may be useful as guidance for medical and follow-up bioassay procedures. For a single radionuclide having no progeny that significantly contribute to the doses, the value of NOD over the standard 50 year interval along with other parameter values from ICRP Publication 30 can be used for calculating custom ALIs and DACs. This can be done for various particle size distributions and chemical compound classes or mixtures for a radioelement that is known to be present in a given working environment. In addition, if metabolic parameter values that reflect the metabolism of exposed workers are available, then they can be used as input to derive more realistic ALIs and DACs.

SPECIFICATIONS BY THE USER

The INDOS programs allow the user to specify the following at various prompts on the input screens:

1. Exposure Condition: (a) single acute intake or (b) contin-

uous intake (excludes program NOD);

2. Intake Pathway: (a) inhalation, (b) ingestion, (c) injection, or (d) delayed uptake through a wound;

3. Metabolic Data and Physical/Chemical Characteristics of Intake: (a) ICRP 30 compound classifications D, W, and Y or mixtures, (b) activity median aerodynamic diameter (AMAD) of inhaled aerosol and (c) ICRP 30 metabolic models or customized models;

4. In Vivo Bioassay Compartments or Measurements: (a) lungs, (b) GI tract, (c) systemic whole body whose uptake retention function is specified, (d) whole body excluding nasal passage (i.e., a + b + c), and (e) individual organ or tissue whose uptake retention function is specified; and

5. In Vitro Bioassay Compartments or Measurements: (a) accumulated urine, (b) incremental urine, (c) urine concentration, (d) accumulated feces, and (e) incremental feces.

With respect to the in vivo bioassay compartments, the somewhat redundant term "systemic whole body" is used to represent all internal organs and tissues and the entire systemic circulation including extracellular fluid. A radionuclide previously absorbed into the systemic circulation and present in the systemic whole body represents systemic internal contamination. A radionuclide deposited and present on the epithelial tissue in the respiratory tract or present in the contents of segments of the GI tract is treated separately and is not considered as part of this systemic contamination.

SUMMARY

Our experience with INDOS has proven it to be a practical way for the design and conduct of bioassay programs that will (1) help to provide adequate protection of workers from internal radiation exposures and (2) provide a rapid and efficient way to obtain estimates of intakes and internal radiation doses.