Taurus Advanced

The Taurus software package performs intake and dose calculations for internal radiological contamination in occupational exposures. It was developed by the UK Health Security Agency's Internal Dosimetry Group.

Taurus provides a simple graphical user interface (GUI) to UKHSA's internal dosimetry computer code Pleiades (Fell T.P. et al, 2007). Pleiades is written in Fortran and has been used for the calculation of reference dose coefficients and bioassay quantities published in the International Commission on Radiological Protection (ICRP) Occupational Intakes of Radionuclides series of publications (ICRP 2016b, 2017, 2019).
Taurus thus implements the most recent ICRP recommendations (ICRP 2007) and the accompanying biokinetic, dosimetric models (ICRP 2009, 2015, 2016a, 2016b, 2017, 2019, 2022) and radiological decay data (ICRP 2008).

In addition to calculating radionuclide activity in organs and excreta and committed doses due to occupational exposures, Taurus also estimates radionuclide intakes from bioassay data. Taurus uses the well proven maximum-likelihood fitting module previously used in UKHSA's IMBA software (Birchall et al,2003) which can produce robust estimates of multiple intakes using several types of bioassay data, including censored observations (e.g. less than the limit of detection results). Activity and doses are given in S.I. units of bequerel (Bq) and sievert (Sv).

Plotting of measurements and bioassay predictions is through Dynamic Data Exchange with Dplot Graph software for scientists and engineers, by Hydesoft computing LLC, a freely distributable restricted functionality version of which (DPlot Jr) is included in the Taurus installation package. If a full version of DPlot is installed Taurus will benefit from the increased functionality which this provides.

The Taurus GUI was built using the Winteracter Portable Fortran user interface and graphics toolset by Interactive Software Services Ltd.

Taurus Advanced is intended to meet the needs of internal dose specialists and researchers and provides more advanced functionality than the base version. As with the base version, Taurus Advanced enables the user to:

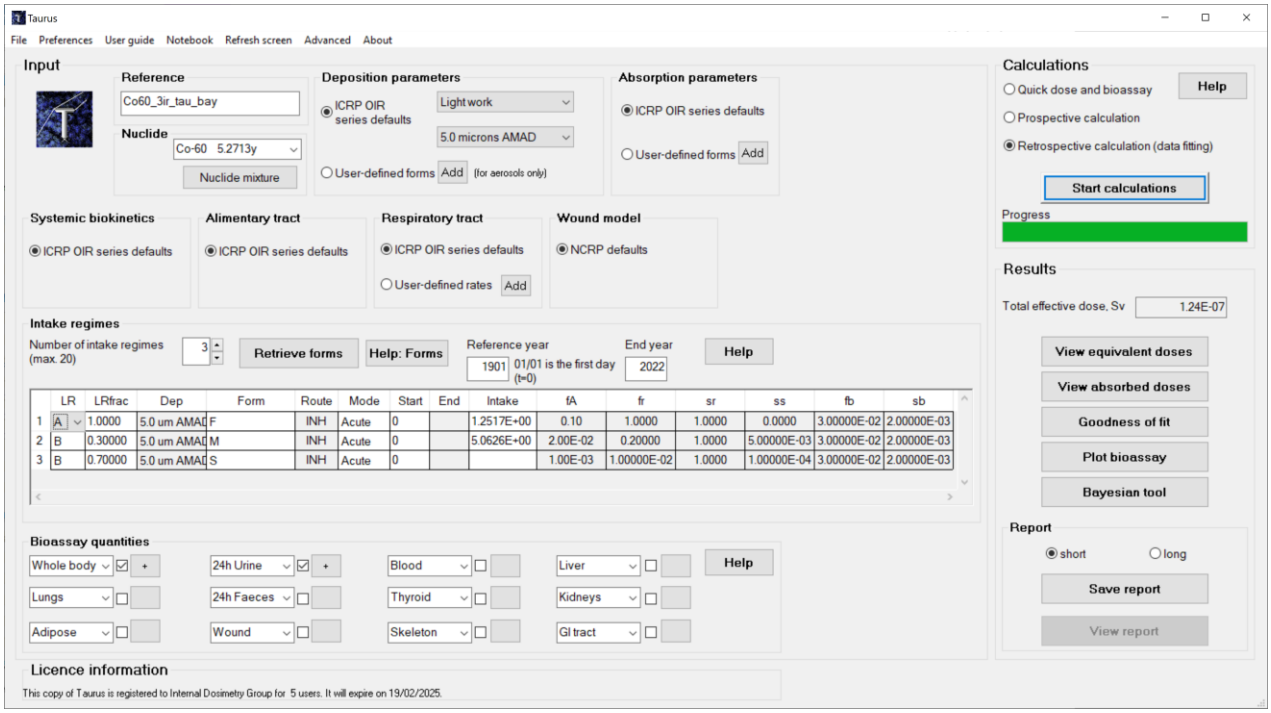
- calculate equivalent organ doses and effective doses and bioassay quantities at pre-defined time-points from one or more specified acute or chronic intakes
- calculate doses and bioassay quantities at user-specified time points from one or more specified acute or chronic intakes
- estimate single or multiple intakes from measurements of activity in the body and/or excreta and to calculate the resulting doses.

Some of the base functionality has been extended and new functions have been added in the advanced version:

- extended list of bioassay quantities
- allows the addition of up to five user-defined forms (absorption parameters)
- user-defined deposition parameters and particle transport rates for the respiratory tract
- uranium mixtures, plutonium-americium mixtures and user-defined mixtures
- NCRP wound model
- annual equivalent and absorbed doses (for compensation scheme calculations), sorted by year or organ/tissue

- linked intake regimes
- Bayesian tool for the calculation of posterior distributions for intake(s) and effective dose

Main screen

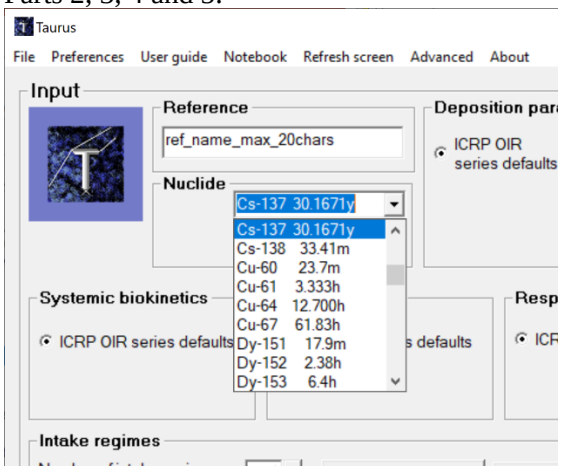


The Main Screen is divided into three main functional areas:

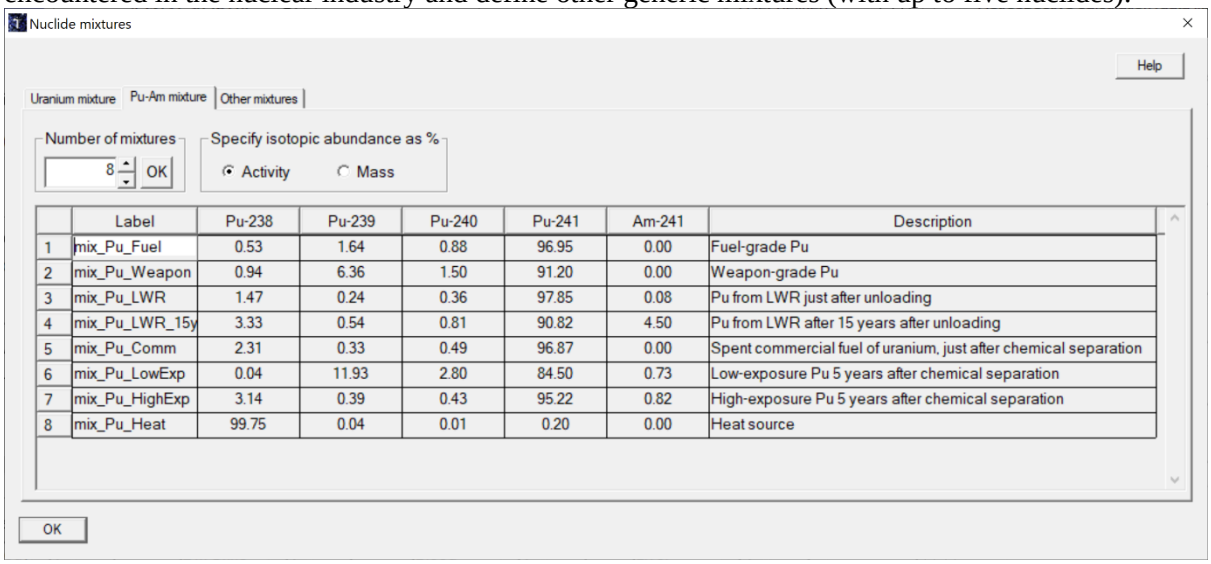
- **Input** - where the user defines the parameters for the calculations
- **Calculations** - where the user can choose between two prospective and one retrospective types of calculation to be performed
- **Results** - where calculated doses, goodness-of-fit metrics, plots of measurements and bioassay predictions are accessible, including summary reports in html format.

Nuclides and nuclide mixtures

The user can select from a drop-down menu one of the 880 nuclides which are included in ICRP OIR Parts 2, 3, 4 and 5.



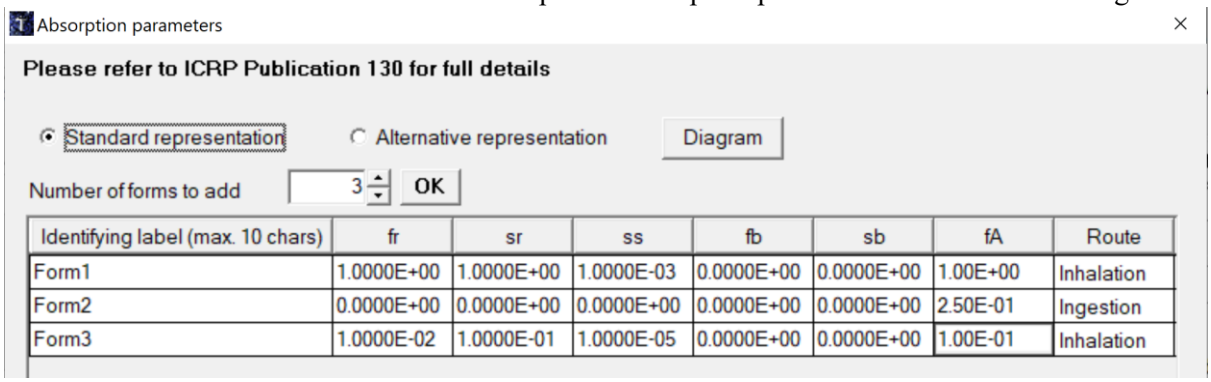
In addition, the user can choose from a number of pre-defined uranium and plutonium mixtures encountered in the nuclear industry and define other generic mixtures (with up to five nuclides).



	Label	Pu-238	Pu-239	Pu-240	Pu-241	Am-241	Description
1	mix_Pu_Fuel	0.53	1.64	0.88	96.95	0.00	Fuel-grade Pu
2	mix_Pu_Weapon	0.94	6.36	1.50	91.20	0.00	Weapon-grade Pu
3	mix_Pu_LWR	1.47	0.24	0.36	97.85	0.08	Pu from LWR just after unloading
4	mix_Pu_LWR_15y	3.33	0.54	0.81	90.82	4.50	Pu from LWR after 15 years after unloading
5	mix_Pu_Comm	2.31	0.33	0.49	96.87	0.00	Spent commercial fuel of uranium, just after chemical separation
6	mix_Pu_LowExp	0.04	11.93	2.80	84.50	0.73	Low-exposure Pu 5 years after chemical separation
7	mix_Pu_HighExp	3.14	0.39	0.43	95.22	0.82	High-exposure Pu 5 years after chemical separation
8	mix_Pu_Heat	99.75	0.04	0.01	0.20	0.00	Heat source

User-defined absorption parameters

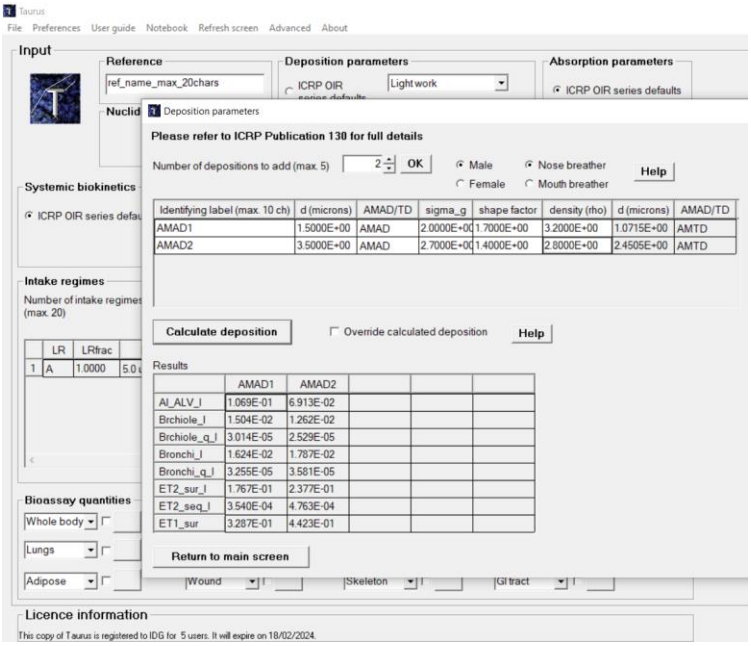
The user can define additional ‘Forms’ with specific absorption parameters for inhalation or ingestion.



Identifying label (max. 10 chars)	fr	sr	ss	fb	sb	fA	Route
Form1	1.0000E+00	1.0000E+00	1.0000E-03	0.0000E+00	0.0000E+00	1.00E+00	Inhalation
Form2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.50E-01	Ingestion
Form3	1.0000E-02	1.0000E-01	1.0000E-05	0.0000E+00	0.0000E+00	1.00E-01	Inhalation

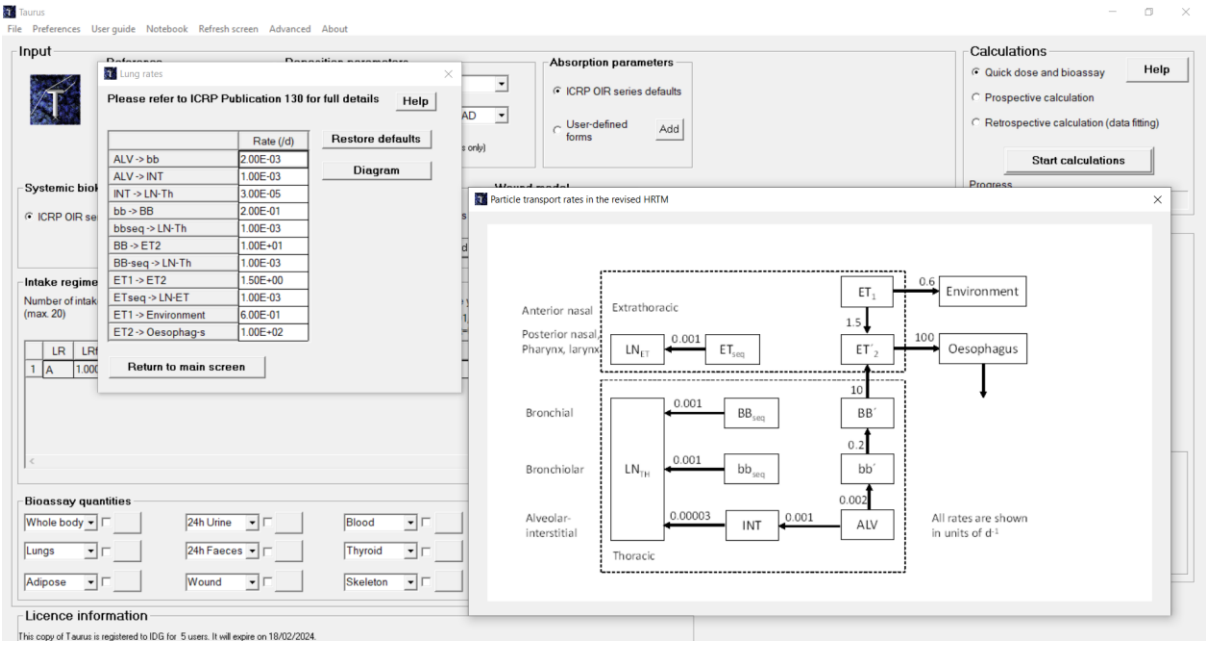
User-defined respiratory tract deposition parameters

The user can set specific values for parameters used in the calculation of the deposition fractions, as aerosol parameters (particle size, density, etc).



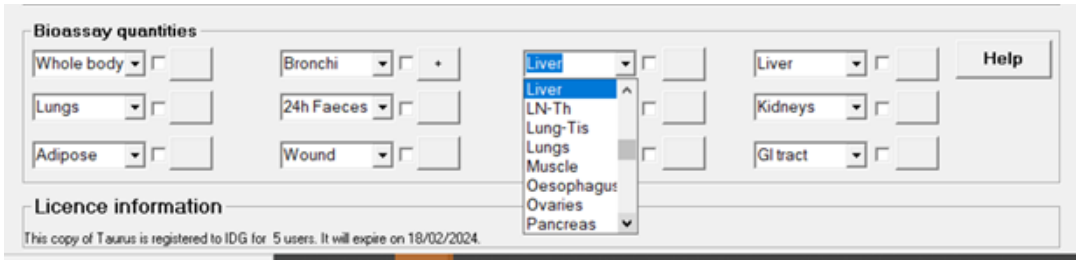
User-defined HRTM particle transport parameters

The user can set specific values for the particle transport rates of the revised Human Respiratory Tract Model (HRTM).

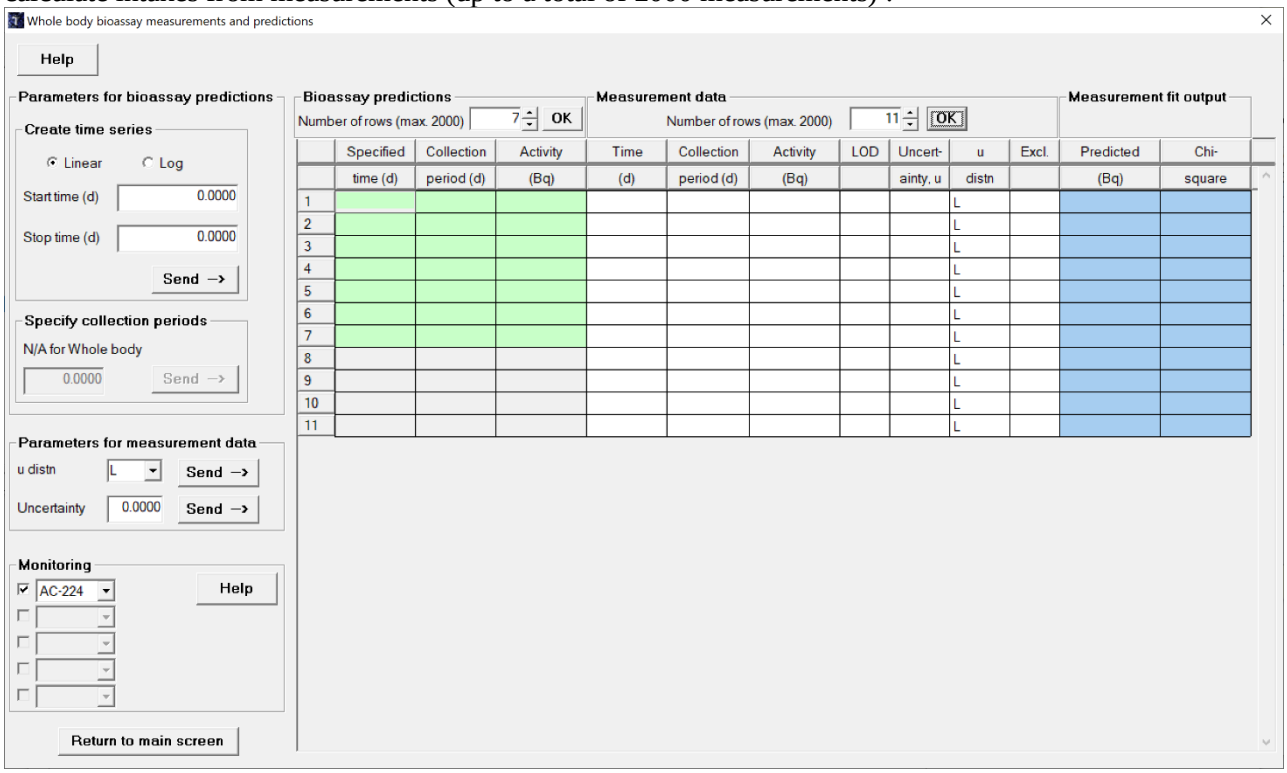


Bioassay

Taurus can simultaneously calculate predictions over time for up to 12 common bioassay quantities. A bioassay quantity can be selected from a list of 52 different bioassay types.



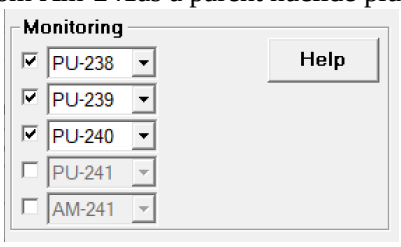
Taurus can calculate bioassay predictions (activity in organs or excretions) at specific time-points and calculate intakes from measurements (up to a total of 2000 measurements) :

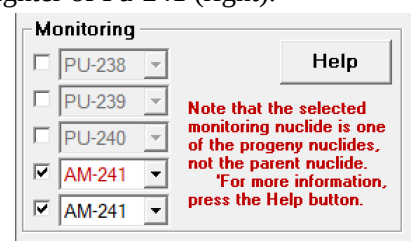


Monitoring

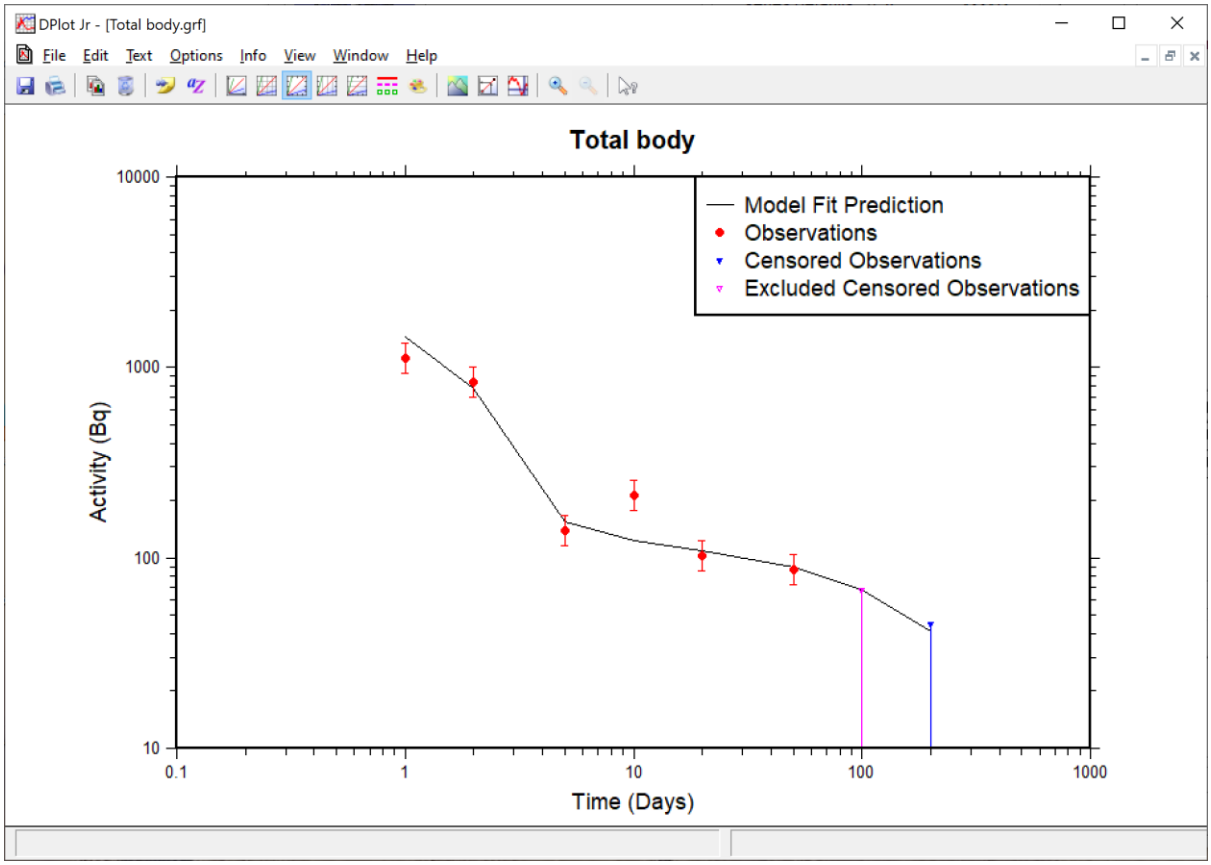
The user can select which nuclide to monitor, either the parent nuclide or one of the progeny nuclides in the decay chain. When calculations are done for a nuclide mixture, the user can specify which nuclide(s) have been monitored and, optionally, whether to monitor the parent nuclide or one nuclide of its progeny in the decay chain.

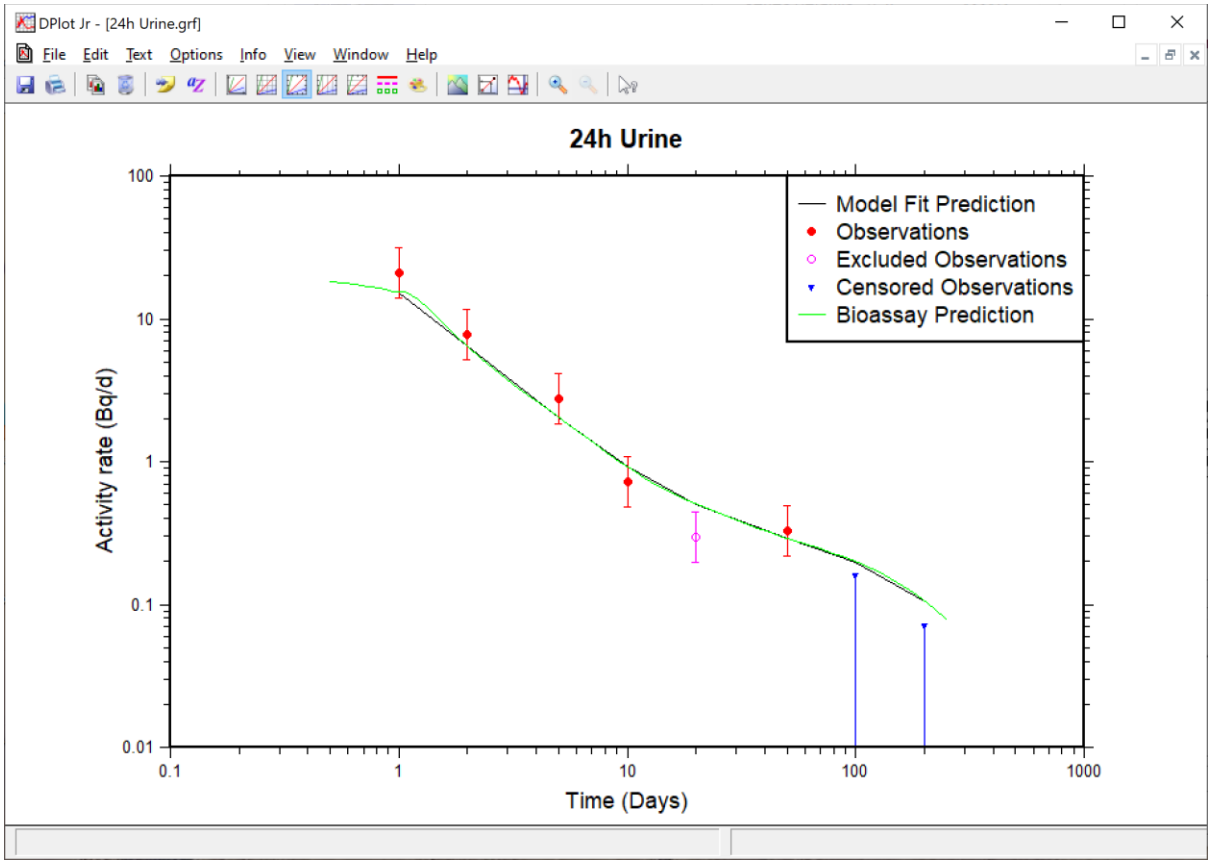
For example, for a Pu-Am mixture: monitoring total activity from Pu-238,Pu-239 and Pu-240 (left) or from Am-241as a parent nuclide plus Am-241 grown in as a daughter of Pu-241 (right).





Plot of bioassay data



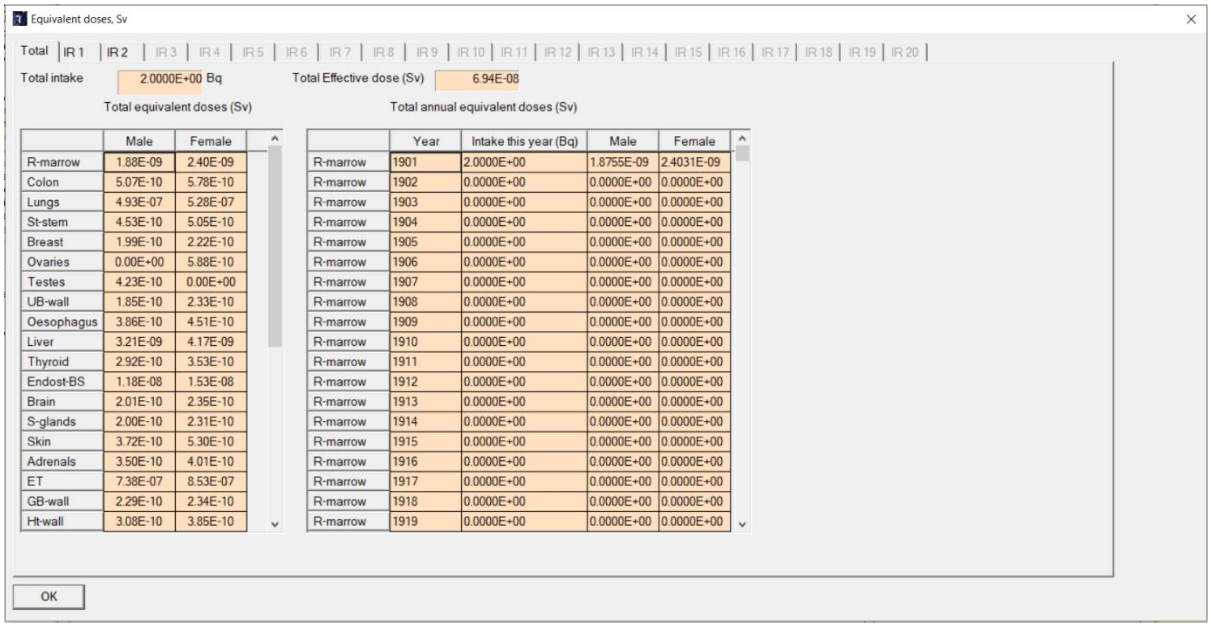


View equivalent doses and annual absorbed doses

Committed effective doses and committed equivalent doses as well as annual absorbed (and equivalent) doses are shown once the selected calculation is completed.

Tables for effective and equivalent doses (total and for each intake regime)

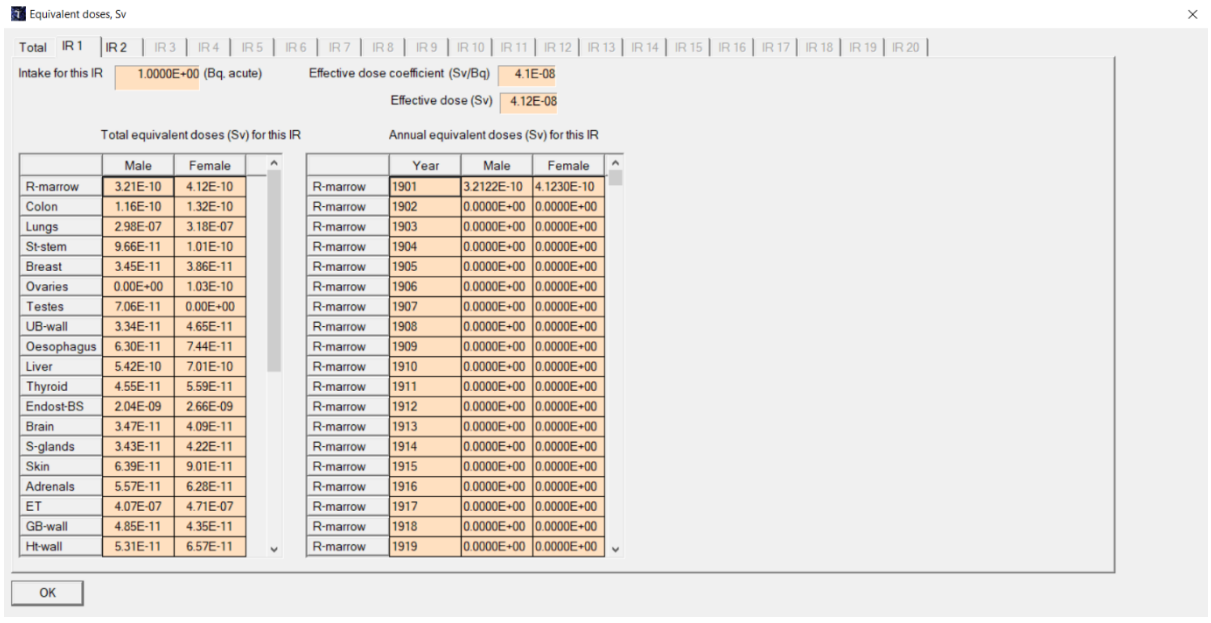
Male and female total equivalent organ doses (summed over all intake regimes) are shown: both the 50-year committed dose (table on the left) and the annual contribution (table on the right). Annual doses can be ordered either by year or by organ.



	Male	Female
R-marrow	1.88E-09	2.40E-09
Colon	5.07E-10	5.78E-10
Lungs	4.93E-07	5.28E-07
St-stem	4.53E-10	5.05E-10
Breast	1.99E-10	2.22E-10
Ovaries	0.00E+00	5.88E-10
Testes	4.23E-10	0.00E+00
UB-wall	1.85E-10	2.33E-10
Oesophagus	3.86E-10	4.51E-10
Liver	3.21E-09	4.17E-09
Thyroid	2.92E-10	3.53E-10
Endost-BS	1.18E-08	1.53E-08
Brain	2.01E-10	2.35E-10
S-glands	2.00E-10	2.31E-10
Skin	3.72E-10	5.30E-10
Adrenals	3.50E-10	4.01E-10
ET	7.38E-07	8.53E-07
GB-wall	2.29E-10	2.34E-10
Ht-wall	3.08E-10	3.85E-10

	Year	Intake this year (Bq)	Male	Female
R-marrow	1901	2.0000E+00	1.8755E-09	2.4031E-09
R-marrow	1902	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1903	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1904	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1905	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1906	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1907	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1908	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1909	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1910	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1911	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1912	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1913	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1914	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1915	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1916	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1917	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1918	0.0000E+00	0.0000E+00	0.0000E+00
R-marrow	1919	0.0000E+00	0.0000E+00	0.0000E+00

Male and female equivalent organ doses for each intake regime are shown: both the 50-year committed dose (table on the left) and the annual contribution (table on the right).

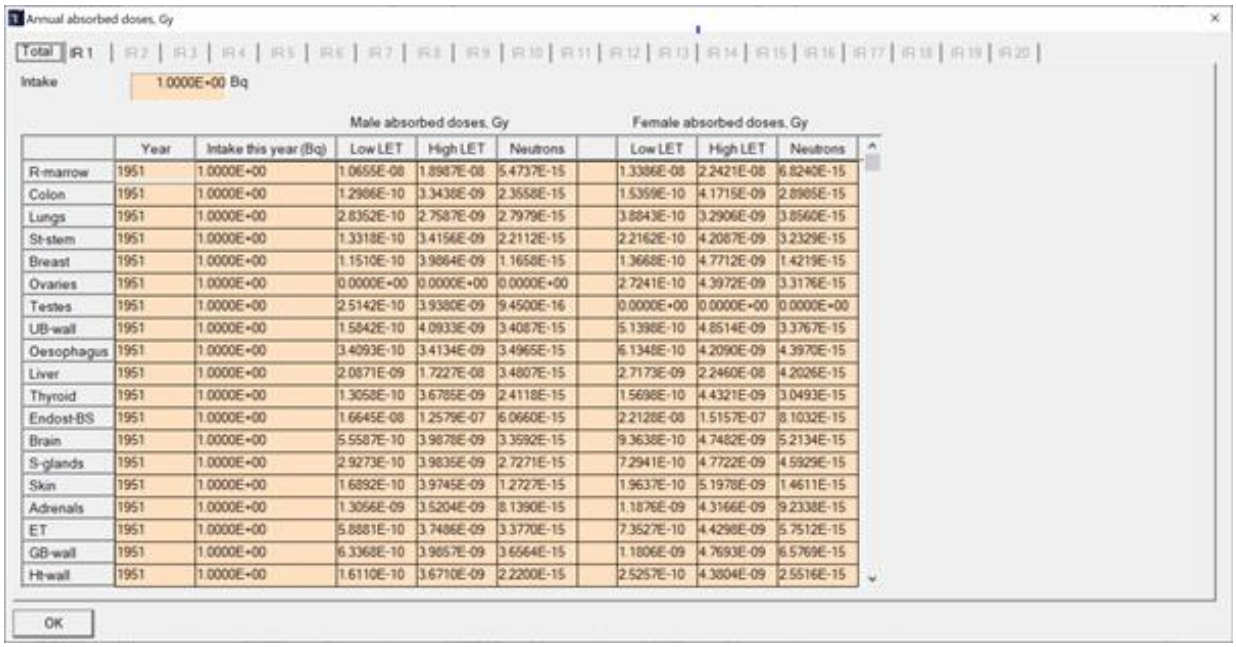


	Male	Female
R-marrow	3.21E-10	4.12E-10
Colon	1.16E-10	1.32E-10
Lungs	2.98E-07	3.18E-07
St-stem	9.66E-11	1.01E-10
Breast	3.45E-11	3.86E-11
Ovaries	0.00E+00	1.03E-10
Testes	7.06E-11	0.00E+00
UB-wall	3.34E-11	4.65E-11
Oesophagus	6.30E-11	7.44E-11
Liver	5.42E-10	7.01E-10
Thyroid	4.55E-11	5.59E-11
Endost-BS	2.04E-09	2.66E-09
Brain	3.47E-11	4.09E-11
S-glands	3.43E-11	4.22E-11
Skin	6.39E-11	9.01E-11
Adrenals	5.57E-11	6.28E-11
ET	4.07E-07	4.71E-07
GB-wall	4.85E-11	4.35E-11
Ht-wall	5.31E-11	6.57E-11

	Year	Male	Female
R-marrow	1901	3.2122E-10	4.1230E-10
R-marrow	1902	0.0000E+00	0.0000E+00
R-marrow	1903	0.0000E+00	0.0000E+00
R-marrow	1904	0.0000E+00	0.0000E+00
R-marrow	1905	0.0000E+00	0.0000E+00
R-marrow	1906	0.0000E+00	0.0000E+00
R-marrow	1907	0.0000E+00	0.0000E+00
R-marrow	1908	0.0000E+00	0.0000E+00
R-marrow	1909	0.0000E+00	0.0000E+00
R-marrow	1910	0.0000E+00	0.0000E+00
R-marrow	1911	0.0000E+00	0.0000E+00
R-marrow	1912	0.0000E+00	0.0000E+00
R-marrow	1913	0.0000E+00	0.0000E+00
R-marrow	1914	0.0000E+00	0.0000E+00
R-marrow	1915	0.0000E+00	0.0000E+00
R-marrow	1916	0.0000E+00	0.0000E+00
R-marrow	1917	0.0000E+00	0.0000E+00
R-marrow	1918	0.0000E+00	0.0000E+00
R-marrow	1919	0.0000E+00	0.0000E+00

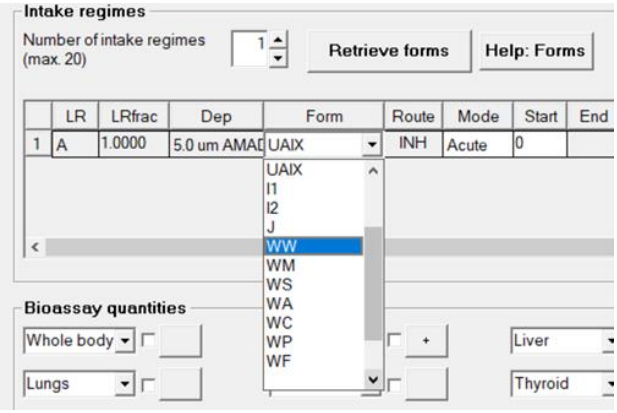
Tables for annual absorbed doses (total and for each intake regime)

Male and female absorbed doses are shown for each organ and for each calendar year in the period specified by the user, as contributions from low and high LET radiation and neutrons. The table shows the total dose and the contribution from each intake regime. Doses can be ordered either by year or by organ.



	Year	Intake this year (Bq)	Male Low LET	Male High LET	Male Neutrons	Female Low LET	Female High LET	Female Neutrons
R-marrow	1951	1.0000E+00	1.0655E-08	1.8987E-08	5.4737E-15	1.3386E-08	2.2421E-08	6.8240E-15
Colon	1951	1.0000E+00	1.2966E-10	3.3438E-09	2.3558E-15	1.5359E-10	4.1715E-09	2.8985E-15
Lungs	1951	1.0000E+00	2.8352E-10	2.7587E-09	2.7979E-15	3.8843E-10	3.2906E-09	3.8560E-15
St-stem	1951	1.0000E+00	1.3318E-10	3.4156E-09	2.2112E-15	2.2162E-10	4.2087E-09	3.2329E-15
Breast	1951	1.0000E+00	1.1510E-10	3.9864E-09	1.1658E-15	1.3668E-10	4.7712E-09	1.4219E-15
Ovaries	1951	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.7241E-10	4.3972E-09	3.3176E-15
Testes	1951	1.0000E+00	2.5142E-10	3.9380E-09	9.4500E-16	0.0000E+00	0.0000E+00	0.0000E+00
UB-wall	1951	1.0000E+00	1.5842E-10	4.0933E-09	3.4087E-15	5.1398E-10	4.8514E-09	3.3767E-15
Oesophagus	1951	1.0000E+00	3.4093E-10	3.4134E-09	3.4965E-15	6.1348E-10	4.2090E-09	4.3970E-15
Liver	1951	1.0000E+00	2.0871E-09	1.7227E-08	3.4807E-15	2.7173E-09	2.2460E-08	4.2026E-15
Thyroid	1951	1.0000E+00	1.3058E-10	3.6785E-09	2.4118E-15	1.5698E-10	4.4321E-09	3.0493E-15
Endost-BS	1951	1.0000E+00	1.6645E-08	1.2579E-07	6.0660E-15	2.2128E-08	1.5157E-07	8.1032E-15
Brain	1951	1.0000E+00	5.5587E-10	3.9878E-09	3.3592E-15	9.3638E-10	4.7482E-09	5.2134E-15
S-glands	1951	1.0000E+00	2.9273E-10	3.9835E-09	2.7271E-15	7.2941E-10	4.7722E-09	4.5929E-15
Skin	1951	1.0000E+00	1.6892E-10	3.9745E-09	1.2727E-15	1.9637E-10	5.1978E-09	1.4611E-15
Adrenals	1951	1.0000E+00	1.3056E-09	3.5204E-09	8.1390E-15	1.1876E-09	4.3166E-09	9.2338E-15
ET	1951	1.0000E+00	5.8881E-10	3.7486E-09	3.3770E-15	7.3527E-10	4.4298E-09	5.7512E-15
GB-wall	1951	1.0000E+00	6.3368E-10	3.9857E-09	3.6564E-15	1.1806E-09	4.7693E-09	6.5769E-15
Ht-wall	1951	1.0000E+00	1.6110E-10	3.6710E-09	2.2200E-15	2.5257E-10	4.3804E-09	2.5516E-15

Wound model



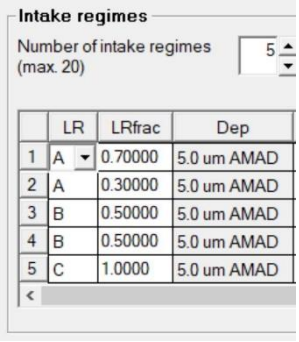
In addition to exposure via inhalation, ingestion and injection, Taurus Advanced enables the user to also analyse cases of wound radionuclide-contamination.

Intakes from contaminated wounds are treated as special cases of injection and the user can select one of the seven predefined NCRP Wound categories. [National Council on Radiation Protection and Measurements Report No. 156, (2006).]

Activity measurements of the wound-site can also be added and used to estimate intakes.

Linked intake regimes

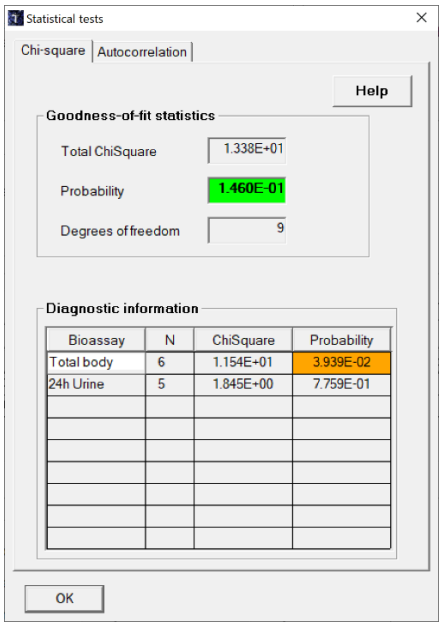
Taurus enables the user to deal with up to 20 separate intake regimes simultaneously. Each regime is characterised by its specific exposure route (inhalation, ingestion, …), absorption parameters (in the respiratory and alimentary tract), by the acute or chronic nature of the exposure and the corresponding time or time-interval of exposure.



By default, the intake regimes are treated as independent, i.e., for a retrospective calculation the contribution to the total intake (Bq) of each intake regime is calculated as an independent contribution.

The concept of ‘linked intake regimes’ is particularly useful in retrospective calculations when the total intake is unknown but the relative contribution of each intake regime in a ‘linked group’ is known.

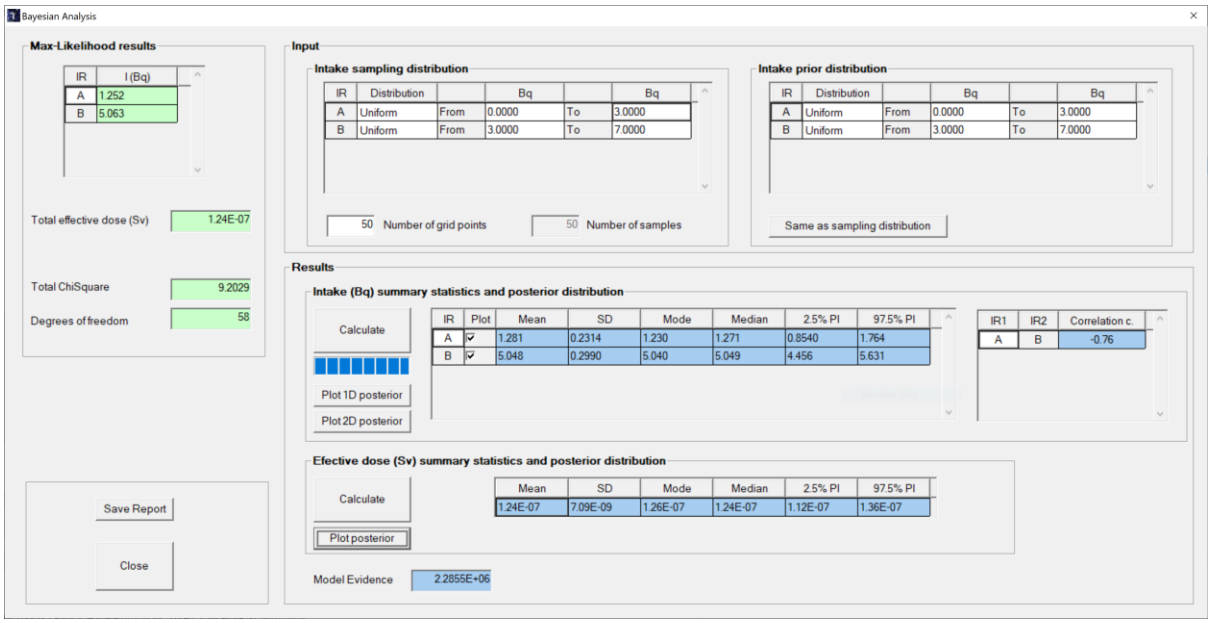
Information on goodness-of-fit



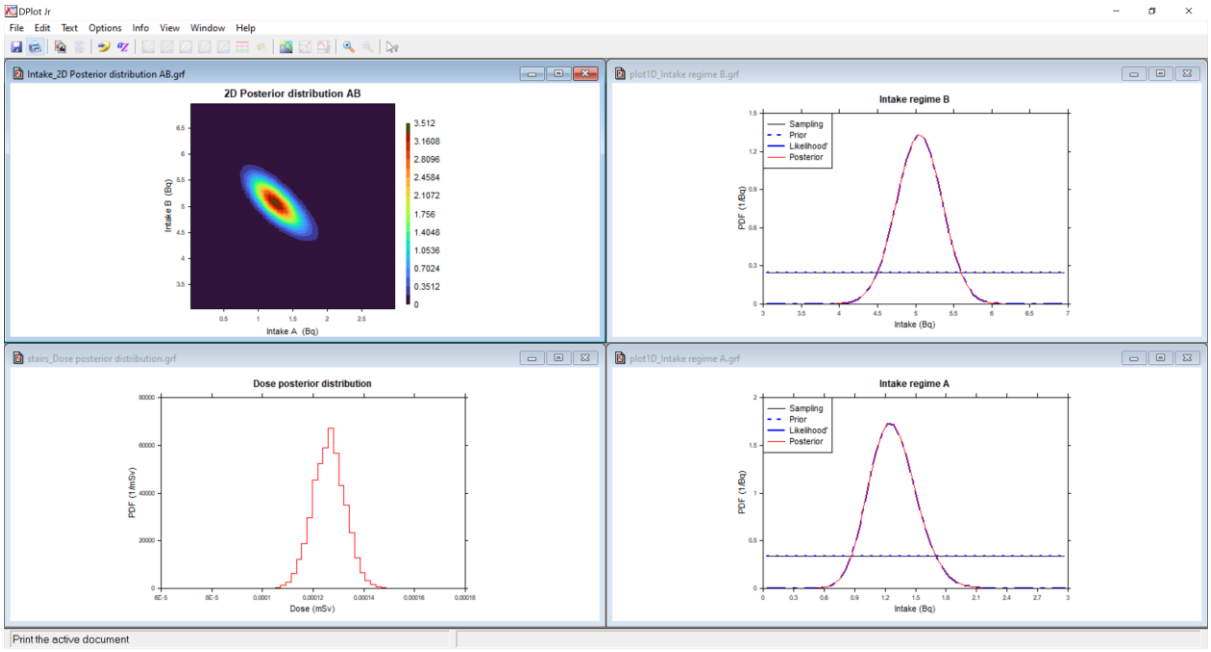
The result of a chi-square test and an autocorrelation test are shown, as well as diagnostic information for each of the bioassay sets used in the maximum-likelihood fitting.

Bayesian analysis tool

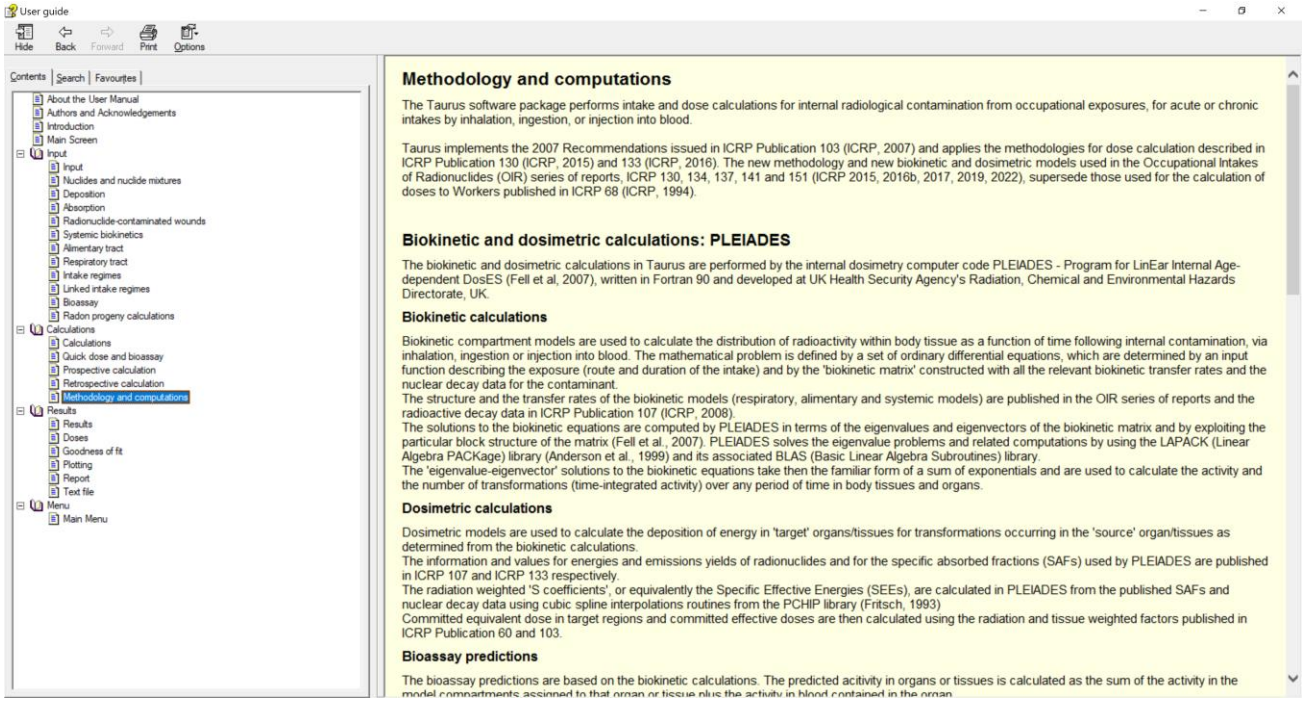
After completing a retrospective calculation, the user can calculate the posterior probability distribution and summary statistics (e.g., mean, standard deviation) of the intake(s) and of the total effective dose providing information on intake prior distribution (Uniform, logUniform, Normal and LogNormal choices are available) using the importance sampling method.

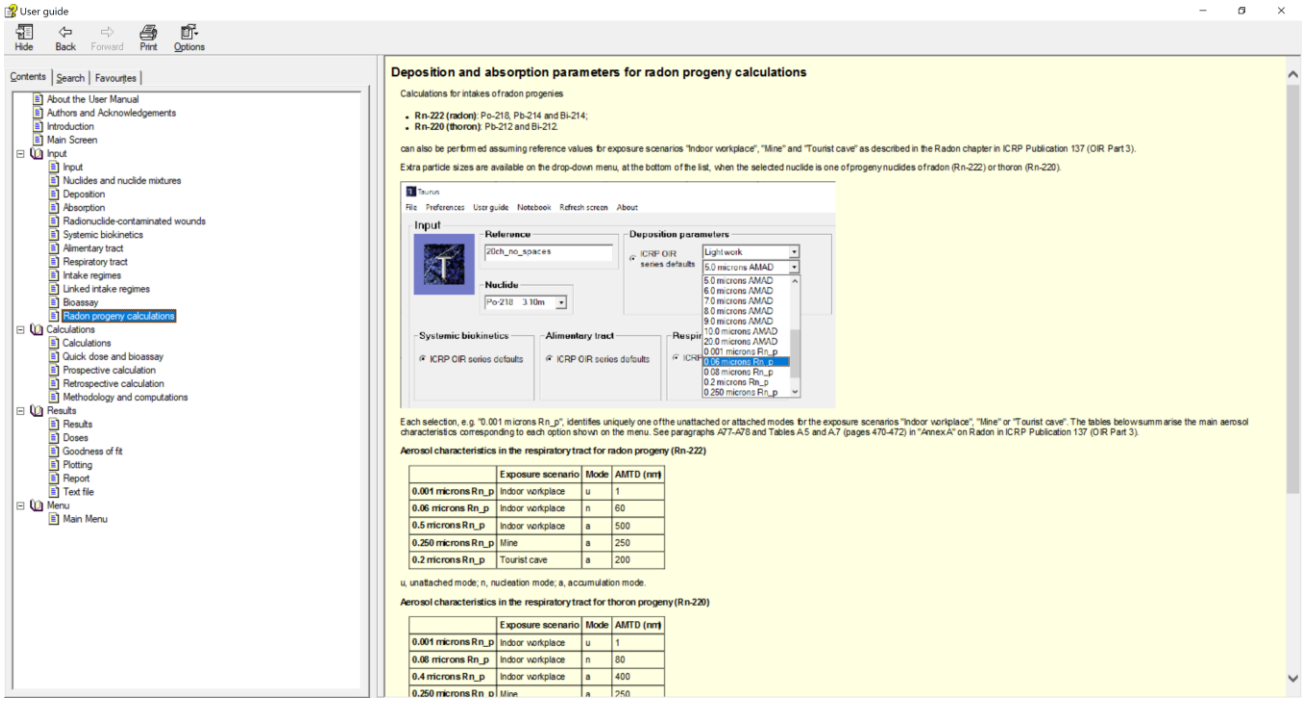


Plots of probability distributions (1D and 2D) are shown for intakes and for the total effective dose.



Comprehensive User Guide





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