A I D E

ACTIVITY AND INTERNAL DOSE ESTIMATES
Reference Manual
(Version 6.0 – July 2007)

Contents

1. Introduction

AIDE is a software for calculations of activities in compartments and committed dose estimates due to occupational exposures, and intake and dose estimates using bioassay data.

This software has been solely prepared by Dr. Luiz Bertelli. Part of it was initially meant to be used as a training tool in Internal Dosimetry. Every effort has been made to reproduce the original predicted values of the measured quantities following a single intake and the Dose Coefficients published by ICRP. However, minor differences might be noted since the calculation methods used in this software differ from those used to derive the original ICRP tables.

Biokinetic models and associated radioactive decay data are available for the following elements listed in ICRP Publication 78[(7)]: H, Fe, Co, Sr, Ru, I, Cs, Ra, Ra, Th, Th, U, Np, Pu, Am, Cm, Cf. Predicted monitoring data tables for inhalation and ingestion associated with their most important isotopes, as appear in the ICRP Publication 78[(7)] tables, are available. Similar data have also been added for other important elements used in medicine, such as: Tc, P, S, C, Sm, Re, Po and Pb. In this way, the calculation of internal doses and interpretation of intakes for any isotope of the listed elements is already possible. In order to help the user predicted values of the measured quantities following single intake and associated dose coefficients are already available for the most common forms of occupational intakes of the following radionuclides: ^{3}H, ^{18}F, ^{59}Fe, ^{57}Co, ^{58}Co, ^{60}Co, ^{85}Sr, ^{89}Sr, ^{90}Sr, ^{106}Ru, ^{125}I, ^{129}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm, ^{252}Cf, ^{99m}Tc, ^{32}P, ^{35}S, ^{14}C, ^{153}Sm, ^{188}Re, ^{210}Po and ^{210}Pb.

As an additional feature calculations of activities and doses can be promptly carried out for the complete list of gases and vapors shown in the recent ICRP Supporting Guidance 3 Publication[(14)].

The latest highlight was the inclusion of the Wound Model recently proposed by the American National Council on Radiation Protection & Measurements (NCRP)[(16)], which shows seven categories to characterize the retention of radionuclides in the wounds, namely: weak soluble, moderate soluble, strong soluble, avid soluble, colloid, particle and fragment.

It must be pointed out that besides having the biokinetic models for the isotopes listed above this software allows the user to enter any biokinetic model and associate any isotope whose decay scheme is available in ICRP Publication 38[(15)]. Predicted values of measured quantities and corresponding equivalent doses can be calculated and stored in tables for later use in bioassay interpretation. This feature together with the ability to simulate inhalation cases using any AMAD, any set of mechanical transport parameters and any set of compound specific absorption parameters makes it particular powerful and useful in site-specific dosimetry applications.

This software has been continuously developed and tested for more than twenty years[(10)]. Its calculation core has been applied in several situations in internal dosimetry ranging from dose estimates due to ^{137}Cs intakes, which occurred during the Goiania accident, through modeling data from intakes of uranium trioxide and octoxide. The last important application of this

software, which needs to be highlighted, was to produce the tables and plots of activities in compartments and dose coefficients as a function of time using the NCRP Wound Model. This NCRP report (NCRP Report no. 156.) is named "Development of a Biokinetic Model For Radionuclide-contaminated Wounds and Procedures for Their Assessment, Dosimetry and Treatment" and it will be released soon by NCRP[16].

Some publications, whose results were produced using this software, have been added to the "Selected Publications Where Previous Versions of This Software Have Been Used" section. Several new features have been implemented in this version, which have been fully tested but might eventually show some discrepancies with results calculated by other authors. The author makes no warranties, expressed or implied, that this software and associated data files are totally free of error. Use of this software in regulatory manners, is at the user's risk. The author disclaims all liabilities for direct or indirect damages resulting from the use of this software.

This author is totally indebted to Dr. Keith Eckerman, from Oak Ridge National Laboratory, for kindly providing the radioactive decay tables and the Biomods help file, for his time dedicated to intercompare many calculation results and for his constant support and encouragement and fruitful discussions. The constant support, friendship, inspiration and encouragement offered by Drs. Dunstana Melo, Joyce Lipsztein, Albert Keane, Raymond Guilmette, Guthrie Miller and by Cremilce and Dante Bertelli are also greatly appreciated. The financial support of the International Atomic Energy Agency during the latest steps of this project was extremely valuable.

This software comprises three basic modules:

A) Activity and Internal Dose Calculations: calculations of activities in bioassay compartments and effective doses for inhalation, ingestion and injection of radionuclides, for single, several, continuous and worker's intake patterns, for infinite or limited time under intake. For the case of inhalation, vapors and gases have also been included besides particulate matter. The case of injection was considerably expanded with the inclusion of the Wound Model recently proposed by NCRP.

B) Bioassay Interpretation: intake and internal dose estimates can be carried out through the use of single or multiple bioassay measurements. All estimate procedures are in accordance with the methods presented in the ICRP-78 Publication[7], in the IAEA Safety Reports Series no. 37 and in the IDEAS Project Guidelines 2006.

C) Edit Models: it allows the user to view all parameters used in the biokinetic models to produce the tables of predicted values of the measured quantities following single intake and corresponding dose coefficients, which are available in this software. It also allows the user to enter, edit and erase own biokinetic models to be used in similar calculations.

Figure 1.1 shows the switchboard, which allows loading each of the three modules: Activity and Internal Dose Calculations, Bioassay Interpretation and Edit Models

The Biomods help file can be seen after pressing the "Biokinetics" button located on the upper left corner of the screen. This manual can be seen by pressing the "Combined Help" button.

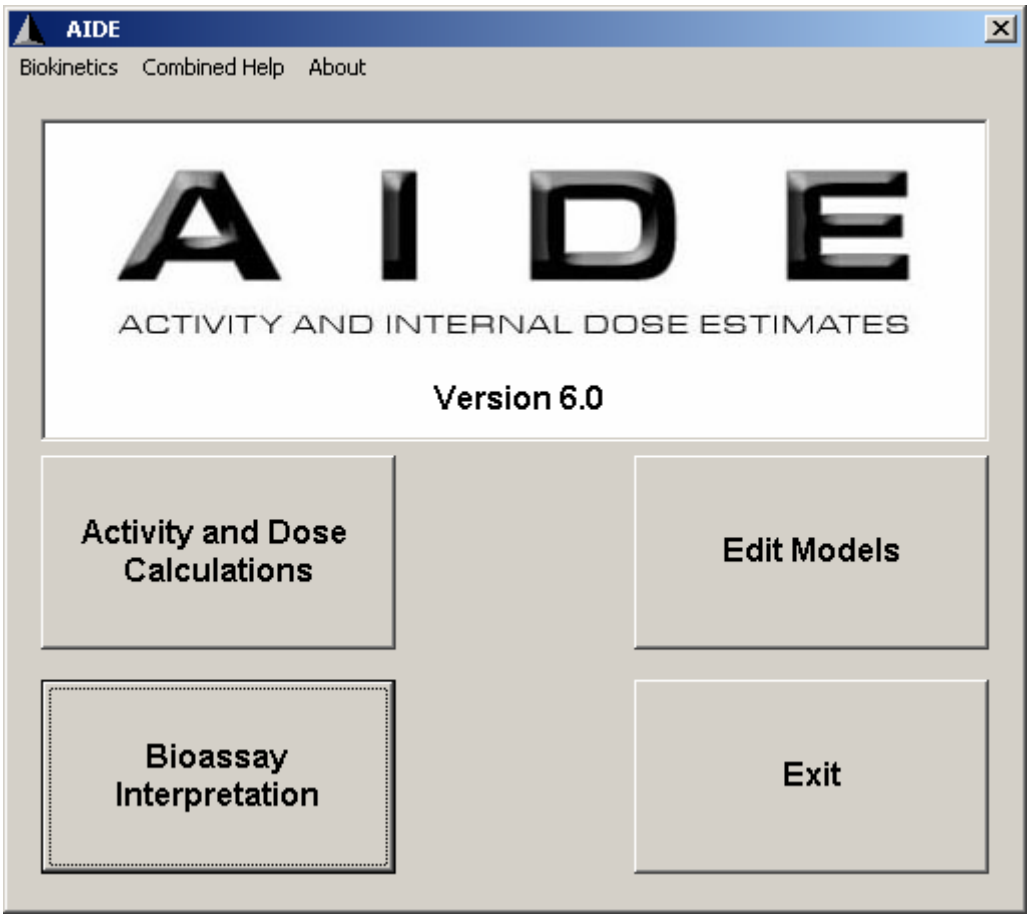


Figure 1.1 Initial switchboard screen of AIDE

1.1 Supporting the IDEAS Guidelines

The "Bioassay Interpretation" module of AIDE was developed to be simple and powerful. It has been tested by users from all levels of expertise in the field, i.e., from its application as a tool in introductory courses on internal dosimetry to tasks of bioassay interpretation involving sophisticated reconstructions of intake scenarios. More recently it has been modified to accommodate the proposals of the IDEAS guidelines[11]. More specifically, to provide means to the practical application of the concepts associated with the philosophy of *Harmonisation*, allowing the user to follow all steps of the series of flow-charts proposed in the guidance.

In order to give such flexibility:
- AIDE has many tested biokinetic models and also allows the user to create its own.
- It allows generating bioassay tables and calculating customized dose coefficients from intakes due to inhalation, ingestion, injection, intakes by gases and vapors as proposed in the ICRP Supporting Guidance 3: Guide for the Practical Application of the ICRP Human Respiratory Tract Model[14] and intakes by wounds using the NCRP Wound Model[16].
- It allows modifying the original systemic model, and/or the HRTM default mechanical and/or blood absorption parameters and generating bioassay tables and calculating customized dose coefficients from intakes due to inhalation.
- AIDE contains all mathematical methods proposed by IDEAS for evaluating intakes, criteria for rejecting fit, dealing with non-single intake exposure scenarios.
- AIDE fully meets the IDEAS approach for dealing with uncertainty on data.
- AIDE can handle accordingly the four "Levels of Task" as defined in the IDEAS Guidelines with respect to operational radiation protection procedures.

Because of its flexibility AIDE can fully execute all stages associated with the "Structured Approach to Dose Assessment", as defined in Chapter 6 of the IDEAS Guidelines[11].

2. Installing AIDE Version 6.0

The software is installed through a simple procedure. The software can be installed in any hard disk drive. However it should reside in the root directory, i.e., C:\AIDE6, or D:\AIDE6, etc. The list of sub-directories is shown on the "Directory Structure" section at the end of this manual.

To install AIDE6.0:

1. Insert the AIDE6.0 distribution disk into the CD ROM drive
2. Doubleclick on the AIDE60Setup.exe file
3. Follow the steps indicated by the installation program
4. Accept the default path name for the directory
5. AIDE6.0 will be available to run on your programs list

3. Activity and Internal Dose Calculations

Figure 3.1 shows the initial screen for this module. This module was especially designed to perform calculations of activities in bioassay compartments and effective doses for intakes of radionuclides and to generate tables of intake retention fractions and dose coefficients. In order to provide a better understanding of the capabilities of this module this chapter first presents a description of the input parameters for running activity and internal dose calculations. The subsequent sections explain the use of the parameters for running each intake case.

The case selection comprises the following steps, according to the intake characteristics:
1) Biokinetic Model, Isotopes and Radioactive Series: selection of biokinetic model, isotope and radioactive series
2) Intake Characteristics: type and pattern of intake, respiratory tract parameters for inhalation cases, intake amount and intake rate, gastrointestinal absorption fraction.
3) Other: dosimetric quantities, dosimetric system, times for calculations, selection of output, options for running calculations, options for generating and editing bioassay tables, saving custom inhalation model.

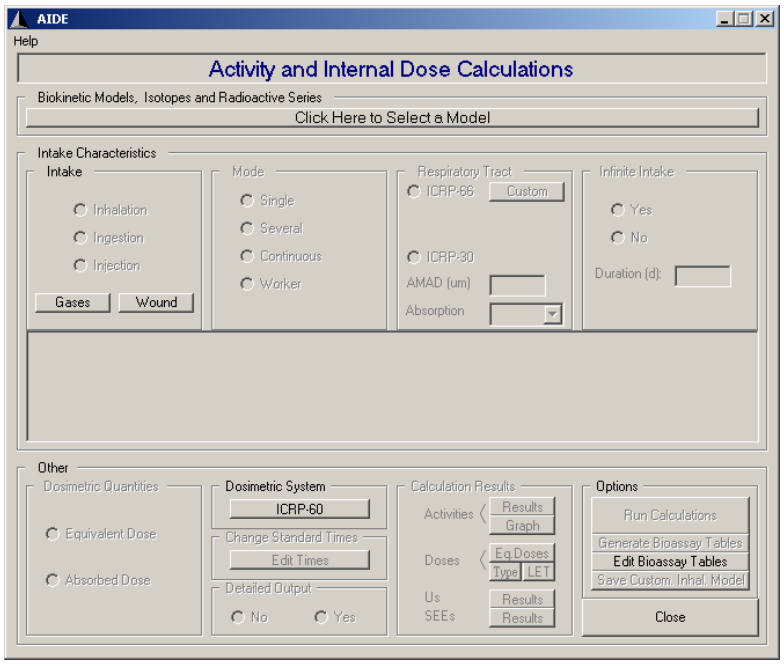


Figure 3.1 Initial screen for the "Activity and Internal Dose Calculations" module

3.1 Description of the Input Parameters for Activity and Internal Dose Calculations

3.1.1 Biokinetic Model, Isotopes and Radioactive Series

3.1.1.1 Selection of the Biokinetic Model

Start the selection by clicking on the "Click Here to Select a Model" button. A form named "Biokinetic Models, Isotopes and Radioactive Series", shown on Figure 3.2, is loaded. As a result the radioactive series and the corresponding biokinetic models can be selected by scrolling and clicking the listbox inside the "Available Biokinetic Models" frame.

3.1.1.2 Selection of the Isotope and Radioactive Series

Once the biokinetic model has been chosen, the next step is to select the isotope representing the mother of the series. Once it is selected, the corresponding radioactive series is shown in the "Radioactive Series" frame located on the lower half of the form. At the bottom of the form a textbox shows a truncation number, which suggests the minimum number of elements of the series to be used for calculating doses, as can be seen on Figure 3.2, where 4 elements of the ^{238}U series are suggested. The user can change this number but the dose results will be different from those published by ICRP, if a standard ICRP case is being run. Once it is changed and "Enter" is pressed the series is automatically truncated. The number shown in the textbox will be adopted in the calculations when the "Close" button is pressed.

The same biokinetic model will be used for the whole series if the checkbox named "Biokinetic Model for the Daughter(s)" is checked. Different biokinetic models can be used for every element of the series, as used in ICRP Publication 71[(5)], once they are available. This last option is the default choice by the software. In this case, once a radioactive series is chosen, the software searches for the appropriate models and lists them under the column "Biokinetic Model for the Isotope"

If the specific models for the daughters of the series are not available they can be entered later by clicking the "Edit Models" button on the main screen, as shown in Figure 1.1 (See "5.3 Model Names for Radioactive Series" at the end of this manual). After the models have been chosen and the "Close" button is pressed the "Activities and Internal Dose Estimates" form will be loaded again.

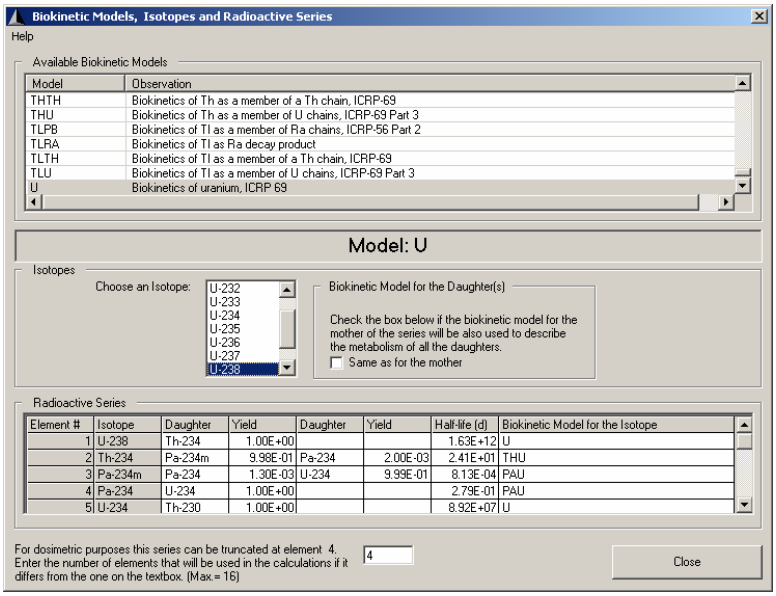


Figure 3.2 The "Biokinetic Models, Isotopes and Radioactive Series" form showing an example for the selection of the U model for uranium, ^{238}U as the isotope and the corresponding radioactive series.

3.1.2 Intake Characteristics

After the model is selected the "Activities and Internal Dose Estimates" form is loaded again. The selected model names, corresponding isotopes and the possible choices for the gastrointestinal absorbed fraction (f1) are shown on the grid located inside the "Intake Characteristics" frame at the lower half of the form, as shown in Figure 3.3 for the example of the ^{238}U series.

The "Intake Characteristics" frame is comprised of the following selections, which are described below:
1) Intake
2) Mode or Intake Pattern
3) Respiratory Tract
4) Activity Median Aerodynamic Diameter (AMAD)
5) Blood Absorption
6) Duration of Intake
7) Intake or Intake Rate
8) Selection of f1

Intake: the available intake cases are inhalation, ingestion, injection, and the special cases of inhalation of gases or vapors and the intake through wounds.

Mode or Intake Pattern: Single (or acute), Several (daily acute intakes with same magnitude), Continuous (chronic intake at a constant rate) and Worker's intake (periodic intakes representing a standard working week with same magnitude steps of 5 days/week, 8 hours/day, 2 days off).

Respiratory Tract: For the particular case of inhalation two respiratory tract models are available for use: the Human Respiratory Tract Model (HRTM) proposed in the ICRP Publication 66[(1)], which is the default choice, and the respiratory model proposed in the ICRP Publication 30[(20)].

Activity Median Aerodynamic Diameter (AMAD): In micron for inhalation intake

Blood Absorption: The F (fast), M (moderate) and S (slow) types, which were proposed in the ICRP Publication 66[(1)], are provided if the AMAD is greater than zero, i.e., it is not a gas or a vapor. These are the default choices. Material-specific absorption parameters can also be entered as explained below. The F, M and S absorption types are replaced by the D, W and Y Classes respectively if the respiratory tract model proposed in ICRP Publication 30[(20)] is used.

Infinite Intake (Duration of Intake): This option is enabled for non-single intake patterns. The intake duration can be infinite or can last a number of days. In this latter case the duration of the intake should be entered in the appropriate textbox. This option is particularly useful when remaining activities in compartments after periods of finite prolonged intakes are calculated.

Intake or Intake Rate: This field is located on the fourth column of the grid at the lower half of the form, which is inside the "Intake Characteristics" frame. This number represents the initial activity (in Bq) if the intake mode is single or intake rate (in $Bq.d^{-1}$) for the non-single intake modes. It must be entered in the appropriate field on the grid. This software also allows the use of initial activities or activity rates for daughters. Committed Equivalent Dose Coefficients (dose per unit intake) can be calculated by entering one for the value of the initial activity. The other columns of the grid have been entered automatically after the systemic model and the radioactive series have been selected.

IMPORTANT NOTE: For cases like tritiated water the activity in urine is proportional to the concentration in the body tissues. So the daily urinary activity in urine must be derived from the activity in the body. Tritiated water mixes rapidly with total body water. Activity in urine must be calculated as activity concentration. Since the reference man has 42 litres (70kg * 600 ml/kg of weight) of total body water the activity concentration in urine will be given by the activity in the total body / 42, so the intake or intake rate must be 1/42 = 2.381E-02 an the urinary excretion result is given in the Whole Body column. Its vapor form is SR-2. So, the 24h-urine table can be generated reading the results on the Whole Body column and using an injection intake of 1/42. For elemental tritium 0.01% (also SR-2) of inhaled activity is assumed to be absorbed rapidly and converted to tritiated water. So an injection intake of 0.0001 should be used.

Selection of f1: In the case of inhalation, when a blood absorption choice is F, M or S (ICRP-66) the gastrointestinal absorption factor f1 is automatically selected. However, for non-inhalation cases, a specific selection must be made by clicking the appropriate f1 column on the grid. Nil f1 values for normally indicate that the absorption type is inexistent. The specific selection is done

by clicking the appropriate f1 column header, namely f1(1), f1(2), or f1(3), on the grid. Nil f1 values for normally indicate that the absorption type is inexistent.

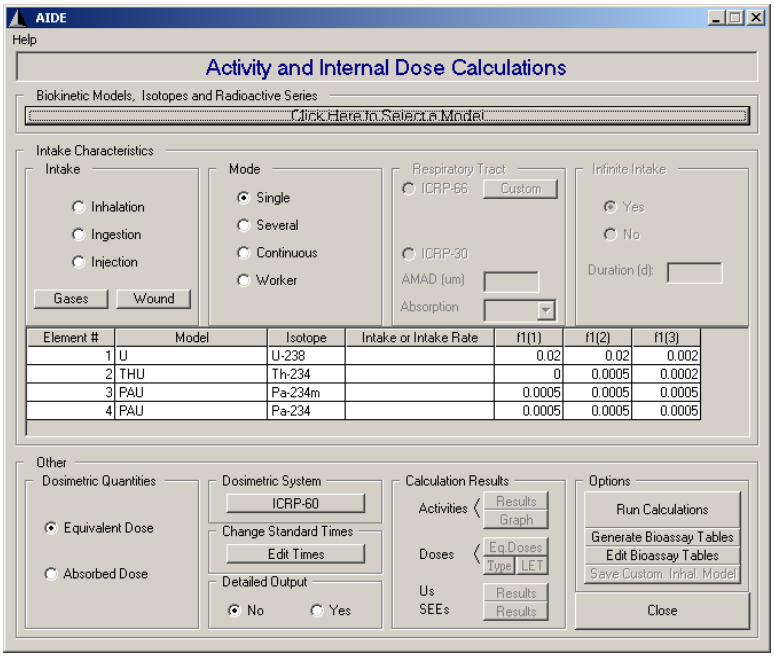


Figure 3.3 The "Activity and Internal Dose Estimates" form showing an example for running activities and dose calculations using the U model for uranium, ^{238}U and the corresponding biokinetic models to represent the metabolism associated with the radioactive series.

3.1.3 Other

The "Other" frame is comprised of the following options for running the calculations, generating and editing tables and retrieving results, which are described below:
1) Dosimetric Quantities
2) Dosimetric System
3) Change Standard Times
4) Detailed Output
5) Calculation Results
6) Run Calculations
7) Generate Bioassay Tables
8) Edit Bioassay Tables
9) Save Custom Inhalation Model

Dosimetric Quantities: Two dosimetric quantities can be selected for calculation: Equivalent Dose and Absorbed Dose.

Dosimetric System: Four dosimetric systems can be used: ICRP-60[17], ICRP-26[18], US-DOE (10 CFR Part 835)[19] and User, as shown in Figure 3.4. The first three systems are named after the corresponding publications, where they have been originally proposed. The "User" system could be one proposed by the user through its own set of tissue weighting factors (WTs). However it must be pointed out that all dose calculations will follow the same method proposed by ICRP Publication 60[17]. In this way, the "User" system would be similar to the ICRP-60 system but using different WTs. Figure 3.4 shows that the "Tissue Weighting Factors" form is comprised of three main columns, namely: "Organ or Tissue", "WT" and "Rem.". The first column contains the names of all organs, which could participate in the committed effective dose calculation: Adrenals, Bladder, Bone Surface, Brain, Breast, Esophagus, Stomach, SI, ULI, LLI, Colon, Kidneys, Liver, ET, Lungs, Muscle, Gonads, Pancreas, Red Marrow, Skin, Spleen, Thymus, Thyroid, Gall Bladder, Heart, Uterus and Remainder. The second column shows the tissue weighting factors, which are used in the calculation of either the committed effective dose for the ICRP-60 and User dosimetric systems or of the committed effective dose equivalent for the ICRP-26 and US-DOE (10CFR Part 835[19]) dosimetric systems. The summation of all WTs must be equal to one. The third column checks if the organ participates on the remainder dose calculation.

The user is able to select but not to modify the parameters related to the ICRP-60, the ICRP-26 and the 10CFR Part 835 dosimetric systems. When the "User" dosimetric system is selected the WT textboxes and the Remainder checkboxes are made available for editing. The parameters will be saved on a table when the "Close" form button is pressed and can be retrieved when opening this form.

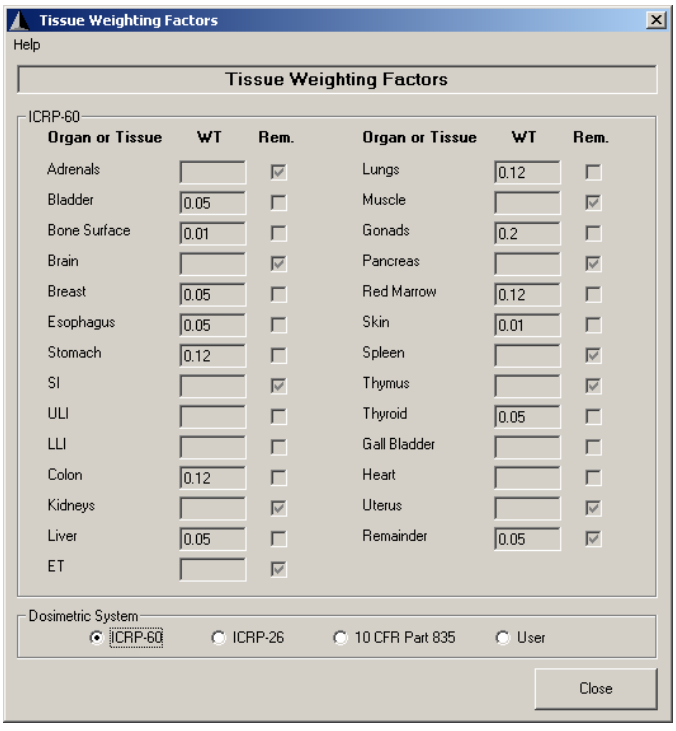


Figure 3.4 The "Tissue Weighting Factors" form showing the WTs for the "ICRP-60" option

Change Standard Times: One hundred default time values ranging from 0.1 to 18250 days are suggested for performing calculations of activities and doses. Since tables of activities can be exported for later use in bioassay interpretations, this number was found to be suitable when interpolation procedures are used to calculate activities for times not listed on the tables.

This list can be modified by clicking the "Edit Times" button in the "Change Standard Times" frame on the main form, as shown in Figure 3.3. A form named "Times for Calculations of Activities and Doses" is then loaded, as shown in Figure 3.5, allowing the user to modify the default values. Two choices for default times are available. One to be used in intake cases excluding those for worker's intake and another option specifically recommended for worker's intake. The reason is because the worker's intake characterizes cycles of periodic intakes representing a standard working week with same magnitude steps of 5 days/week, 8 hours/day and 2 days off. In many cases the calculation of activities measured in *in vitro* bioassay compartments differs significantly if the collection was right after the last day of intake (Friday) or during the day before the start of the shift (Sunday). The latter was chosen to compose default times list for worker's intake and are multiples of seven to account for a whole seven day cycle. Nevertheless the user can always enter with time values corresponding to any day of the week.

A maximum of one hundred time values are available with choices of units in years, days, hours or minutes. The default times will be used in the calculations in case the time values are cleared from the form.
Note: Once the user has changed the default times they will be saved in an auxiliary file and will be used in all calculations to be performed thereafter.

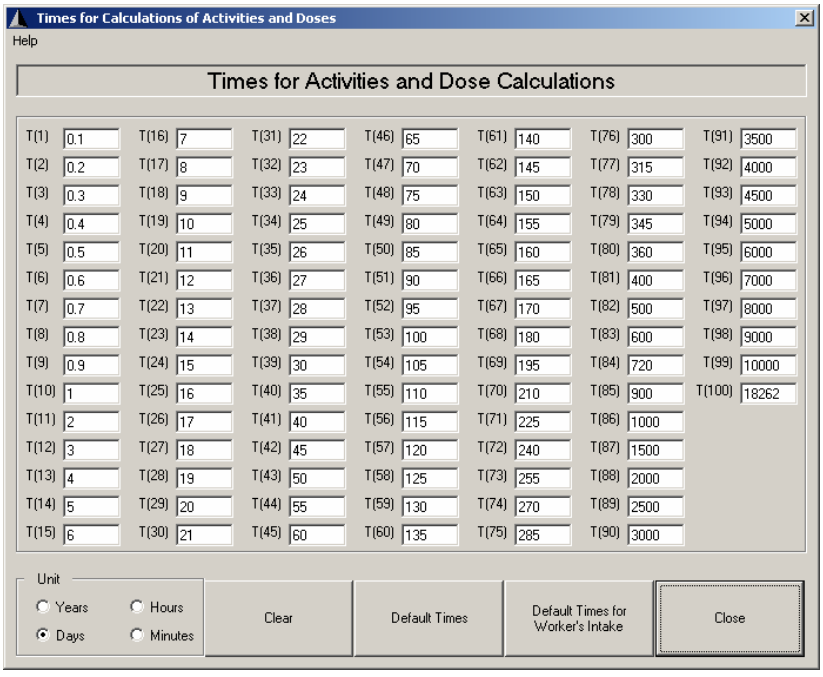


Figure 3.5 The "Times for Calculations of Activities and Doses" form showing the time values for the "Default Times" option

Detailed Output: When the choice is "Yes" the results for Number of Nuclear Transformations (Us) and Specific Effective Energies (SEEs) can also be seen.

Calculation Results: Results for activities and doses are available. The calculation results of activities can be seen by pressing the corresponding "Results" button. When more then one time value was used in the calculations the "Graph" button shows the calculated activities in a graphical form. When the equivalent dose quantity is chosen the results can be seen by pressing the "Eq.Doses" button. When the absorbed dose quantity was chosen the results will be given by radiation type and by LET and can be seen by pressing the "Type" and "LET" buttons respectively. Results for Number of Nuclear Transformations (Us) and Specific Effective Energies (SEEs) can also be seen depending on the "Detailed Output" choice.

Run Calculations: The requested calculations will be executed after all suitable data have been entered. The buttons indicating the corresponding results will be enabled and turned to green after the calculation is successfully finalized. At this time all files containing results can be edited or printed.

Generate Bioassay Tables: Bioassay tables and corresponding dose coefficients can be generated using all options described above except that for Absorbed Dose as a dosimetric quantity. The calculations will always employ the Equivalent Dose quantity option. These customized tables can be used to interpret bioassay results in the bioassay interpretation module. The software automatically composes a standard name for the file that will contain the table and suggests a comment sentence to later identify the table to be generated. The user is able to modify the comment sentence only. Figure 3.6 shows an example for inhalation of Type S compounds of ^{238}U with 3 μm AMAD.

It is advisable to produce and scrutinize run cases, as described above in the item "Calculation Results", before generating the final tables through this option. As explained above in the item "Standard Times", it is also advisable to use as many time values as possible. Nevertheless any table generated by the user can be rewritten and absolutely no table, which comes originally with this software, can be accidentally deleted due to the generation of new bioassay tables using the same parameters. It must be pointed out that it should be expected to take considerable time when running long series like those for Ra, U and Th isotopes.

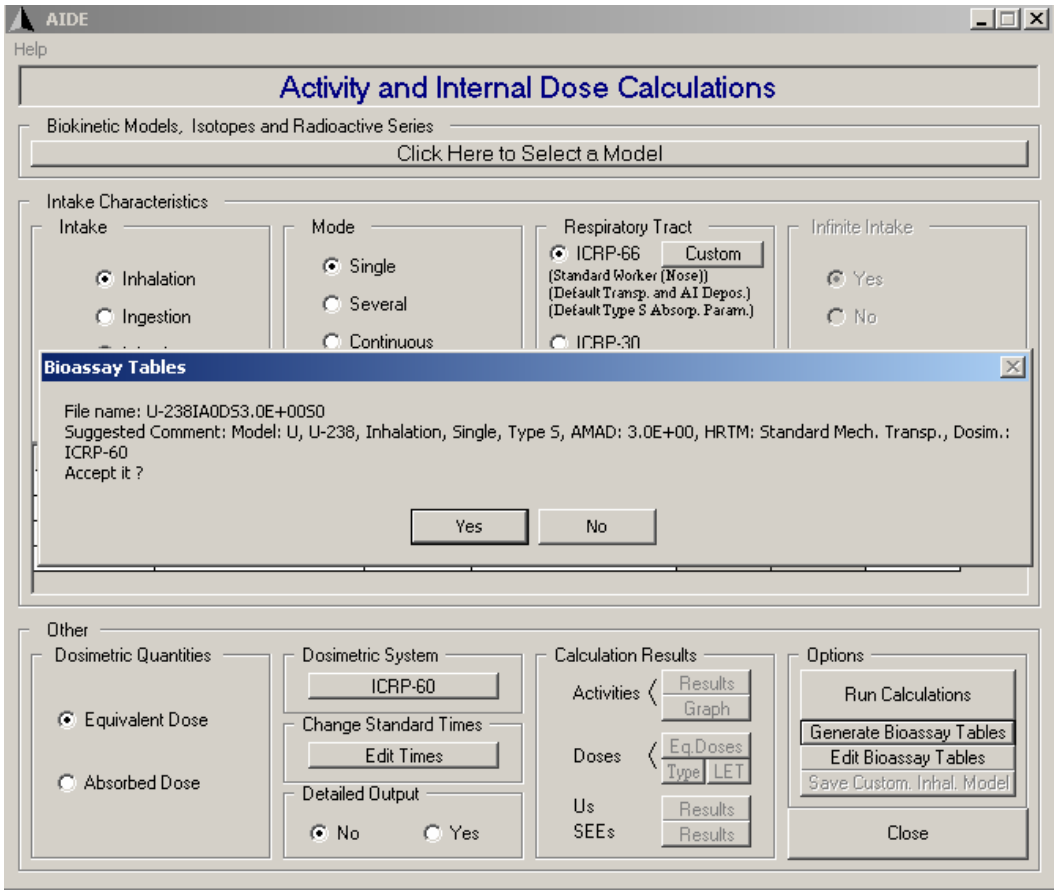


Figure 3.6 An example for generating bioassay tables for the case of inhalation of Type S compounds of ^{238}U with 3 μm AMAD.

Edit Bioassay Tables: The "Bioassay Tables" form is shown (Figure 3.7) listing all available bioassay tables. Table names shown on the grid on a yellow background refer to those tables that are part of the software. Table names shown on a white background refer to those generated by the user. The grid contains three columns, namely: "Number", "Table Name" and "Comments". This form also presents a handy feature, which allows the user to filter the tables by applying a filter on any of the columns. For instance, if the user wishes to see table names for Pu-239 only, then the "Table Name" Field should be selected and the text "Pu-239" should be typed in the "Text:" field. The filter is applied by pressing the "Apply Filter" button. The filter can be removed by pressing the "Remove Filter" button.

The desired table name and associated comments can be selected by clicking on the corresponding line on the grid. Both fields are then copied to the "Table Name:" and "Comments" textboxes located inside the "Edit Bioassay Table" frame. The latter field can be edited if it corresponds to a table, which was generated by the user.

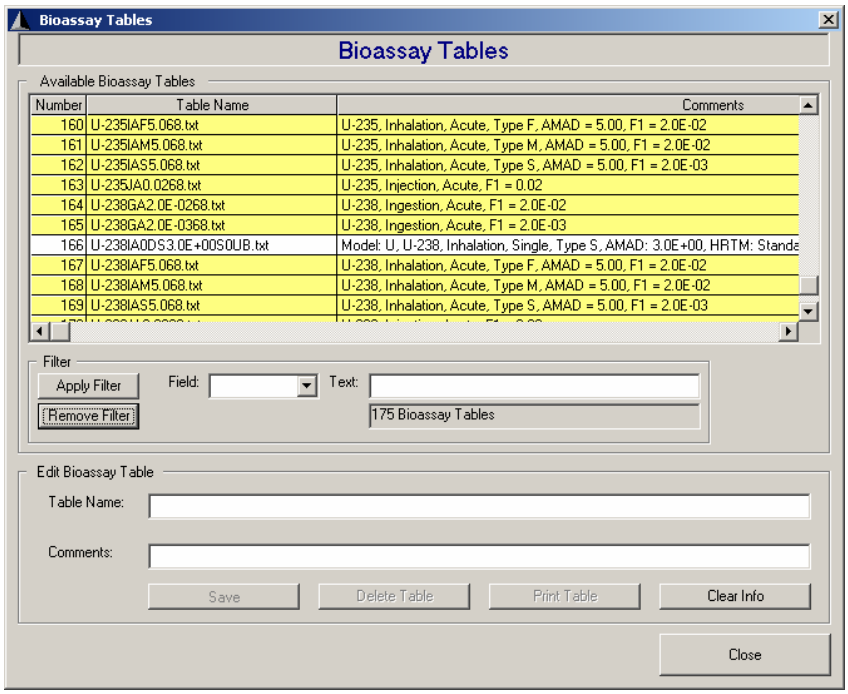


Figure 3.7 The "Bioassay Tables" form

Save Custom Inhalation Model: This feature is explained in the section 3.2.2.1 below.

3.2 Intake by Inhalation

Figure 3.8 shows the available options for running calculations for the intake case by inhalation.

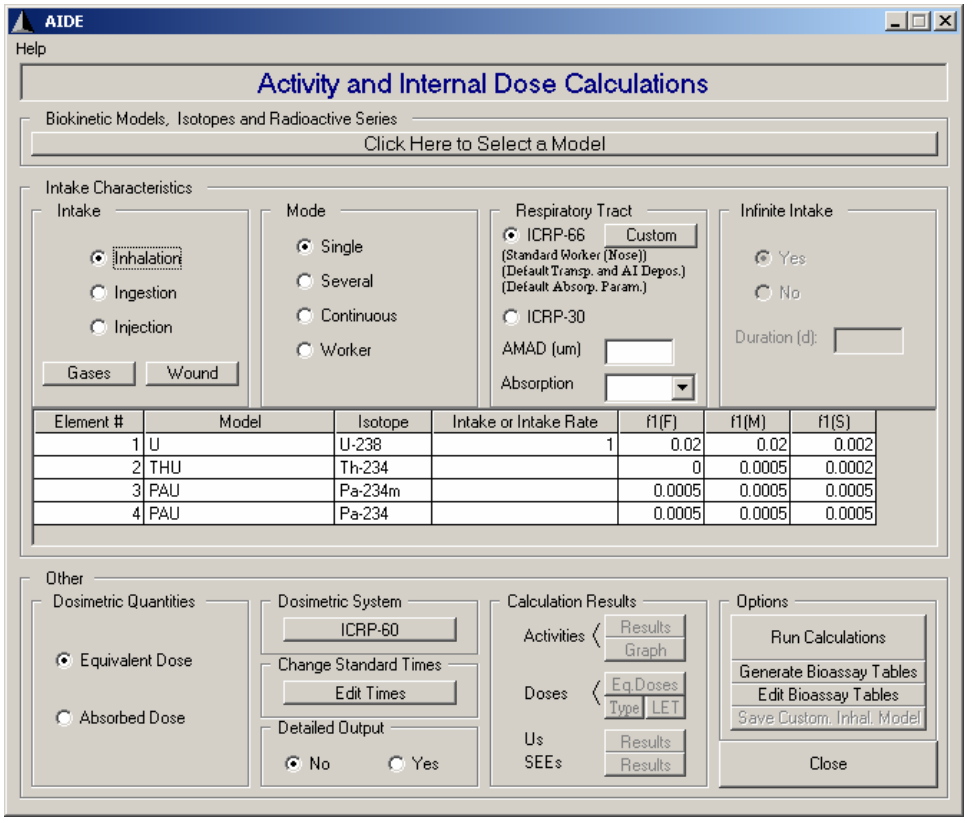


Figure 3.8 The "Activity and Internal Dose Calculations" form showing an example for running activities and dose calculations for single inhalation of ^{238}U

3.2.1 Mode or Intake Pattern

As explained above: Acute (or single), Several, Continuous and Worker's.

3.2.2 Respiratory Tract

The ICRP-66 Human Respiratory Tract Model (HRTM)[1] is the default choice. This choice allows selecting customized options for the subject and for the transport and absorption parameters associated with the HRTM. An additional feature allowing the use of non-default parameters for partitions of deposit in the AI region was also incorporated in this version. The default options are: Standard Worker (Nose), Default Transport Parameters and Default Absorption Parameters. After clicking on the "Custom" button the "HRTM-Customization" form is shown. It contains three main framed areas: "Subject", "Mechanical Transport and Partition of Deposit in AI Region" and "Absorption into Blood". Figure 3.9 shows the details.

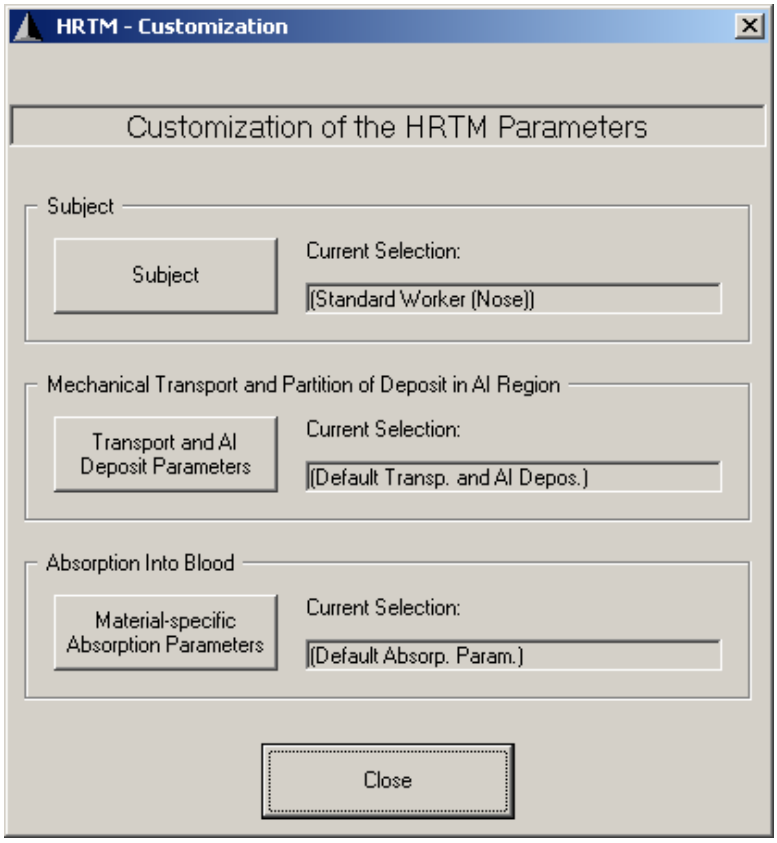


Figure 3.9 The "HRTM-Customization" form with selections of "Subject", "Mechanical Transport and Partition of Deposit in AI Region" and "Absorption Into Blood"

After clicking on the "Subject" button twenty-three different kinds of subjects can be chosen regarding breathing patterns and gender, as shown in Figure 3.10. The standard worker is the default software choice. The only time the user needs to enter this form to select the "Standard Worker" subject is when previous calculations were performed using another subject in the same program session. The "Close" button will take the program back to the "HRTM-Customization" form.

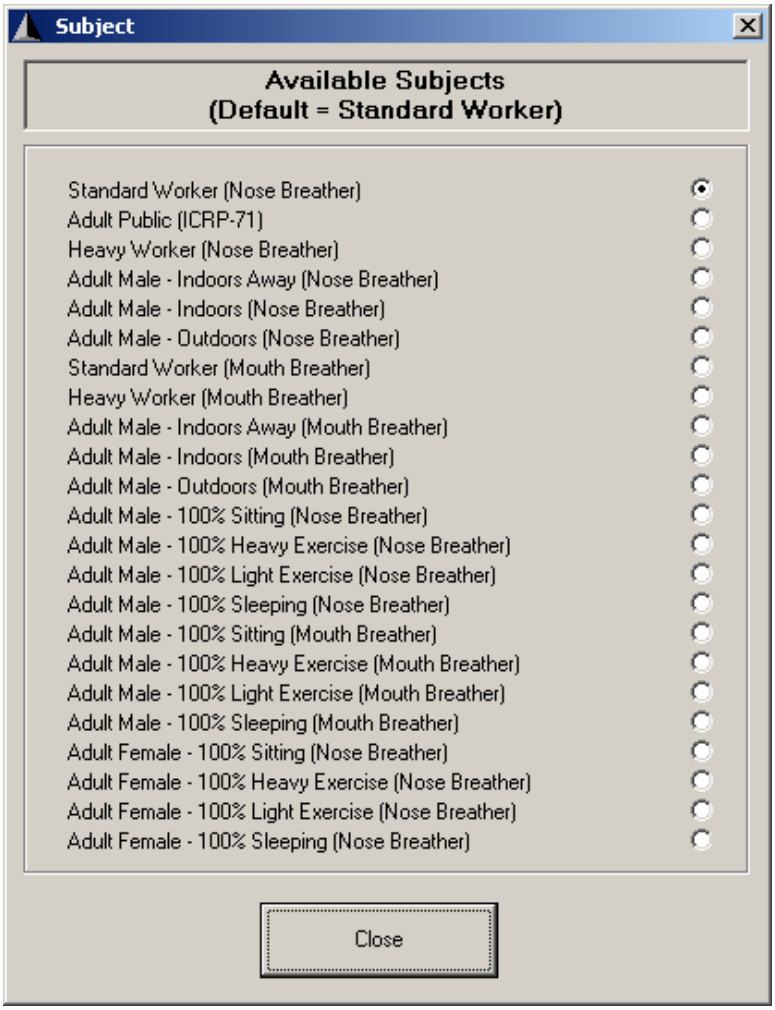


Figure 3.10 Available subjects to be used with the HRTM

Clicking on the "Transport and AI Deposit Parameters" button inside the "Mechanical Transport and Partition of Deposit in AI Region" frame of the "HRTM-Customization" form (Figure 3.9) will load the "HRTM: Mechanical Clearance Rates and Partition of Deposit in AI Region" form, as shown in Figure 3.11. This form allows modifying and saving any transport parameter value associated with the HRTM for posterior use in calculations. New values should be directly edited on the corresponding textboxes. The default values for the partitions of deposit in the AI Region can also be modified. All modified parameters will be shown in textboxes with red background color. The parameters can be saved and read to be used later in the software. The default transport parameters can be retrieved by clicking the "Reset Parameters to Default Values" button. The most common applications of modified parameters are in calculations of customized dose coefficients and in the generation of bioassay tables for inhalation of compounds of radionuclides, which present lung transport characteristics that cannot be described by the default HRTM parameters. The "Close" button will take the program back to the "HRTM-Customization" form (Figure 3.9).

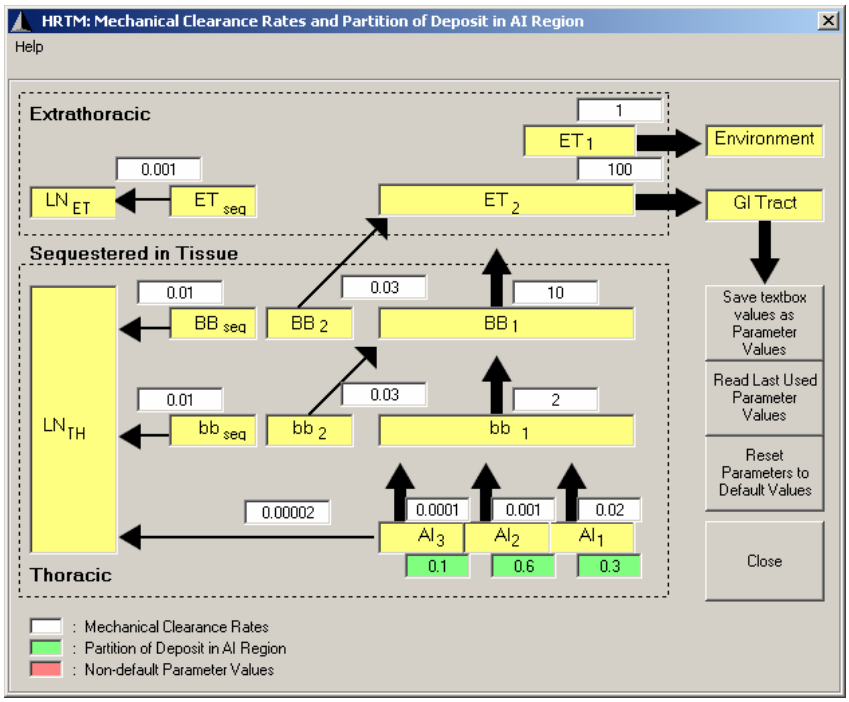


Figure 3.11 The "HRTM: Mechanical Clearance Rates and Partition of Deposit in AI Region" form

Clicking on the "Material-specific Absorption Parameters" button inside the "Absorption Into Blood" frame of the "HRTM-Customization" form will load the "Material-specific Absorption" form, as shown in Figure 3.12. As explained above for the mechanical clearance parameters, the user can also read, modify and save these parameters for using in posterior calculations. Figure 3.12 shows the schematics with the "Alternative 2" representation, i.e. using S_p, S_{pt}, S_t, f_B and S_b absorption parameters. The "Alternative 1" representation of the blood absorption parameters is also available and uses the f_r, S_r, S_s, f_B and S_b absorption parameters. It can be reached by clicking the "Alternative 1" button, which is located on the lower left corner of the form. The "Close" button will take the program back to the "HRTM-Customization" form (Figure 3.9).

After closing the "HRTM-Customization" form all customized selected options will be seen on the label under the ICRP-66 option button of the "Activity and Internal Dose Calculations" form, which will be reloaded. Figure 3.8 shows the default options.

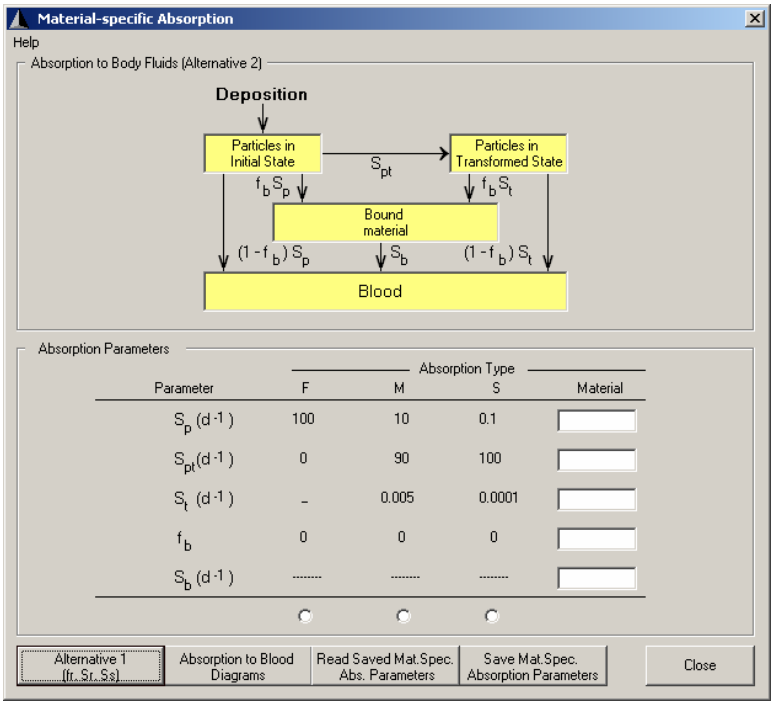


Figure 3.12 The "Material-specific Absorption" form with the "Alternative 2" representation

The default F, M and S types can also be directly selected by using the "Absorption" combo box located in the "Respiratory Tract" frame on the "Activity and Internal Dose Calculations" form (Figure 3.8). If the respiratory tract model proposed in ICRP Publication 30[20] is selected in the "Activity and Internal Dose Estimates" form the F, M and S absorption types are replaced by the D, W and Y Classes respectively.

Activity Median Aerodynamic Diameter (AMAD): In micron for inhalation intake. The AMAD must be a positive number. For gases and vapors the appropriate button in the intake frame must be pressed.

Blood Absorption: The F, M or S choices are provided if the AMAD is greater than zero, i.e., it is not a gas or a vapor. Material-specific absorption parameters can be entered as explained above in this section.

3.2.2.1 Save Custom Inhalation Model

This feature was especially made to be employed in situations where the user wishes to make repetitive runs using a particular customized combination of parameters associated with the selections of "Subject", "Mechanical Transport and Partition of Deposit in AI Region" and "Absorption into Blood", as shown in Figures 3.9, 3.10, 3.11 and 3.12.

For instance, the user wants to run an inhalation case of inhalation of ^{238}U using the "U" biokinetic model for uranium, and has selected the combination of non-default mechanical clearance rates and partition of deposit in AI Region, as shown in Figure 3.13.

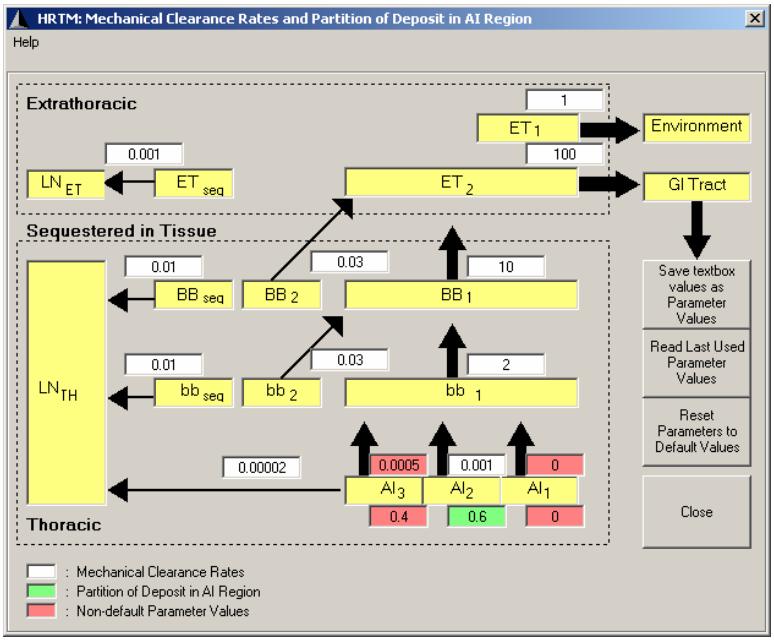


Figure 3.13 The "HRTM: Mechanical Clearance Rates and Partition of Deposit in AI Region" form showing a non-default selection of parameters

After properly closing the form with the customized selection and returning to the "Activity and Internal Dose Calculations" form (Figure 3.8) the "Save Custom. Inhal. Model" button is available. Figure 3.14 shows a typical message to be displayed if the user wants to save a particular combined model. As can be seen, in order to avoid having the original "U" model overwritten the new biokinetic model would be saved with the name "U2". The new model would comprise the data from the "U" biokinetic model together with the customized HRTM parameters, and it would be part of the list of the available biokinetic models as shown in Figure 3.2.

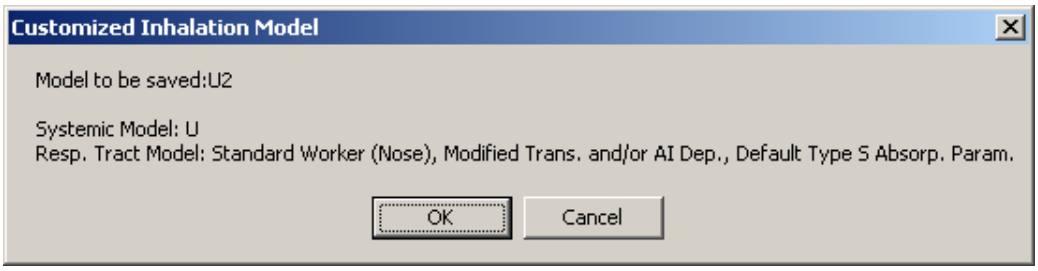


Figure 3.14 Typical message occurring when a customized inhalation model is about to be saved

3.2.3 Infinite Intake

As defined in section 3.1.2 Intake Characteristics, it is used for non-single intake patterns. If the intake duration is infinite then click on the "Yes" option. Click on the "No" option otherwise and provide the number of days that it lasts by entering it in the appropriate textbox.

3.2.4 Intake or Intake Rate

Enter with a number on the cell located on the first row and on the fourth column of the grid at the lower half of the form, which is inside the "Intake Characteristics" frame, as can be seen in Figure 3.8. This number represents the initial activity (in Bq) if the intake mode is single or intake rate (in $Bq.d^{-1}$) for the non-single intake modes. Initial activities or activity rates for considering intakes of daughters can be entered on the second row and thereafter.

3.2.5 Other

In order to have selected the rest of the options which are necessary to run the desired inhalation case, just follow the instructions from the section "3.1.3 Other" from the "Description of the Input Parameters for Activity and Internal Dose Calculations".

3.2.6 Results

Figure 3.15 shows the "Activity and Internal Dose Calculations" form, with the highlighted green buttons in the "Calculation Results" frame, after running an example for calculations of activities and doses for single inhalation of ^{238}U. Figure 3.16 shows typical views of calculation results for activities and doses. The results are given on a tabular form are printed on text files. In this way they can be edited, printed, or copied and exported to another text editor.

The results for activities are given for all times shown in the form shown in Figure 3.5 and for:
- the individual compartments forming the gastrointestinal tract,
- total gastrointestinal tract,
- the individual compartments forming the respiratory tract,
- the corresponding respiratory tract regions (ET1, ET2, LN-ET, BB, bb, AI, LN-TH),
- the total extrathoracic,
- the total thoracic,
- total respiratory tract,
- Accumulated and daily urinary and fecal excretions,
- the individual compartments forming the systemic model,
- totals for selected organs and tissues, like kidneys, liver and skeleton

In addition, a summary of the case run is printed on the beginning of the printout like the one below for calculation of activities:

```
Date: 3/24/2007 , 10:55:15 PM
```

```
Model: U , Isotope: U-238
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)
Intake: Inhalation , Single
Element:  1 (Series with  4 element(s))
Initial ou Daily Activity:  1.000E+00 Bq
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Tract Absorption Factor: F1 = 2.000E-03
AMAD (um): 5.000E+00
```

The dose results are given for all times shown in the form displayed in Figure 3.5 and for the following organs and tissues: Adrenals, Bladder Wall, Bone Surface, Brain, Breasts, Esophagus, St Wall, SI Wall, ULI Wall, LLI Wall, Colon, Kidneys, Liver, Muscle, Ovaries, Pancreas, Red Marrow, ET Airways, Lungs, Skin, Spleen, Testes, Thymus, Thyroid, Uterus, Remainder and Effective Dose.

A summary of the case run is printed on the beginning of the printout like the one below:

```
Series with  4 element(s):
Isotope(s): U-238    Th-234   Pa-234m  Pa-234

Model(s):   U THU PAU PAU
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)

Intake: Inhalation, Single, without intake of progeny.
Element: U-238
Initial or daily activity:  1.000E+00 Bq
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Absorption Fraction: f1 = :  2.000E-03
AMAD (um): 5.000E+00
Dosimetric System: ICRP-60
```

A full printout example showing calculations of activities and doses for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm is available for perusal in section 3.8.

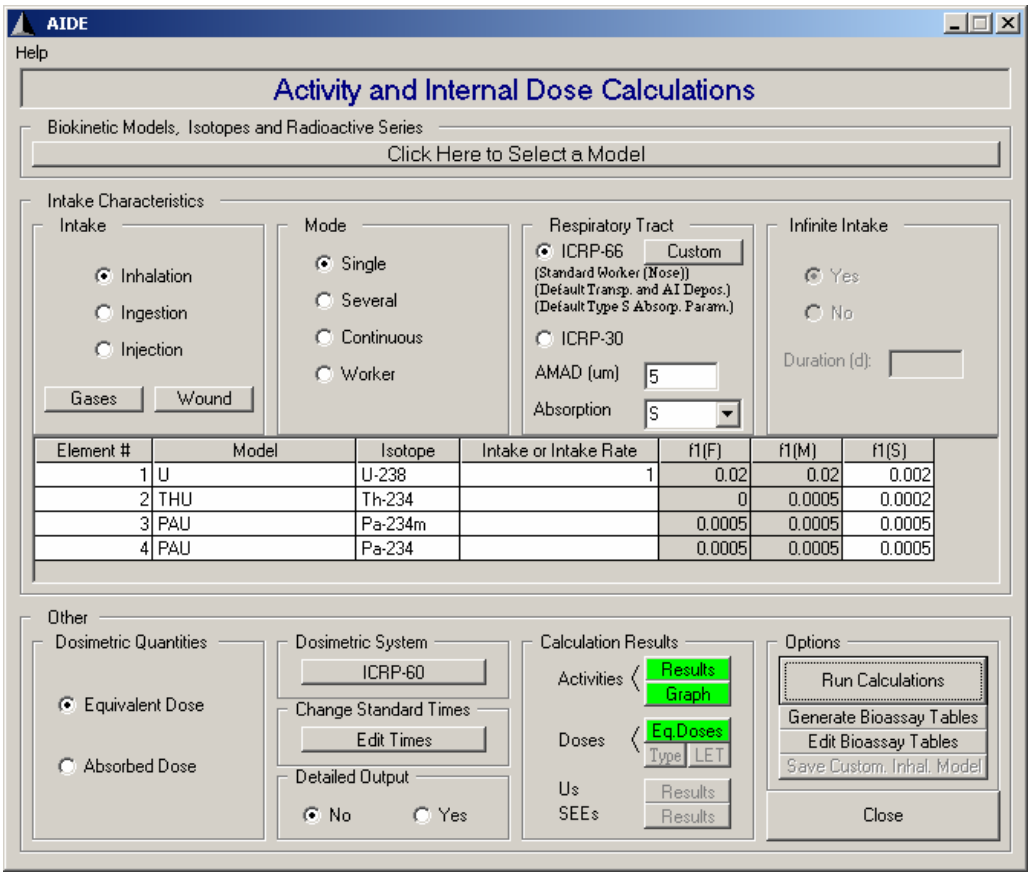
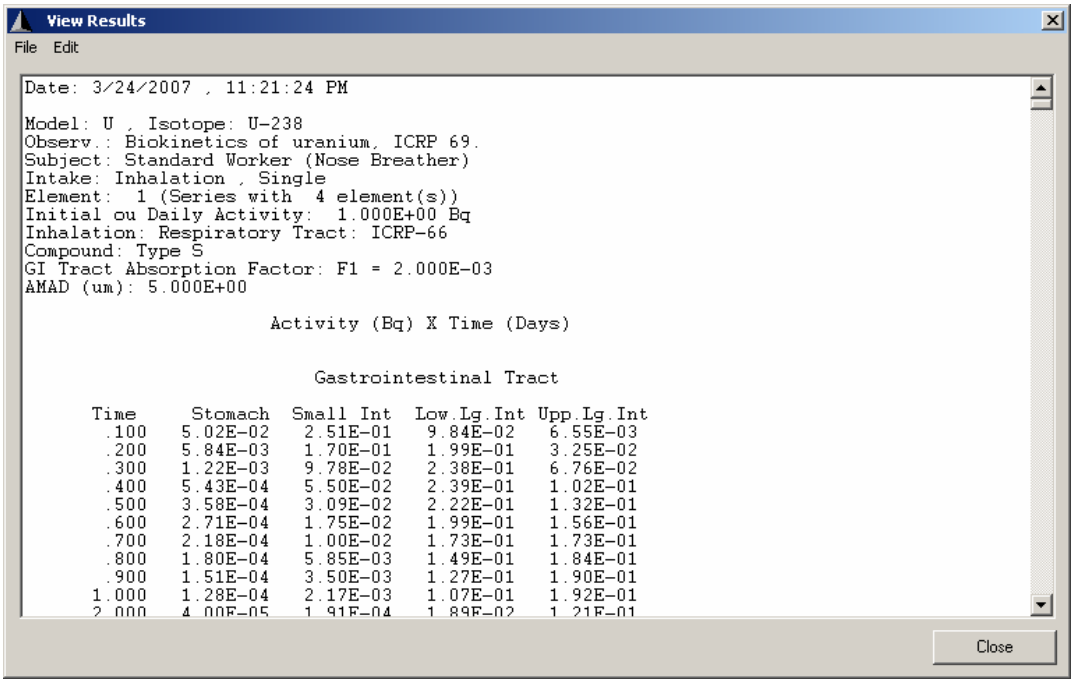


Figure 3.15 The "Activity and Internal Dose Calculations" form showing the highlighted green buttons after running calculations of activities and doses for single inhalation of ^{238}U



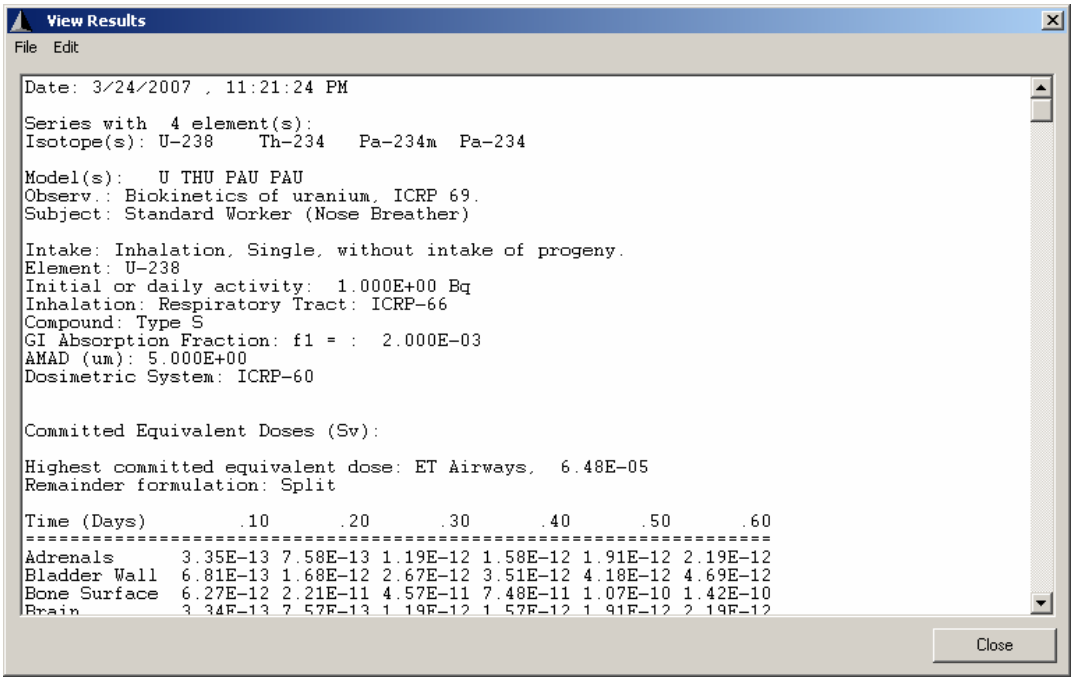


Figure 3.16 Activity and dose calculation results corresponding to the input parameters of Figure 3.15

3.3 Intake by Ingestion

The selection of the case of intake by ingestion is comprised of the Type of Intake (ingestion), the Intake Mode or Pattern (single, several continuous, or worker) and Duration of Intake for non-single intake cases.

Intakes by ingestion and by injection require the selection of the appropriate f1 (gastrointestinal absorption fraction), which can be made by clicking the appropriate f1 column on the grid on the "Activity and Internal Dose Calculations" form. Nil f1 values for normally indicate that the absorption type is inexistent. The specific selection is done by clicking the appropriate f1 column header, namely f1(1), f1(2), or f1(3), on the grid. Nil f1 values for normally indicate that the absorption type is inexistent.

The selection of the rest of the options, which are located in the "Other" frame, can be done by following the instructions on the "Section 3.1.3 Other" from the "Description of the Input Parameters for Activity and Internal Dose Calculations".

After pressing the "Run Calculations" button the calculation results should be available as shown in section "3.2.6 Results" above.

3.4 Intake by Injection

Similarly to the previously shown examples for inhalation and ingestion intakes the selection of the case of intake by injection is comprised of the Type of Intake (injection), the Intake Mode or Pattern (single, several continuous, or worker) and Duration of Intake for non-single intake cases.

As explained above the gastrointestinal absorption fraction f1 can be selected by clicking the appropriate f1 column on the grid. The case is run similarly to the ones explained above and the results can be retrieved in the same way.

The only important observation for this case is that injection cases are normally associated with intakes by wounds, whose procedure is explained in section "3.6 Intake by Wound" below in more details.

3.5 Intake by Gases and Vapors

For running intake cases by gases and vapors the appropriate button in the Intake frame on the "Activity and Internal Dose Calculations" form (Figure 3.1) must be pressed, which will load the "Gases and Vapors" form shown in Figure 3.17. This allows the selection of twenty-three gases or vapors, as proposed in the ICRP Supporting Guidance 3[14] document. The selection is comprised of the automatic assignment of:
a) The Percentage of Deposition in each of the following regions of the HRTM: ET1, ET2, BB, bb and AI,
b) The blood absorption Class (F or V)
c) The specific absorption parameter S_b associated with clearance from "Bound Material" compartment as described in ICRP Publication 66[1] and in the Supporting Guidance 3[14].

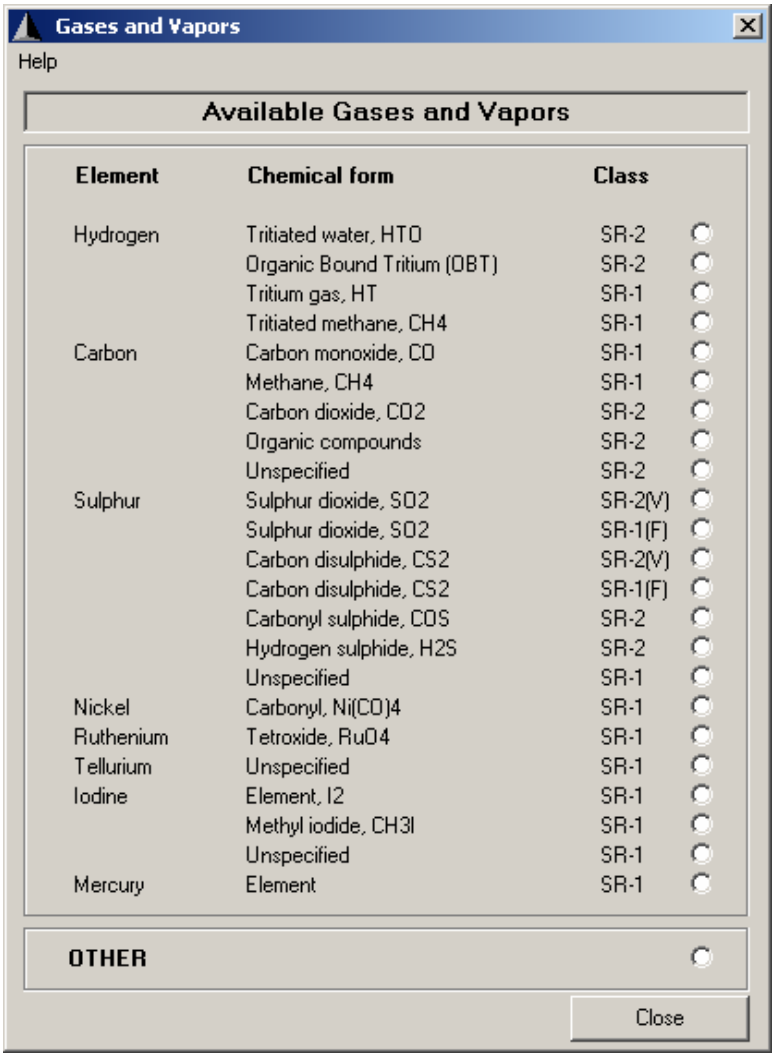


Figure 3.17 The available gases and vapors extracted from the ICRP Supporting Guidance 3 document.

In case the user wants to run another specific case, which is not contemplated on the list above, the option "OTHER" at the end of the form shown in Figure 3.17 can be used. When this option is selected the form shown in Figure 3.18 is displayed. The following additional options with respect to deposition in the HRTM regions are possible for SR-1 Class (soluble and reactive) of gases, as originally assigned with Class SR-1 in ICRP Publication 68[3]: "ICRP-66 Default", "Gas with Low Solubility", "100% in AI Region" and "Other". The corresponding choices for blood absorption Class are F or V. The specific absorption parameter S_b associated with clearance from "Bound Material" compartment, if any, can also be entered.

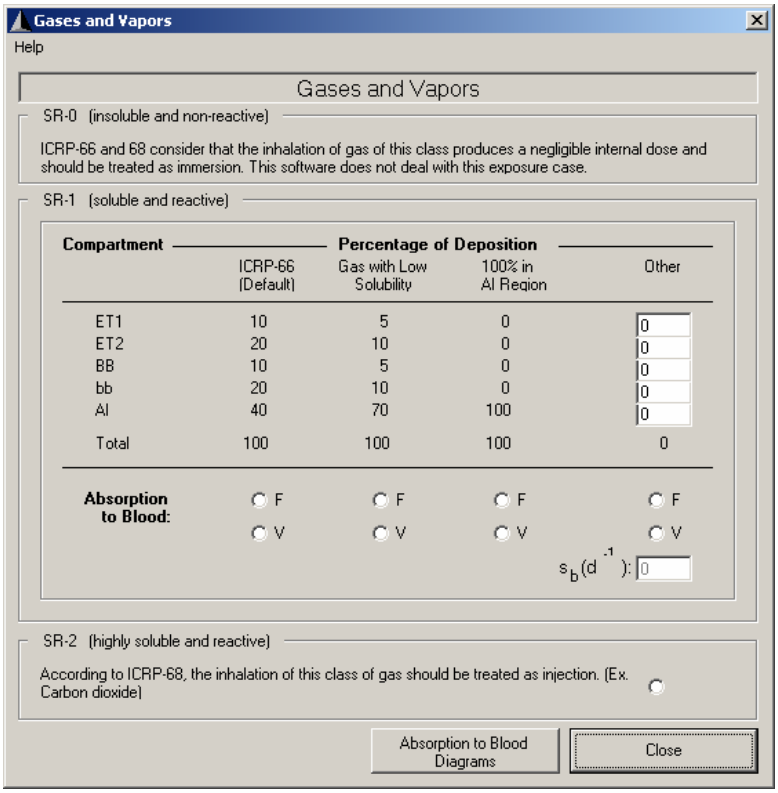


Figure 3.18 Form for assigning intake parameters for gases and vapors

As an example, let's assume that the "Iodine Element I2" option was selected on the "Gases and Vapors" form shown in Figure 3.17. The "Biokinetic Models, Isotopes and Radioactive Series" form is then loaded, as shown Figure 3.19. The biokinetic model for iodine, as proposed in ICRP-67[2], is automatically selected and the user is prompted to select the isotope of iodine and the corresponding series. Figure 3.19 shows that the ^{131}I was selected for this particular example. The "Activity and Internal Dose Calculations" form is subsequently loaded, as shown in Figure 3.20. The rest of the parameters can be entered and the case can be run as shown above for other intake cases.

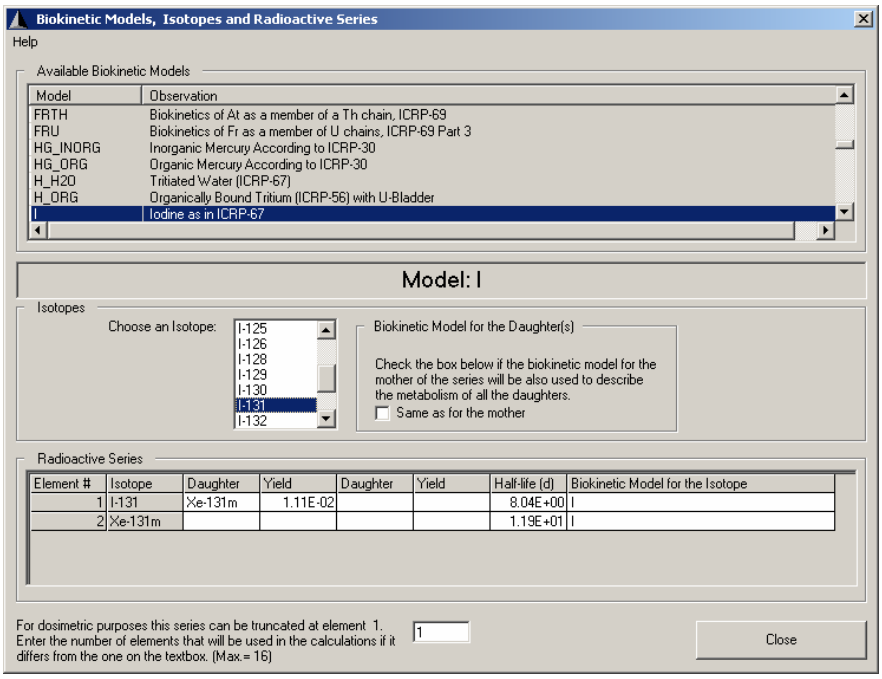


Figure 3.19 The "Biokinetic Models, Isotopes and Radioactive Series" form after the selection of the Iodine Element I2

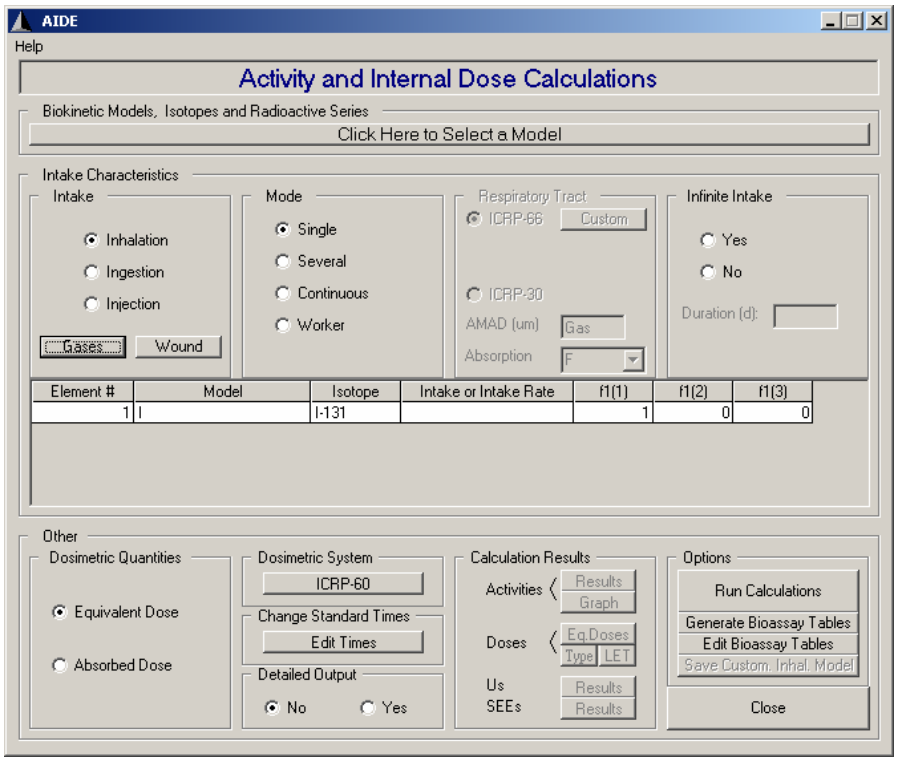


Figure 3.20 The "Activity and Internal Dose Calculations" form after the selection of the Iodine Element I2

3.6 Intake by Wound

In order to run this particular kind of intake press the "Wound" button located in the Intake frame of the "Activity and Internal Dose Calculations" form, as shown in Figure 3.1. The "Intake by Wound" form will be loaded, as shown in Figure 3.21. The case can be run by selecting both a category of wound model and a systemic biokinetic model.

Seven Categories for the Wound Model can be selected, which is comprised of the Soluble Model (with four categories: Weak, Moderate, Strong and Avid), the Colloid Model, the Particle Model and the Fragment Model. A category can be selected by clicking the button, which shows the category name.

The biokinetic diagram for the selected category of radionuclides in wounds is shown on a picturebox and the corresponding default transfer rates (d^{-1}) are shown on the grid located on the right side of the picturebox. A diagram for the "General Model" can also be visualized.

After the Wound Model category was selected the user must select a corresponding systemic model from the "Available Systemic Biokinetic Models" listbox to run the case. When both models are properly selected click on the "Select and/or Close" button to continue running the case. The "Biokinetic Models, Isotopes and Radioactive Series" form is then loaded in the exact way as shown on Figure 3.19 for the case of intake by gases and vapors and the isotope can be selected. After this step the program will return to the "Activity and Internal Dose Calculations" form where the user will complete the data entry to run the case.

The program will return directly to the "Activity and Internal Dose Calculations" form when the user does not select both models and wants to leave the form.

It must be pointed out that the great flexibility given to the user to select and run a hypothetical combination of a wound model with any systemic model does not imply that in reality such combination exists. More details can be found on the NCRP Report no. 156, "Development of a Biokinetic Model For Radionuclide-contaminated Wounds and Procedures for Their Assessment, Dosimetry and Treatment"[16], which will be released soon.

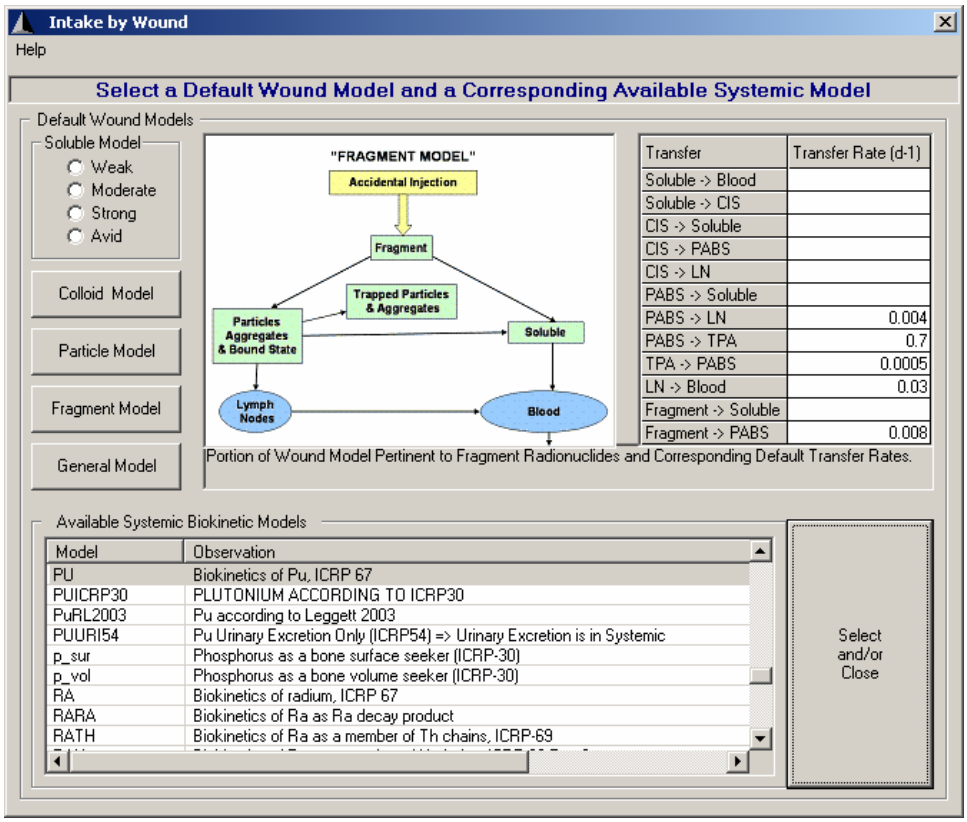


Figure 3.21 The "Intake by Wound" form

3.7 Quality Assurance of Calculations of Activities and Dose Coefficients

Four basic steps are required for calculating committed dose coefficients: a) calculations of activities in compartments for all elements of the radioactive series, b) calculations of number of transformations (Us) in compartments for all elements of the radioactive series, which use the results from calculations of activities, c) calculations of Specific Effective Energy (SEE(T←S)) from all source organs to all target organs for all types of radiations, and d) calculations of committed dose coefficients, which use the results from Us and SEE(T←S). As a result, the quality assurance procedure for the committed dose coefficients must encompass the quality assurance of all four steps.

As explained earlier in this manual, AIDE contains biokinetic models and associated radioactive decay data for the following elements listed in ICRP Publication 78[7]: H, Fe, Co, Sr, Ru, I, Cs, Ra, Ra, Th, Th, U, Np, Pu, Am, Cm, Cf. In addition, Tc, P, S, C, Sm, Re, Po and Pb were added to this list. The full checking involved comparison of results for the four steps mentioned above for all forms of occupational intakes of the following radionuclides: ^{3}H, ^{18}F, ^{59}Fe, ^{57}Co, ^{58}Co, ^{60}Co, ^{85}Sr, ^{89}Sr, ^{90}Sr, ^{106}Ru, ^{125}I, ^{129}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm, ^{252}Cf, ^{99m}Tc, ^{32}P, ^{35}S, ^{14}C, ^{153}Sm, ^{188}Re, ^{210}Po and ^{210}Pb.

In this way, the calculation of the activities were promptly checked against the predicted values of the measured quantities following single intake, which are listed in ICRP Publication 78[7]. The calculations of the dose coefficients were checked against the values of the ICRP CD[21]. All SEE(T←S) calculations were checked against the calculation values from the SEECAL[22] program.

It must be pointed out that the broad set of selected biokinetic models and corresponding radionuclides allowed performing very comprehensive run checks. The biokinetic models comprised the main patterns of metabolic pathways of the elements: uniformly distributed in the whole body, bone seekers, other organ seekers (like iodine in thyroid) and gases. The radionuclides belonged to long and short decay series and presented all types of radiation decays. More comprehensive tests involving all details of calculations for activities and number of transformations for all compartments and for times ranging from 0.1 days to 50 years after the intake and SEE(T←S) calculations for all possible source-target relationships were performed for the following radionuclides: ^{3}H (HT, vapor and OBT), ^{54}Mn, ^{60}Co, ^{90}Sr, ^{95}Zr, ^{106}Ru, ^{125}Sb, ^{131}I, ^{137}Cs, ^{226}Ra, ^{232}Th, ^{238}U, ^{239}Pu and ^{241}Am.

These thorough intercomparison tests were carried out in person with Dr. Keith Eckerman, at Oak Ridge National Laboratory. The author wishes to thank him once more for his kindness, patience, his time dedicated to intercompare many calculation results and for his constant support and encouragement.

Table 3.1 shows the results for calculated Committed Effective Doses using AIDE (E_calc), reference Committed Effective Doses (E_ref), which were extracted from the ICRP CD[21], and calculated to reference Committed Effective Dose ratios for several radionuclides.

As can be seen, 93.5% of ratios lie on the $\pm$ 3% range with reference to the value 1, 97.6% lie on the $\pm$ 5% range and all calculation results lie on the $\pm$ 9% range

These results can be rated as excellent taking into account that the programs and algorithms used by AIDE to calculate activities in compartments, number of transformations, Specific Effective Energies and committed dose coefficients are totally different from those used to derive the reference values.

Table 3.1: Calculated Committed Effective Doses (E_calc), reference Committed Effective Doses (E_ref) and calculated to reference Committed Effective Dose ratios for several radionuclides

Radionuclide, Type of Intake	E_calc	E_ref	E_calc/E_ref
H-3, HTO	1.8E-11	1.8E-11	1
H-3, OBT	4.1E-11	4.1E-11	1
H-3, HT	1.8E-15	1.8E-15	1
F-18, Type F	5.4E-11	5.4E-11	1
F-18, Type M	8.9E-11	8.9E-11	1
F-18, Type S	9.3E-11	9.3E-11	1
F-18, Ingestion	4.9E-11	4.9E-11	1
Fe-59, Type F	3.0E-09	3.0E-09	1
Fe-59, Type M	3.1E-09	3.2E-09	0.97
Fe-59, Ingestion	1.8E-09	1.8E-09	1
Co-57, Type M	3.9E-10	3.9E-10	1
Co-57, Type S	6.0E-10	6.0E-10	1
Co-57, Ingestion, f1=0.1	2.2E-10	2.1E-10	1.05
Co-57, Ingestion, f1=0.05	1.9E-10	1.9E-10	1
Co-58, Type M	1.4E-09	1.4E-09	1
Co-58, Type S	1.7E-09	1.7E-09	1
Co-58, Ingestion, f1=0.1	7.5E-10	7.4E-10	1.01
Co-58, Ingestion, f1=0.05	7.0E-10	7.0E-10	1
Co-60, Type M	7.1E-09	7.1E-09	1
Co-60, Type S	1.7E-08	1.7E-08	1
Co-60, Ingestion, f1=0.1	3.4E-09	3.4E-09	1
Co-60, Ingestion, f1=0.05	2.5E-09	2.5E-09	1
Sr-85, Type F	5.6E-10	5.6E-10	1
Sr-85, Type S	6.5E-10	6.4E-10	1.02
Sr-85, Ingestion, f1=0.3	5.6E-10	5.6E-10	1
Sr-85, Ingestion, f1=0.01	3.3E-10	3.3E-10	1
Sr-89, Type F	1.4E-09	1.4E-09	1
Sr-89, Type S	5.6E-09	5.6E-09	1
Sr-89, Ingestion, f1=0.3	2.6E-09	2.6E-09	1
Sr-89, Ingestion, f1=0.01	2.3E-09	2.3E-09	1
Sr-90, Type F	3.0E-08	3.0E-08	1
Sr-90, Type S	7.7E-08	7.7E-08	1
Sr-90, Ingestion, f1=0.3	2.8E-08	2.8E-08	1
Sr-90, Ingestion, f1=0.01	2.7E-09	2.7E-09	1
Ru-106, Type F	9.9E-09	9.8E-09	1.01
Ru-106, Type M	1.7E-08	1.7E-08	1
Ru-106, Type S	3.4E-08	3.5E-08	0.97
Ru-106, Ingestion, f1=0.05	7.1E-09	7.0E-09	1.01
I-125, Type F	7.4E-09	7.3E-09	1.01
I-125, Ingestion	1.5E-08	1.5E-08	1
I-125, Element I2	1.4E-08	1.4E-08	1
I-129, Type F	5.1E-08	5.1E-08	1
I-129, Ingestion	1.1E-07	1.1E-07	1

I-129, Element I2	9.6E-08	9.6E-08	1
I-131, Type F	1.0E-08	1.1E-08	0.91
I-131, Ingestion	2.2E-08	2.2E-08	1
I-131, Element I2	2.0E-08	2.0E-08	1
Cs-134, Type F	9.7E-09	9.6E-09	1.01
Cs-134, Ingestion	1.9E-08	1.9E-08	1
Cs-137, Type F	6.7E-09	6.7E-09	1
Cs-137, Ingestion	1.4E-08	1.3E-08	1.08
Ra-226, Type M	2.2E-06	2.2E-06	1
Ra-226, Ingestion, f1=0.2	2.8E-07	2.8E-07	1
Ra-228, Type M	1.7E-06	1.7E-06	1
Ra-228, Ingestion, f1=0.2	6.6E-07	6.7E-07	0.99
Th-228, Type M	2.3E-05	2.2E-05	1.05
Th-228, Type S	2.6E-05	2.5E-05	1.04
Th-228,Ingestion, f1=0.0005	7.0E-08	7.2E-08	0.97
Th-228,Ingestion, f1=0.0002	3.4E-08	3.5E-08	0.97
Th-232, Type M	2.9E-05	2.9E-05	1
Th-232, Type S	1.2E-05	1.2E-05	1
Th-232, Ingestion, f1=0.0005	2.3E-07	2.2E-07	1.05
Th-232, Ingestion, f1=0.0002	9.4E-08	9.2E-08	1.02
U-234, Type F	6.5E-07	6.4E-07	1.02
U-234, Type M	2.1E-06	2.1E-06	1
U-234, Type S	6.8E-06	6.8E-06	1
U-234, Ingestion, f1=0.02	4.9E-08	4.9E-08	1
U-234, Ingestion, f1=0.002	8.4E-09	8.3E-09	1.01
U-235, Type F	6.0E-07	6.0E-07	1
U-235, Type M	1.8E-06	1.8E-06	1
U-235, Type S	6.1E-06	6.1E-06	1
U-235, Ingestion, f1=0.02	4.6E-08	4.6E-08	1
U-235, Ingestion, f1=0.002	8.3E-09	8.3E-09	1
U-238, Type F	5.8E-07	5.8E-07	1
U-238, Type M	1.6E-06	1.6E-06	1
U-238, Type S	5.7E-06	5.7E-06	1
U-238, Ingestion, f1=0.02	4.4E-08	4.4E-08	1
U-238, Ingestion, f1=0.002	7.6E-09	7.6E-09	1
Np-237, Type M	1.5E-05	1.5E-05	1
Np-237, Ingestion	1.1E-07	1.1E-07	1
Pu-238, Type M	3.0E-05	3.0E-05	1
Pu-238, Type S	1.0E-05	1.1E-05	0.91
Pu-238, Ingestion, f1=5E-04	2.3E-07	2.3E-07	1
Pu-238, Ingestion, f1=1E-05	8.8E-09	8.8E-09	1
Pu-239, Type M	3.2E-05	3.2E-05	1
Pu-239, Type S	8.3E-06	8.3E-06	1
Pu-239, Ingestion, f1=5E-04	2.5E-07	2.5E-07	1
Pu-239, Ingestion, f1=1E-05	9.0E-09	9.0E-09	1
Pu-240, Type M	3.2E-05	3.2E-05	1
Pu-240, Type S	8.3E-06	8.3E-06	1
Pu-240, Ingestion, f1=5E-04	2.5E-07	2.5E-07	1
Pu-240, Ingestion, f1=1E-05	9.0E-09	9.0E-09	1

Am-241 Type M	2.7E-05	2.7E-05	1
Am-241, Ingestion	2.0E-07	2.0E-07	1
Cm-242, Type M	3.6E-06	3.7E-06	0.97
Cm-242, Ingestion	1.2E-08	1.2E-08	1
Cm-244, Type M	1.7E-05	1.7E-05	1
Cm-244, Ingestion	1.2E-07	1.2E-07	1
Cf-252 Type M	1.3E-05	1.3E-05	1
Cf-252, Ingestion	8.9E-08	9.0E-08	0.99
Tc-99m, Type F	2.0E-11	2.0E-11	1
Tc-99m, Type M	2.9E-11	2.9E-11	1
Tc-99m, Ingestion, f1=0.8	2.2E-11	2.2E-11	1
P-32, Type F	1.1E-09	1.1E-09	1
P-32, Type M	2.9E-09	2.9E-09	1
P-32, Ingestion, f1=0.8	2.4E-09	2.4E-09	1
S-35, Type F	8.0E-11	8.0E-11	1
S-35, Type M	1.1E-09	1.1E-09	1
S-35, SO2, Type V	1.2E-10	1.2E-10	1
S-35, Inorg, Inges, f1=0.8	1.4E-10	1.4E-10	1
C-14,CO	8.0E-13	8.0E-13	1
C-14,CO2	6.5E-12	6.5E-12	1
C-14, Organic	5.8E-10	5.8E-10	1
Sm-153, Type M	6.8E-10	6.8E-10	1
Sm-153, Ingestion	7.6E-10	7.4E-10	1.03
Re-188, Type F	6.6E-10	6.6E-10	1
Re-188, Type M	7.5E-10	7.4E-10	1.01
Re-188, Ingestion, f1=0.8	1.4E-09	1.4E-09	1
Po-210, Type F	7.1E-07	7.1E-07	1
Po-210, Type M	2.1E-06	2.2E-06	0.95
Po-210, Ingestion, f1=0.1	2.4E-07	2.4E-07	1
Pb-210, Type F	1.1E-06	1.1E-06	1
Pb-210, Ingestion, f1=0.2	6.8E-07	6.8E-07	1

3.8 Example of Printout for Calculations of Activities and Dose Coefficients

Tables 3.2 and 3.3 show respectively the results of calculations of activities and doses for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm. The times after the intake to run this particular example were: 0.1, 0.5, 1, 5, 10, 50, 100, 500, 1000, 5000 and 10000 days.

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm

```
Date: 3/24/2007 , 10:55:15 PM

Model: U , Isotope: U-238
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)
Intake: Inhalation , Single
Element:  1 (Series with  4 element(s))
Initial ou Daily Activity:  1.000E+00 Bq
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Tract Absorption Factor: F1 = 2.000E-03
AMAD (um): 5.000E+00

                    Activity (Bq) X Time (Days)


                         Gastrointestinal Tract

     Time     Stomach  Small Int  Low.Lg.Int Upp.Lg.Int
      .100   5.02E-02   2.51E-01   9.84E-02   6.55E-03
      .500   3.58E-04   3.09E-02   2.22E-01   1.32E-01
     1.000   1.28E-04   2.17E-03   1.07E-01   1.92E-01
     5.000   2.46E-05   9.86E-05   4.21E-04   8.55E-03
    10.000   2.18E-05   8.75E-05   2.96E-04   6.00E-04
    50.000   9.04E-06   3.63E-05   1.22E-04   2.25E-04
   100.000   3.64E-06   1.46E-05   4.92E-05   9.01E-05
   500.000   7.78E-07   3.15E-06   1.06E-05   1.92E-05
  1000.000   4.51E-07   1.85E-06   6.23E-06   1.14E-05
  5000.000   3.61E-09   6.04E-08   2.64E-07   6.19E-07
 10000.000   0.00E+00   1.92E-08   1.26E-07   3.70E-07

                    Activity (Bq) X Time (Days)


    Time    -------- Extrathoracic --------  Bronchial  Bronchiolar
              (ET1)      (ET2)      (LN-ET)      (BB)       (bb)
      .100   3.06E-01   7.70E-04   1.99E-08   1.11E-02   9.84E-03
      .500   2.05E-01   2.74E-04   9.96E-08   6.62E-03   6.90E-03
     1.000   1.25E-01   2.28E-04   1.99E-07   6.09E-03   5.34E-03
     5.000   2.28E-03   2.04E-04   9.94E-07   5.22E-03   3.98E-03
    10.000   1.54E-05   2.02E-04   1.98E-06   4.50E-03   3.44E-03
    50.000   6.53E-23   1.91E-04   9.67E-06   1.40E-03   1.09E-03
   100.000   1.26E-44   1.79E-04   1.88E-05   3.43E-04   2.79E-04
   500.000   0.00E+00   1.15E-04   7.46E-05   2.69E-06   9.94E-06
  1000.000   0.00E+00   6.65E-05   1.14E-04   1.11E-06   5.53E-06
  5000.000   0.00E+00   8.56E-07   1.20E-04   3.07E-08   1.54E-07
 10000.000   0.00E+00   4.41E-08   7.33E-05   5.94E-09   3.00E-08
```

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Time	Alveolar Interstit (AI)	Thoracic Lymph Nod. (LN-TH)	Extratho. Total	Thoracic Total	RT-TOTAL	GIT-TOTAL
.100	5.31E-02	2.13E-07	3.07E-01	7.40E-02	3.81E-01	4.06E-01
.500	5.30E-02	1.06E-06	2.06E-01	6.65E-02	2.72E-01	3.86E-01
1.000	5.28E-02	2.11E-06	1.25E-01	6.42E-02	1.89E-01	3.02E-01
5.000	5.14E-02	1.03E-05	2.49E-03	6.06E-02	6.31E-02	9.09E-03
10.000	4.99E-02	2.02E-05	2.20E-04	5.78E-02	5.80E-02	1.00E-03
50.000	4.13E-02	8.41E-05	2.01E-04	4.38E-02	4.40E-02	3.93E-04
100.000	3.59E-02	1.36E-04	1.98E-04	3.67E-02	3.69E-02	1.58E-04
500.000	2.32E-02	2.39E-04	1.90E-04	2.34E-02	2.36E-02	3.37E-05
1000.000	1.49E-02	2.73E-04	1.81E-04	1.52E-02	1.53E-02	1.99E-05
5000.000	1.90E-03	3.64E-04	1.21E-04	2.26E-03	2.38E-03	9.47E-07
10000.000	5.89E-04	3.02E-04	7.34E-05	8.91E-04	9.64E-04	5.16E-07

Activity (Bq) X Time (Days)

Time	Accumulat Urine	24-Hour Urine	Accumulat Feces	24-Hour Feces
.100	9.14E-05	0.00E+00	1.73E-04	0.00E+00
.500	5.62E-04	0.00E+00	2.73E-02	0.00E+00
1.000	7.10E-04	7.04E-04	1.14E-01	1.14E-01
5.000	8.24E-04	2.16E-05	4.10E-01	1.40E-02
10.000	9.13E-04	1.58E-05	4.21E-01	6.45E-04
50.000	1.25E-03	5.68E-06	4.35E-01	2.27E-04
100.000	1.49E-03	4.09E-06	4.42E-01	9.05E-05
500.000	2.65E-03	2.33E-06	4.55E-01	1.89E-05
1000.000	3.60E-03	1.52E-06	4.62E-01	1.11E-05
5000.000	5.91E-03	2.47E-07	4.73E-01	3.09E-07
10000.000	6.71E-03	1.01E-07	4.73E-01	6.00E-08

Activity (Bq) X Time (Days)

Time	Other_0	Blood_1	UB_Cont	Kidneys_1	Kidneys_2	Liver_1
.100	8.50E-05	2.97E-06	1.06E-04	3.01E-05	1.51E-07	4.51E-06
.500	6.08E-05	8.68E-06	5.57E-05	1.07E-04	4.81E-07	1.40E-05
1.000	9.25E-06	8.65E-06	8.45E-06	1.19E-04	5.56E-07	1.55E-05
5.000	9.71E-07	2.66E-06	1.73E-06	9.00E-05	6.07E-07	1.17E-05
10.000	7.48E-07	8.44E-07	1.28E-06	6.25E-05	6.47E-07	8.10E-06
50.000	3.75E-07	2.15E-07	4.72E-07	1.08E-05	8.25E-07	1.35E-06
100.000	2.78E-07	1.57E-07	3.41E-07	6.88E-06	9.62E-07	8.60E-07
500.000	1.60E-07	8.96E-08	1.95E-07	3.79E-06	1.54E-06	4.74E-07
1000.000	1.05E-07	5.86E-08	1.28E-07	2.48E-06	1.84E-06	3.10E-07
5000.000	1.73E-08	9.50E-09	2.12E-08	4.00E-07	1.03E-06	5.00E-08
10000.000	7.31E-09	3.90E-09	9.07E-09	1.64E-07	3.61E-07	2.05E-08

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Time	Other_1	Other_2	T_Bone-S	C_Bone-S	Liver_2	T_Bone-V_e
.100	2.01E-05	9.09E-07	2.50E-05	2.00E-05	1.70E-09	9.44E-08
.500	6.36E-05	2.90E-06	7.70E-05	6.16E-05	3.05E-08	1.67E-06
1.000	7.24E-05	3.35E-06	8.39E-05	6.71E-05	8.30E-08	4.50E-06
5.000	6.94E-05	3.66E-06	5.54E-05	4.42E-05	4.61E-07	2.23E-05
10.000	6.33E-05	3.91E-06	3.44E-05	2.75E-05	7.99E-07	3.41E-05
50.000	2.86E-05	5.05E-06	9.80E-06	7.83E-06	1.66E-06	3.87E-05
100.000	1.44E-05	5.97E-06	7.10E-06	5.68E-06	2.00E-06	2.87E-05
500.000	6.11E-06	1.05E-05	3.10E-06	2.48E-06	3.44E-06	9.75E-06
1000.000	3.99E-06	1.42E-05	2.01E-06	1.61E-06	4.40E-06	6.27E-06
5000.000	6.36E-07	2.20E-05	3.19E-07	2.55E-07	4.08E-06	9.68E-07
10000.000	2.60E-07	2.30E-05	1.31E-07	1.04E-07	2.25E-06	3.95E-07

Activity (Bq) X Time (Days)

Time	C_Bone-V_e	T_Bone-V	C_Bone-V	Testes	Ovaries	C_Bone-S_1
.100	7.54E-08	1.90E-11	1.52E-11	0.00E+00	0.00E+00	0.00E+00
.500	1.34E-06	1.79E-09	1.43E-09	0.00E+00	0.00E+00	0.00E+00
1.000	3.59E-06	1.07E-08	8.52E-09	0.00E+00	0.00E+00	0.00E+00
5.000	1.78E-05	3.39E-07	2.71E-07	0.00E+00	0.00E+00	0.00E+00
10.000	2.73E-05	1.17E-06	9.39E-07	0.00E+00	0.00E+00	0.00E+00
50.000	3.10E-05	1.05E-05	8.45E-06	0.00E+00	0.00E+00	0.00E+00
100.000	2.30E-05	1.98E-05	1.61E-05	0.00E+00	0.00E+00	0.00E+00
500.000	7.79E-06	4.68E-05	4.24E-05	0.00E+00	0.00E+00	0.00E+00
1000.000	5.01E-06	5.64E-05	5.84E-05	0.00E+00	0.00E+00	0.00E+00
5000.000	7.74E-07	2.52E-05	7.69E-05	0.00E+00	0.00E+00	0.00E+00
10000.000	3.16E-07	7.77E-06	6.25E-05	0.00E+00	0.00E+00	0.00E+00

Activity (Bq) X Time (Days)

Time	R_Marrow	Spleen	Excreta	Plasma	Systemic	Whole Body
.100	0.00E+00	9.66E-19	0.00E+00	1.05E-04	4.00E-04	7.87E-01
.500	0.00E+00	1.68E-18	0.00E+00	2.92E-05	4.84E-04	6.59E-01
1.000	0.00E+00	1.71E-18	0.00E+00	4.01E-06	4.00E-04	4.91E-01
5.000	0.00E+00	1.71E-18	0.00E+00	7.63E-07	3.22E-04	7.25E-02
10.000	0.00E+00	1.71E-18	0.00E+00	5.89E-07	2.68E-04	5.93E-02
50.000	0.00E+00	1.71E-18	0.00E+00	2.97E-07	1.56E-04	4.46E-02
100.000	0.00E+00	1.71E-18	0.00E+00	2.20E-07	1.32E-04	3.71E-02
500.000	0.00E+00	1.71E-18	0.00E+00	1.27E-07	1.39E-04	2.38E-02
1000.000	0.00E+00	1.71E-18	0.00E+00	8.29E-08	1.57E-04	1.55E-02
5000.000	0.00E+00	1.71E-18	0.00E+00	1.35E-08	1.33E-04	2.52E-03
10000.000	0.00E+00	1.71E-18	0.00E+00	5.54E-09	9.73E-05	1.06E-03

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Kidneys	Liver	CortBo.Vol	TrabBo.Vol	U.BladCont	Other Tiss
.100	3.02E-05	4.51E-06	7.54E-08	9.44E-08	1.06E-04	1.06E-04
.500	1.07E-04	1.41E-05	1.34E-06	1.67E-06	5.57E-05	1.27E-04
1.000	1.20E-04	1.56E-05	3.60E-06	4.51E-06	8.45E-06	8.50E-05
5.000	9.06E-05	1.22E-05	1.81E-05	2.27E-05	1.73E-06	7.41E-05
10.000	6.32E-05	8.90E-06	2.82E-05	3.53E-05	1.28E-06	6.80E-05
50.000	1.16E-05	3.02E-06	3.94E-05	4.92E-05	4.72E-07	3.40E-05
100.000	7.84E-06	2.86E-06	3.91E-05	4.85E-05	3.41E-07	2.07E-05
500.000	5.33E-06	3.91E-06	5.02E-05	5.65E-05	1.95E-07	1.68E-05
1000.000	4.32E-06	4.70E-06	6.34E-05	6.27E-05	1.28E-07	1.83E-05
5000.000	1.43E-06	4.13E-06	7.77E-05	2.62E-05	2.12E-08	2.26E-05
10000.000	5.25E-07	2.27E-06	6.28E-05	8.17E-06	9.07E-09	2.33E-05

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Blood	CortBo.Sur	TrabBo.Sur	Skeleton
.100	1.08E-04	2.00E-05	2.50E-05	4.52E-05
.500	3.79E-05	6.16E-05	7.70E-05	1.42E-04
1.000	1.27E-05	6.71E-05	8.39E-05	1.59E-04
5.000	3.43E-06	4.42E-05	5.54E-05	1.40E-04
10.000	1.43E-06	2.75E-05	3.44E-05	1.25E-04
50.000	5.12E-07	7.83E-06	9.80E-06	1.06E-04
100.000	3.78E-07	5.68E-06	7.10E-06	1.00E-04
500.000	2.16E-07	2.48E-06	3.10E-06	1.12E-04
1000.000	1.41E-07	1.61E-06	2.01E-06	1.30E-04
5000.000	2.30E-08	2.55E-07	3.19E-07	1.04E-04
10000.000	9.44E-09	1.04E-07	1.31E-07	7.12E-05

Model: THU , Isotope: Th-234
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)
Intake: Inhalation , Single
Element: 2 (Series with 4 element(s))
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Tract Absorption Factor: F1 = 2.000E-04
AMAD (um): 5.000E+00

Activity (Bq) X Time (Days)

Gastrointestinal Tract

Time	Stomach	Small Int	Low.Lg.Int	Upp.Lg.Int
.100	1.44E-04	7.20E-04	2.82E-04	1.88E-05
.500	5.11E-06	4.43E-04	3.18E-03	1.89E-03
1.000	3.63E-06	6.18E-05	3.05E-03	5.44E-03
5.000	3.29E-06	1.33E-05	5.64E-05	1.15E-03
10.000	5.46E-06	2.20E-05	7.39E-05	1.50E-04
50.000	6.90E-06	2.77E-05	9.33E-05	1.72E-04
100.000	3.44E-06	1.38E-05	4.63E-05	8.53E-05

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

500.000	7.86E-07	3.20E-06	1.04E-05	1.94E-05
1000.000	4.59E-07	1.89E-06	6.03E-06	1.15E-05
5000.000	1.19E-08	9.71E-08	5.45E-08	7.33E-07
10000.000	1.53E-09	5.58E-08	0.00E+00	4.84E-07

Activity (Bq) X Time (Days)

Time	Extrathoracic (ET1)	Extrathoracic (ET2)	Extrathoracic (LN-ET)	Bronchial (BB)	Bronchiolar (bb)
.100	8.80E-04	2.21E-06	5.73E-11	3.17E-05	2.83E-05
.500	2.93E-03	3.91E-06	1.42E-09	9.45E-05	9.85E-05
1.000	3.53E-03	6.46E-06	5.65E-09	1.73E-04	1.51E-04
5.000	3.06E-04	2.73E-05	1.33E-07	6.99E-04	5.33E-04
10.000	3.84E-06	5.06E-05	4.95E-07	1.12E-03	8.59E-04
50.000	4.98E-23	1.46E-04	7.38E-06	1.07E-03	8.29E-04
100.000	1.12E-44	1.69E-04	1.77E-05	3.23E-04	2.63E-04
500.000	0.00E+00	1.15E-04	7.46E-05	2.69E-06	9.94E-06
1000.000	0.00E+00	6.65E-05	1.14E-04	1.11E-06	5.53E-06
5000.000	0.00E+00	8.19E-07	1.20E-04	3.07E-08	1.54E-07
10000.000	0.00E+00	4.58E-09	7.33E-05	5.94E-09	2.97E-08

Time	Alveolar Interstit (AI)	Thoracic Lymph Nod. (LN-TH)	Extratho. Total	Thoracic Total	RT-TOTAL	GIT-TOTAL
.100	1.53E-04	6.07E-10	8.82E-04	2.13E-04	1.09E-03	1.17E-03
.500	7.56E-04	1.51E-08	2.94E-03	9.49E-04	3.88E-03	5.51E-03
1.000	1.50E-03	5.98E-08	3.54E-03	1.82E-03	5.36E-03	8.55E-03
5.000	6.89E-03	1.39E-06	3.33E-04	8.12E-03	8.45E-03	1.22E-03
10.000	1.25E-02	5.05E-06	5.49E-05	1.45E-02	1.45E-02	2.52E-04
50.000	3.15E-02	6.41E-05	1.53E-04	3.34E-02	3.36E-02	3.00E-04
100.000	3.39E-02	1.29E-04	1.87E-04	3.46E-02	3.48E-02	1.49E-04
500.000	2.32E-02	2.39E-04	1.90E-04	2.34E-02	2.36E-02	3.37E-05
1000.000	1.49E-02	2.73E-04	1.80E-04	1.52E-02	1.53E-02	1.99E-05
5000.000	1.90E-03	3.64E-04	1.21E-04	2.26E-03	2.38E-03	8.97E-07
10000.000	5.89E-04	3.02E-04	7.33E-05	8.91E-04	9.64E-04	5.42E-07

Activity (Bq) X Time (Days)

Time	Accumulat Urine	24-Hour Urine	Accumulat Feces	24-Hour Feces
.100	1.72E-04	0.00E+00	7.10E-07	0.00E+00
.500	1.72E-04	0.00E+00	3.90E-04	0.00E+00
1.000	1.76E-04	7.15E-06	3.23E-03	3.23E-03
5.000	2.18E-04	1.79E-05	5.49E-02	1.31E-02
10.000	2.88E-04	2.27E-05	1.05E-01	1.21E-02
50.000	8.66E-04	3.58E-05	3.32E-01	1.25E-02
100.000	1.29E-03	4.25E-05	4.18E-01	1.26E-02
500.000	2.58E-03	7.54E-05	4.55E-01	1.29E-02
1000.000	3.55E-03	1.02E-04	4.62E-01	1.31E-02
5000.000	5.90E-03	1.68E-04	4.73E-01	1.34E-02
10000.000	6.70E-03	1.90E-04	4.73E-01	1.34E-02

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Time	Other_0	Blood_1	UB_Cont	Kidneys_1	Kidneys_2	Liver_1
.100	0.00E+00	4.56E-09	0.00E+00	0.00E+00	2.91E-07	1.47E-06
.500	0.00E+00	7.08E-08	0.00E+00	0.00E+00	2.64E-07	1.43E-06
1.000	0.00E+00	1.57E-07	0.00E+00	0.00E+00	2.40E-07	1.48E-06
5.000	0.00E+00	1.55E-07	0.00E+00	0.00E+00	1.76E-07	2.28E-06
10.000	2.38E-07	4.76E-08	0.00E+00	0.00E+00	2.53E-07	3.34E-06
50.000	2.89E-06	8.68E-09	3.24E-08	4.23E-06	1.26E-06	5.95E-06
100.000	3.01E-06	6.31E-09	3.36E-08	4.45E-06	1.89E-06	6.40E-06
500.000	2.03E-06	3.57E-09	2.09E-08	2.56E-06	2.30E-06	4.34E-06
1000.000	1.32E-06	2.34E-09	1.36E-08	1.67E-06	2.33E-06	2.82E-06
5000.000	2.09E-07	3.78E-10	2.15E-09	2.65E-07	1.11E-06	4.38E-07
10000.000	8.50E-08	1.55E-10	8.71E-10	1.08E-07	3.92E-07	1.78E-07

Activity (Bq) X Time (Days)

Time	Other_1	Other_2	T_Bone-S	C_Bone-S	Liver_2	T_Bone-V_e
.100	3.68E-06	5.82E-07	1.02E-05	1.02E-05	0.00E+00	2.67E-12
.500	3.83E-06	5.45E-07	9.81E-06	9.65E-06	0.00E+00	4.80E-11
1.000	4.41E-06	5.26E-07	9.85E-06	9.46E-06	0.00E+00	1.29E-10
5.000	1.04E-05	6.52E-07	1.27E-05	1.09E-05	3.57E-08	6.42E-10
10.000	1.80E-05	1.11E-06	1.73E-05	1.46E-05	1.30E-07	9.81E-10
50.000	4.07E-05	4.85E-06	3.76E-05	3.53E-05	1.14E-06	1.11E-09
100.000	3.42E-05	7.27E-06	4.60E-05	4.50E-05	1.86E-06	8.27E-10
500.000	1.62E-05	1.19E-05	3.14E-05	3.15E-05	3.47E-06	2.80E-10
1000.000	1.05E-05	1.51E-05	2.04E-05	2.04E-05	4.41E-06	1.80E-10
5000.000	1.63E-06	2.21E-05	3.16E-06	3.16E-06	4.08E-06	2.78E-11
10000.000	6.63E-07	2.31E-05	1.28E-06	1.28E-06	2.25E-06	1.14E-11

Activity (Bq) X Time (Days)

Time	C_Bone-V_e	T_Bone-V	C_Bone-V	Testes	Ovaries	C_Bone-S_1
.100	2.13E-12	0.00E+00	0.00E+00	1.02E-08	3.14E-09	0.00E+00
.500	3.83E-11	1.69E-09	5.88E-09	9.11E-09	2.81E-09	0.00E+00
1.000	1.03E-10	4.67E-08	4.11E-08	7.98E-09	2.46E-09	0.00E+00
5.000	5.13E-10	1.63E-06	1.30E-06	3.57E-09	1.10E-09	1.46E-09
10.000	7.84E-10	5.41E-06	4.32E-06	3.67E-09	1.13E-09	7.06E-09
50.000	8.90E-10	3.40E-05	2.73E-05	2.44E-08	7.54E-09	8.53E-08
100.000	6.61E-10	4.51E-05	3.64E-05	3.76E-08	1.16E-08	1.59E-07
500.000	2.24E-10	5.50E-05	4.89E-05	2.89E-08	8.92E-09	1.81E-07
1000.000	1.44E-10	6.16E-05	6.25E-05	1.88E-08	5.80E-09	1.87E-07
5000.000	2.22E-11	2.60E-05	7.75E-05	2.91E-09	8.97E-10	1.82E-07
10000.000	9.08E-12	8.10E-06	6.27E-05	1.18E-09	3.64E-10	1.45E-07

Activity (Bq) X Time (Days)

Time	R_Marrow	Spleen	Excreta	Plasma	Systemic	Whole Body
.100	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E-05	2.29E-03
.500	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.56E-05	9.42E-03
1.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.62E-05	1.39E-02
5.000	1.13E-08	0.00E+00	0.00E+00	0.00E+00	4.02E-05	9.71E-03
10.000	5.13E-08	0.00E+00	0.00E+00	5.53E-07	6.55E-05	1.48E-02
50.000	5.94E-07	0.00E+00	0.00E+00	1.71E-06	1.98E-04	3.41E-02
100.000	1.08E-06	0.00E+00	0.00E+00	1.76E-06	2.35E-04	3.52E-02
500.000	1.17E-06	0.00E+00	0.00E+00	1.19E-06	2.12E-04	2.38E-02
1000.000	1.12E-06	0.00E+00	0.00E+00	7.76E-07	2.05E-04	1.56E-02
5000.000	3.99E-07	0.00E+00	0.00E+00	1.23E-07	1.40E-04	2.53E-03
10000.000	1.28E-07	0.00E+00	0.00E+00	4.99E-08	1.00E-04	1.07E-03

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Kidneys	Liver	CortBo.Vol	TrabBo.Vol	U.BladCont	Other Tiss
.100	2.91E-07	1.47E-06	2.13E-12	2.67E-12	0.00E+00	4.27E-06
.500	2.64E-07	1.43E-06	5.92E-09	1.73E-09	0.00E+00	4.38E-06
1.000	2.40E-07	1.48E-06	4.12E-08	4.69E-08	0.00E+00	4.95E-06
5.000	1.76E-07	2.32E-06	1.30E-06	1.63E-06	0.00E+00	1.11E-05
10.000	2.53E-07	3.47E-06	4.32E-06	5.41E-06	0.00E+00	1.94E-05
50.000	5.48E-06	7.09E-06	2.73E-05	3.40E-05	3.24E-08	4.91E-05
100.000	6.34E-06	8.26E-06	3.64E-05	4.51E-05	3.36E-08	4.58E-05
500.000	4.87E-06	7.81E-06	4.89E-05	5.50E-05	2.09E-08	3.15E-05
1000.000	4.01E-06	7.23E-06	6.25E-05	6.16E-05	1.36E-08	2.82E-05
5000.000	1.37E-06	4.52E-06	7.75E-05	2.60E-05	2.15E-09	2.45E-05
10000.000	5.00E-07	2.43E-06	6.27E-05	8.10E-06	8.71E-10	2.41E-05

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Blood	CortBo.Sur	TrabBo.Sur	Skeleton
.100	4.56E-09	1.02E-05	1.02E-05	2.04E-05
.500	7.08E-08	9.65E-06	9.81E-06	1.95E-05
1.000	1.57E-07	9.46E-06	9.85E-06	1.94E-05
5.000	1.55E-07	1.09E-05	1.27E-05	2.65E-05
10.000	6.01E-07	1.46E-05	1.73E-05	4.17E-05
50.000	1.71E-06	3.53E-05	3.76E-05	1.34E-04
100.000	1.77E-06	4.50E-05	4.60E-05	1.73E-04
500.000	1.20E-06	3.15E-05	3.14E-05	1.67E-04
1000.000	7.79E-07	2.04E-05	2.04E-05	1.65E-04
5000.000	1.23E-07	3.16E-06	3.16E-06	1.10E-04
10000.000	5.01E-08	1.28E-06	1.28E-06	7.34E-05

Model: PAU , Isotope: Pa-234m
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)
Intake: Inhalation , Single
Element: 3 (Series with 4 element(s))
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Tract Absorption Factor: F1 = 5.000E-04
AMAD (um): 5.000E+00

Activity (Bq) X Time (Days)

Gastrointestinal Tract

Time	Stomach	Small Int	Low.Lg.Int	Upp.Lg.Int
.100	1.42E-04	7.10E-04	2.78E-04	1.86E-05
.500	5.08E-06	4.41E-04	3.16E-03	1.88E-03
1.000	3.60E-06	6.15E-05	3.04E-03	5.42E-03
5.000	3.27E-06	1.32E-05	5.60E-05	1.14E-03

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

10.000	5.43E-06	2.18E-05	7.34E-05	1.50E-04
50.000	6.88E-06	2.76E-05	9.28E-05	1.72E-04
100.000	3.42E-06	1.37E-05	4.59E-05	8.50E-05
500.000	7.72E-07	3.11E-06	1.01E-05	1.92E-05
1000.000	4.46E-07	1.81E-06	5.73E-06	1.14E-05
5000.000	0.00E+00	2.27E-08	0.00E+00	6.35E-07
10000.000	0.00E+00	0.00E+00	0.00E+00	3.86E-07

Activity (Bq) X Time (Days)

Time	Extrathoracic (ET1)	Extrathoracic (ET2)	Extrathoracic (LN-ET)	Bronchial (BB)	Bronchiolar (bb)
.100	8.68E-04	2.11E-06	5.65E-11	3.13E-05	2.79E-05
.500	2.92E-03	3.81E-06	1.42E-09	9.41E-05	9.80E-05
1.000	3.52E-03	6.36E-06	5.63E-09	1.72E-04	1.51E-04
5.000	3.05E-04	2.72E-05	1.33E-07	6.97E-04	5.32E-04
10.000	3.84E-06	5.04E-05	4.94E-07	1.12E-03	8.57E-04
50.000	1.03E-08	1.45E-04	7.36E-06	1.06E-03	8.27E-04
100.000	1.03E-08	1.69E-04	1.77E-05	3.23E-04	2.62E-04
500.000	1.03E-08	1.15E-04	7.45E-05	2.68E-06	9.92E-06
1000.000	1.03E-08	6.63E-05	1.14E-04	1.11E-06	5.51E-06
5000.000	1.03E-08	8.35E-07	1.20E-04	3.09E-08	1.54E-07
10000.000	1.03E-08	2.51E-08	7.32E-05	6.18E-09	3.03E-08

Time	Alveolar Interstit (AI)	Thoracic Lymph Nod. (LN-TH)	Extratho. Total	Thoracic Total	RT-TOTAL	GIT-TOTAL
.100	1.50E-04	8.90E-10	8.70E-04	2.10E-04	1.08E-03	1.15E-03
.500	7.53E-04	1.53E-08	2.92E-03	9.45E-04	3.87E-03	5.49E-03
1.000	1.49E-03	5.99E-08	3.53E-03	1.81E-03	5.34E-03	8.53E-03
5.000	6.87E-03	1.38E-06	3.32E-04	8.10E-03	8.44E-03	1.22E-03
10.000	1.24E-02	5.04E-06	5.47E-05	1.44E-02	1.45E-02	2.51E-04
50.000	3.14E-02	6.40E-05	1.53E-04	3.34E-02	3.35E-02	2.99E-04
100.000	3.38E-02	1.29E-04	1.87E-04	3.45E-02	3.47E-02	1.48E-04
500.000	2.31E-02	2.39E-04	1.89E-04	2.34E-02	2.35E-02	3.32E-05
1000.000	1.48E-02	2.72E-04	1.80E-04	1.51E-02	1.53E-02	1.94E-05
5000.000	1.90E-03	3.64E-04	1.21E-04	2.26E-03	2.38E-03	6.57E-07
10000.000	5.88E-04	3.01E-04	7.32E-05	8.89E-04	9.63E-04	3.86E-07

Activity (Bq) X Time (Days)

Time	Accumulat Urine	24-Hour Urine	Accumulat Feces	24-Hour Feces
.100	1.61E-06	0.00E+00	7.69E-07	0.00E+00
.500	6.49E-06	0.00E+00	3.88E-04	0.00E+00
1.000	1.61E-05	1.61E-05	3.22E-03	3.22E-03
5.000	9.94E-05	9.94E-05	5.48E-02	5.48E-02
10.000	2.06E-04	2.06E-04	1.05E-01	1.05E-01
50.000	8.61E-04	8.61E-04	3.31E-01	3.31E-01
100.000	1.28E-03	1.28E-03	4.17E-01	4.17E-01
500.000	2.57E-03	2.57E-03	4.54E-01	4.54E-01
1000.000	3.54E-03	3.54E-03	4.61E-01	4.61E-01
5000.000	5.89E-03	5.89E-03	4.72E-01	4.72E-01
10000.000	6.69E-03	6.69E-03	4.72E-01	4.72E-01

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Time	Other_0	Blood_1	UB_Cont	Kidneys_1	Kidneys_2	Liver_1
.100	0.00E+00	4.45E-09	9.54E-08	1.25E-06	2.90E-07	1.46E-06
.500	0.00E+00	7.03E-08	1.53E-07	2.06E-06	2.64E-07	1.43E-06
1.000	0.00E+00	1.56E-07	1.62E-08	3.59E-06	2.39E-07	1.48E-06
5.000	0.00E+00	1.54E-07	5.03E-08	1.31E-05	1.76E-07	2.28E-06
10.000	2.38E-07	4.74E-08	7.81E-08	1.83E-05	2.52E-07	3.33E-06
50.000	2.88E-06	8.66E-09	4.79E-08	8.24E-06	1.26E-06	5.94E-06
100.000	3.01E-06	6.29E-09	3.39E-08	4.54E-06	1.89E-06	6.39E-06
500.000	2.03E-06	3.56E-09	2.08E-08	2.56E-06	2.30E-06	4.33E-06
1000.000	1.32E-06	2.33E-09	1.36E-08	1.67E-06	2.33E-06	2.82E-06
5000.000	2.09E-07	3.78E-10	2.14E-09	2.65E-07	1.10E-06	4.37E-07
10000.000	8.49E-08	1.55E-10	8.66E-10	1.08E-07	3.91E-07	1.78E-07

Activity (Bq) X Time (Days)

Time	Other_1	Other_2	T_Bone-S	C_Bone-S	Liver_2	T_Bone-V_e
.100	3.67E-06	5.81E-07	1.02E-05	1.02E-05	0.00E+00	1.21E-12
.500	3.82E-06	5.44E-07	9.79E-06	9.63E-06	0.00E+00	2.20E-11
1.000	4.40E-06	5.25E-07	9.83E-06	9.44E-06	0.00E+00	5.93E-11
5.000	1.04E-05	6.50E-07	1.27E-05	1.08E-05	3.55E-08	2.95E-10
10.000	1.80E-05	1.10E-06	1.73E-05	1.46E-05	1.29E-07	4.51E-10
50.000	4.06E-05	4.84E-06	3.75E-05	3.52E-05	1.13E-06	5.12E-10
100.000	3.41E-05	7.26E-06	4.59E-05	4.49E-05	1.85E-06	3.80E-10
500.000	1.61E-05	1.18E-05	3.14E-05	3.14E-05	3.46E-06	1.29E-10
1000.000	1.05E-05	1.50E-05	2.04E-05	2.04E-05	4.40E-06	8.28E-11
5000.000	1.63E-06	2.21E-05	3.15E-06	3.16E-06	4.07E-06	1.28E-11
10000.000	6.62E-07	2.30E-05	1.28E-06	1.28E-06	2.25E-06	5.22E-12

Activity (Bq) X Time (Days)

Time	C_Bone-V_e	T_Bone-V	C_Bone-V	Testes	Ovaries	C_Bone-S_1
.100	9.69E-13	0.00E+00	0.00E+00	1.02E-08	3.14E-09	0.00E+00
.500	1.76E-11	1.66E-09	5.83E-09	9.09E-09	2.81E-09	0.00E+00
1.000	4.74E-11	4.66E-08	4.09E-08	7.97E-09	2.46E-09	0.00E+00
5.000	2.36E-10	1.63E-06	1.30E-06	3.56E-09	1.10E-09	1.46E-09
10.000	3.60E-10	5.40E-06	4.31E-06	3.66E-09	1.13E-09	7.05E-09
50.000	4.09E-10	3.40E-05	2.72E-05	2.44E-08	7.52E-09	8.52E-08
100.000	3.03E-10	4.50E-05	3.63E-05	3.75E-08	1.16E-08	1.59E-07
500.000	1.03E-10	5.49E-05	4.88E-05	2.88E-08	8.90E-09	1.81E-07
1000.000	6.62E-11	6.15E-05	6.24E-05	1.87E-08	5.78E-09	1.87E-07
5000.000	1.02E-11	2.60E-05	7.74E-05	2.90E-09	8.94E-10	1.82E-07
10000.000	4.17E-12	8.08E-06	6.26E-05	1.18E-09	3.62E-10	1.44E-07

Activity (Bq) X Time (Days)

Time	R_Marrow	Spleen	Excreta	Plasma	Systemic	Whole Body
.100	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.77E-05	2.26E-03
.500	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.78E-05	9.39E-03
1.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-05	1.39E-02
5.000	1.13E-08	0.00E+00	0.00E+00	0.00E+00	5.33E-05	9.70E-03
10.000	5.12E-08	0.00E+00	0.00E+00	5.52E-07	8.37E-05	1.48E-02
50.000	5.93E-07	0.00E+00	0.00E+00	1.70E-06	2.01E-04	3.40E-02
100.000	1.08E-06	0.00E+00	0.00E+00	1.76E-06	2.34E-04	3.51E-02
500.000	1.17E-06	0.00E+00	0.00E+00	1.19E-06	2.12E-04	2.38E-02
1000.000	1.11E-06	0.00E+00	0.00E+00	7.75E-07	2.05E-04	1.55E-02

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

5000.000	3.98E-07	0.00E+00	0.00E+00	1.23E-07	1.40E-04	2.52E-03
10000.000	1.28E-07	0.00E+00	0.00E+00	4.98E-08	1.00E-04	1.06E-03

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Kidneys	Liver	CortBo.Vol	TrabBo.Vol	U.BladCont	Other Tiss
.100	1.54E-06	1.46E-06	9.69E-13	1.21E-12	9.54E-08	4.26E-06
.500	2.32E-06	1.43E-06	5.85E-09	1.68E-09	1.53E-07	4.37E-06
1.000	3.83E-06	1.48E-06	4.10E-08	4.66E-08	1.62E-08	4.93E-06
5.000	1.33E-05	2.31E-06	1.30E-06	1.63E-06	5.03E-08	1.11E-05
10.000	1.86E-05	3.46E-06	4.31E-06	5.40E-06	7.81E-08	1.94E-05
50.000	9.50E-06	7.07E-06	2.72E-05	3.40E-05	4.79E-08	4.90E-05
100.000	6.42E-06	8.24E-06	3.63E-05	4.50E-05	3.39E-08	4.57E-05
500.000	4.86E-06	7.79E-06	4.88E-05	5.49E-05	2.08E-08	3.14E-05
1000.000	4.00E-06	7.22E-06	6.24E-05	6.15E-05	1.36E-08	2.82E-05
5000.000	1.37E-06	4.51E-06	7.74E-05	2.60E-05	2.14E-09	2.45E-05
10000.000	4.99E-07	2.42E-06	6.26E-05	8.08E-06	8.66E-10	2.40E-05

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Blood	CortBo.Sur	TrabBo.Sur	Skeleton
.100	4.45E-09	1.02E-05	1.02E-05	2.04E-05
.500	7.03E-08	9.63E-06	9.79E-06	1.94E-05
1.000	1.56E-07	9.44E-06	9.83E-06	1.94E-05
5.000	1.54E-07	1.08E-05	1.27E-05	2.64E-05
10.000	6.00E-07	1.46E-05	1.73E-05	4.16E-05
50.000	1.71E-06	3.52E-05	3.75E-05	1.34E-04
100.000	1.77E-06	4.49E-05	4.59E-05	1.72E-04
500.000	1.19E-06	3.14E-05	3.14E-05	1.67E-04
1000.000	7.78E-07	2.04E-05	2.04E-05	1.65E-04
5000.000	1.23E-07	3.16E-06	3.15E-06	1.10E-04
10000.000	5.00E-08	1.28E-06	1.28E-06	7.32E-05

Model: PAU , Isotope: Pa-234
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)
Intake: Inhalation , Single
Element: 4 (Series with 4 element(s))
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Tract Absorption Factor: F1 = 5.000E-04
AMAD (um): 5.000E+00

Activity (Bq) X Time (Days)

Gastrointestinal Tract

Time	Stomach	Small Int	Low.Lg.Int	Upp.Lg.Int
.100	5.44E-08	2.69E-07	1.06E-07	7.09E-09
.500	7.63E-09	6.23E-07	4.48E-06	2.66E-06

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

1.000	8.00E-09	1.28E-07	6.36E-06	1.13E-05
5.000	1.05E-08	3.95E-08	1.72E-07	3.49E-06
10.000	1.78E-08	6.89E-08	2.35E-07	4.77E-07
50.000	2.31E-08	9.02E-08	3.07E-07	5.64E-07
100.000	1.18E-08	4.47E-08	1.53E-07	2.80E-07
500.000	3.02E-09	9.63E-09	3.45E-08	6.26E-08
1000.000	1.94E-09	5.32E-09	2.01E-08	3.67E-08
5000.000	4.69E-10	0.00E+00	3.58E-10	1.18E-09
10000.000	4.35E-10	0.00E+00	0.00E+00	3.60E-10

Activity (Bq) X Time (Days)

Time	Extrathoracic (ET1)	Extrathoracic (ET2)	Extrathoracic (LN-ET)	Bronchial (BB)	Bronchiolar (bb)
.100	3.29E-07	8.34E-10	2.14E-14	1.19E-08	1.06E-08
.500	4.13E-06	5.51E-09	2.01E-12	1.33E-07	1.39E-07
1.000	7.36E-06	1.35E-08	1.18E-11	3.60E-07	3.16E-07
5.000	9.31E-07	8.33E-08	4.06E-10	2.13E-06	1.62E-06
10.000	1.24E-08	1.61E-07	1.58E-09	3.58E-06	2.73E-06
50.000	1.43E-10	4.78E-07	2.42E-08	3.50E-06	2.72E-06
100.000	1.43E-10	5.58E-07	5.84E-08	1.07E-06	8.66E-07
500.000	1.43E-10	3.80E-07	2.46E-07	8.87E-09	3.28E-08
1000.000	1.43E-10	2.19E-07	3.76E-07	3.67E-09	1.82E-08
5000.000	1.43E-10	2.70E-09	3.96E-07	1.13E-10	5.13E-10
10000.000	1.43E-10	1.82E-11	2.42E-07	3.17E-11	1.04E-10

Time	Alveolar Interstit (AI)	Thoracic Lymph Nod. (LN-TH)	Extratho. Total	Thoracic Total	RT-TOTAL	GIT-TOTAL
.100	5.71E-08	0.00E+00	3.30E-07	7.96E-08	4.10E-07	4.36E-07
.500	1.07E-06	2.04E-11	4.14E-06	1.34E-06	5.47E-06	7.77E-06
1.000	3.12E-06	1.24E-10	7.38E-06	3.80E-06	1.12E-05	1.78E-05
5.000	2.10E-05	4.22E-09	1.01E-06	2.47E-05	2.58E-05	3.71E-06
10.000	3.97E-05	1.61E-08	1.75E-07	4.60E-05	4.62E-05	7.99E-07
50.000	1.03E-04	2.11E-07	5.03E-07	1.10E-04	1.10E-04	9.84E-07
100.000	1.12E-04	4.24E-07	6.17E-07	1.14E-04	1.15E-04	4.89E-07
500.000	7.64E-05	7.89E-07	6.26E-07	7.72E-05	7.78E-05	1.10E-07
1000.000	4.91E-05	8.99E-07	5.95E-07	5.00E-05	5.06E-05	6.40E-08
5000.000	6.26E-06	1.20E-06	3.99E-07	7.46E-06	7.86E-06	2.01E-09
10000.000	1.94E-06	9.95E-07	2.42E-07	2.94E-06	3.18E-06	7.94E-10

Activity (Bq) X Time (Days)

Time	Accumulat Urine	24-Hour Urine	Accumulat Feces	24-Hour Feces
.100	4.67E-11	0.00E+00	6.85E-11	0.00E+00
.500	5.95E-09	0.00E+00	5.49E-07	0.00E+00
1.000	2.79E-08	2.79E-08	6.74E-06	6.74E-06
5.000	3.00E-07	2.81E-07	1.67E-04	1.57E-04
10.000	6.54E-07	6.05E-07	3.35E-04	3.09E-04
50.000	2.83E-06	2.60E-06	1.09E-03	1.00E-03
100.000	4.23E-06	3.88E-06	1.38E-03	1.26E-03
500.000	8.49E-06	7.78E-06	1.50E-03	1.37E-03
1000.000	1.17E-05	1.07E-05	1.52E-03	1.40E-03
5000.000	1.95E-05	1.78E-05	1.56E-03	1.43E-03
10000.000	2.21E-05	2.03E-05	1.56E-03	1.43E-03

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Activity (Bq) X Time (Days)

Time	Other_0	Blood_1	UB_Cont	Kidneys_1	Kidneys_2	Liver_1
.100	5.28E-11	1.19E-12	3.34E-11	1.58E-11	3.07E-13	3.06E-12
.500	1.98E-09	7.62E-11	1.36E-10	1.16E-09	1.76E-11	2.05E-10
1.000	4.25E-09	2.77E-10	5.68E-11	5.09E-09	5.99E-11	8.24E-10
5.000	3.19E-09	4.27E-10	1.69E-10	3.94E-08	3.76E-10	6.21E-09
10.000	3.72E-09	1.32E-10	2.49E-10	5.86E-08	7.83E-10	1.06E-08
50.000	9.66E-09	2.24E-11	1.57E-10	2.71E-08	4.17E-09	1.98E-08
100.000	1.01E-08	1.63E-11	1.12E-10	1.49E-08	6.27E-09	2.13E-08
500.000	6.86E-09	9.21E-12	7.04E-11	8.42E-09	7.62E-09	1.45E-08
1000.000	4.49E-09	6.03E-12	4.67E-11	5.49E-09	7.72E-09	9.41E-09
5000.000	7.24E-10	9.75E-13	8.14E-12	8.73E-10	3.65E-09	1.46E-09
10000.000	2.92E-10	4.00E-13	3.49E-12	3.56E-10	1.29E-09	5.94E-10

Activity (Bq) X Time (Days)

Time	Other_1	Other_2	T_Bone-S	C_Bone-S	Liver_2	T_Bone-V_e
.100	1.13E-11	8.45E-13	1.86E-11	1.71E-11	0.00E+00	1.68E-17
.500	7.90E-10	5.42E-11	1.23E-09	1.07E-09	1.81E-13	3.07E-16
1.000	3.35E-09	2.07E-10	4.82E-09	4.12E-09	1.79E-12	8.30E-16
5.000	2.97E-08	1.66E-09	3.35E-08	2.79E-08	1.05E-10	4.13E-15
10.000	5.73E-08	3.47E-09	5.52E-08	4.65E-08	4.03E-10	6.31E-15
50.000	1.35E-07	1.60E-08	1.25E-07	1.17E-07	3.73E-09	7.17E-15
100.000	1.14E-07	2.40E-08	1.53E-07	1.50E-07	6.12E-09	5.32E-15
500.000	5.37E-08	3.92E-08	1.05E-07	1.05E-07	1.14E-08	1.80E-15
1000.000	3.49E-08	4.97E-08	6.81E-08	6.82E-08	1.45E-08	1.16E-15
5000.000	5.43E-09	7.29E-08	1.06E-08	1.06E-08	1.35E-08	1.79E-16
10000.000	2.21E-09	7.60E-08	4.29E-09	4.29E-09	7.42E-09	7.30E-17

Activity (Bq) X Time (Days)

Time	C_Bone-V_e	T_Bone-V	C_Bone-V	Testes	Ovaries	C_Bone-S_1
.100	1.34E-17	2.09E-14	1.57E-14	8.56E-15	2.63E-15	2.25E-16
.500	2.46E-16	7.67E-12	6.08E-12	4.50E-13	1.39E-13	2.11E-14
1.000	6.63E-16	7.76E-11	6.16E-11	1.34E-12	4.13E-13	1.72E-13
5.000	3.30E-15	4.62E-09	3.68E-09	5.32E-12	1.64E-12	6.60E-12
10.000	5.04E-15	1.67E-08	1.33E-08	1.10E-11	3.39E-12	2.38E-11
50.000	5.73E-15	1.12E-07	8.96E-08	8.15E-11	2.52E-11	2.85E-10
100.000	4.25E-15	1.48E-07	1.20E-07	1.25E-10	3.87E-11	5.31E-10
500.000	1.44E-15	1.81E-07	1.61E-07	9.65E-11	2.98E-11	6.05E-10
1000.000	9.26E-16	2.03E-07	2.06E-07	6.27E-11	1.94E-11	6.24E-10
5000.000	1.43E-16	8.58E-08	2.56E-07	9.71E-12	2.99E-12	6.08E-10
10000.000	5.84E-17	2.67E-08	2.07E-07	3.94E-12	1.21E-12	4.83E-10

Activity (Bq) X Time (Days)

Time	R_Marrow	Spleen	Excreta	Plasma	Systemic	Whole Body
.100	6.35E-16	2.07E-24	0.00E+00	1.78E-10	3.32E-10	8.46E-07
.500	1.37E-13	0.00E+00	0.00E+00	1.61E-09	8.34E-09	1.33E-05
1.000	1.12E-12	0.00E+00	0.00E+00	1.61E-09	2.48E-08	2.90E-05
5.000	4.14E-11	3.89E-25	0.00E+00	1.58E-09	1.52E-07	2.96E-05
10.000	1.48E-10	8.13E-25	0.00E+00	2.37E-09	2.70E-07	4.72E-05
50.000	1.68E-09	8.53E-25	0.00E+00	5.83E-09	6.67E-07	1.12E-04
100.000	3.04E-09	8.53E-25	0.00E+00	6.13E-09	7.78E-07	1.16E-04
500.000	3.31E-09	8.53E-25	0.00E+00	4.25E-09	7.03E-07	7.86E-05
1000.000	3.15E-09	8.53E-25	0.00E+00	2.85E-09	6.79E-07	5.13E-05

Table 3.2: Results of calculations of activities for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

5000.000	1.12E-09	8.53E-25	0.00E+00	5.04E-10	4.63E-07	8.33E-06
10000.000	3.61E-10	8.53E-25	0.00E+00	1.95E-10	3.31E-07	3.51E-06

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Kidneys	Liver	CortBo.Vol	TrabBo.Vol	U.BladCont	Other Tiss
.100	1.61E-11	3.06E-12	1.58E-14	2.09E-14	3.34E-11	6.50E-11
.500	1.17E-09	2.05E-10	6.08E-12	7.67E-12	1.36E-10	2.83E-09
1.000	5.15E-09	8.26E-10	6.16E-11	7.76E-11	5.68E-11	7.82E-09
5.000	3.98E-08	6.31E-09	3.68E-09	4.62E-09	1.69E-10	3.46E-08
10.000	5.94E-08	1.10E-08	1.33E-08	1.67E-08	2.49E-10	6.47E-08
50.000	3.13E-08	2.35E-08	8.96E-08	1.12E-07	1.57E-10	1.62E-07
100.000	2.12E-08	2.74E-08	1.20E-07	1.48E-07	1.12E-10	1.51E-07
500.000	1.60E-08	2.59E-08	1.61E-07	1.81E-07	7.04E-11	1.04E-07
1000.000	1.32E-08	2.40E-08	2.06E-07	2.03E-07	4.67E-11	9.30E-08
5000.000	4.52E-09	1.49E-08	2.56E-07	8.58E-08	8.14E-12	8.08E-08
10000.000	1.65E-09	8.02E-09	2.07E-07	2.67E-08	3.49E-12	7.94E-08

Activity (Bq) X Time (Days)

Totals for Selected Organs or Tissues

Time	Blood	CortBo.Sur	TrabBo.Sur	Skeleton
.100	1.79E-10	1.71E-11	1.86E-11	3.58E-11
.500	1.69E-09	1.07E-09	1.23E-09	2.31E-09
1.000	1.88E-09	4.12E-09	4.82E-09	9.08E-09
5.000	2.01E-09	2.79E-08	3.35E-08	6.96E-08
10.000	2.50E-09	4.65E-08	5.52E-08	1.32E-07
50.000	5.85E-09	1.17E-07	1.25E-07	4.44E-07
100.000	6.15E-09	1.50E-07	1.53E-07	5.72E-07
500.000	4.26E-09	1.05E-07	1.05E-07	5.52E-07
1000.000	2.86E-09	6.82E-08	6.81E-08	5.46E-07
5000.000	5.05E-10	1.06E-08	1.06E-08	3.63E-07
10000.000	1.95E-10	4.29E-09	4.29E-09	2.42E-07

Table 3.3: Results of calculations of committed equivalent doses for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm

```
Date: 3/24/2007 , 10:55:15 PM

Series with  4 element(s):
Isotope(s): U-238    Th-234   Pa-234m  Pa-234

Model(s):   U THU PAU PAU
Observ.: Biokinetics of uranium, ICRP 69.
Subject: Standard Worker (Nose Breather)

Intake: Inhalation, Single, without intake of progeny.
Element: U-238
Initial or daily activity:  1.000E+00 Bq
Inhalation: Respiratory Tract: ICRP-66
Compound: Type S
GI Absorption Fraction: f1 = :  2.000E-03
AMAD (um): 5.000E+00
Dosimetric System: ICRP-60


Committed Equivalent Doses (Sv):

Highest committed equivalent dose: ET Airways,  6.48E-05
Remainder formulation: Split
```

Time (Days)	.10	.50	1.00	5.00	10.00	50.00
Adrenals	3.35E-13	1.91E-12	3.05E-12	9.36E-12	1.65E-11	5.81E-11
Bladder Wall	6.81E-13	4.18E-12	5.93E-12	1.28E-11	2.01E-11	5.91E-11
Bone Surface	6.27E-12	1.07E-10	2.88E-10	1.51E-09	2.52E-09	5.81E-09
Brain	3.34E-13	1.91E-12	3.04E-12	9.28E-12	1.62E-11	5.38E-11
Breasts	3.34E-13	1.91E-12	3.04E-12	9.35E-12	1.65E-11	5.83E-11
Esophagus	3.35E-13	1.91E-12	3.05E-12	9.38E-12	1.66E-11	5.92E-11
St Wall	3.48E-10	4.07E-10	4.10E-10	4.20E-10	4.31E-10	4.91E-10
SI Wall	2.57E-10	9.40E-10	1.02E-09	1.04E-09	1.06E-09	1.15E-09
ULI Wall	1.00E-10	2.38E-09	4.60E-09	6.35E-09	6.41E-09	6.76E-09
LLI Wall	7.88E-12	1.20E-09	5.05E-09	1.87E-08	1.92E-08	2.02E-08
Colon	6.04E-11	1.88E-09	4.79E-09	1.17E-08	1.19E-08	1.26E-08
Kidneys	5.31E-12	1.22E-10	3.39E-10	1.91E-09	3.34E-09	7.15E-09
Liver	3.71E-13	3.56E-12	8.65E-12	4.51E-11	7.91E-11	2.01E-10
Muscle	3.42E-13	1.94E-12	3.10E-12	9.46E-12	1.65E-11	5.60E-11
Ovaries	3.46E-13	2.03E-12	3.36E-12	1.04E-11	1.74E-11	5.50E-11
Pancreas	3.40E-13	1.91E-12	3.05E-12	9.35E-12	1.64E-11	5.69E-11
Red Marrow	8.76E-13	1.14E-11	2.86E-11	1.44E-10	2.42E-10	5.99E-10
ET Airways	7.13E-09	3.56E-08	7.12E-08	3.55E-07	7.07E-07	3.46E-06
Lungs	7.44E-08	3.05E-07	5.35E-07	2.00E-06	3.59E-06	1.08E-05
Skin	3.34E-13	1.91E-12	3.04E-12	9.30E-12	1.63E-11	5.45E-11
Spleen	3.36E-13	1.91E-12	3.05E-12	9.35E-12	1.64E-11	5.69E-11
Testes	3.34E-13	1.91E-12	3.04E-12	9.31E-12	1.62E-11	5.35E-11
Thymus	3.35E-13	1.91E-12	3.05E-12	9.38E-12	1.66E-11	5.92E-11
Thyroid	3.34E-13	1.91E-12	3.04E-12	9.31E-12	1.63E-11	5.53E-11
Uterus	3.37E-13	1.92E-12	3.09E-12	9.47E-12	1.64E-11	5.40E-11
Rem.ICRP-60	3.57E-09	1.78E-08	3.56E-08	1.77E-07	3.54E-07	1.73E-06
Eff. Dose:	9.15E-09	3.78E-08	6.66E-08	2.50E-07	4.50E-07	1.39E-06

Table 3.3: Results of calculations of committed equivalent doses for single inhalation of Type S compounds of ^{238}U with AMAD = 5 μm (cont.)

Time (Days)	100.00	500.00	1000.00	5000.00	10000.00	18262.00
Adrenals	9.01E-11	2.65E-10	4.72E-10	2.18E-09	4.42E-09	8.00E-09
Bladder Wall	8.56E-11	2.23E-10	3.98E-10	2.03E-09	4.25E-09	7.81E-09
Bone Surface	8.44E-09	2.28E-08	3.87E-08	1.28E-07	1.88E-07	2.44E-07
Brain	7.95E-11	2.13E-10	3.86E-10	2.01E-09	4.23E-09	7.79E-09
Breasts	9.06E-11	2.67E-10	4.77E-10	2.18E-09	4.43E-09	8.01E-09
Esophagus	9.29E-11	2.79E-10	4.96E-10	2.22E-09	4.47E-09	8.06E-09
St Wall	5.33E-10	7.11E-10	9.15E-10	2.60E-09	4.83E-09	8.40E-09
SI Wall	1.20E-09	1.40E-09	1.61E-09	3.29E-09	5.51E-09	9.07E-09
ULI Wall	6.99E-09	7.49E-09	7.88E-09	9.83E-09	1.21E-08	1.56E-08
LLI Wall	2.09E-08	2.21E-08	2.29E-08	2.55E-08	2.77E-08	3.13E-08
Colon	1.30E-08	1.38E-08	1.43E-08	1.66E-08	1.88E-08	2.24E-08
Kidneys	8.88E-09	1.80E-08	2.71E-08	6.46E-08	8.14E-08	9.02E-08
Liver	3.03E-10	1.24E-09	2.70E-09	1.53E-08	2.56E-08	3.31E-08
Muscle	8.45E-11	2.36E-10	4.25E-10	2.08E-09	4.31E-09	7.88E-09
Ovaries	8.09E-11	2.16E-10	3.90E-10	2.00E-09	4.20E-09	7.72E-09
Pancreas	8.71E-11	2.50E-10	4.47E-10	2.13E-09	4.36E-09	7.94E-09
Red Marrow	8.99E-10	2.64E-09	4.63E-09	1.53E-08	2.12E-08	2.68E-08
ET Airways	6.74E-06	2.74E-05	4.32E-05	6.45E-05	6.48E-05	6.48E-05
Lungs	1.39E-05	1.91E-05	2.26E-05	3.05E-05	3.27E-05	3.36E-05
Skin	8.11E-11	2.21E-10	3.99E-10	2.03E-09	4.26E-09	7.82E-09
Spleen	8.71E-11	2.50E-10	4.48E-10	2.13E-09	4.36E-09	7.94E-09
Testes	7.90E-11	2.12E-10	3.85E-10	1.99E-09	4.19E-09	7.71E-09
Thymus	9.29E-11	2.79E-10	4.96E-10	2.22E-09	4.47E-09	8.06E-09
Thyroid	8.32E-11	2.31E-10	4.16E-10	2.07E-09	4.30E-09	7.86E-09
Uterus	7.96E-11	2.12E-10	3.84E-10	2.01E-09	4.22E-09	7.78E-09
Rem.ICRP-60	3.37E-06	1.37E-05	2.16E-05	3.22E-05	3.24E-05	3.24E-05
Eff. Dose:	1.84E-06	2.98E-06	3.80E-06	5.28E-06	5.55E-06	5.67E-06

4. Bioassay Interpretation

This module refers to intake and dose estimates due to occupational exposures to radionuclides.

The software allows performing calculation of internal doses and interpretation of intakes for any isotope. However, predicted values of the measured quantities following single intake and associated dose coefficients are already available only for the most common forms of occupational intakes of the following radionuclides: ^{3}H, ^{18}F, ^{59}Fe, ^{57}Co, ^{58}Co, ^{60}Co, ^{85}Sr, ^{89}Sr, ^{90}Sr, ^{106}Ru, ^{125}I, ^{129}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm, ^{252}Cf, ^{99m}Tc, ^{32}P, ^{35}S, ^{14}C, ^{153}Sm, ^{188}Re, ^{210}Po, ^{210}Pb.

The words bioassay tables will be used throughout this text to designate “predicted values of the measured quantities following single intake”.

Four types of dosimetric systems can be used on the interpretations of the bioassay measurements: a) ICRP-60, b) ICRP-26, c) 10CFR Part 835 (US-DOE) and d) User. The latter would be a dosimetric system similar to the one proposed in ICRP Publication 60[(17)] but with different tissue weighting factors. The “User” dosimetric system can only be used if the corresponding W_Ts have been previously generated in the “Activity and Internal Dose Calculations” module, as explained in the “Dosimetric System” item in the “3.1.3 Other” section.

The bioassay tables, which are comprised by an extended set of those proposed in the ICRP Publication 78[(7)], together with the ICRP-60 dosimetric system are the default options when the program is installed. For convenience, the following units of activities can be used: Bq, dpm, uCi, nCi and pCi. The available units of doses are Sv, rem and mrem.

The capability for employing different combinations of units and dosimetric systems gives great flexibility to the use of the software. The dose coefficients and corresponding bioassay tables, which were calculated using a certain dosimetric system different than the selected one can promptly be used in the bioassay interpretation because the effective dose coefficient and the dose coefficient to the “Remainder” tissues are automatically recalculated according to the selected option.

Besides the available bioassay tables related to the radionuclides mentioned above, the user can generate customized tables in the “Activity and Internal Dose Calculations” module, as explained in the “Generate Bioassay Tables” item in the “3.1.3 Other” section. For this reason, the selection of bioassay tables is divided into two categories “ICRP-78” and “Own”, as shown in the “Case Selection” frame of the “Internal Dosimetry Tools” form in Figure 4.1.

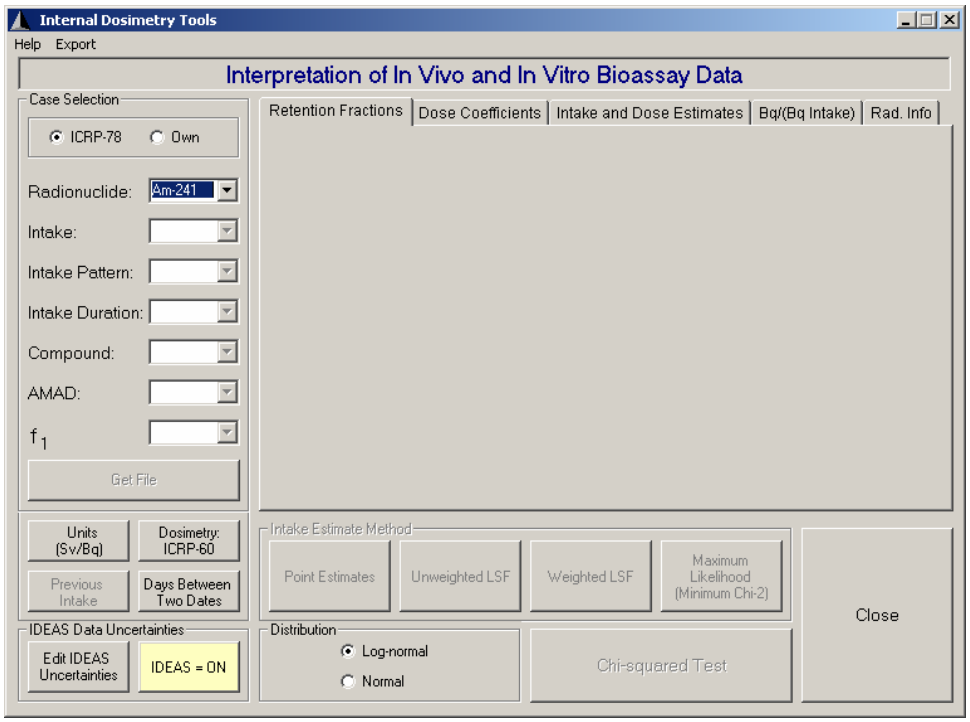


Figure 4.1 The "Internal Dosimetry Tools" form

4.1 Case Selection for Bioassay Tables

4.1.1 The ICRP-78 Bioassay Tables Category

The case selection for the "ICRP-78" category is comprised of the following mandatory choices, according to the intake characteristics, as shown in Figure 4.1:

- Radionuclide: There are thirty-seven radionuclides for selection in the combo box.

- Intake: The available intake cases are inhalation, ingestion or injection.

- Intake Pattern: Acute (or single), Several, Continuous or Worker. The single intake pattern is the most commonly used.

- Intake Duration: Number of days under intake for non-Acute cases.

- Compound: F, M, S (ICRP-68[3] and ICRP-78[7]) and Gases and Vapors or D, W, Y (ICRP-30[20]). Gases and vapors have normally been assigned as V. However in order to match the bioassay tables with the associated dose coefficients table, special notations were used to include the several kinds of gases and vapors of hydrogen, carbon and iodine. The hydrogen compounds are organically bound tritium, elemental hydrogen vapor, tritiated methane and

tritiated water, which have been identified as o, V, e and t respectively. The carbon compounds are carbon dioxide, carbon monoxide, carbon labeled methane, organic gases and vapors, which have been identified as d, m, e and V respectively. The iodine compounds are methyl iodide and elemental iodine vapor, which have been identified as e and V respectively.

- Activity Median Aerodynamic Diameter (AMAD): In micron if intake is inhalation. Zero when it is the case of gases and vapors.

- Fractional Absorption in the Gastrointestinal Tract (f1): For all ingestion cases and for the injection cases with recycling involving compartments of the GI Tract.

When these choices are properly selected the "Get File" button will be enabled and the table can be selected by clicking on this button.

4.1.2 The Own Bioassay Tables Category

When the "Own" category is selected the "Bioassay Tables" form (Figure 4.2) is displayed listing all available customized bioassay tables, which were generated by the user in the "Activity and Internal Dose Calculations" module. In this case, the intake choices could be inhalation, ingestion, injection and wound. Figure 4.2 shows an example of the list of bioassay tables, which were generated by the user, as explained in the "Generate Bioassay Tables" item in section "3.1.3 Other".

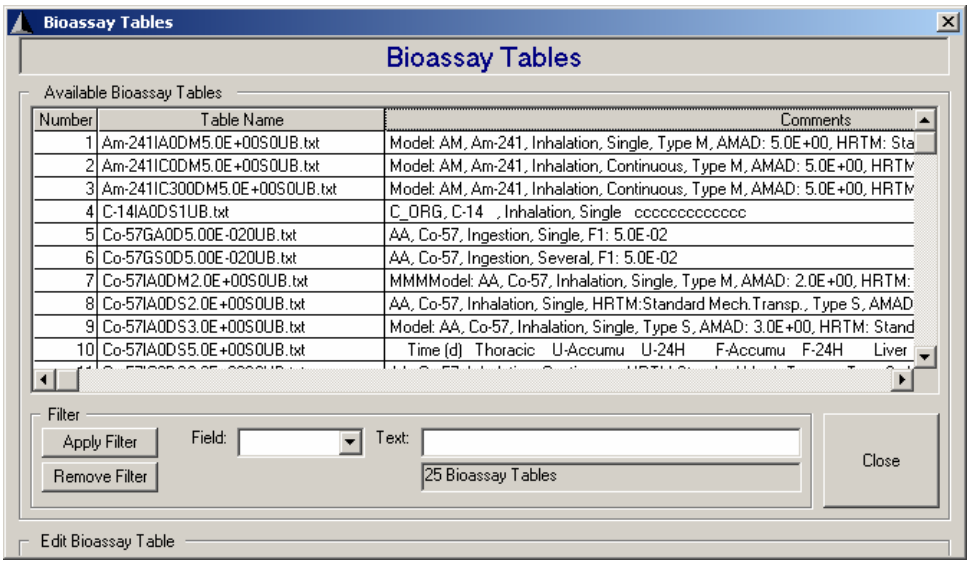


Figure 4.2 The list of Bioassay Tables for the "Own" category

The grid contains three columns, namely: "Number", "Table Name" and "Comments". This form also presents a handy feature, which allows the user to filter the tables by applying a filter on any of the columns. For instance, if the user wishes to see table names for ^{239}Pu only, then the "Table Name" field should be selected and the text "Pu-239" should be typed in the "Text:" field. The

filter is applied by pressing the "Apply Filter" button. The filter can be removed by pressing the "Remove Filter" button.

The desired table can be selected by clicking on the corresponding line on the grid. Once it was selected the "Bioassay Table Name:", "Case:" and "Comments" textboxes located inside the "Case Selection" frame will show the bioassay table file name, the observation which describes the intake case and the comments, which were produced by the user respectively.

The tables retrieved using either the "ICRP-78" or the "Own" case selection are the corresponding predicted values of the measured quantities as a function of time (or Intake Retention Fractions (IRF), or simply Retention Fractions) and the dose coefficients. These tables will be used to perform the intake and dose estimates and are loaded according to the selected dosimetric system.

4.2 Additional Auxiliary Features

After a case has been selected the following buttons shown in Figure 4.3 are made available: "Units", "Dosimetry", "Previous Intake", "Days Between Two Dates", "Edit IDEAS Uncertainties" and the "IDEAS ON/OFF". If the selected statistical distribution of the measured data is the log-normal then the "IDEAS = ON" option is automatically selected.

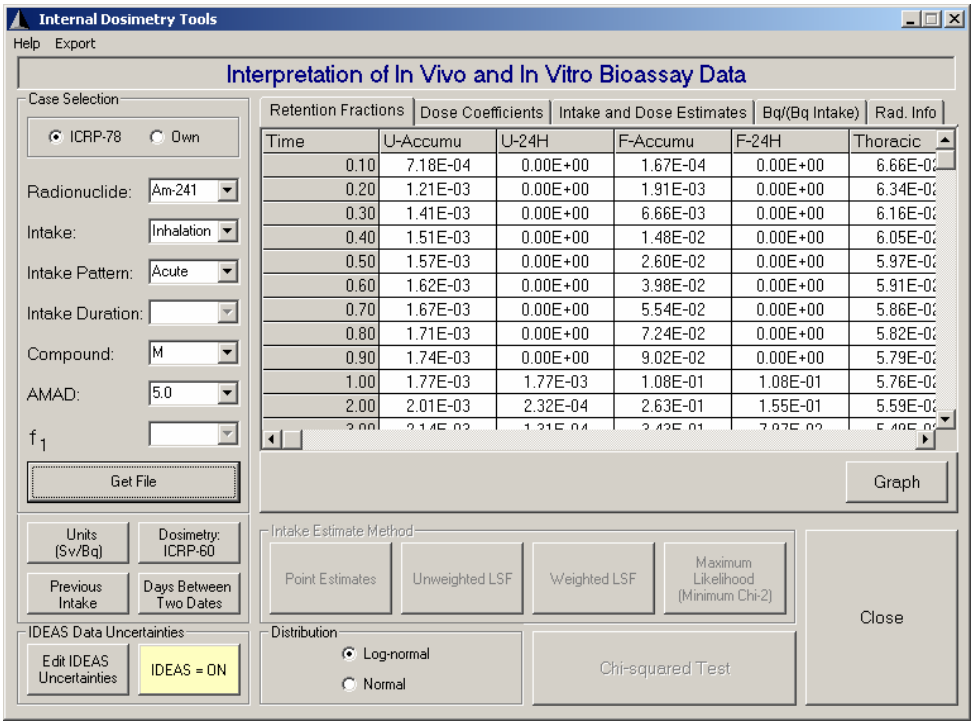


Figure 4.3 The "Internal Dosimetry Tools" form showing the selection of the inhalation case of ^{241}Am, Type M, AMAD = 5 μm from the "ICRP-78" category

4.2.1 Units

The "Units" button allows the user to choose units for activities and doses. The corresponding options are: Bq, dpm, uCi, nCi and pCi for activities and Sv, rem and mrem for doses. When an activity-dose option is selected all related tables, calculations and numbers entered by the user are automatically converted. The current selected choices are displayed as "Units (Dose Unit / Activity Unit), for instance, "Units (Sv/Bq)".

4.2.2 Dosimetric Systems

The "Dosimetry" button allows the user to select among the four dosimetric systems: ICRP-60, ICRP-26, 10CFR Part 835 (US-DOE) and User.

4.2.3 Previous Intakes

The "Previous Intake" button allows the user to subtract activity contributions in bioassay measurements, which would be due to the previous positive estimated intake. The estimated intake activity from the previous analysis and the time in days between the two most recent intakes will be required to run this option, as shown in Figure 4.4.

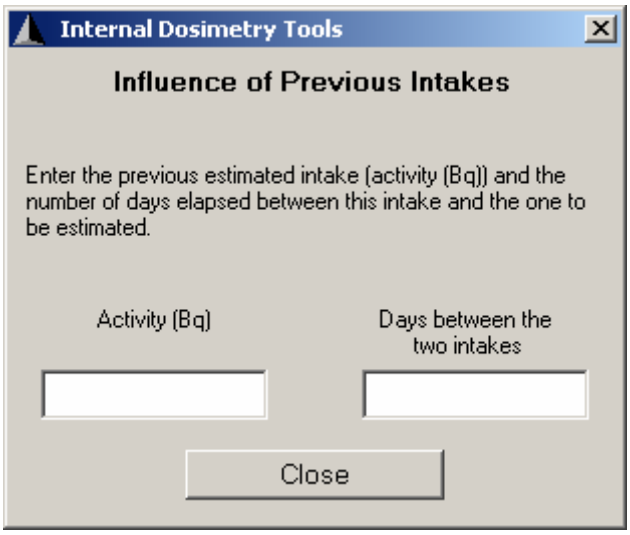


Figure 4.4 Influence of Previous Intakes

4.2.4 Days Between Two Dates

The "Days Between Two Dates" option was meant to be used when the user needs to estimate the elapsed days between two bioassay measurements.

4.3 Selections Associated With the IDEAS Project

The frame entitled "IDEAS Data Uncertainties", shown in Figure 4.3, was specially designed to accommodate the features presented in the IDEAS Project Document[11]. In this document default scattering factors for Type A and B errors for *in vivo* and *in vitro* measurements were proposed. The document recommends the use of such factors as measurement uncertainty parameters when performing intakes estimates using log-normally distributed bioassay data. The section "4.4.3.1 Definitions of Fields and Their Usages" shows more details on the practical applications of the scattering factors. The "Edit IDEAS Uncertainties" button gives access to "Log-normal Scattering Factors SF for In Vivo and In Vitro Measurements (IDEAS)" form, which is shown in Figure 4.5 below, and contains the parameter values that can be edited. It shows the default values of log-normal scattering factors for Type A (uncertainties due to counting statistics) and B errors (all other uncertainties) for *in vivo* and *in vitro* measurements as recommended by the IDEAS publication.

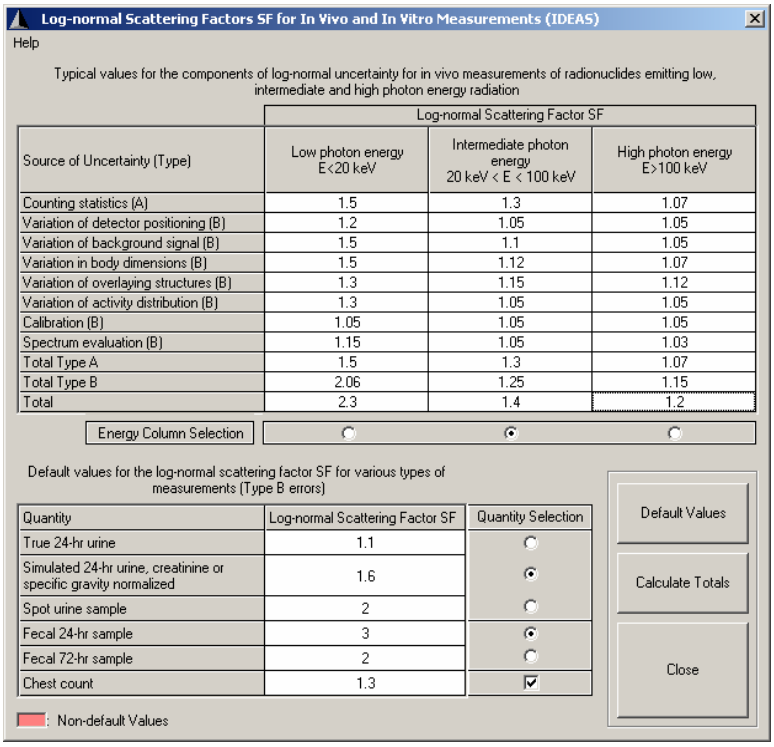


Figure 4.5 Log-normal Scattering Factors SF for In Vivo and In Vitro Measurements (IDEAS)

The default values can be edited and the corresponding modified cells will be shown with a red background to indicate that non-default values are in use. All modified parameters can be saved for later use.

The "IDEAS = ON/OFF" button, shown in Figure 4.3, gives the user the choice to use the IDEAS Project recommendations. When the button face shows a light yellow color and the text shows "IDEAS = ON" (default value) the IDEAS method will be used. The button face will show "IDEAS = OFF" otherwise.

4.4 The Internal Dosimetry Tools

It is comprised of a set of useful tools for intake and dose evaluations. The following corresponding features can be seen after the intake case has been properly selected: retention fractions table, the dose coefficients table, intake and dose estimates, Bq/(Bq intake), Rad. Info. These features can be accessed through a tabstrip control, which is like the dividers in a notebook or the labels on a group of file folders. Figure 4.3 shows an example for the inhalation case of ^{241}Am, Type M, AMAD = 5 μm from the "ICRP-78" category.

General descriptions on the use of each feature will be given in this section. However more details on the practical use of these features can be found on the help screens.

4.4.1 Retention Fractions

The first tab shows the "predicted values of the measured quantities as a function of time following a single intake of unit activity or a protracted intake of one unit of activity per day" or "Intake Retention Fractions" - IRF for the corresponding "*in vivo*" and "*in vitro*" bioassay compartments. When the ICRP-78 Bioassay Tables Category is selected the retention fractions correspond to biokinetic compartments related to the most commonly recommended *in vivo* and *in vitro* bioassay methods, as shown in Figure 4.3 for the inhalation case of ^{241}Am, Type M, AMAD = 5 μm. When the Own Bioassay Tables Category is selected the retention fractions may correspond to any biokinetic compartment related or not to a feasible bioassay method. The objective was to give the user flexibility to choose a non-default bioassay method. For example, *in vivo* monitoring of ^{241}Am in liver was not recommended in ICRP Publication 78[7]. As a result, *in vivo* measurement of americium deposited in the liver cannot be interpreted by using the corresponding bioassay table from the ICRP-78 Bioassay Tables Category. The user can thus generate its own table (see the Section 3. Activity and Internal Dose Calculations) having the liver as a bioassay compartment, which enables such interpretations of measurements. Figure 4.6 shows an example of bioassay table for the inhalation case of ^{241}Am, Type M, AMAD = 5 μm from the "Own" category having "Liver" as one of the bioassay compartments.

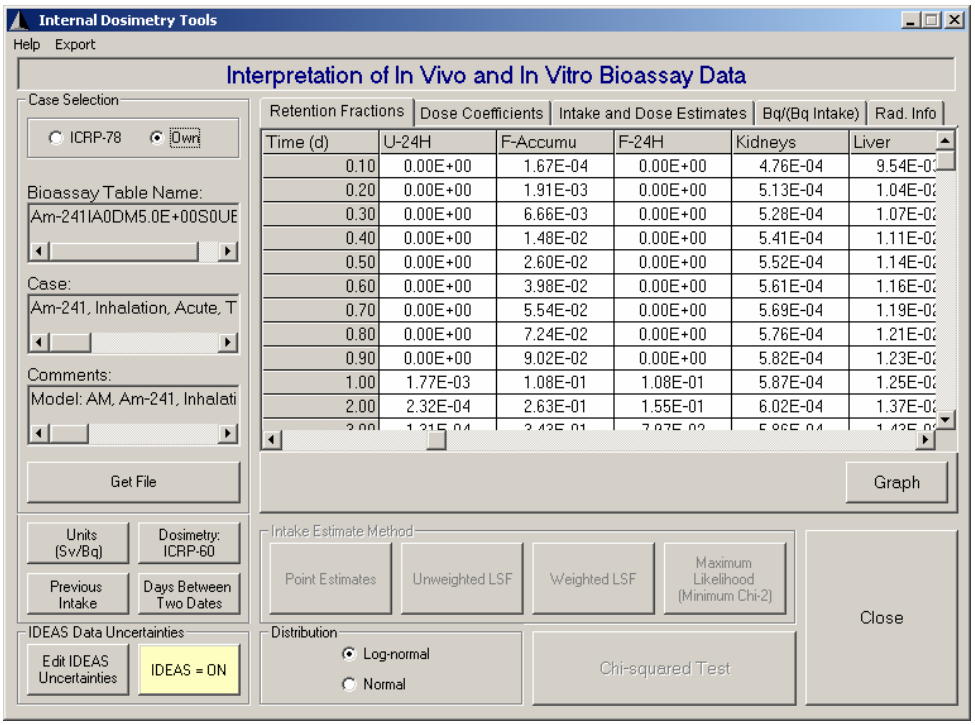


Figure 4.6 The "Internal Dosimetry Tools" form showing the selection of a inhalation case of ^{241}Am, Type M, AMAD = 5 μm from the "Own" category

4.4.2 Dose Coefficients

The second tab shows the committed equivalent dose coefficients for twenty-six organs and the committed effective dose coefficient for the "ICRP-60" and "User" dosimetric systems. These coefficients denote the committed doses per unit of intake. The corresponding quantities for the "ICRP-26" and for the "10CFR Part 835" dosimetric systems are the committed dose equivalent coefficients and the committed effective dose equivalent coefficient respectively. Figure 4.7 shows an example for the inhalation case of ^{241}Am, Type M, AMAD = 5 μm from the "ICRP-78" category.

As explained above the organ dose coefficients, which were calculated using a certain dosimetric system different than the selected one can promptly be used in the bioassay measurements interpretation because the committed effective dose coefficient (or the committed effective dose equivalent coefficient) and the dose coefficient to the "Remainder" tissues are automatically recalculated according to the selected option.

The committed organ and effective doses, for a particular case under study, are evaluated by multiplying the estimated intake by the dose coefficients shown on this form.

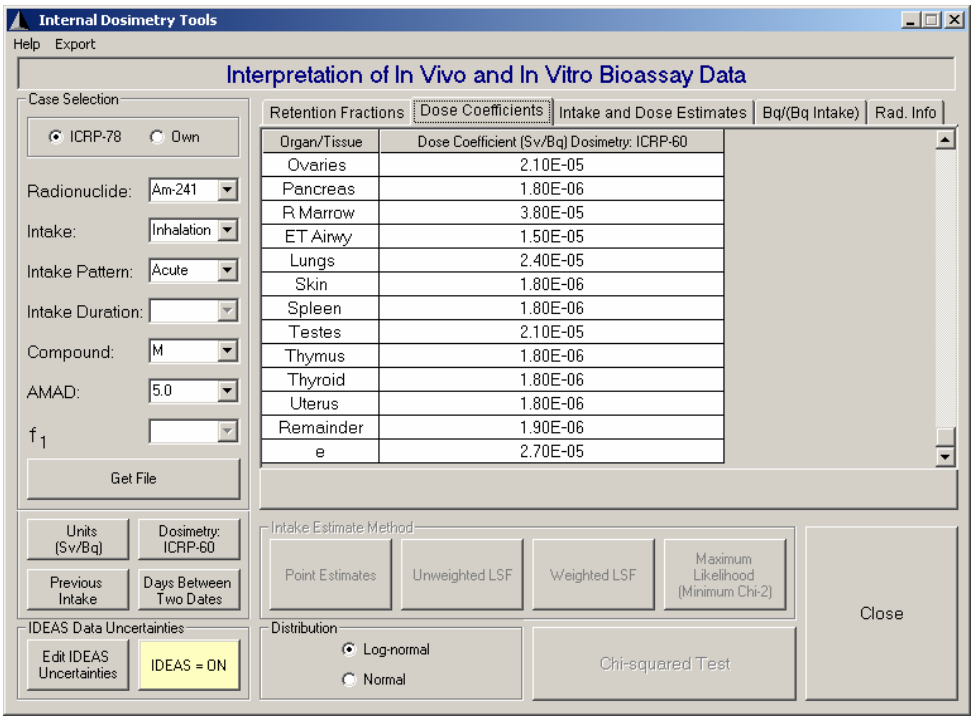


Figure 4.7 The "Internal Dosimetry Tools" form showing the contents of the "Dose Coefficients" tab for the case of inhalation of ^{241}Am, Type M, AMAD = 5 μm from the "ICRP-78" category

4.4.3 Intake and Dose Estimates

4.4.3.1 Definitions of Fields and Their Usages

The third tab allows the user to perform intake and dose estimates for a single result or multiple bioassay results. Bioassay results can be typed on the grid or be imported from a Microsoft Excel spreadsheet using the "Import Bioassay Data" button. Figure 4.8 shows an example of the "Internal Dosimetry Tools" form showing the contents of the "Intake and Dose Estimates" tab. The corresponding grid is comprised of the following columns: "Used", "Date (mm/dd/yy)", "Time After Intake(d)", "Bioassay Method", "IRF", "Measurem.", "Std. Dev.", "SF_B", "SF" and "Intake".

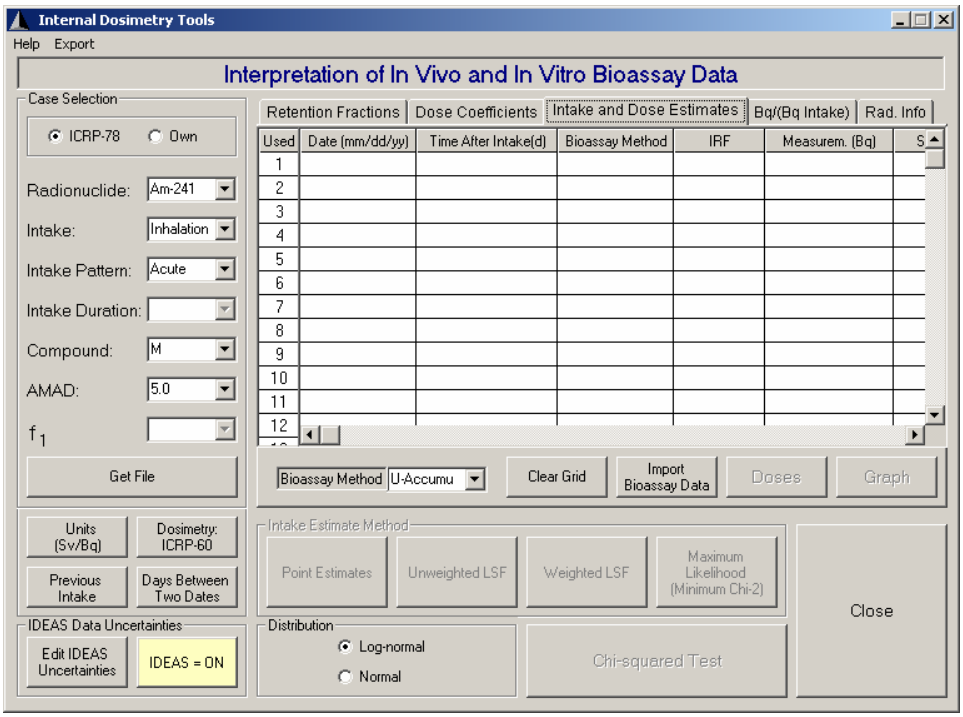


Figure 4.8 The "Internal Dosimetry Tools" form showing the contents of the "Intake and Dose Estimates" tab

The first step is to select the appropriate "Bioassay Method". If the intake estimate is based on a single type of bioassay measurements, then the bioassay method can be selected either by using the bioassay method combo box at the end of the grid or by directly clicking the cells under the "Bioassay Method" column (Figure 4.8). The later choice is also suitable for cases with multiple measurements using different bioassay types.

The next step is to enter the time after or under intake. When the *in vivo* or *in vitro* bioassay results are directly typed on the grid the dates or times after the intake can be entered. For the case of *in vitro* bioassay the dates or times correspond to the date the sample was collected. For the case of *in vivo* bioassay the dates or times correspond to the date the measurement was carried out. The dates should be typed on the "Date (mm/dd/yy)" column of the grid using the indicated format mm/dd/yy, which corresponds to month/day/year. The times in units of days should be typed on the "Time After Intake (d)" column. However, if dates will be used on the first column, at least the first row must contain both numbers. The results will be automatically converted into days if dates are entered after the first row.

Once the time is entered the corresponding IRF for the bioassay method, which is shown on the "Bioassay Method" column, is automatically displayed on the "IRF" column. The corresponding bioassay result can then be entered on the "Measurem." column as well as the associated standard deviation, if any.

Since there are several methods to normalize bioassay data coming from urinary (standard daily excretion volumes, creatinine excretion levels, gravimetric density, etc) or fecal excretion, these data must be normalized to daily excretion before entering the grid.

After the bioassay measurement result is properly entered the corresponding point estimated intake is shown on the last column. Single point estimated intakes are calculated by simply dividing the bioassay measurement by the corresponding IRF. Figure 4.9 shows an example for the acute inhalation intake of ^{241}Am, Type M, AMAD = 5 μm. In this case, a single measurement result of 0.1 Bq of a daily urinary excretion sample corresponding to a time of 10 days after the intake was entered (upper part of Figure 4.9) resulting in an intake estimate of 2060 Bq, which is shown on the lower part of Figure 4.9.

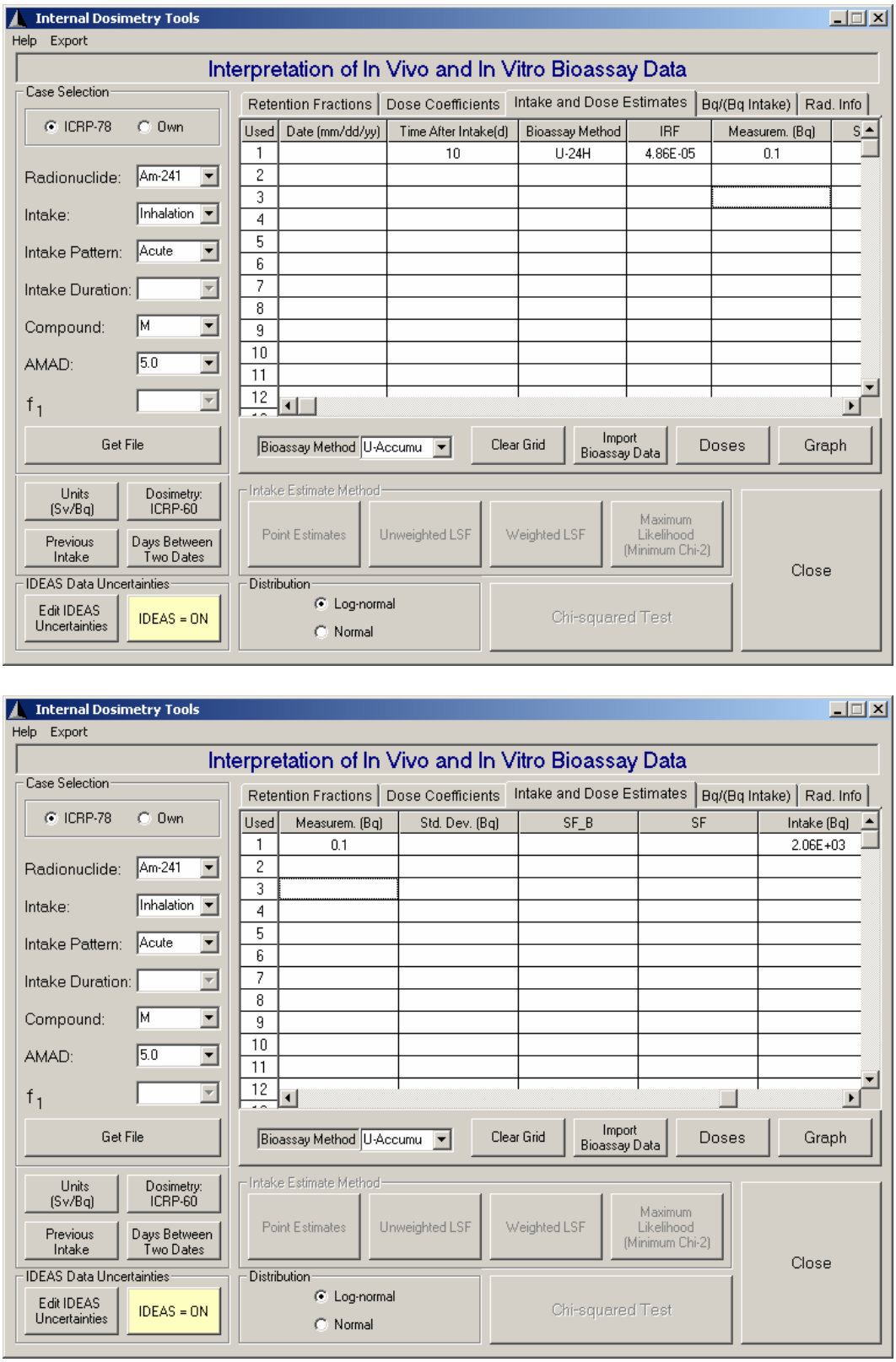


Figure 4.9 The "Internal Dosimetry Tools" form showing a single point estimated intake

The "Doses" button is enabled right after the first intake has been calculated and shown on the last column. In this case committed doses will be calculated after the estimate of an intake, which was derived from a single bioassay result. Figure 4.10 shows the result for the committed effective dose corresponding to the estimated ^{241}Am intake of 2060 Bq from Figure 4.9.

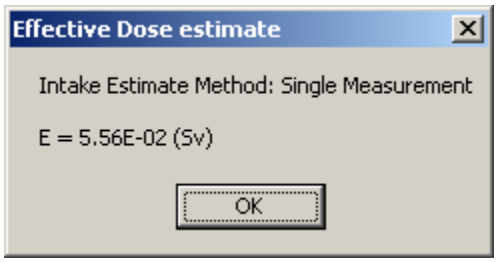


Figure 4.10 The Committed Effective Dose estimate corresponding to the data shown in Figure 4.9

The columns "Std. Dev.", "SF-B" and "SF" are related to the uncertainties on the data measurement. They were especially designed to allow intake estimates from multiple bioassay measurements using the IDEAS project proposal.

The following text was extracted from the IDEAS Project Document[11], where the "[IAEA, 2004]" reference corresponds to reference 9 of this manual: "Numerous statistical methods for data fitting are available [IAEA, 2004]. The two accepted scientific approaches are the maximum likelihood method and the Bayesian approach. These two methods are most widely applicable and can be applied to the cases where it is assumed that the measurements are log-normally distributed as recommended in these guidelines. Other methods, such as the least squares method are special cases of the maximum likelihood method under certain assumptions. The standard equations given for the least square method apply to cases where the measurements are normally distributed and therefore do not strictly apply to these guidelines."

In this way, the maximum likelihood method was selected as the fitting technique used in this software to determine the best estimate of intake from multiple measurement data for cases where it is assumed that the measurements are log-normally distributed. However in order to contemplate cases of normally distributed data as well and to keep consistency with previous versions of this software three techniques for estimating intake from multiple bioassay samples are available for the case of acute intake[9],[11]: Point Estimates, Unweighted Least Squares Fit and Weighted Least Squares Fit.

According to the IDEAS Project document[11] the total uncertainty for the measurements which are log-normally distributed can be given as:

$$SF_i = e^{\sqrt{[\ln(SF_{A,i})]^2 + [\ln(SF_{B,i})]^2}} \qquad (4\text{-}1)$$

where:
SF_i is the total scattering factor for the log-normal distribution. It describes the overall uncertainty for the measurement M_i, and
$SF_{A,i}$ and $SF_{B,i}$ are the scattering factors for Type A and B errors respectively associated with the measurement M_i

The "Std. Dev." field is associated with the uncertainties due to counting statistics, or Type A error. When the measurements are log-normally distributed the measurement standard deviation is related to $SF_{A,i}$ through the following relationship:

$$\ln(SF_{A,i}) = \frac{\sigma_{Mi}}{M_i} \qquad (4\text{-}2)$$

where σ_{Mi} is the standard deviation of the measurement M_i

Figure 4.5 shows recommendations from the IDEAS document for $SF_{A,i}$ values for *in vivo* measurements. The saved parameter values, which can be the default or modified values, are suggested to the user when entering data from *in vivo* measurement results. In this case, the values of σ_{Mi} shown on the "Std. Dev." column will be given by $Mi.\ln(SF_{A,i})$. Therefore the user has the choice either to enter the standard deviation of the measurement or to use the suggested value on the field corresponding to the "Std. Dev." column. Once more, it must be pointed out that this procedure is only applicable to cases where the measurements are log-normally distributed and the IDEAS treatment was selected (IDEAS = ON button on section 4.3 Selections Associated With the IDEAS Project).

The SF_B value recommended by the IDEAS document will automatically be inserted on the field corresponding to the "SF-B" column and the value corresponding to the field under the "SF" column will then be automatically calculated according to the equation (4-1) and shown. As explained above the SF value corresponds to the total uncertainty on the data measurement.

When the measurements are normally distributed the "Std. Dev." column will contain the standard deviation of the measurements and the fields under the "SF-B" and the "SF" columns will have no use.

4.4.3.2 Intake Estimates

When the pattern of intake is acute and the intake estimate will be obtained from multiple bioassay results, then the buttons in the "Intake Estimate Method" frame are made available.

The bioassay data are assumed to be either normally or log-normally distributed. As explained in the previous section, the maximum likelihood method was selected as the fitting technique to determine the best estimate of intake from multiple measurement data for cases where it is assumed that the measurements are log-normally distributed. When the data are normally

distributed three techniques for estimating intake from multiple bioassay samples are available, for the case of acute intake[9],[11]: Point Estimates, Unweighted Least Squares Fit, Weighted Least Squares Fit. All techniques are described as follows:

4.4.3.2.1 Point Estimates

An arithmetic mean of the individual (point) intake estimates, or simply the average of the intakes.

The error on the estimate is given by the standard deviation[12], or

$$\sigma_I = \sqrt{[[\Sigma_i (I_i^2) - (\Sigma_i I_i)^2] / N] / [N-1]} \qquad (4\text{-}3)$$

where: I is the average of the intakes
I_i is the individual intake estimate calculated from a single bioassay measurement
N is the total number of bioassay measurements

The final average calculated intake result will be represented as $I \pm \sigma_I$

4.4.3.2.2 Unweighted Least Squares Fit (LSF)

The resulting intake (I) is calculated by minimizing the sum of the squares of the deviations of the observed measurements from the model predictions.

$$I = \Sigma_i [M_i . m(t_i)] / \Sigma_i [m(t_i)]^2 \qquad (4\text{-}4)$$

where: t_i is the time since the intake.
M_i is the bioassay result observed at time t_i
$m(t_i)$ is the value taken from the tables for time t_i

The error on the estimate is given by the standard deviation[12].

$$\sigma_I = \Sigma_i [\sigma_{Mi} . m(t_i)] / \Sigma_i [m(t_i)]^2 \qquad (4\text{-}5)$$

where σ_{Mi} is the standard deviation of the measurement M_i

The final average calculated intake result will be represented as $I \pm \sigma_I$

4.4.3.2.3 Weighted Least Squares Fit (WLSF)

The resulting intake (I) is calculated by applying the inverse of the square of the standard deviation (σ_{Mi}) of the measurement as a weighting factor when minimizing the sum of the squares of the deviations of the observed measurements from the model predictions.

$$I = \Sigma_i [M_i . m(t_i)/\sigma^2_{Mi}] / \Sigma_i [m(t_i)^2/\sigma^2_{Mi}] \quad (4\text{-}6)$$

Where: t_i is the time since the intake.
M_i is the bioassay result observed at time t_i
$m(t_i)$ is the value taken from the tables for time t_i
σ_{Mi} is the standard deviation of the measurement.

The error on the estimate is given by the standard deviation[12].

$$\sigma_I = \Sigma_i [\sigma_{Mi} . m(t_i)/\sigma^2_i] / \Sigma_i [m(t_i)^2/\sigma^2_i] \quad (4\text{-}7)$$

The final average calculated intake result will be represented as $I \pm \sigma_I$

4.4.3.2.4 Maximum Likelihood Method

$$\ln(I) = \Sigma_i [\ln(I_i) / [\ln(SF_i)]^2] / \Sigma_i [1/[\ln(SF_i)]^2] \quad (4\text{-}8)$$

where: ln(I) is the weighted average of $\ln(I_i)$, which is the log of the individual intake estimates calculated from a single bioassay measurement.

SFi is the total scattering factor for the log-normal distribution describing the overall uncertainty for measurement M_i as described in formula (4-1).

The error on the estimate is given by the standard deviation[12].

$$\sigma_I = I . \Sigma_i [\sigma_{Mi} / [M_i . [\ln(SF_i)]^2]] / \Sigma_i [1/[\ln(SF_i)]^2] \quad (4\text{-}9)$$

The final average calculated intake result will be represented as $I \pm \sigma_I$

4.4.3.2.5 Criteria for Rejecting Fit

In order to test goodness of fit for the fitted intakes the X^2 Test is employed.

Formulas (4-10) and (4-11) are employed to test fitted intakes coming from log-normally distributed data and normally distributed data respectively.

$$X_0^2 = \sum_{i=1}^{n} [(\ln(M_i) - \ln(I.m(t_i))) / \ln(SF_i)]^2 \qquad (4\text{-}10)$$

$$X_0^2 = \sum_{i=1}^{n} [(M_i - I.m(t_i)) / \sigma_i]^2 \qquad (4\text{-}11)$$

where I is the estimated intake and $m(t_i)$ is the predicted bioassay quantity for unit intake. So the product $I\ m(t_i)$ is the predicted value. If the predictions are inconsistent with the data, then the calculated value of χ^2_0 is inconsistent with the theoretical *chi-squared* (χ^2) distribution with (n-1) degrees of freedom. According to the IDEAS[11] guidelines, the probability of observing a larger χ^2 value than χ^2_0 for (n-1) degrees of freedom is given by the p-value, which can be obtained from the statistical tables. The p-value is the fraction of the theoretical χ^2 distribution that lies above the calculated χ^2_0 value. So if the p-value is very small, the calculated χ^2_0 value is very much larger than expected and therefore, it can be concluded that the predictions are likely to be inconsistent with the data and the assumed uncertainties.

The IDEAS document proposes that the fits to data are judged to be inadequate if:
- the probability that χ^2 is greater than χ^2_0 is 5% or less (i.e. p-value < 0.05). In other words the fit is inadequate at the 5% level of significance, or if
- the fit displayed graphically looks unreasonable by eye.

For convenience, the chi-squared test for intake estimates implemented in this software already contains the p-value tables.

4.4.3.2.6 Identification of rogue data

A special feature was developed to help the user identify outliers above or below the trend of a sequence of data points. The IDEAS[11] guidelines defines outliers as rogue data. The characterization of such measurement data includes a check on whether the inclusion or the exclusion significantly affects the intake. Additional visual help through graphically displaying data against the fitted curve is also available as explained in section "4.4.3.3 Graph Capabilities".

The upper part of Figure 4.11 shows the "Internal Dosimetry Tools" form with the corresponding intake estimates and chi-squared tests considering all data points entered on the grid for a hypothetical inhalation case of Type M ^{241}Am. The first column on the left, which is named "Used", shows the numbers of the rows on the grid, which contain data that are used to estimate the intake and consequently the dose. The data on a certain row can be excluded from the analysis by clicking its corresponding number on column one. At this point the row number will be converted into an "X" and the corresponding data will not be used on the calculations. The user can exclude as many rows as necessary. The data on the rows marked with X can be used again by simply clicking on the "X". This will cause the original row number to be shown again and the corresponding data available for use.

As an example the form shown on the lower part of Figure 4.11 shows the same estimates excluding the data shown on row number 3.

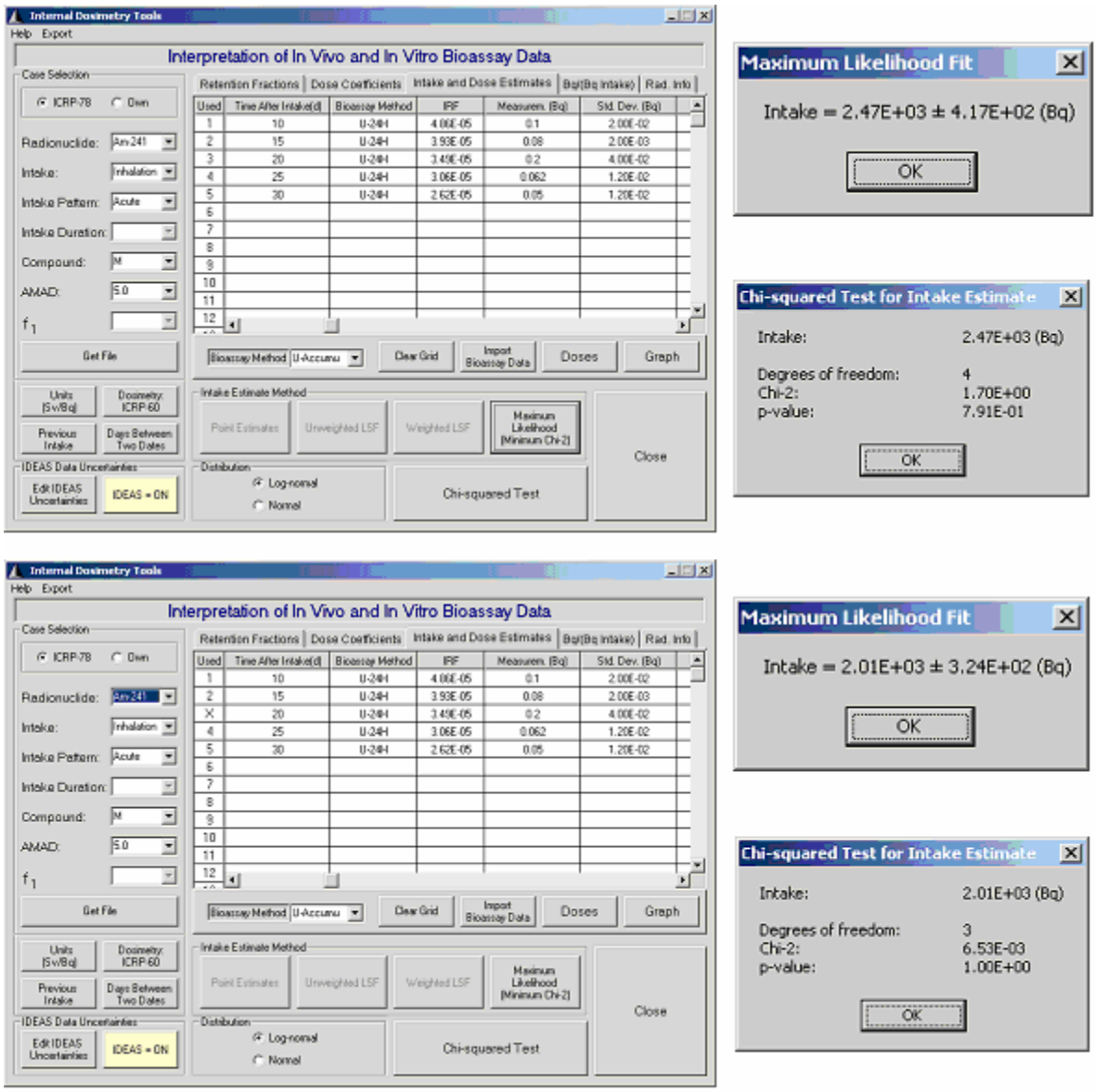


Figure 4.11 The "Internal Dosimetry Tools" form showing intake estimates and corresponding chi-squared tests considering all (upper part) or selected data points (lower part)

4.4.3.3 Graph Capabilities

The "Graph" button is available after the intake has been estimated. The graphs of all expected bioassay quantities after a single intake are plotted with all entered data points. It must be mentioned that the graph capabilities of this software were developed just to give the user a tool for visual perception of the quality of the fitted intake with respect to the measured data points. For more detailed graphs it is recommended to export the data into more sophisticated graphing software.

4.4.3.4 Further Considerations on Intake and Effective Dose Estimates

For the case of non-acute exposures the intake and the cumulative effective dose are also estimated. However two cases can occur: a) the bioassay measurement was obtained while the subject was still under intake; b) The bioassay measurement was obtained after the cessation of the protracted intake.

As recommended by ICRP[7], intake and dose estimates based on measurements, which were obtained under conditions of protracted intake should be used as guidance for estimating tendency of exposure in the workplace. In these cases, the following text is displayed on the message box: "Doses due to this kind of intake are calculated assuming that the intake pattern and the intake rate are kept constant until the end of the intake period. Since the measurement was obtained while the intake period was still active the calculated dose represents only an estimate of a projected dose, which would be committed if the intake conditions are kept. In this way, this dose result should be seen as a reference value for the evaluation of intake tendency. This software uses only one bioassay measurement for this kind of estimate!"

When the duration of the prolonged intake is finite, the following type of message is printed: "Note: If this intake pattern is kept constant the total predicted intake amount after X days will be Y and the Cumulative Effective Dose will be Z".

Similarly, when the duration is infinite, the message is like: "Note: If this intake pattern is kept constant the total predicted intake amount at 50 years will be Y and the Cumulative Effective Dose will be Z".

When the bioassay measurements were obtained after the cessation of the protracted intake regular intake and dose estimates can be carried out. In these cases, the average intake can be estimated according to the options described in the section 4.4.3.2 Intake Estimates.

4.4.3.5 Importing Bioassay Measurement Results with built-in data acceptance criteria

The bioassay results can also be imported from a Microsoft Excel spreadsheet using the "Import Bioassay Data" button, as shown in Figure 4.9. When this button is clicked the "Select a Excel Spreadsheet to open" dialog box is shown. This dialog box allows the user to browse and to select the desired spreadsheet, which contains the bioassay data. The Excel file is then read and its contents are shown on a grid on the "Importing from Excel" form like the one in Figure 4.12 below is shown.

All columns are named with Field 1, Field 2, etc. The combo boxes inside the "Field Associations With Bioassay Data" frame allow associating the fields imported from the Excel file with the quantities to be used to interpret the bioassay data, namely: "Date (mm/dd/yy)", "Time After Intake (d)", "Measurement", "Standard Deviation", "SF_A", "SF_B" and "Bioassay Method".

Each combo box contains the list of all field names. In order import the results from the Excel file all table fields must be associated with the corresponding quantities by selecting the desired field on each appropriate combo box. Since more than one bioassay method can be used to obtain the measurements it is possible to associate every bioassay type with its measurement. In the example shown in Figure 4.12 the column named "Field 4" contains the codes denoting the bioassay methods. The combo box named "Selected Method" contains the bioassay compartments from the bioassay tables, the combo box named "Select Cell Text" contains all fields denoting the bioassay measurement types which belongs to the imported spreadsheet. The "Link Method to Cell Text" button allows correlating the fields from the imported results with those from the bioassay tables. The "Links" textbox shown in the example of Figure 4.12 illustrates the connections between the several bioassay compartments Thoracic, Skeleton, U-24h, etc. with the respective symbols of the imported spreadsheet: C, S, U, etc. The data measurement results are successfully imported into the grid on the "Intake and Dose estimates" tab as shown in Figure 4.13.

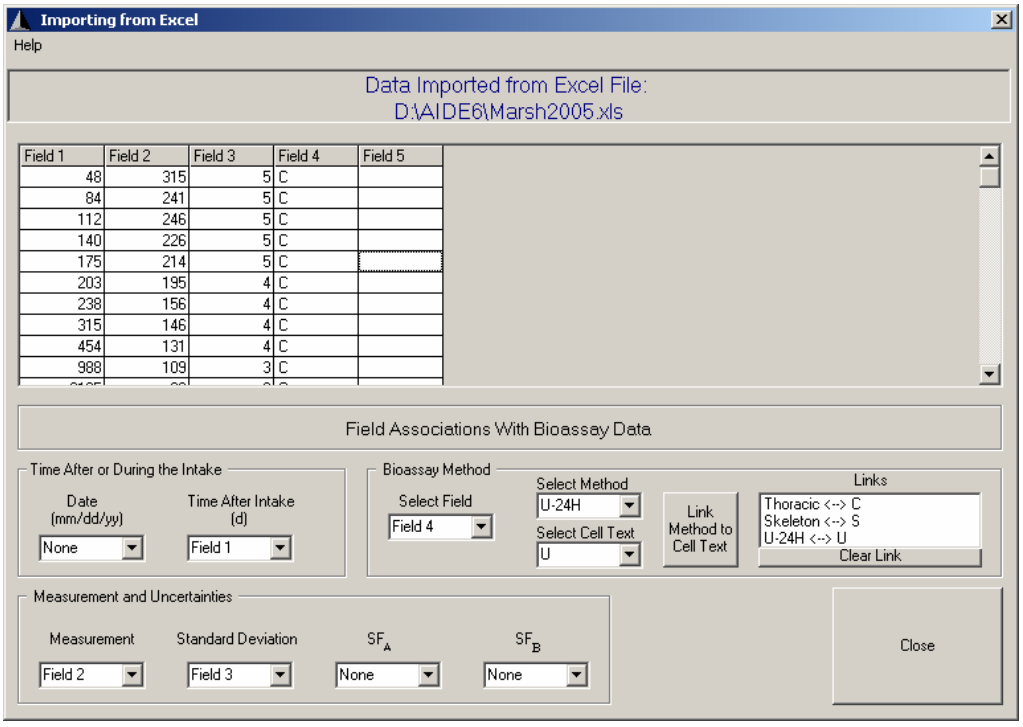


Figure 4.12 Typical form showing bioassay data imported from an Excel spreadsheet

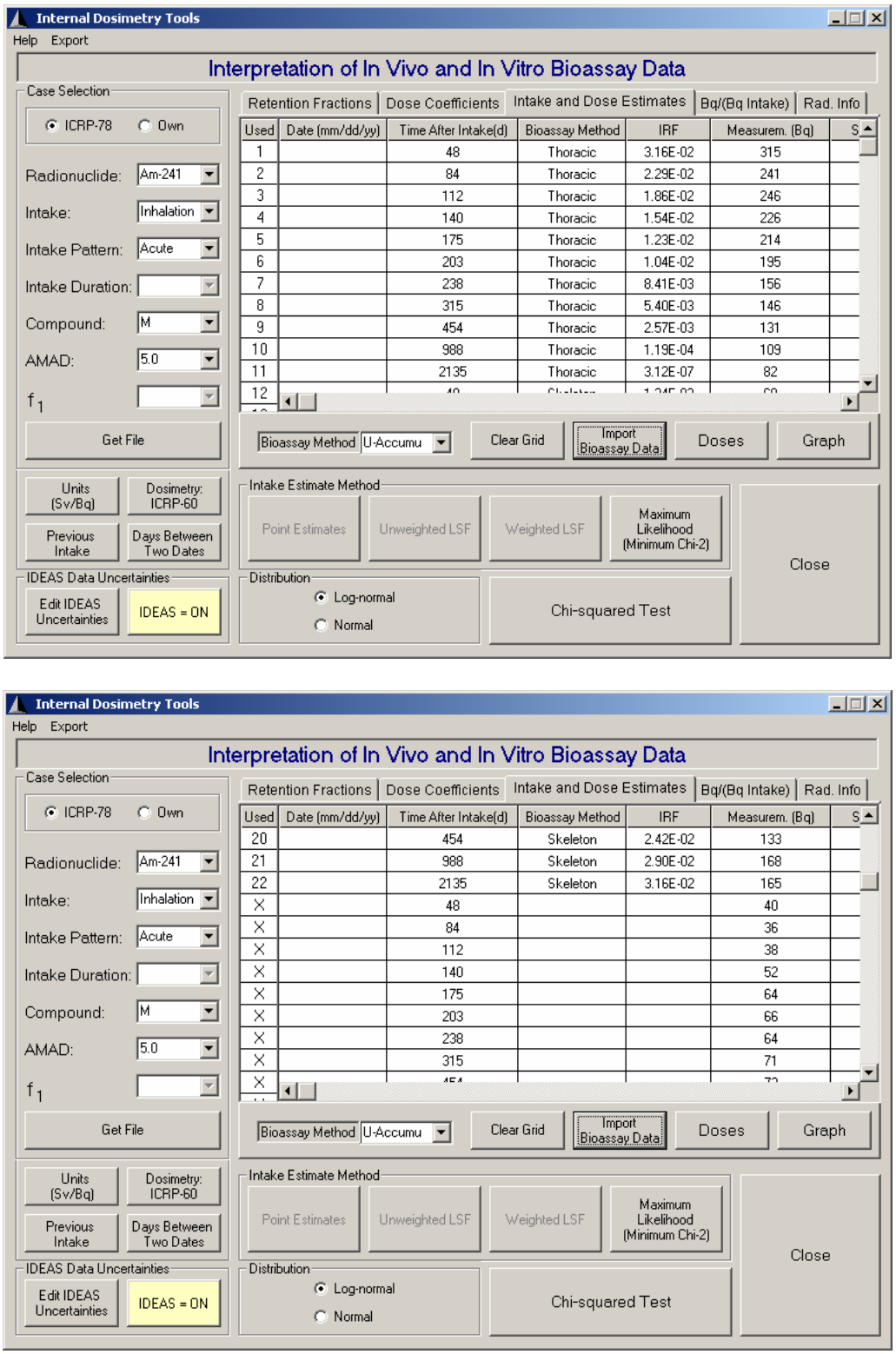


Figure 4.13 The Internal Dosimetry Tools form after importing bioassay data from an Excel spreadsheet

The upper part of Figure 4.13 shows the imported data on the corresponding cells of the grid on the Internal Dosimetry Tools form. The first column, which is named "Used", shows the row numbers for each imported data point. As described in section "4.4.3.2.6 Identification of rogue data", data on numbered rows are used to estimate the intake and consequently the dose. However the lower part of Figure 4.13 shows rows marked with "X" in the first column. This means that some information was lost during the importing process and consequently these data cannot be used to estimate the intake. In this particular case Figure 4.12 showed that enough fields in the Excel spreadsheet were associated with columns of the grid. However some data pertained to a bioassay method, which is not listed on the Intake Retention Fractions (like liver measurements, for example). Consequently these data measurements could not be linked to an available bioassay method and cannot be used in the intake estimate. As can be seen the cells under the "Bioassay Method" column for row numbers after 22 are blank.

In this way, AIDE has a very useful tool for importing bioassay data from an Excel spreadsheet with built-in robust acceptance criteria for imported data.

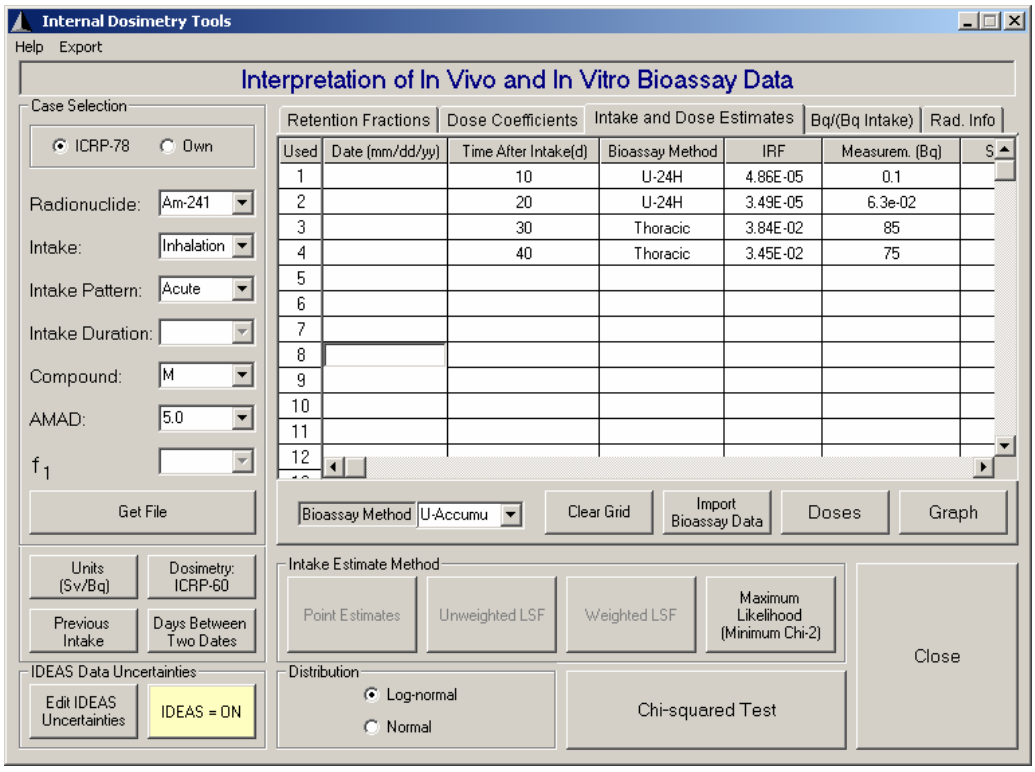
4.4.3.6 Exporting Calculation Results

All results and reference values used in the calculations can be exported to either a txt file (Report.txt located in the RESULTS folder) or a Microsoft Excel file after the "Export" choice has been selected on the upper menu, shown in Figure 4.9. These files contain the data used to calculate the intake and doses and other important basic information like the predicted values of the measured quantities as a function of time following single intake of unit activity and the dose coefficients used to estimate the intake and dose results. In this way, all estimates could be reproduced in the future. In addition, this file can be edited, printed and stored, allowing the user to complement the text with own information and to store the file in any appropriate folder.

4.4.3.7 A Case Study of Intake and Dose Estimates Due to an Acute Inhalation of Type M Compounds of ^{241}Am with AMAD = 5 μm

A very simple case involving the intake by acute inhalation of Type M Compounds of ^{241}Am with AMAD = 5 μm was shown in section "4.4.3.1 Definitions of Fields and Their Usages". There the intake and dose estimates were performed using a single bioassay measurement. In this section the same case will be illustrated. However the best estimate of intake will be obtained from multiple bioassay measurements, which are assumed to be log-normally distributed.

In this example, shown in Figure 4.14, two urine measurements collected 10 and 20 days after the intake and two chest measurements performed at 30 and 40 days after the intake were used. The hypothetical standard deviations used for the urinary measurements were around 30% of the measurement value. It is obvious that *in vivo* measurements are always accompanied by their corresponding standard deviations, however, as a matter of illustration no particular values of standard deviations will be entered for the chest measurements. In this case, the values proposed in the IDEAS tables are automatically selected when leaving the corresponding field empty and they will be used instead.



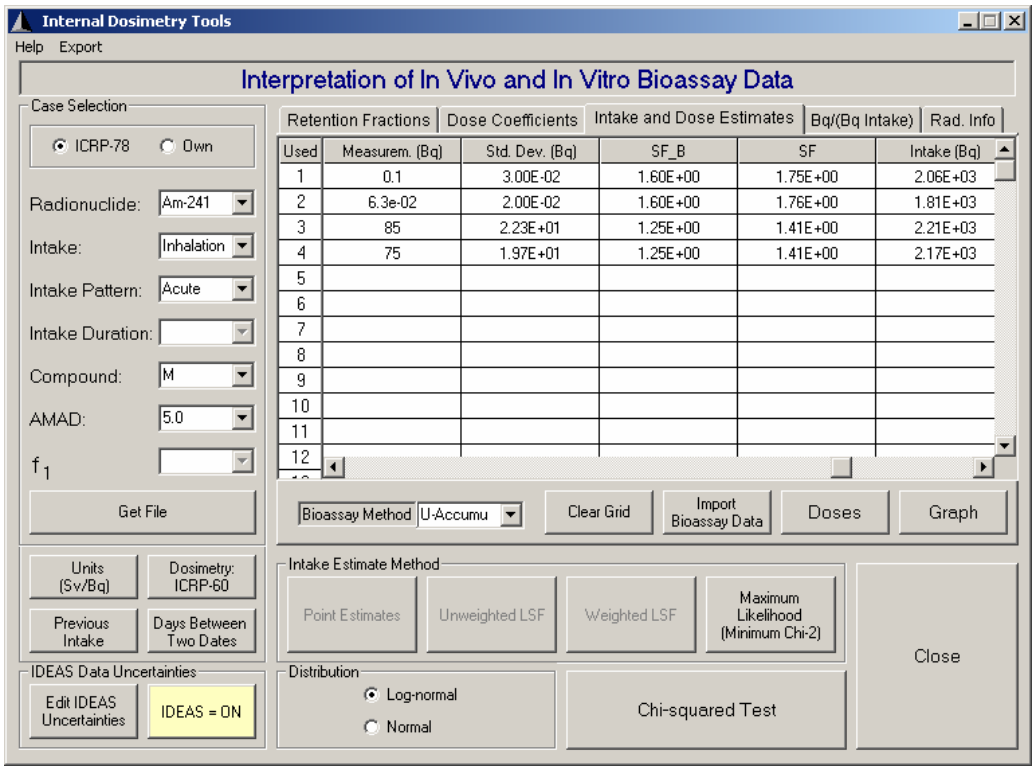


Figure 4.14 A case study of intake estimate using multiple bioassay measurements

Figure 4.15 shows the log-normal scattering factors SF for *in vivo* and *in vitro* measurements proposed by the IDEAS project, which can be seen when the "IDEAS = ON" button is pressed asking the user if the proposed scattering factors SF will be used in the calculations. Assuming that the answer in this case was "Yes" it can be seen values of 22.3 and 19.7 Bq on the "Std. Dev. (Bq)" column for the standard deviations corresponding to the measurements 85 and 75 Bq respectively. The standard deviation values can promptly be obtained by using equation 4-2. The "SF_B" column on the grid shows that the values corresponding to the urine and chest measurements are 1.6 and 1.25 respectively. These are the same values for Type B error shown in Figure 4.15. The values for the total scattering factor SF shown on the "SF" column can promptly be verified by using equation 4-1.

The intake is estimated by pressing the "Maximum Likelihood" button, which results in 2120 $\pm$ 582 Bq, as shown in Figure 4.16. Figure 4.17 shows that the corresponding result of the chi-squared test for three degrees of freedom (number of measurements -1) is 0.105. The associated "p-value" is 0.991, which means that the intake calculation can be accepted. The estimated committed effective dose is 57 mSv, as shown in Figure 4.18

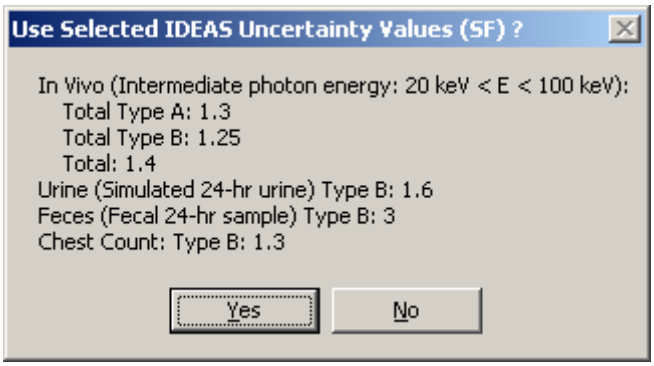


Figure 4.15 Log-normal Scattering Factors SF for In Vivo and In Vitro Measurements (IDEAS)

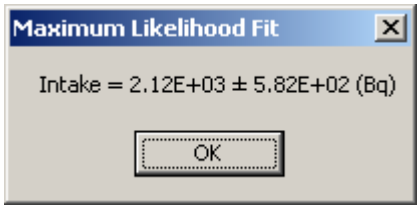


Figure 4.16 Estimated intake using the Maximum Likelihood Fit method

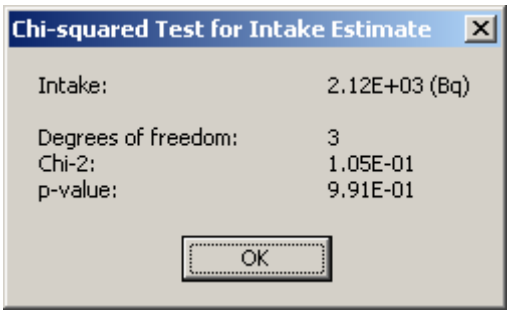


Figure 4.17 Chi-squared Test corresponding to the estimated intake of 2120 Bq

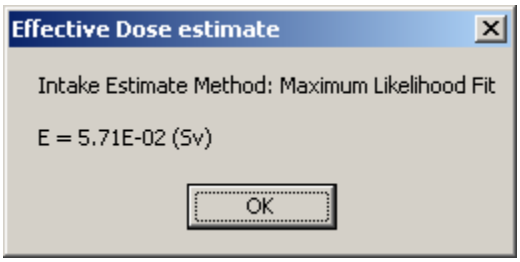


Figure 4.18 Effective dose estimate

If the data are assumed to be normally distributed the option "Normal" in the "Distribution" frame located at the bottom of the form must be selected. The three remaining techniques for estimating intake from multiple bioassay samples will then be available (Point Estimates, Unweighted Least Squares Fit and Weighted Least Squares Fit). The procedures for intake and effective dose estimate are essentially the same and will not be exemplified here.

As explained in "4.4.3.6 Exporting Calculation Results" all results and reference values used in the calculations can be exported to either a txt file (Report.txt located in the RESULTS folder) or a Microsoft Excel file after the "Export" choice has been selected.

4.4.4 Bq per Bq intake

The fourth tab shows either the predicted values (Bq per Bq intake) or DILs, according to the dosimetry choice. Monitoring intervals, which do not meet the bioassay criteria established in ICRP Publication 78[7] and consequently are not recommended for bioassay, are shown with a red background color. Results for activity in sample per activity intake can be seen for *in vivo* and for *in vitro* bioassay. The results for the later are reported in activities or in concentrations and for male and female subjects. Figure 4.19 shows an example using acute inhalation of Type F ^{131}I compounds with AMAD = 5 µm. As can be seen, monitoring intervals greater than 30 days are not recommended for *in vitro* bioassay and those greater than 14 days are not recommended for *in vivo* bioassay.

In order to calculate the results in concentrations the following reference values are used for normalization and were extracted from ICRP Publication 89[13]:
Wet weight in g/day for daily fecal excretion: 150 g for adult man and 120 g for adult woman
Daily urinary excretion in L: 1.6 L for adult man and 1.2 L for adult woman

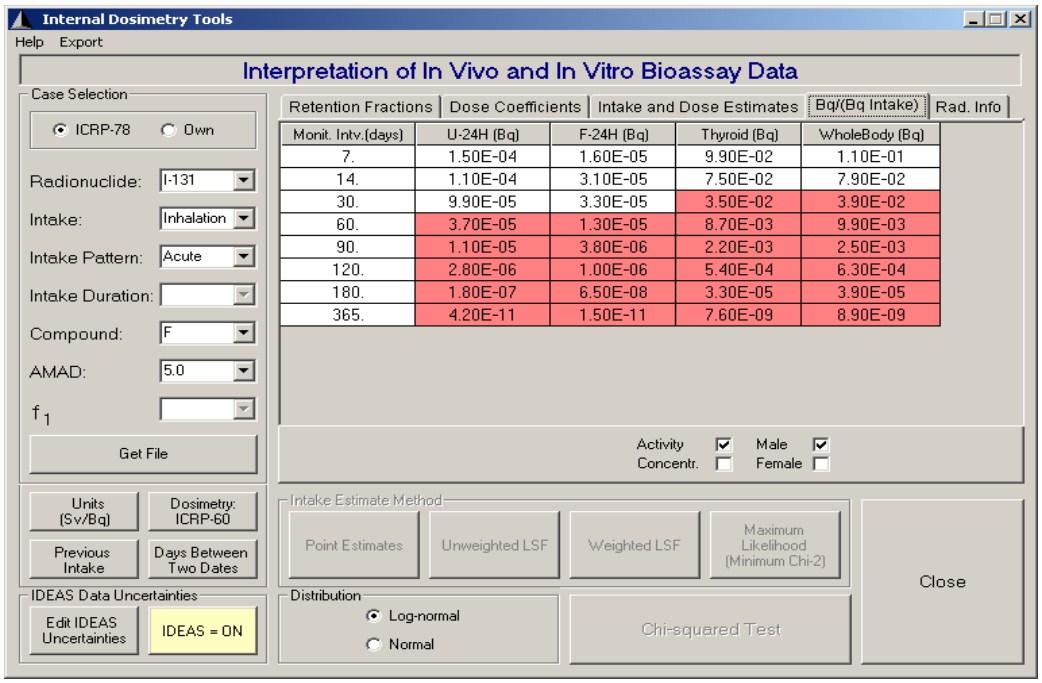


Figure 4.19 Example of recommended monitoring intervals as proposed in ICRP Publication 78

4.4.5 Rad. Info

The fifth tab (Rad. Info) shows information about the selected radionuclide and its series. The corresponding daughters, yields and half-lives are shown for every element of the series. Furthermore, the complete decay information can be seen for every element of the series (including all types of emitted radiations with corresponding energies and yields) by clicking on the cell with the isotope name located on either the "Isotope" or on the "Daughter" column. Figure 4.20 shows an example using the ^{131}I series.

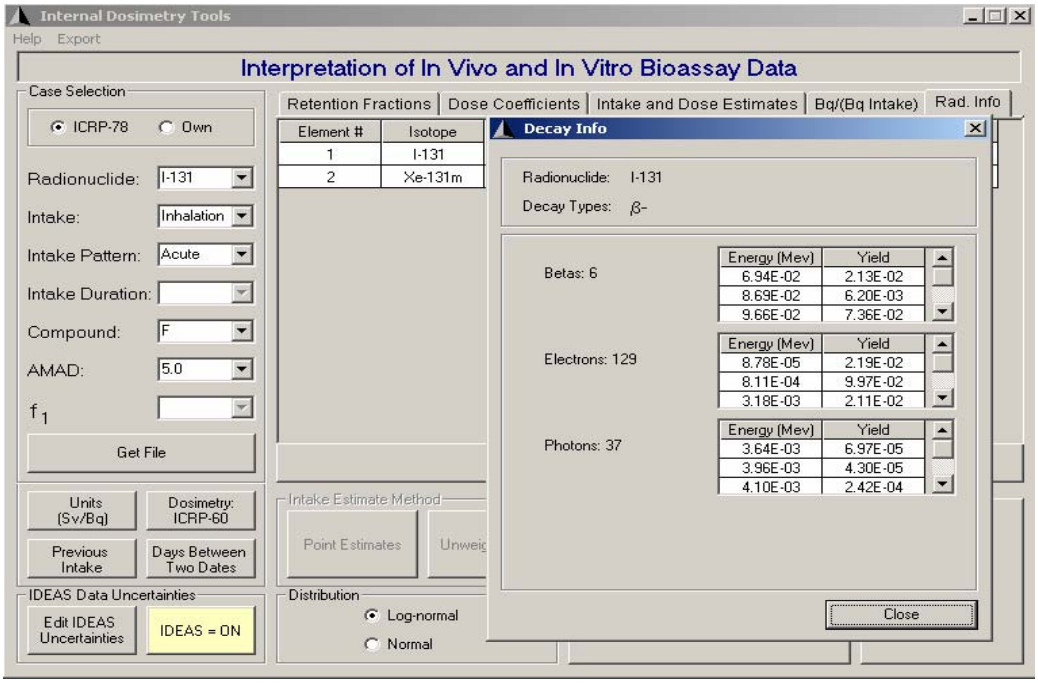


Figure 4.20 Example of radiation information provided by the "Rad. Info" tab

4.5 Quality Assurance of Intakes and Dose Estimates

A comprehensive discussion on the quality assurance of calculations of activities and dose coefficients was carried out on section 3.7 of this manual. Since the Retention Fractions and the Dose Coefficients shown in the first two tabs (Figures 4.3, 4.6 and 4.7) come directly from these calculations no further analysis will be done in this section.

The quality assurance procedures associated with the four methods for estimating intakes (Point Estimates, Unweighted Least Squares Fit, Weighted Least Squares Fit, Maximum Likelihood Fit) were done manually. Combined hypothetical data sets ranging from two to twenty *in vivo* and *in vitro* bioassay results were used. The sets were directly typed or imported into the grid shown in Figure 4.14, and the resulting intake was compared against the hand calculation result.

The results shown in the Bq/(Bq intake) tab (Figure 4.19) were also directly compared against those from hand calculations using short and long-lived nuclides. The results from the "Rad. Info" tab (Figure 4.20) were directly checked against the values given by the ICRP Publication 38[15].

5. Edit Models

Information on available biokinetic models can be edited and new models, even involving recycling, can be introduced. Figure 5.1 shows the "Model Editing" form, which is described below.

In order to avoid accidental deletion of the original models used to generate the bioassay tables that come with the software the data from these models will be shown with yellow background. In these cases the user will be able to see and print the information but will not be able to edit it. However the original models can be copied and then edited as explained below. The "Biokinetics" button provided on the top of the form allows the user to see the schematics of all models recently used by ICRP. This feature was kindly provided by Dr. Keith Eckerman from Oak Ridge National Laboratory and was originally developed for the United States Environmental Protection Agency as a part of the Federal Guidance Report 13[8].

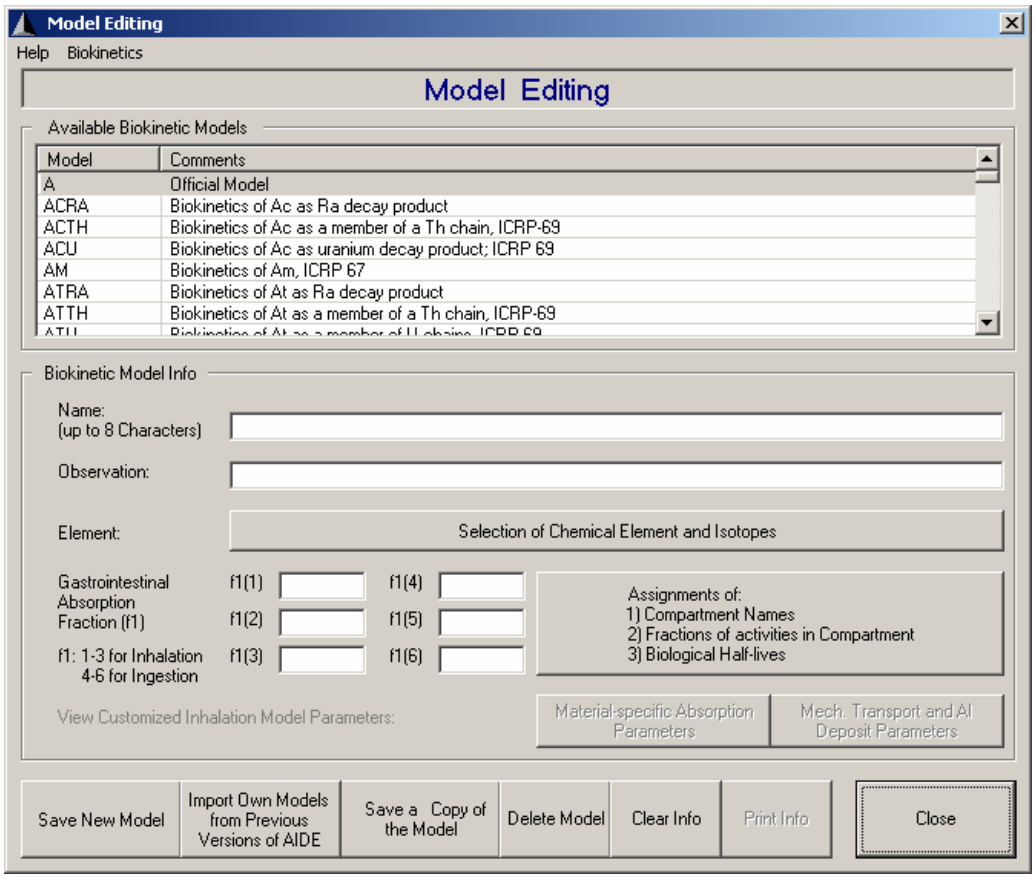


Figure 5.1 The "Model Editing" form

5.1 Original Models

The "Available Biokinetic Models" frame located on the upper part of the "Model Editing" form contains a listbox which allows the selection of the biokinetic model to be edited. The lower part of the form contains the "Biokinetic Model Info" frame, which shows the information regarding name, observation and the f1 values pertaining to the model.

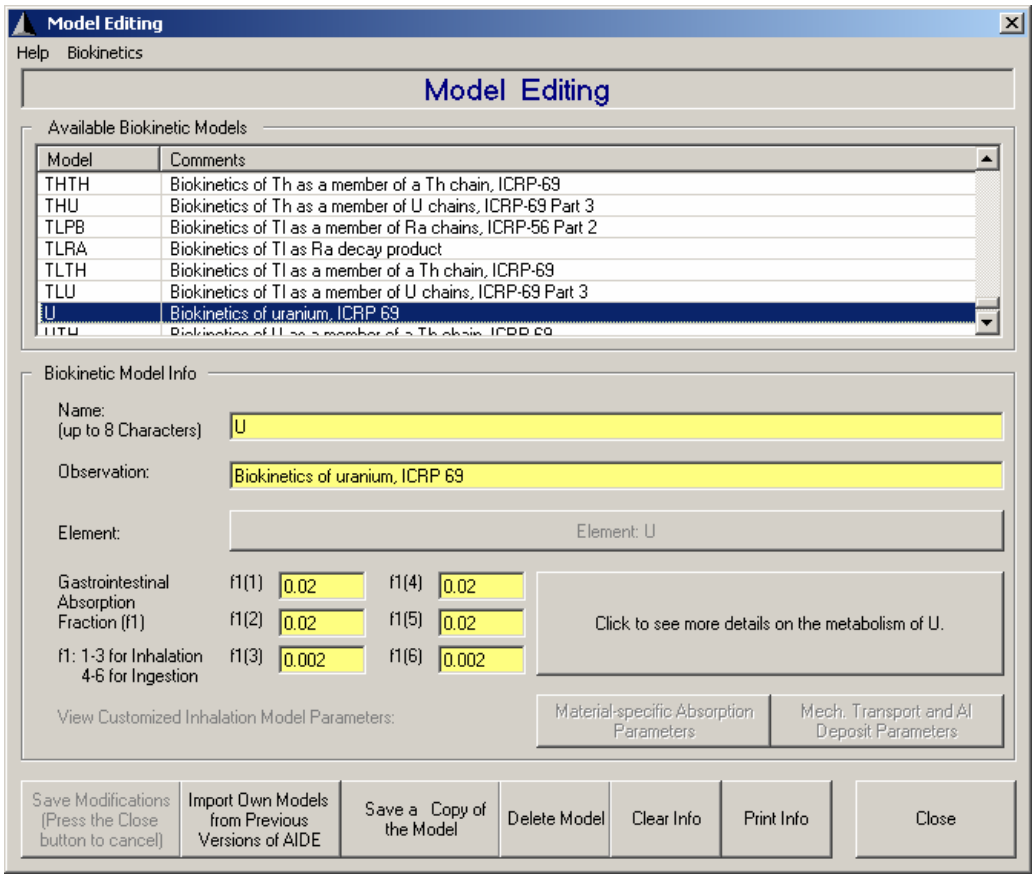


Figure 5.2 The "Model Editing" form showing information of an original model

In most cases the f1 values are the same for inhalation and ingestion intakes. However some exceptions show different values. In this way, the f1 textboxes numbered 1 to 3 were designed to be used for inhalation intake. The textboxes numbered 4 to 6 should be used for ingestion intake.

When an available model is chosen all fields inside the "Biokinetic Model Data" frame will be filled, as shown in Figure 5.2.

The model names have been chosen in the following manner:
a) In cases where the element can be either a bone surface seeker or a bone volume seeker the following pattern has been adopted: the suffix _SUR indicates when the isotopes are bone

surface seeker (Ex. ^{30}P and ^{32}P) and the suffix _VOL indicates when the isotopes are bone volume seeker (^{33}P)
b) There is no general rule for choosing a model name for the mother of the chain.
c) Models for daughters of radioactive series have been chosen according to the standard shown in the "5.3 Model Names for Radioactive Series" section.

As can be seen in Figure 5.2, the button named "Element:" will display "Element: and the chemical symbol associated with the model". This button will be available only when a new model is entered. It will then allow the user to select a chemical element associated with the biokinetic model (See 5.2 User Models).

When the "Click to see more details on the metabolism" button is pressed the form "Compartments" is loaded, as shown in Figure 5.3. This form shows the names of the compartments used in the model and the associated standard organ or tissue names (Organ/Tissue column). In the case of "Existing Models" the user is only able see the compartment names used in the models with their corresponding associations with a standard source compartment name.

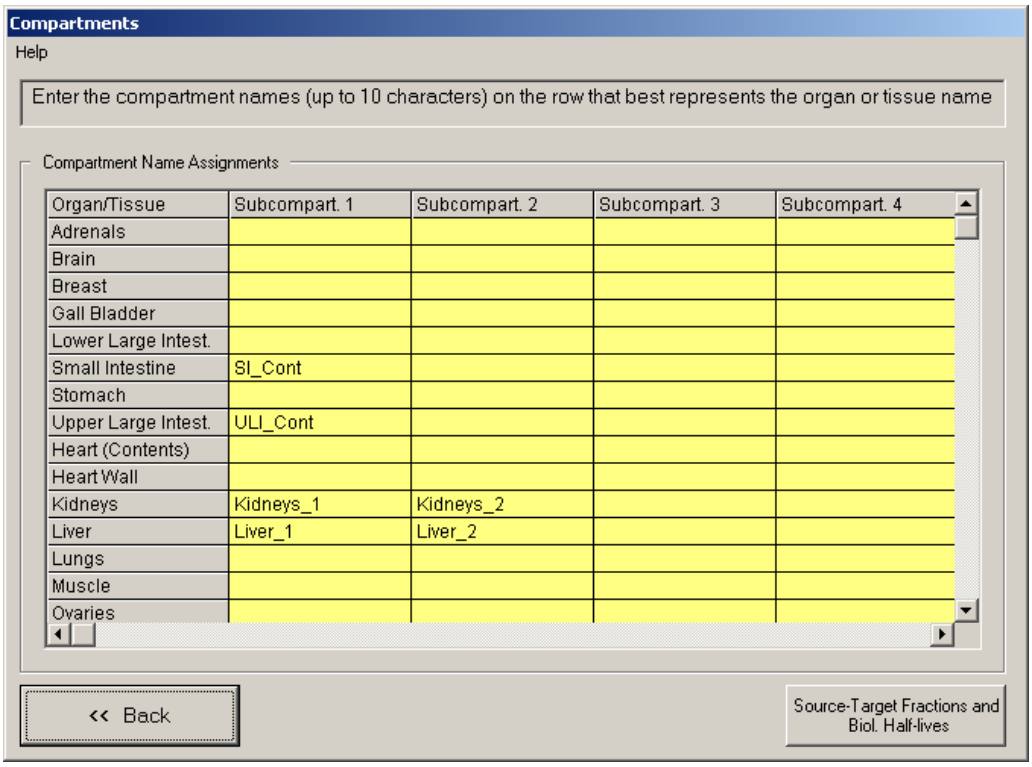
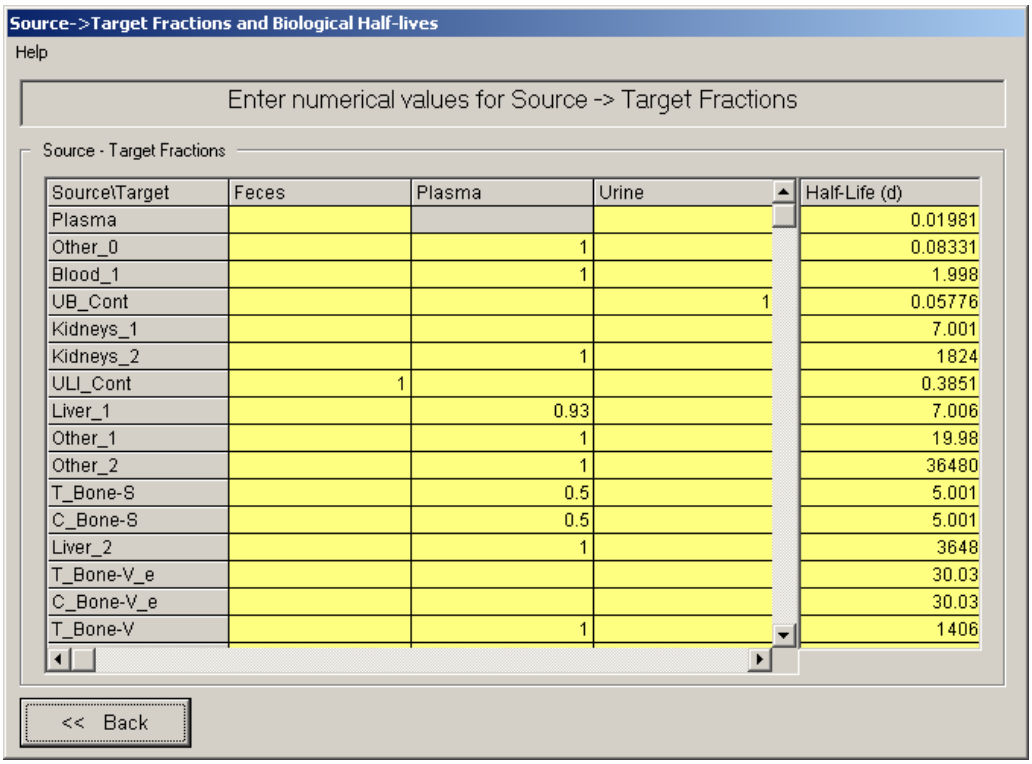


Figure 5.3 The "Compartments" form showing information of an original model

Pressing the "Source-Target Fractions and Biol. Half-lives" button a form with the same name is loaded, as seen in Figure 5.4, showing the respective information for all compartment names given in the previous form. Fractions of activity going from and to the several compartments belonging to the model, including the "Plasma" compartment, and those going to urine and feces are also shown. The associated biological half-lives in days for each source compartment is shown on the last column.

Pressing the "Back" buttons will direct the user to the starting "Model Editing" form.



Source\Target	Feces	Plasma	Urine	Half-Life (d)
Plasma				0.01981
Other_0		1		0.08331
Blood_1		1		1.998
UB_Cont			1	0.05776
Kidneys_1				7.001
Kidneys_2		1		1824
ULI_Cont	1			0.3851
Liver_1		0.93		7.006
Other_1		1		19.98
Other_2		1		36480
T_Bone-S		0.5		5.001
C_Bone-S		0.5		5.001
Liver_2		1		3648
T_Bone-V_e				30.03
C_Bone-V_e				30.03
T_Bone-V		1		1406

Figure 5.4 The "Source->Target Fractions and Biol. Half-lives" form showing information of an original model

On the bottom of Figure 5.2 it can be seen that four buttons are enabled besides the "Close" button. They are: "Save a Copy of the Model", "Delete Model", "Clear Info" and "Print Info", whose description follows below.

Save a Copy of the Model: As mentioned earlier, in order to avoid accidental deletion or alteration of the original models used to generate the bioassay tables that come with the software the data in these models will be shown with yellow background. As a result, the "Save a Copy of the Model" button was created to allow the user to modify and use original models without changing the original ones.

First select the original model, as shown for "U", which designates the ICRP-69 systemic uranium model, as shown in Figure 5.2. Then press the "Save a Copy of the Model" button. In this case, the model "U2", which is a copy of "U", will be automatically created (Figure 5.5) and it will be a part of the list shown in the "Available Biokinetic Models" frame. It can then be selected as done for the original model. The difference is that the cells on the grids shown on Figures 5.2, 5.3 and 5.4 will be seen with a white background and all the corresponding information will be available for editing.

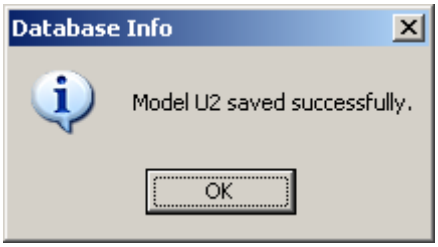


Figure 5.5 The message shown when a copy of a model is created

Delete Model: Any user model can be deleted after it has been selected and its info is shown on the textboxes shown in the "Biokinetic Model Info" frame.

Clear Info: Erases all information on the "Model Editing" form, on the "Compartments" form and on the "Source->Target Fractions and Biological Half-lives" form. However no data or entire model information will be erased on the data files unless the "Delete Model" button is used.

Print Info: To print information from any retrieved model. The resulting output can also be edited or transferred into another text editor.

Import Own Models from Previous Versions of AIDE: All the user's models developed in previous versions of AIDE can be imported to be used with the latest version. The message box titled "Find the MODELS sub-directory from the previous version and select the OWN biokinetic model to be imported into AIDE6\MODELS" will be shown and subsequently a dialog box will appear providing the interface between AIDE and the directory where the biokinetic models are stored. The user models can then be selected and imported.

Figure 5.2 also shows the "Save Modifications" button, which is not enabled. The case shown in this figure refers to an "original" model, which cannot be edited. However this button will be enabled when the user is editing a non-original model.

5.2 User Models

Figure 5.6 shows the "Model Editing" form with empty textboxes. The "Clear Info" button on the form resets all fields and allows the user to enter the information for saving a new biokinetic model. A model name can be up to 8 characters long. A field for observation was provided for inserting comments.

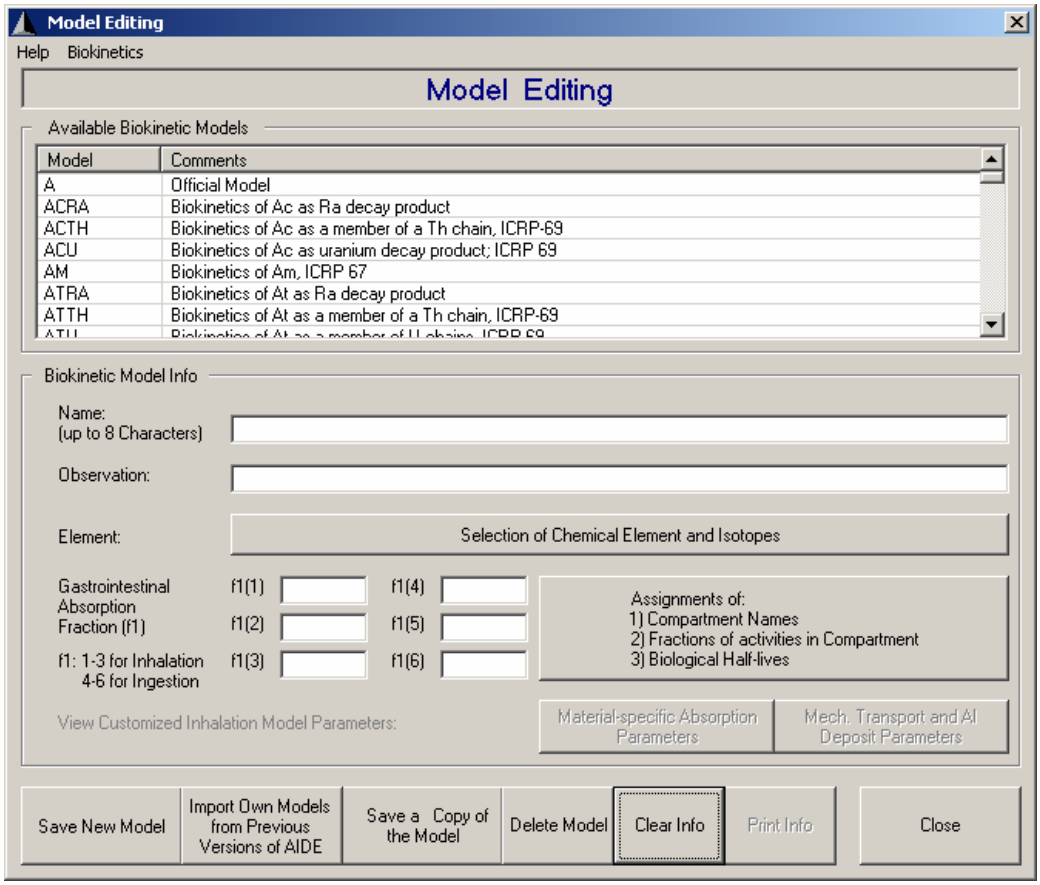


Figure 5.6 The "Model Editing" form ready for new data entry

When the "Selection of Chemical Elements and Isotopes" button is pressed the form named "ICRP-38 Database", shown in Figure 5.7, is loaded. The Periodic Table of the Elements is shown and an element can be selected by clicking on its symbol. When an existing user's model is being edited the chemical element can be reselected. This simple selection procedure means that all possible radioisotopes corresponding to the selected element and associated radioactive decay data and series present in the ICRP Publication 38[15] are automatically selected and will be available when running calculations for activities and doses.

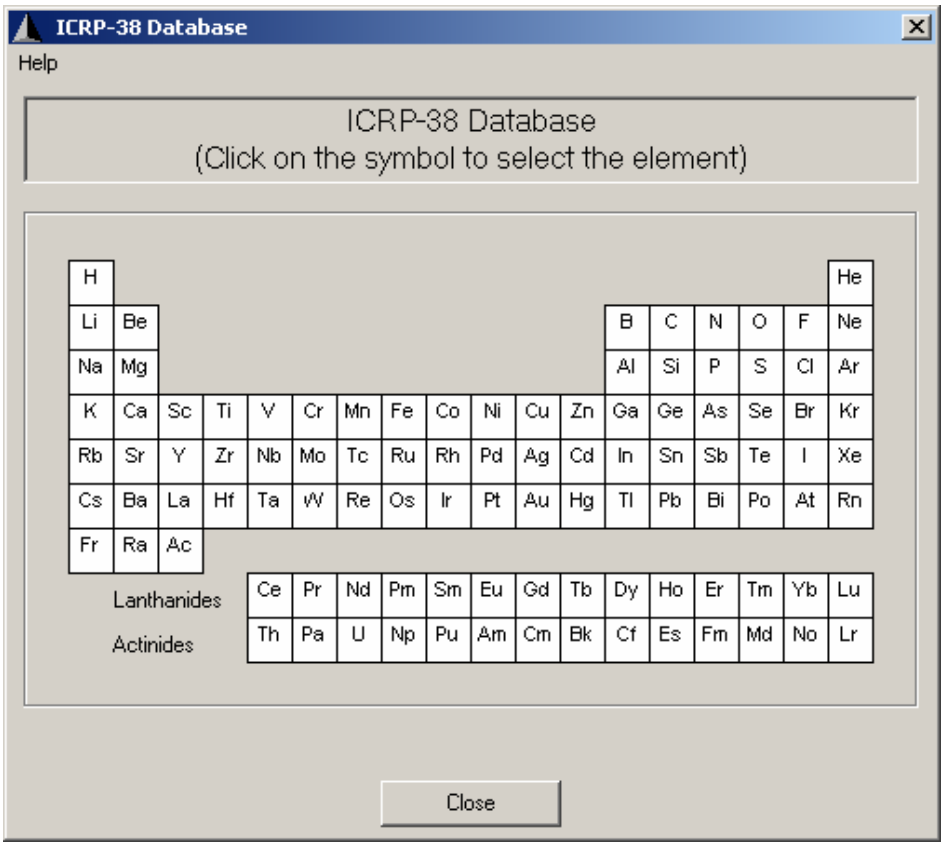


Figure 5.7 The "ICRP-38 Database" form

When a new model is selected and the button named "Assignments of Compartment names ...", shown in Figure 5.6, is pressed the "Compartments" form (Figure 5.3) is loaded and shows the standard organ or tissue names. New compartment names can then be entered providing that these names are limited to 10 characters. Any compartment name can be used. However they must be related to an organ or tissue name from the list shown on the first column. If the organ or tissue has sub-compartments their names should be entered horizontally on the respective cells under the columns named "Subcompart. 1", "Subcompart. 2", etc. When an existing user model is selected compartment names can be inserted or edited. A maximum of fifty compartments can be used.

As already explained above, pressing the "Source-Target Fractions and Biol. Half-lives" button a form with the same name is loaded (Figure 5.4) showing the respective information for all compartment names given in the previous form. Fractions of activity going from and to the several compartments belonging to the model, including the "Plasma" compartment, and those going to urine and feces can be inserted or edited. The associated biological half-lives in days for each source compartment must be placed on the last column. The sum of fractions going from a certain source cannot exceed one and the biological half-lives must be positive numbers.

Back to the "Model Editing" form, in most cases the f1 values are the same for inhalation and ingestion intakes. However some exceptions show different values. In this way, the f1 textboxes numbered 1 to 3 were designed to be used for inhalation intake. The textboxes numbered 4 to 6 should be used for ingestion intake. Nil f1 values for inhalation intake indicate that the absorption type is inexistent.

The section "5.1 Original Models" provides information about the description of the functions of the buttons: "Save a Copy of the Model", "Delete Model", "Clear Info" and "Print Info".

Pressing the "Save New Model" button all the information entered in the forms described above will be saved onto a new file with the selected model name.

As explained above, a model can also be deleted from the list by pressing "Delete Model" providing that it is a user's mode, i.e. the model information is not shown with yellow background.

It was explained in section "3.2.2.1 Save Custom Inhalation Model" how to save a biokinetic model together with customized parameters associated with the Human Respiratory Tract Model, HRTM (ICRP Publication 66[1]), which describe mechanical transport, deposition in the AI Region and material-specific blood absorption. The buttons named "Material-specific Absorption Parameters" and "Mech. Transport and AI Deposit Parameters" will be enabled when a model saved, as explained in section 3.2.2.2, is retrieved for editing in the "Model Editing" form. It must be pointed out that the saved parameters relative to the HRTM can be viewed but cannot be edited and that a only the systemic part of the model can be copied onto another model but not the HRTM parameters.

5.3 Model Names for Radioactive Series

In order to make the software to be able to automatically associate an individual model name to every element of a radioactive series the following format must be followed:
It is not necessary for the model of the mother of the chain to be named after the element symbol. However every model name associated to a daughter must be named by using the element symbol of the daughter followed by the element symbol of the mother. The example below shows how names for the chain associated to ^{238}U have been chosen.

Example for the U-238 series:

U-238	U
Th-234	THU
Pa-234m	PAU
Pa-234	PAU
U-234	U
Th-230	THU
Ra-226	RAU
Rn-222	RNU
Po-218	POU
Pb-214	PBU
At-218	ATU
Bi-214	BIU
Po-214	POU
Pb-210	PBU
Bi-210	BIU
Po-210	POU

5.4 Quality Assurance

The models utilized in this software were adapted from the original models employed by the members of the ICRP Task Group on Dose Calculations to calculate and intercompare doses. The original model parameters were transfer rates, which were "translated" into fractions and biological half-lives and copied into the models, which are used in this software. Activities and dose calculations results have been successfully compared against all those from ICRP Publication 78[(7)] and the ICRP CD[(21)] (Database of Dose Coefficients: Workers and Members of the Public) attesting that the adaptation was properly implemented. Section "3.7 Quality Assurance of Calculations of Activities and Dose Coefficients" gives more details on the quality assurance tests.

6. Directory Structure

This software has the following structure:

AIDE6: It is the root directory. All executables and necessary elements to run the front end application are stored in this directory

AIDE6\DB: All tables to run the dose calculations and the BioMods help file are stored in this directory.

AIDE6\HELP: All help files called by all screens are stored in this directory.

AIDE6\MODELS: All sorts of biokinetic models are stored in this directory.

AIDE6\RESULTS: All files resulting from calculations are stored in this directory. They are overwritten every time a new calculation is carried out.

AIDE6\TABLES: All tables used to store the bioassay quantities and dose coefficients, which will be used to interpret bioassay data are stored in this directory.

REFERENCES

1) International Commission on Radiological Protection, "Human Respiratory Tract Model for Radiological Protection", ICRP Publication 66 (Pergamon Press, Oxford), 1994.

2) International Commission on Radiological Protection, “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 2, Ingestion Dose Coefficients”, ICRP Publication 67, Elsevier Science Ltd, 1993.

3) International Commission on Radiological Protection. “Dose Coefficients for Intakes of Radionuclides by Workers”; ICRP Publication 68, Elsevier Science Ltd., Oxford, 1994.

4) International Commission on Radiological Protection, “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 3, Ingestion Dose Coefficients”, ICRP Publication 69, Elsevier Science Ltd, 1995.

5) International Commission on Radiological Protection, “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 4, Inhalation Dose Coefficients”, ICRP Publication 71, Elsevier Science Ltd., Oxford, 1996.

6) International Commission on Radiological Protection, “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5, Compilation of Ingestion and Inhalation Dose Coefficients”; ICRP Publication 72, Elsevier Science Ltd., Oxford, 1996.

7) International Commission on Radiological Protection, "Individual Monitoring for Internal Exposure of Workers - Replacement of ICRP Publication 54", ICRP Publication 78 (Pergamon Press, Oxford), 1998

8) U.S. Environmental Protection Agency, “Cancer Risk Coefficients for Environmental Exposure to Radionuclides”, Federal Guidance Report 13, EPA 402-R-99-001 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC), 1999.

9) “Methods for Assessing Occupational Radiation Doses Due to Intakes of Radionuclides”, IAEA Safety Reports Series No. 37, IAEA, Vienna 2004.

10) Bertelli, L., Lipsztein, J.L. “A Mathematical Simulation for the Study of Radionuclide Kinetics in the Human Body”, Rad. Prot. Dosim. 18, 4, 209-214, 1987.

11) “General Guidelines For The Estimation Of Committed Effective Dose From Incorporation Monitoring Data (Project IDEAS - EU contract No. FIKR-CT2001-00160), H. Doerfel, A. Andrasi, M. Bailey, V. Berkovski, E. Blanchardon, C.-M. Castellani, C. Hurtgen, B. LeGuen, I. Malatova, J. Marsh, J. Stather, Forschungszentrum Karlsruhe, Wissenschaftliche Berichte, FZKA-7243, 2006.

12) Data Reduction and Error Analysis fro the Physical Sciences, Philip R. Bevington, McGraw-Hill (1969).

13) International Commission on Radiological Protection, "Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values", ICRP Publication 89 (Pergamon Press, Oxford), 2002

14) International Commission on Radiological Protection, “ICRP Supporting Guidance 3: Guide for the Practical Application of the ICRP Human Respiratory Tract Model” (Elsevier), 2003

15) International Commission on Radiological Protection, “Radionuclide Transformations: Energy and Intensity of Emissions”, ICRP Publication 38, (Pergamon Press, Oxford), 1983.

16) National Council on Radiological Protection and Measurements, “Development of a Biokinetic Model For Radionuclide-contaminated Wounds and Procedures for Their Assessment, Dosimetry and Treatment”, NCRP Report no. 156, in Press.

17) International Commission on Radiological Protection, “1990 Recommendations of the International Commission on Radiological Protection”, ICRP Publication 60, (Pergamon Press, Oxford), 1991.

18) International Commission on Radiological Protection, “Recommendations of the International Commission on Radiological Protection”, ICRP Publication 26, (Pergamon Press, Oxford), 1977.

19) Code of Federal Regulations, 10 CFR Part 835, "Occupational Radiation Protection", United States Department of Energy, 1992.

20) International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers", ICRP Publication 30, (Pergamon Press, Oxford), 1979.

21) International Commission on Radiological Protection, "ICRP CD1: Database of Dose Coefficients: Workers and Members of the Public", (Pergamon Press, Oxford), 2002.

22) Cristy, M., Eckerman, K.F., SEECAL: Program to Calculate Age-dependent Specific Effective Energies, ORNL/TM-12351, Oak Ridge National Laboratory, 1993.

Selected Publications Where Previous Versions of This Software Have Been Used.

1) Age-dependent Cs-137 Biological Half-lives Under the Effect of "Prussian Blue" in the Goiania Accident (Bertelli, L., Lipsztein, J.L.), Health Physics abstracts, Health Physics, Vol. 54, Supplement 1, 1988.

2) An Analytical Mathematical Method to Calculate Activity in Body Organs and Excreta (Bertelli, L., Lourenco, M.C., Oliveira, C.A.N., Lipsztein, J.L.), Proceedings of an International Seminar on the Application of Computer Technology to Radiation Protection, IAEA-SR-136/52, 1989.

3) Pharmacokinetic Models Relevant to Toxicity and Metabolism for Uranium in Humans and Animals (Wrenn, M.E., Lipsztein, J.L., Bertelli, L.), Radiation Protection Dosimetry, Vol, 26, 1/4, 1989.

4) Internal Cs-137 Contamination in the Goiania, Brazil Accident (Bertelli, L., Lipsztein, J.L., Oliveira, C.A.N., Melo, D.R.), Proceedings of the Conference on the Medical Basis for Radiation Accident Preparedness, North Holland.

5) Proposal for Optimization in the Interpretation of Bioassay Data for Workers Exposed to Internal Contamination, Ph.D. Thesis, (in Portuguese) Instituto de Biofisica Carlos Chagas Filho, Federal University of Rio de Janeiro, 1990.

6) Studies of Cesium Retention in the Human Body Related to Body Parameters and Prussian Blue Administration (Lipsztein, J.L., Bertelli, L., Oliveira, C.A.N., Dantas, B.M.), Health Physics, Vol. 60, no.1, pp.43-49, 1991.

7) Influence of Tissue Weighting Factors on Risk Weighted Dose Equivalent Quantities (Bertelli, L., Nascimento, J.E.C., Drexler, G.), Radiation Protection Dosimetry, Vol. 37, no. 2, 1991.

8) A Case Study of the Transfer of ^{137}Cs to the Human Fetus and Nursing Infant (Bertelli, L., Oliveira, C.A.N., Lipsztein,. J.L., Wrenn, M.E.), Radiation Protection Dosimetry, Vol. 41, nos. 2-4, 1992.

9) A Comprehensive Metabolic Model for Uranium Metabolism and Dosimetry Based on Human and Animal Data (Wrenn, M.E., Bertelli, L., Durbin P.W., Singh, N.P., Lipsztein, J.L., Eckerman, K.F.), Radiation Protection Dosimetry, Vol. 53, nos. 1-4, 1994.

10) Interpretation of *In Vivo* and Bioassay Results and Dose and ALI Calculations Using a New Uranium Model (Bertelli, L., Wrenn, M.E.), Radiation Protection Dosimetry, Vol. 53, nos. 1-4, 1994.

11) ^{137}Cs Internal Contamination of Members of the Public Involved in an Accident in Brazil and the Efficacy of Prussian Blue Therapy (Melo D.R., Lipsztein J.L., Oliveira C.A.N., Bertelli L.), Health Physics, Vol. 66, no.3, pp 245-251, 1994.

12) A Biokinetic and Dosimetric Model for the Metabolism of Uranium, (M.E. Wrenn, L. Bertelli, P.W. Durbin, K.F. Eckerman, J.L. Lipsztein, N.P. Singh), AECB Report INFO Series 500, Atomic Energy Control Board, Ottawa, Canada, 1995.

13) Interpretation of Bioassay Measurements Using Different Systemic Models for Plutonium, (L. Bertelli , M.E. Wrenn), Journal of Radioanalytical and Nuclear Chemistry, Vol. 197, no. 1, 67-78 (1995).

14) Modified Respiratory Tract Model for Uranium: Its Implications on Bioassay Interpretations, (M.E. Wrenn, L. Bertelli), Journal of Radioanalytical and Nuclear Chemistry, Vol. 197, no. 1, 196-202 (1995).

15) Specific Absorption Parameters for Uranium Octoxide and Dioxide: Comparison of Values Derived from Human Data and Those Predicted from Animal Studies (Bertelli L., Puerta A., Wrenn M.E., Lipsztein J.L., Moody J.C., Stradling G.N., Hodgson A. and Fell T.P.) Radiation Protection Dosimetry, Vol. 79, nos. 1-4, 87-90, 1998.

16) Bioassay Interpretation and Dosimetry Using Specific Absorption Parameters For UO_2 and U_3O_8 (Bertelli L., Puerta A., Wrenn M.E., Lipsztein J.L.) Radiation Protection Dosimetry, Vol. 79, nos. 1-4, 111-113, 1998

17) Sensitivity of Doses and Associated Uncertainties in Bioassay Estimates to ICRP Publication 66 Respiratory Tract Dosimetric Model With Respect to the Parameters: Ventilation Rates, Time Budget, Total and Regional Deposition, Oral versus Nasal Breathing and Clearance Rates of Compartments (Bertelli, L., Guilmette, R.A., Singh, N.P.) Journal of Radioanalytical and Nuclear Chemistry, Vol. 252, No.2, 327-338, Akademiai Kiado, Budapest, Hungary and Kuwer Academic Publishers, Dordrecht, The Netherlands, 2002.