EXERCISE 1: CALCULATION OF OUTDOOR EXPOSURE OF REFERENCE INDIVIDUAL USING RADIATION MONITORING DATA

1. General description of problem

In this exercise we use NORMALYSA to calculate radiation exposure of an individual carrying out works at radioactively contaminated site. As an input data for dose calculations we use radiation monitoring (measurements) data on ambient dose rate and radionuclide concentrations in the air and in the soil.

1.1 Contamination source term (contaminated site)

We consider a radioactively contaminated site that is used as an industrial area.

The soil of site is contaminated by Cs-137 and Sr-90.

Within the site, two areas are distinguished: "Area A" and "Area B", that differ with regard to contamination level, and for which different sets of radiation monitoring data are available (FIG 1).

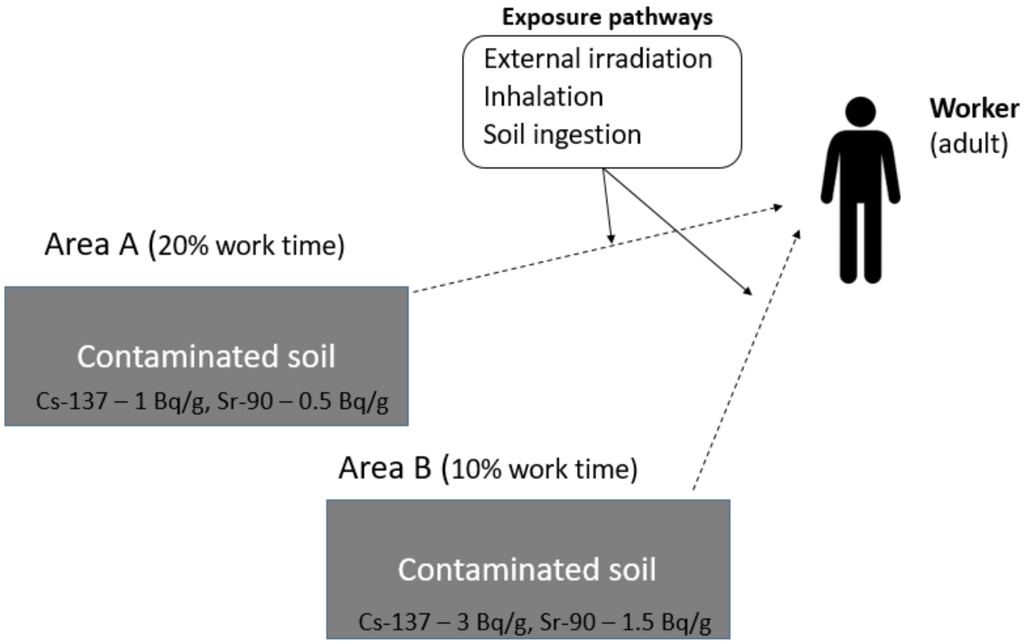

FIG 1. Illustrative scheme of exposure of reference individual for Exercise 1a.

1.2 Reference persons and exposure scenario

The reference individual for dose calculations is an adult (industrial worker) visiting contaminated site (including both Areas A and B) to carry out outdoor works at these sites.

It is assumed that the reference individual passes annually 20% of his working time in Area A, and 10% of his time in Area B.

The following *exposure pathways* are taken into account:

- External exposure;
- Inhalation of radioactive aerosols;
- Inadvertent ingestion of contaminated soil.

It is assumed that the reference individual does not use any protective means (e.g., respirator).

1.3 Calculation end-points

The calculation end-points are annual effective doses received by reference individual for the described above exposure scenario.

The doses shall be calculated:

- For each exposure pathway;
- For each area (Area A and B);
- For each radionuclide (Cs-137 and Sr-90) – for Area B.

In addition, the total annual effective dose shall be calculated.

2. Input data

The input data include radiation monitoring data for areas A and B. All radiation monitoring data presented below shall be interpreted as an excess above background contamination levels.

2.1 Radiation monitoring data for Area A

For “Area A” known radiation monitoring data include annual average ambient dose rate and radionuclide concentrations in air and soil.

Annual average ambient dose rate above background is 0.12 µSv/hour. Soil and air activity data are listed in Table 1.

Table 1. Radionuclide concentrations in air and soil of Area A

Radionuclide	Soil concentration, Bq/g	Air concentration, Bq/m^3
Cs-137	1	4E-5
Sr-90	0.5	1.5E-5

2.2 Radiation monitoring data for Area B

For “Area B” the only known parameter is radionuclide concentration is soil.

We complement the soil activity data with air activity data. Air activity is calculated from soil concentration assuming dust load of 5E-8 kg/m^3 (Table 2).

Table 2. Radionuclide concentrations in air and soil of Area B.

Radionuclide	Soil concentration, Bq/g	Air concentration, Bq/m^3 *
Cs-137	3	1.5 E-4
Sr-90	1.5	0.75 E-4

* Calculated from soil concentration assuming dust load of 5E-8 kg/m^3.

2.3 Habits of reference individual

It is assumed that the reference individual passes annually 20% of his working time in Area A, and 10% of his time in Area B.

3. General description of implementation of problem in NORMALYSA

3.1 Modules and modelling options used

To carry out calculations for the discussed above problem we will use two modules 'Dose from occupancy outdoors' from 'Doses' library of NORMALYSA. These modules will be configured to carry out calculations respectively for area A and B.

To calculate the total (integral) dose received in area A and B the 'Total Dose' module will be used, that will carry out summing of doses calculated by respective 'Dose from occupancy outdoors' modules.

To calculate some end-point parameters (e.g., doses per work area, doses per radionuclide for Area B) we will export calculation results to Excel file, and will carry out additional calculations using Excel spreadsheet.

Modelling options

When calculating radiation exposure in Area A we will use immediately radiation monitoring data on annual average ambient dose rate and radionuclide concentrations in soil and air.

When calculating radiation exposure in Area B we will use modeling option allowing calculate ambient dose rate (that is not available from monitoring data) from radionuclide concentrations in soil and air.

3.2 NORMALYSA model structure and data exchanges between modules

The structure of NORMAYSA model for Exercise 1 in the form of block-scheme is shown in FIG 2.

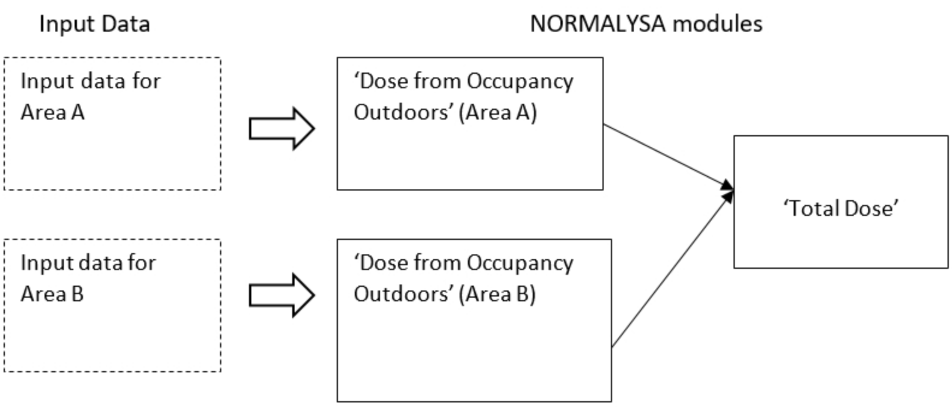

FIG 3. The structure of NORMAYSA model for Exercise 1.

3.3 General description of modelling steps

To solve the describe above problem using NORMALYSA, modeller needs to carry out the general sequence of steps shown in FIG 4. This is accomplished by going through different positions of the NORMALYSA main menu (shown to the left in the main software interface window).

The rationale of each NORMALYSA menu position (and respective modelling step) is briefly explained below.

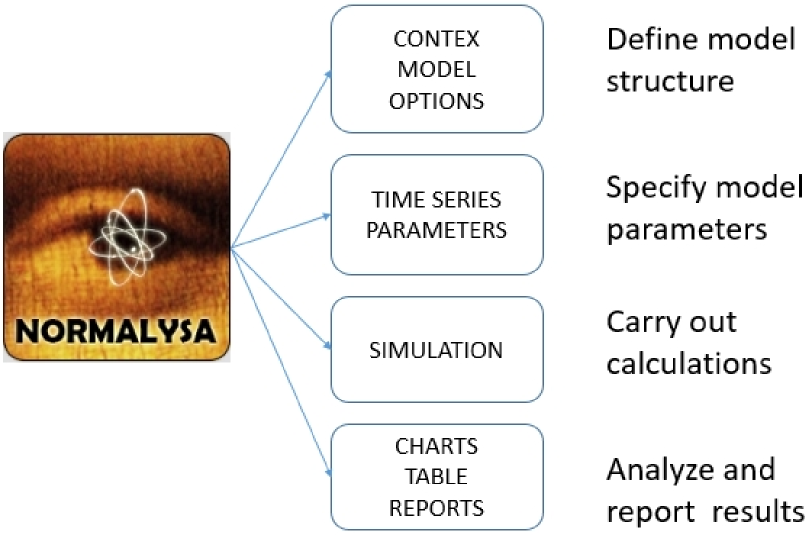

FIG 4. Sequence of modelling steps.

Setting the assessment context ('Context')

In this step, the NORMALYSA project file is created defining the simulation case. In particular, user specifies the name of the project file, and selects radionuclides to be included to the simulation case.

Modeler also has a possibility to activate or de-activate specific index lists relevant to modeled case such as, for example, 'Exposed Groups', included to simulation, etc.

User can also manage here specific interface options, such as language of software interface and some other options.

Defining the model ('Model')

This is the key step in setting up the modelling case, where user sets up the radioecological model. For composing the model, the Simulator supports classical "Interaction Matrix" interface and graphical "Block-Scheme" ("Graph") interface.

The radiecological model can be composed from modules included to libraries. User selects particular modules needed for his modelling case, and sets up data exchanges between modules.

Specifying modelling options ('Options')

In this step, user specifies particular modelling options available in relevant modules used to setup the radioecological model.

Specifying time-dependent input parameters in table format ('Time Series')

In case model includes time-dependent input parameters that need to be specified in table format, input of such parameters is carried out in this menu position

Entering model parameters ('Parameters')

In this menu, user has possibility to modify all model parameters.

The NORMALYSA modules are supplied with the default values of all model parameters. Some of these need not to be necessarily changed (for example, dose coefficients for dose assessment calculations). However, almost any model includes site-specific and/or modelling case specific parameters that will need to be specified by user.

Running the simulation ('Simulation')

This menu allows user to set up simulation options (e.g., starting and ending times, specify output parameters, etc.), and eventually to run the model.

Analysing results ('Tables' and 'Charts')

The Simulator menu includes two menu items for analysing simulation results: 'Charts' and 'Tables'. These menu items allow modeller to view data either in chart or table format. Simulation data can be also exported to MS Excel file format.

Generating reports ('Reports')

This menu allows to generate automatically modelling report describing the simulation case, model used, input parameters, and simulation results. The report can be printed or exported to PDF format.

Additional information on user interface of NORMALYSA Simulator can be obtained from context sensitive '*Help Contents*' menu.

Below we will explain in detail how to carry out modelling operations for the considered exercise for the each specified above step (i.e., for the main menu positions).

4. Detailed description of composing and running the model in NORMALYSA

As already discussed, in this exercise we will get experience in using the following modules from ’Doses’ library: ’Dose from occupancy outdoors‘ and ’Total dose’.

We will use two modules ’Dose from occupancy outdoors‘ that are configured for two areas (Area A and Area B), and in addition we will use ‘Total Dose’ module for summing resulting doses for specific areas to integral dose.

4.1 ‘Context’ menu position

We start by defining the “context” for the model simulation, which includes defining the model name and selecting the list of radionuclides included in the simulation.

By default, the ‘*Context’* window is shown in NORMALYSA when you open the tool.

1. Click the *‘New’* button in the context menu to create a new model file. Press the *‘Edit’* button to get access to the model description field (FIG 5).
   Give a name to the model (“Exercise 1”), fill in your name in the *‘Author’* field (optional) and type a short description of the exercise in the *‘Description’* field (optional).
2. In the context menu, click the *‘Save As’* button, then name and save the model file on an appropriate location in your computer.

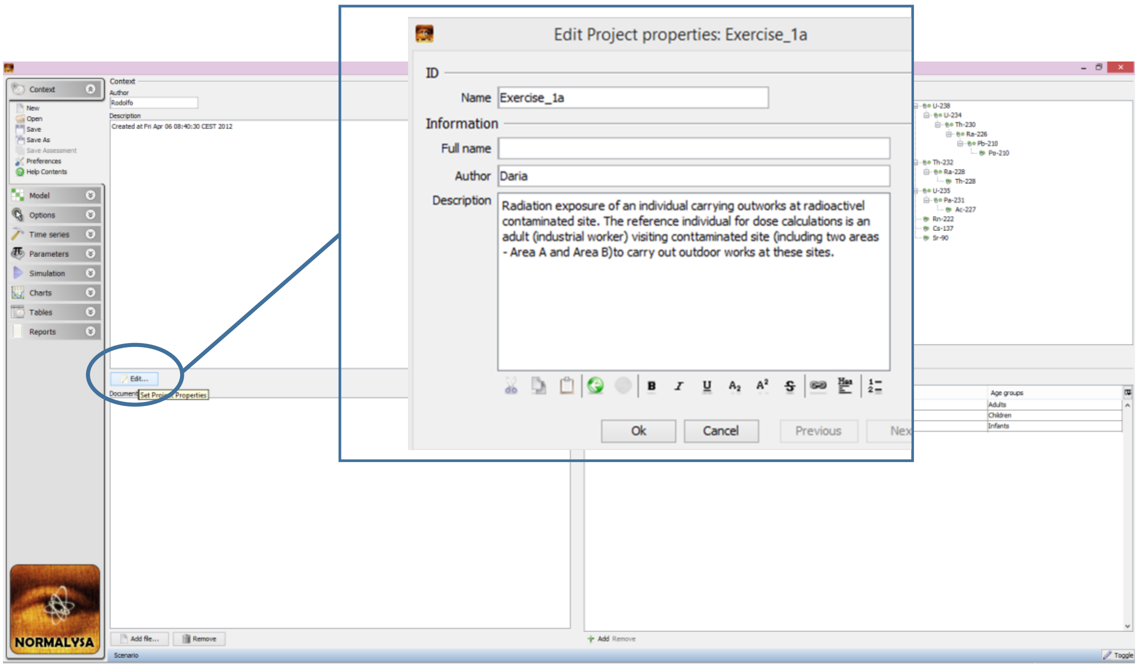

FIG 5. Editing ‘*Project properties*’ window.

List of ‘*Contaminants*’ (radionuclides) are shown on the right-hand side of the ‘*Context’* window. When you create a new model, all radionuclides and decay chains are enabled by default.

We want to calculate doses from Cs-137 and Sr-90. To select these radionuclides first disable all radionuclides in the ‘*Nuclides’* window. Then select Sr-90 and Cs-137 (FIG 6).

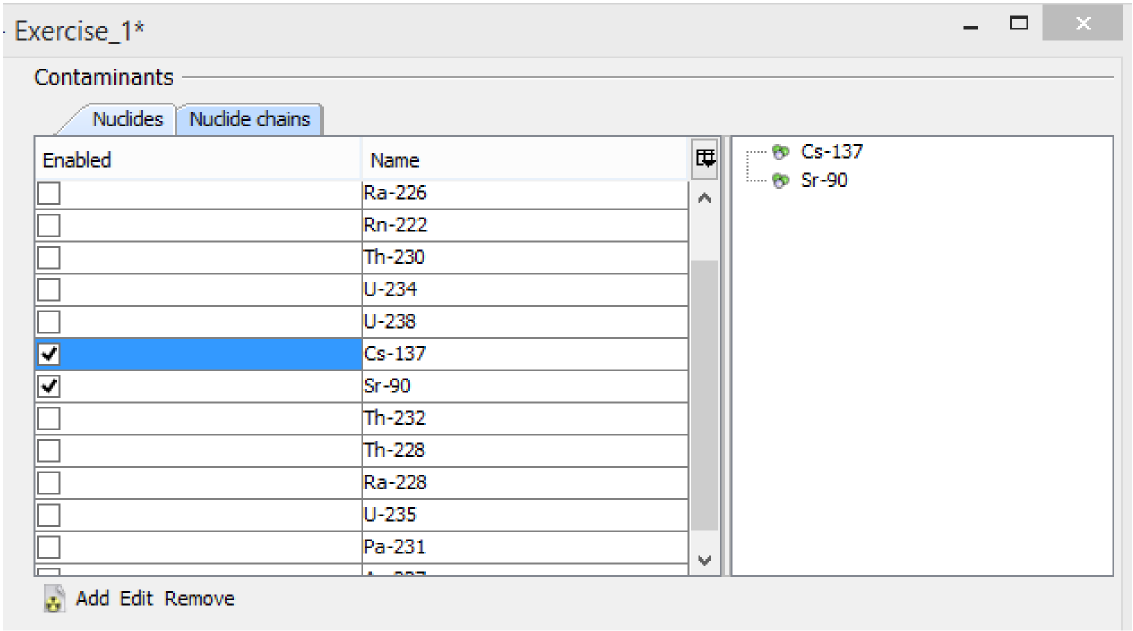

FIG 6. '*Contaminants'* window with selected radionuclides.

4.2 'Model' menu position

Next, you will assemble the model. In this menu position, we will create the model by using the module library and "connectors" to exchange output and input data between the different modules.

Click on the *'Model'* button in the menu to open the model window. NORMALYSA provides two means to visualize the model; either as a box diagram (graph) or as an interaction matrix. You can toggle between the two modes at any time by clicking on the tabs in the upper right corner of the '*Model'* window (FIG 7).

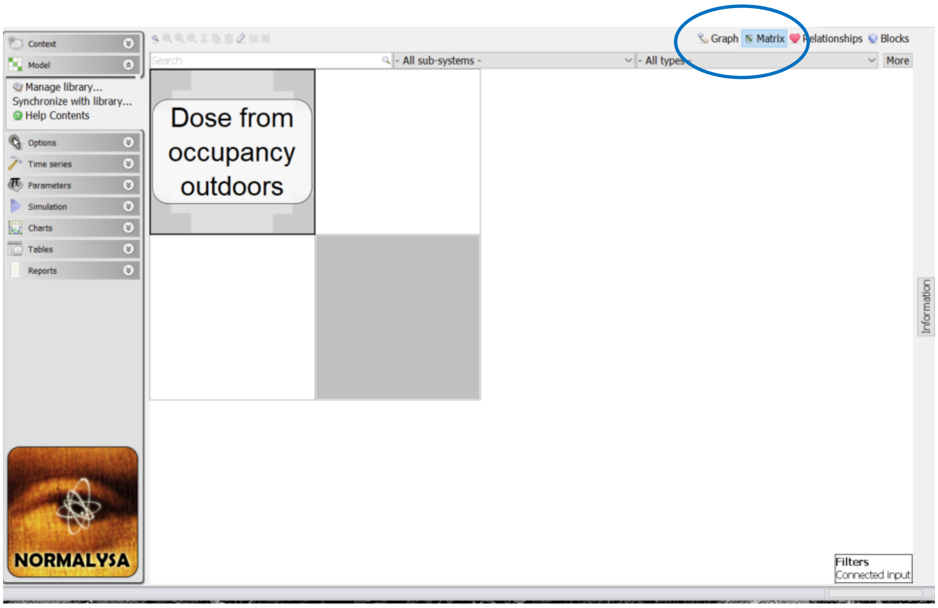

FIG 7. Tabs corresponding to different options ('*Graph*', '*Matrix*') of model visualization.

Next to the *'Graph'* button (which is selected by default), you find the *'Matrix'* button. Click on it to select the "matrix view".

Now we will compose the NORMALYSA model for Exercise 1 using the modules from 'Dose' library.

1. Right-click on an empty diagonal element in the matrix (or empty graph area for a graph model view) and choose *'Get from the library...'* (or '*Add…*') from the pop-up menu that appears.
   (Please note that to add more empty diagonal elements to the matrix you can right click with the mouse on a diagonal element and choose *'Insert Above'* or *'Insert Below'***)**.
2. In the list of modules, select the *'Dose from occupancy outdoors'* module from the *'Doses from occupancy'* folder inside the *'Doses'* folder (FIG 7). You can read a short description of the selected model in the *'Description'* field of '*Library'* window (FIG 9). You can see that this module calculates doses from outdoor occupancy, and it accounts for dose via inhalation, soil ingestion and external exposure.
3. Click '*Ok***'.** You should now see the selected module as a "box" on the model area.
4. Right-click in the matrix and choose *'Insert Above'* or *'Insert Below'* to add new diagonal elements.
5. Repeat steps 1 – 4 to insert the second module 'Dose from occupancy outdoors' for the second area.
6. Repeat steps 1 – 4 to insert the '*Total Dose*' module.
7. Each 'Dose from occupancy outdoors' module must now be connected to the 'Total dose' module using *'Connector'* blocks to exchange data.
8. To create a new "connector" block, right-click on the off-diagonal element of the matrix window projected (horizontally, vertically) on blocks that need to be connected, and chose *'Connector'* from the pop-up menu (see FIG 10).
9. Repeat the process of connecting modules until both 'Dose from occupancy outdoors' boxes are connected to the 'Total Dose' box (FIG 11).
   Remark: do not connect 'Dose from occupancy outdoors' blocks with each other.

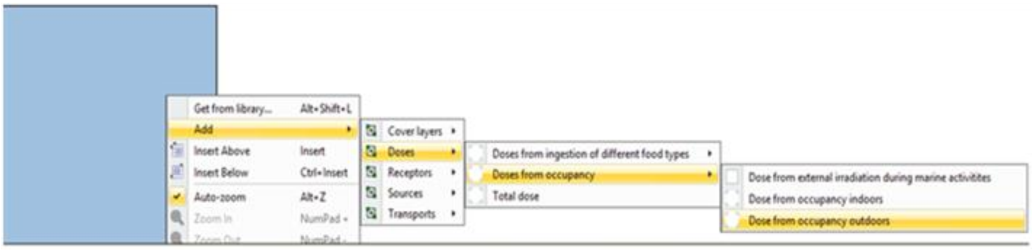

FIG 8. Inserting ‘Dose from occupancy outdoors’ module to the model.

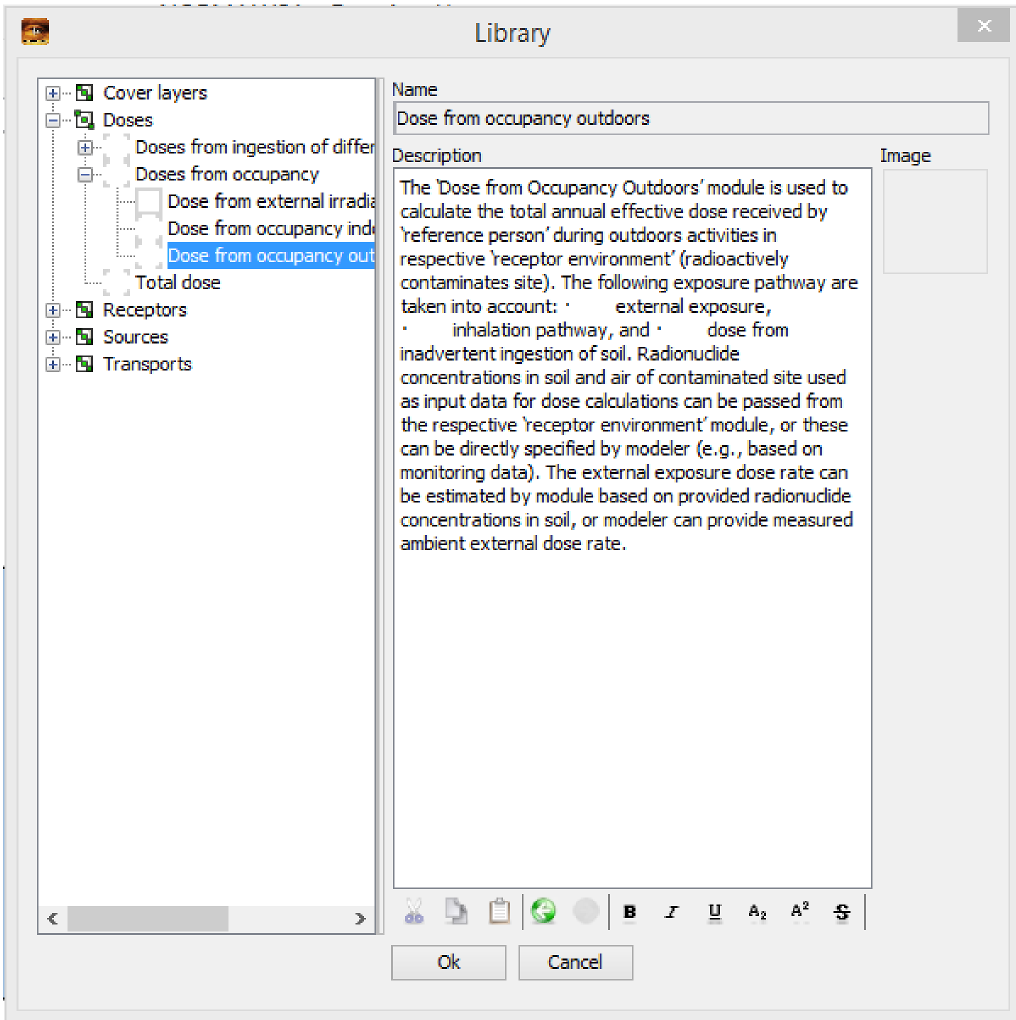

FIG 9. *‘Library’* window showing the explanatory text for the ‘Dose from occupancy outdoors’ module from the ‘Doses’ library.

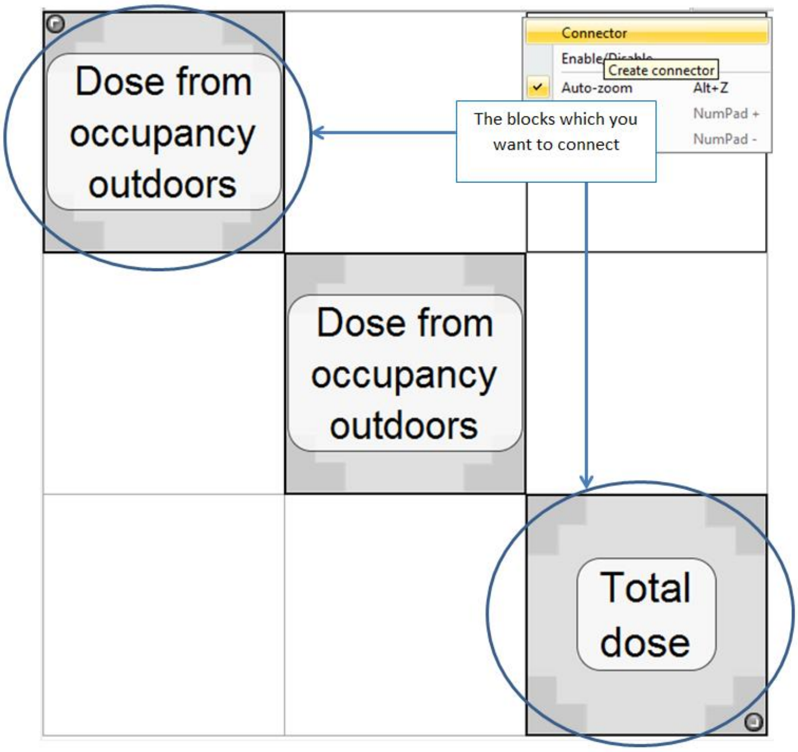

FIG 10. Connecting modules using “connector” blocks for data exchanges.

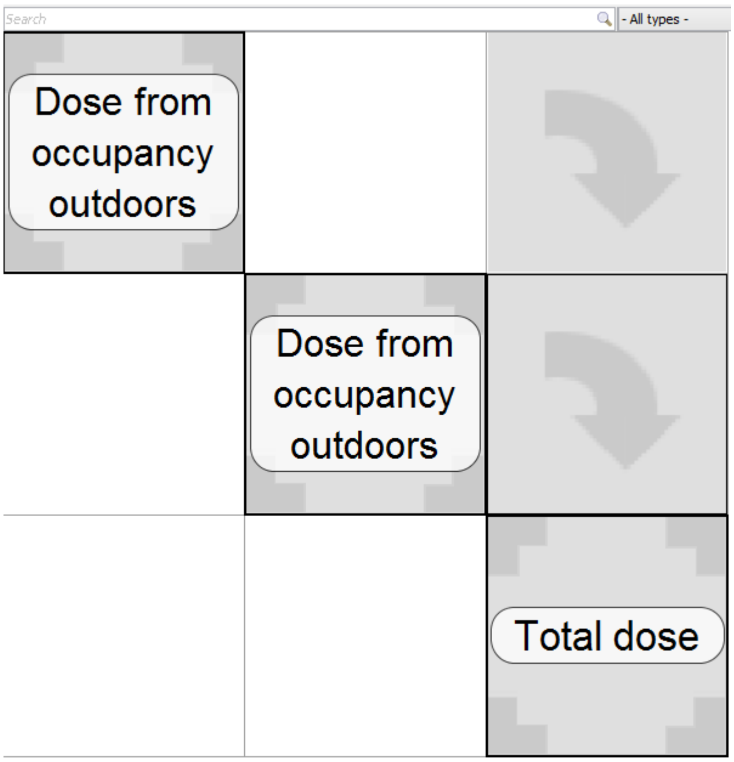

FIG 11. Full model for Exercise 1a including main modules and “connectors” in ‘*Matrix’* view.

To avoid confusion with two similar ‘Dose from occupancy outdoors’ modules, we will rename these modules to ‘Dose from work on the Area A’ and ‘Dose from work on the Area B’ respectively.

The following operations shall be carried out to rename modules:

1. Double click on the first ‘Dose from occupancy outdoors’ module.
2. In the tab ‘*Properties*’ change the field ‘*Full name*’ to ‘Dose from work on the Area A’ (FIG 12).
3. In the tab ‘*Appearance*’ change the field ‘*Display name*’ to ‘Area A’.
4. Click ‘*Ok*’ button.
5. Rename in a similar way the second ‘Dose from occupancy outdoors’ module to “Dose from work on the Area B” and ‘Area B’.

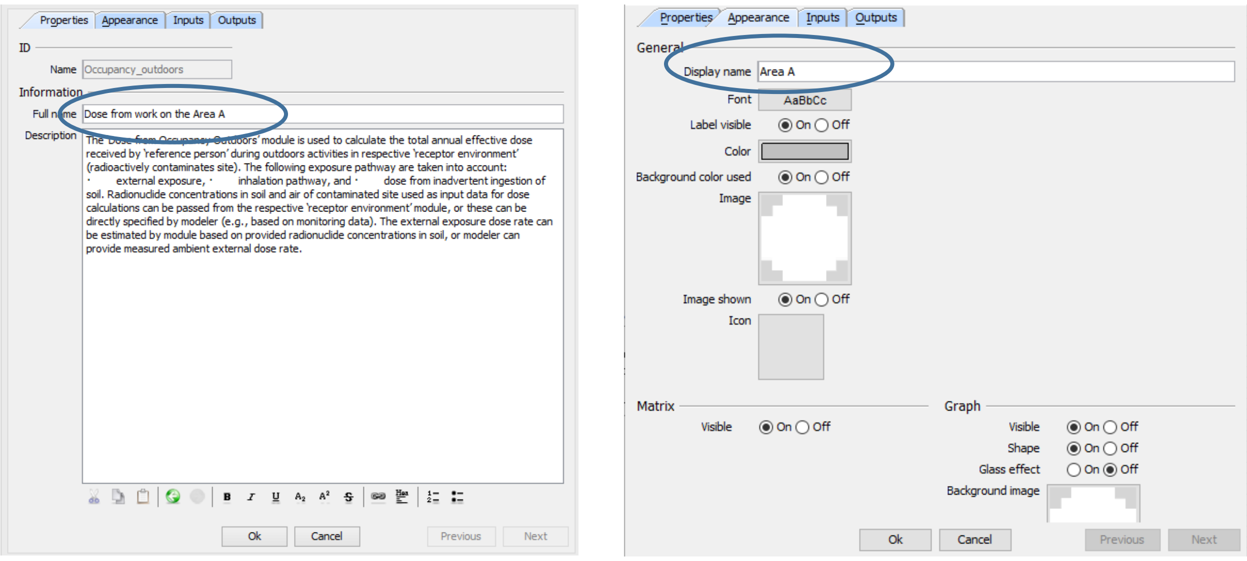

FIG 12. Renaming the ‘*Dose from occupancy outdoors*’ modules.

Your next task is to tune the “connector” blocks in order to set proper data exchanges between modules. This process is described below.

1. Double click on the “connector” block between ‘Dose from work on the Area A’ and ‘Total Dose’ modules. The ‘*Edit Connector*’ window will be opened allowing to set up data exchanges between these modules (FIG 13). The left column of window lists output parameters of the ‘Dose from work on the Area A’ module, while the right column lists the input parameters of the ‘Total Dose’ module. You have to match properly ‘output – input’ parameters between these two columns. The specific parameter can be selected by right-clicking the particular table cell, and selecting the need parameter from the pop-up list that appears.
2. You have to connect the following ‘output (left column) – input (right column)’ parameter pairs:
   ‘*Annual effective dose from external exposure outdoors*’ and ‘*Total dose from external exposure summed over all radionuclides*’,
   ‘*Dose from soil ingestion summed over all radionuclides*’ and ‘*Total dose from soil ingestion summed over all radionuclides*’,
   ‘*Dose from inhalation outdoors summed over all radionuclides*’ and ‘*Total dose from inhalation summed over all radionuclides*’.
3. Repeat the described above operations for the “connector” block between ‘Dose from work on the Area B’ module and ‘Total Dose’ module.

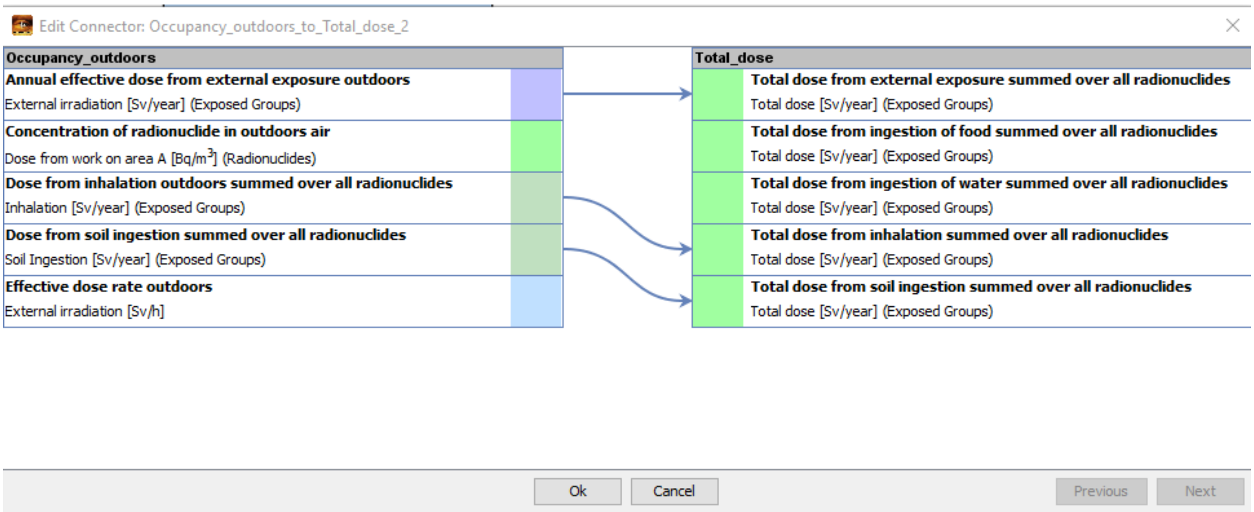

FIG 13. Using ‘*Edit Connector*’ window to set up data exchanges between modules.

With the described above operations the setup of NORMALYSA model structure and data exchanges is completed.

Before leaving the '*Model*' window, you can have a look at the NORMALYSA model that you have built in the '*Matrix*' view (see FIG 11) and '*Graph'* view (see FIG 14).

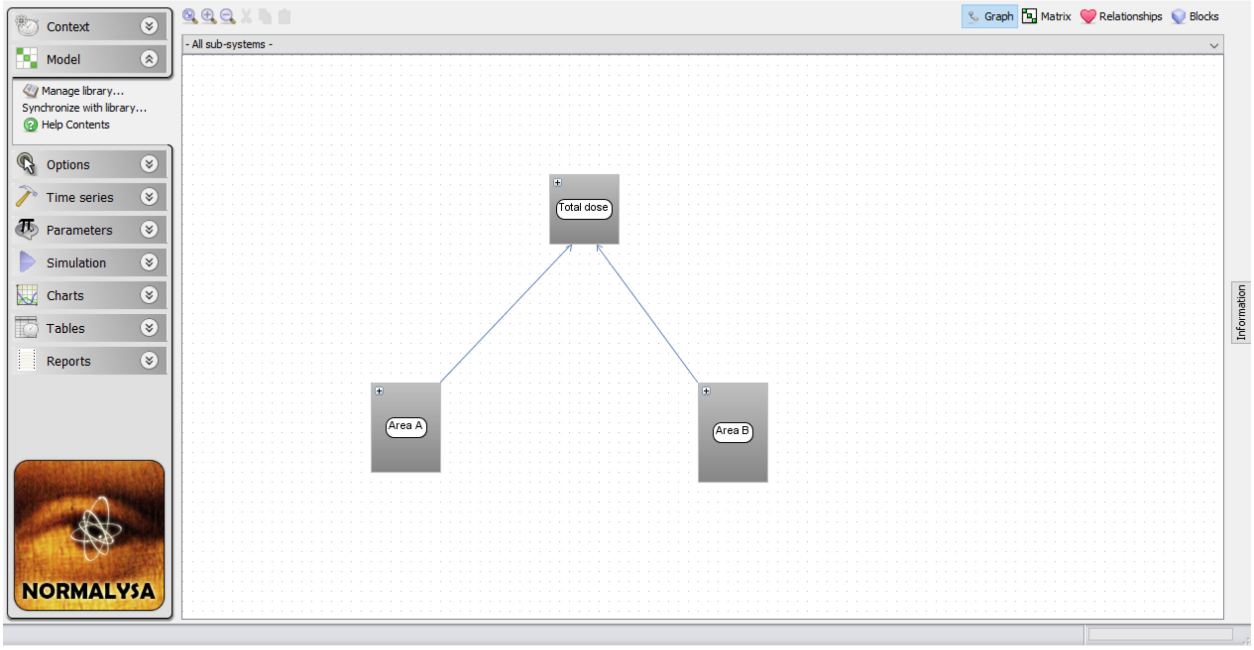

FIG 14. NORMALYSA model for Exercise 1 in the '*Graph*' view.

When the NORMALYSA model is created using one or other combination of modules, a set of different “Indices” (or “index lists”) required by these modules is added automatically to the ‘*Context’* window.

Now once we have set up the model, we need to re-iterate to the ‘*Context*’ window.

Defining the ‘Exposed Groups’ index list

To inspect the “index lists” included to our model click on the ‘*Context*’ button in the main menu on the left side to re-open the respective window. The ‘*Context*’ window displays list of ‘*Indices*’ in the bottom right corner (see FIG 15).

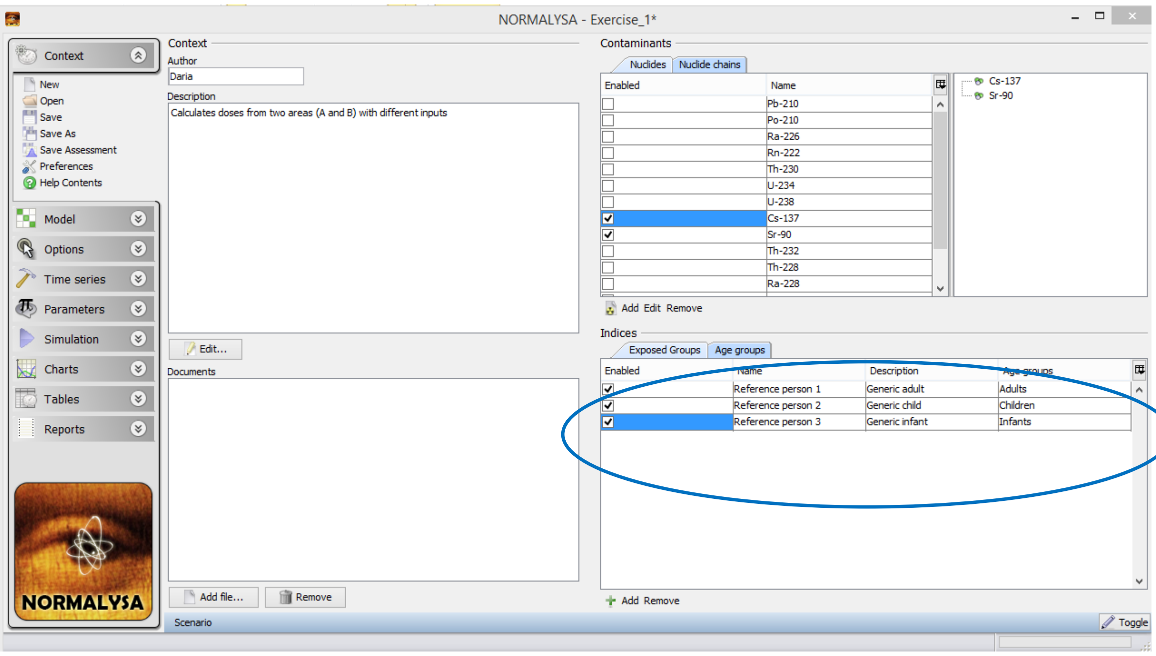

FIG 15. Viewing lists of ‘*Indices*’ of the newly created NORMALYSA model in ‘*Context*’ window.

Browse through the respective tabs to see which index lists have been added to NORMALYSA model. You will see two “index lists”: ‘*Exposed Groups*’ and ‘*Age Groups*’. By default, all available entries in index lists are selected (activated).

In case of Exercise 1, we will need no to use ‘*Exposed Groups*’ index list to define age characteristics of reference person considered in this exercise.

1. Click the ‘*Exposed Groups*’ tab.
2. Rename the existing group “Reference person 1” to “Worker”. By default, this reference person belongs to ‘*Age Group*’ category ‘*Adults*’. Do not change this last setting.
3. Deselect all other reference persons.

The result of adjustments of ‘*Exposed Groups*’ index list are shown in (FIG 16).

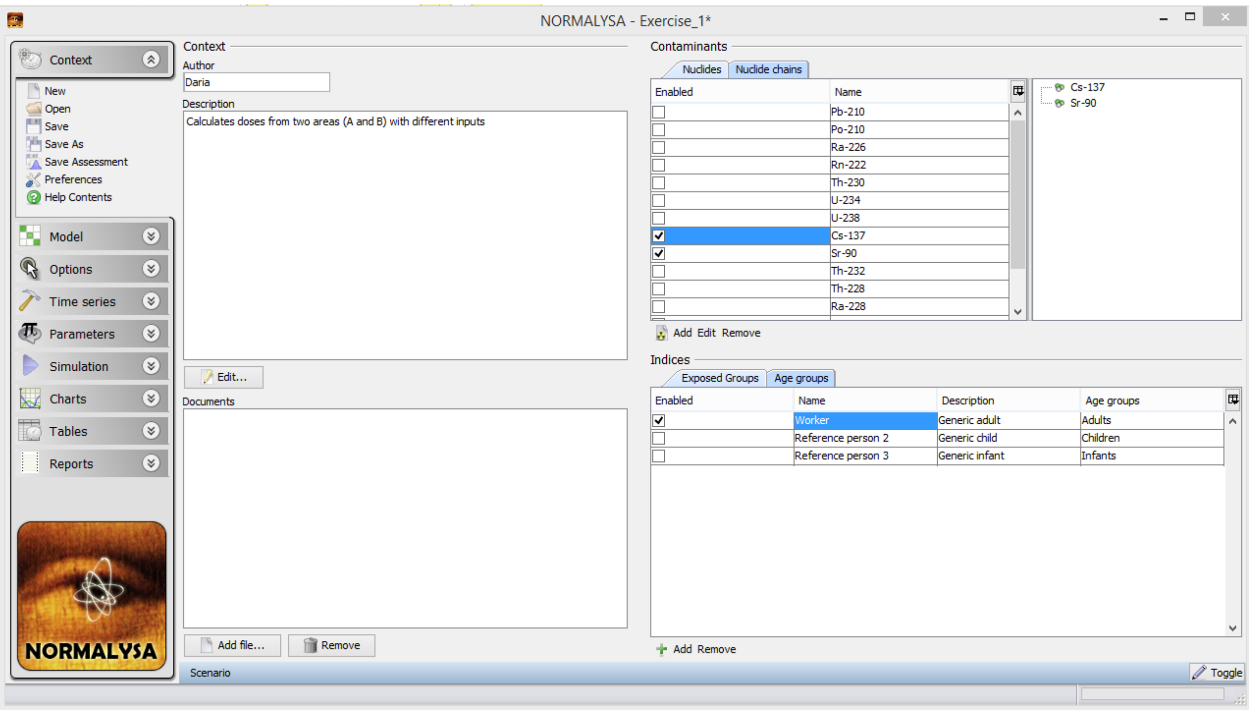

FIG 16. Defining the '*Exposed Groups*' index list.

WARNING!

The '*Age groups*' index list cannot be changed in NORMALYSA. You can only assign respective age groups from this list to the reference persons listed in '*Exposed Groups*' window.

4.3 'Options' menu position

In some NORMALYSA modules you can choose among a number of different options for calculation of model variables (parameters). These options (if available) are accessed through the '*Options*' button.

In our case, we will be using two ways of calculating of external irradiation of reference person; (1) from measured ambient dose rates (this method is used for "Area A") or, (2) indirectly from measured radionuclide concentrations in soil and air using respective dose conversion coefficients (this method is used for "Area B").

To carry necessary model adjustments, the following operations shall be carried out:

1. Click the '*Options*' menu button to open the respective window.
2. . For the dose module corresponding to "Area A" (pre-selected in the left column of window) we choose '*Effective dose rate outdoors calculated from ambient dose rates*' option (FIG 17).
3. For the dose module corresponding to "Area B" we choose '*Effective dose rate outdoors calculated from air and soil concentrations*' option.

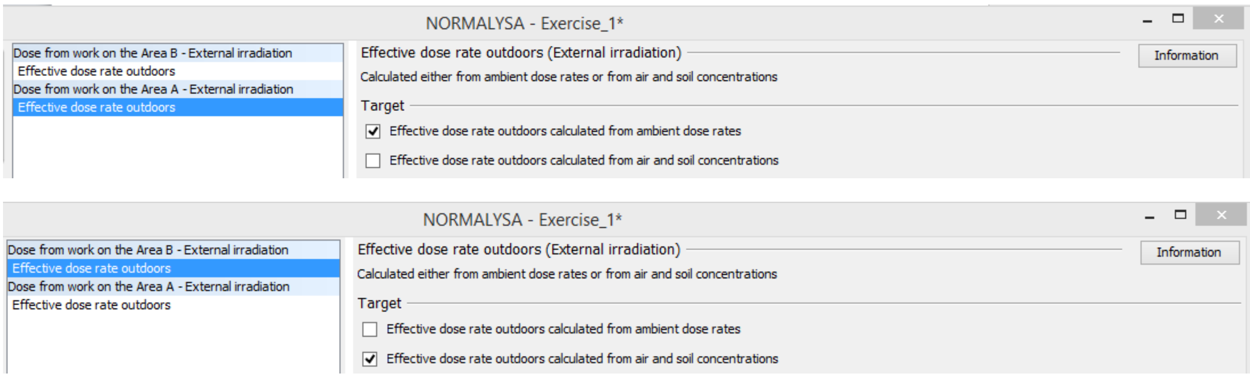

FIG 17. Specifying modelling options for calculating the ‘*Effective dose rate outdoors*’ parameter.

4.4 ‘Time series’ menu positions

In the considered exercise, we do not need to make any inputs or adjustments in ‘*Time series*’ menu position.

4.5 ‘Parameters’ menu position

Our next task is to define various model parameters. To do so open the ‘*Parameters’* window by clicking on the respective button in the main menu.

The ‘*Parameters*’ window displays to the left all parameters needed by the model (

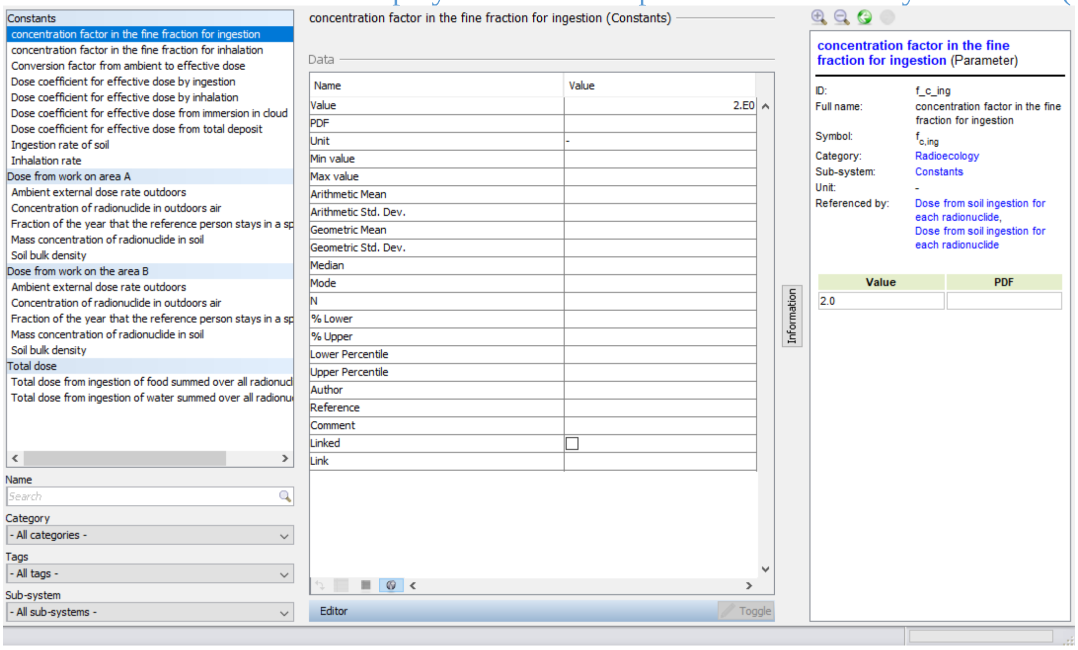

FIG 18).

In the upper right part of the window, you see information on parameter that is currently selected. Click the button ‘*Information*’ in the right side to view parameter units and other relevant information.

In the bottom right part of the window the ‘*Data*’ table is displayed, where you can view and edit parameter value. For some parameters you can use the default values, but for some you may want to use values specific to your study, and these must be entered. When you input data be careful with parameter units.

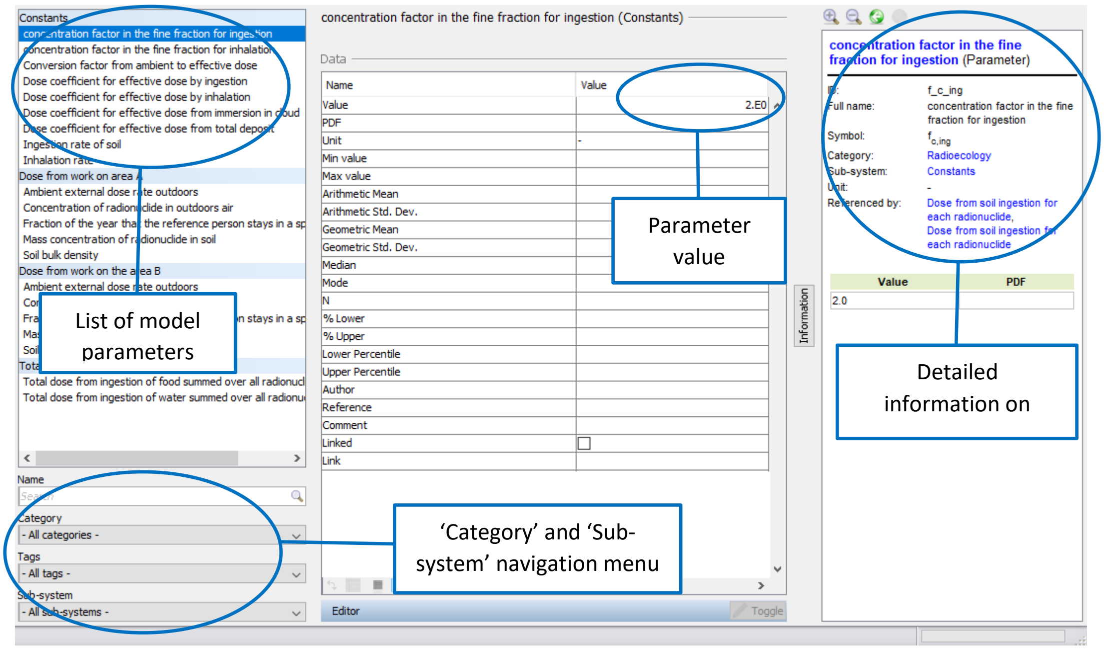

FIG 18. '*Parameters*' window.

You can use the controls in the left bottom corner of the window below the parameter list to search for specific parameters. The '*Category*' drop-down list allows you to display only parameters of a specific category. The '*Sub-system*' drop-down list allows you to display parameters only for a specific sub-system / module. (In our case these are 'Dose from work on the Area A', 'Dose from worn on the Area B', 'Total Dose', and '*Constants*' block where various constants used in the model such as dose conversion coefficients, inhalation rate, etc. are compiled).

Before proceeding to entering parameter values, we need to carry out conversion of parameter units for some model parameters (see below).

Conversion of units for time of exposure of reference person

The NORMALYSA model for Exercise 1a requires as an input parameter time of exposure of reference person expressed as '*Fraction of the year that the reference person stays in a specific receptor*'.

Initially, time of exposure was provided as a percentage of "work time" (see Section 2.3). So, we have to re-calculate this parameter to the needed unit.

The following formula is used to recalculate time of exposure from percentage of work time ($Time_{work,percent}$) to time value expressed as a fraction of year ($Time_{fraction.year}$):

$$Time_{fraction.year} = (Time_{work,percent}/100\% \times N_{work.days.year})/N_{total.year}$$

Here $N_{work.days.year} = 250\ days$ is number of working days per year, and $N_{total.}year = 365.25\ days$ is total number of days per year.

For the "Area A" the resulting parameter value is:

$Time_{fraction.year}$ [*Area A*] = (20%/100% × 250 days)/365.25 days =0.14

For the "Area B" this parameter is calculated as follows:

$Time_{fraction.year}$ [*Area B*] = (10%/100% × 250 days)/365.25 days = 0.07

Data input for Exercise 1a

For each of the parameter sets listed below carry out the following operations:

- Select the needed sub-system / module ('Dose from work on the Area A' or 'Dose from worn on the Area B')
- Select one-by-one each parameter in the list
- Enter the needed parameter value(s).

All needed parameter values are provided in Section 2 of this exercise. For convenience, these parameters are repeatedly presented below in Table 3 and Table 4. Please, pay attention to the units!

Table 3. Input parameter values for sub-system 'Dose from work on the Area A'

Name	Value		Unit
Ambient external dose rate outdoors	1.2E-7		Sv/h
Fraction of the year that the reference person stays in a specific receptor	0.14		Unitless
Concentration of radionuclide in outdoors air	Cs-137	4E-5	Bq/m^3
	Sr-90	1.5E-5	
Mass concentration of radionuclide in soil	Cs-137	1000	Bq/kg
	Sr-90	500	

Table 4. Input parameter values for sub-system 'Dose from work on the Area B'

Name	Value		Unit
Fraction of the year that the reference person stays in a specific receptor	0.07		Unitless
Concentration of radionuclide in outdoors air	Cs-137	1.5E-4	Bq/m^3
	Sr-90	7.5E-5	
Mass concentration of radionuclide in soil	Cs-137	3000	Bq/kg
	Sr-90	1500	

4.6 'Simulation' menu position

Now when we have composed the NORMALYSA model, and have defined input parameters, we are ready to carry out simulation.

Open the simulation window by clicking on the *'Simulation'* button in the menu. This window allows you to adjust/change simulation settings and eventually to carry out the simulation.

The table in the bottom part of the window will display any errors and/or warnings (if present) – for instance if a value of some parameter is missing (is not defined) in the model. You cannot start a simulation if errors are shown in this table.

Adjusting the list of model outputs

Now we will adjust the list of NORMALYSA model outputs that will be included to the list of modeling results upon completion of simulation. (We need to do so as we are interested in a larger list compared to the default list of output parameters).

1. Click the '*Simulation Settings*' sub-menu to the left, and choose '*Outputs'* tab in the '*Edit Simulation Settings*' window that appears. The window will be opened listing in the right sub-window model outputs. The left sub-window lists all other available model parameters. Output parameters are grouped according to respective sub-systems.
2. Click button  to clear the right window.
3. Choose '*Dose from work on the Area A*' sub-system and click '>' button (FIG 19).

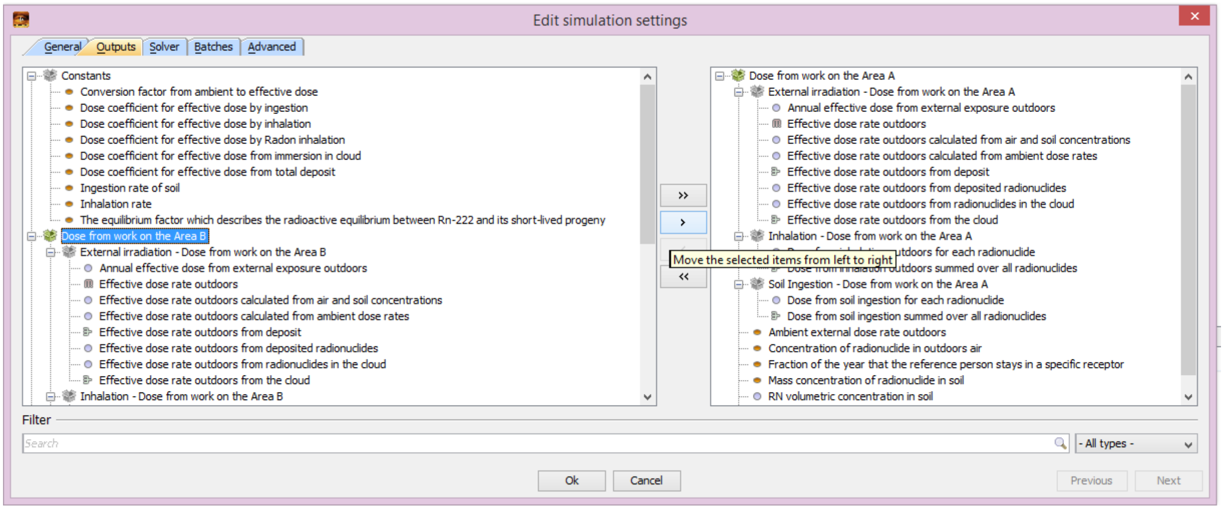

FIG 19. Adjusting the list of NORMALYSA model outputs

4. Repeat Step 3 to include to the output parameter list '*Dose from work on the Area B*' and '*Total Dose*' sub-systems outputs.
5. Click '*Ok*' button in the bottom of window.

Running the model

Click the '*Run*' button in the upper corner to perform the simulation (FIG 20).

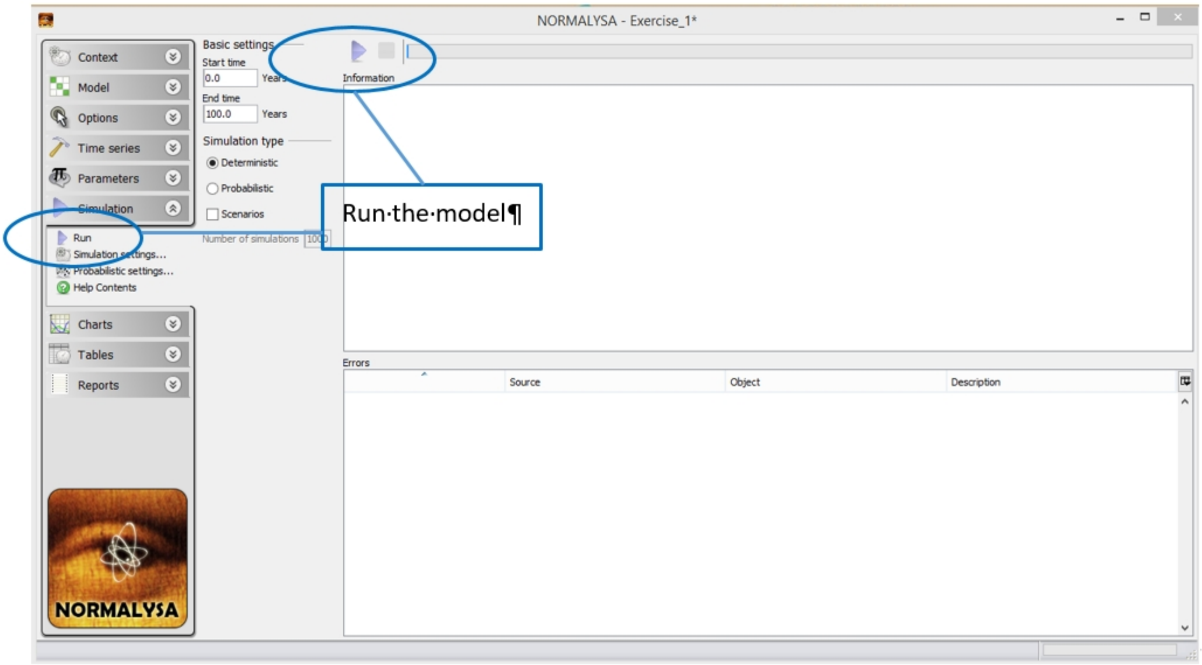

FIG 20 Running the NORMAYSA model.

4.7 Viewing simulation results

Simulation results can be viewed either in charts or in tables using the respective buttons of the main menu.

Some calculation end-points such as total annual effective dose and doses per exposure pathway can be viewed directly in NORMALYSA.

For some other calculation end points such as doses per Area A and Area B, and doses per radionuclides for Area B, the 'raw' output results of NORMALYSA need to be exported first to MS Excel spreadsheet and additional calculations need to be carried out in the MS Excel.

Viewing simulation results in NORMALYSA (table format)

To view results of the calculation in table format, open the respective window by clicking the '*Tables*' button in the main menu to the left.

The available simulation results are listed in a sub-window immediately to the right from the main menu. Similarly to '*Parameters*' window, you can use the controls below this sub-window to search and filter out needed contents from the list of outputs.

The results are grouped in "folders" where the root folder has as a name the date and time of simulation.

To create a table either click an output parameter in the displayed tree of simulation results with the left mouse button or right-click in '*Quick View*' window to the right, and select a specific type of table from the pop-up menu that appears.

To create a table showing the results of calculation of the total dose, the following operations have to be carried out:

1. By clicking '+' icons in the displayed tree of simulation results in the left column with model outputs open the root folder, and the '*Total Dose*' sub-folder within it.
2. Choose '*Total dose from all exposure pathways summed over all radionuclides*' in '*Total Dose*' sub-folder. A table will now be displayed in '*Quick View*' window to the right showing the total dose for the reference person ('Worker'). This is the total annual effective dose to reference person received in both work Areas A and B through the external exposure, soil ingestion and inhalation pathways.

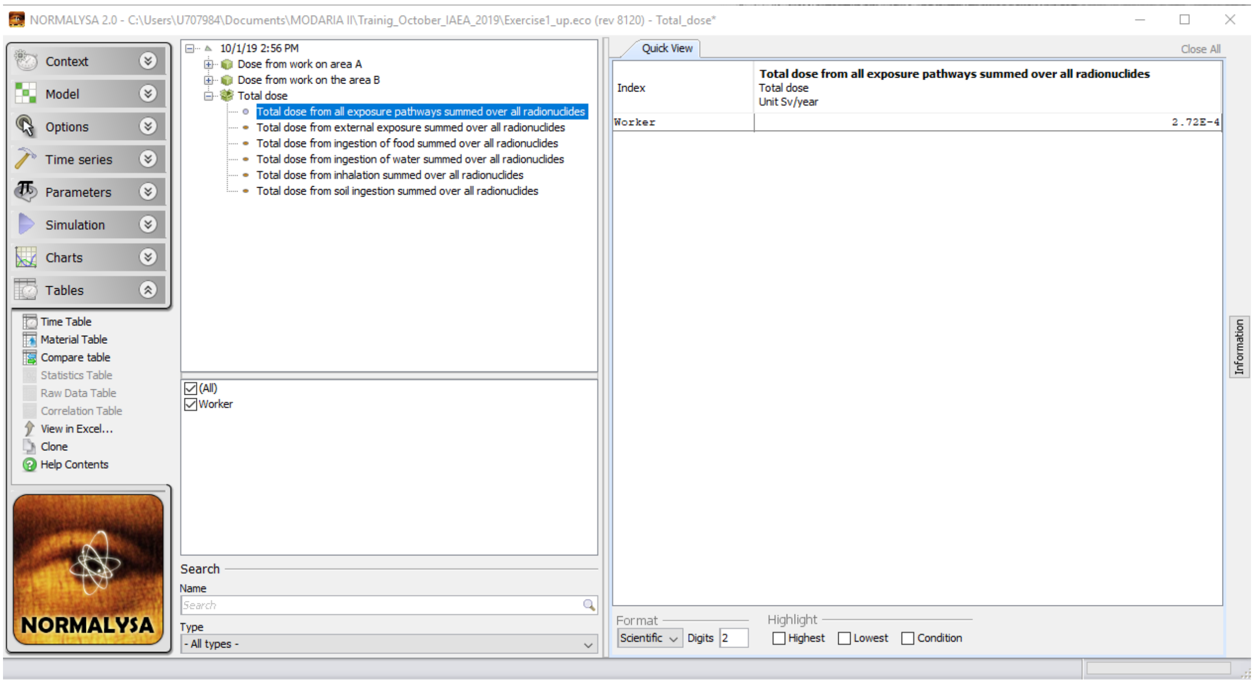

FIG 21. Viewing simulation results for Exercise 1 in table format (‘*Total dose from all exposure pathways over all radionuclides*’).

4. Listed in the outputs for the ‘*Total Dose*’ sub-system you will also see the total dose received for each exposure pathway. Click the different simulation outputs of ‘*Total Dose*’ sub-system, and investigate the dose contribution for each pathway.
5. You can continue investigation of simulation outputs by viewing calculation results for specific work area (by selecting in the list of outputs sub-systems ‘*Dose from work in Area A*’ and/or ‘*Dose from work in Area B*’ respectively). When you select for viewing a parameter that depends from radionuclides, you can also select specific radionuclides in respective index list (FIG 22).

You may note that for sub-system ‘*Dose from work in Area B*’ estimated from soil concentration ‘*Effective dose rate outdoors from deposit*’ is 2.98 E-07 µSv/h.

Calculated dose rate is higher compared to ambient dose rate in Area A due to higher Cs-137 concentration in soil of Area B.

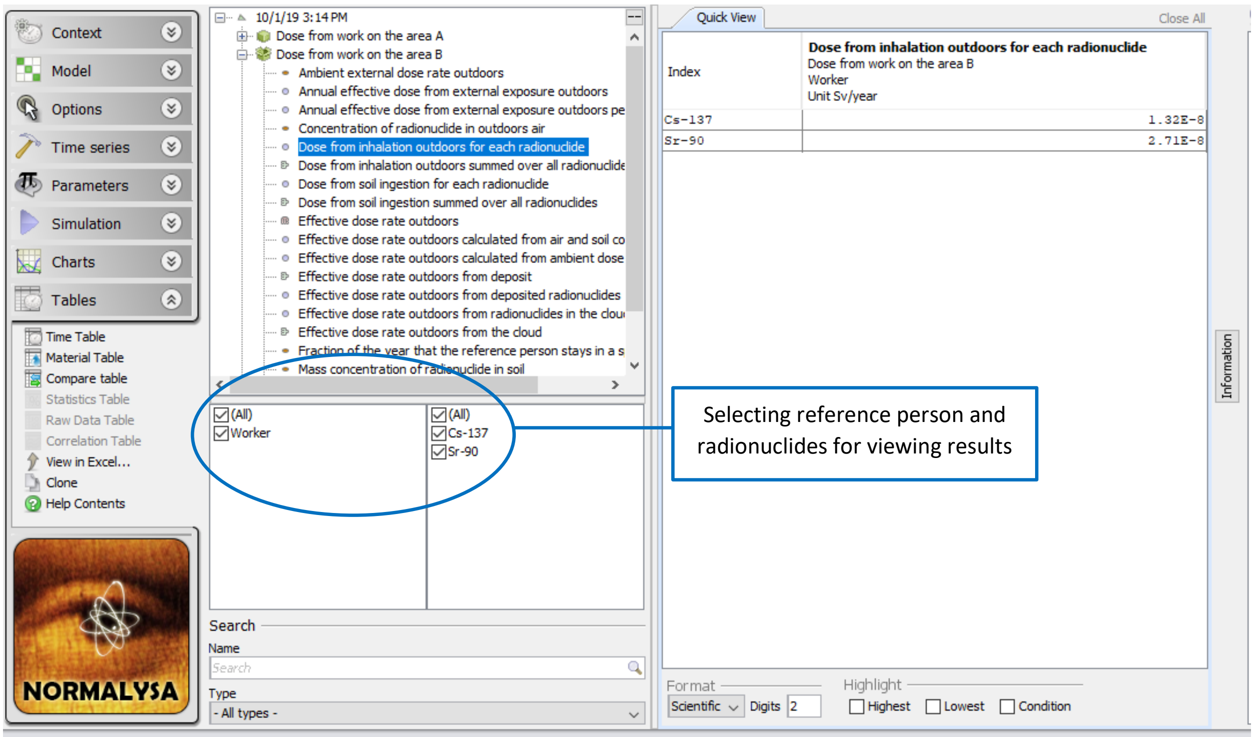

FIG 22 Viewing results of dose calculations for Exercise 1 for specific radionuclides.

Exporting simulation results to MS Excel spreadsheet and carrying out additional calculations

Calculating total doses per Area A and B

Some of our needed calculation end-points (see Section 1.3) cannot be obtained directly from NORMALYSA output. So, we need first to export NORMALYSA outputs to the MS Excel and carry out additional spreadsheet calculations on these outputs.

To calculate total doses by reference person received separately in Area A and in Area B, we need to extract from the list of outputs the following parameters: '*Dose from soil ingestion summed over all radionuclides*', '*Dose from inhalation outdoors summed over all radionuclides*' and '*Annual effective dose from external exposure outdoors*' for both areas.

The following operations need to be carried to accomplish the above task:

1. Choose the listed above needed outputs for respective sub-systems from the tree with simulation results. Use '*Ctrl'* button for multiple choices (FIG 23).
2. Click the '*View in Excel*' button in the sub-menu of the main '*Tables*' menu in the left column. The MS Excel file will be opened with chosen output parameters.
3. Carry out needed calculations on simulation results to calculate total doses (summed on all pathways) for each of areas A and B. Sum up '*Dose from soil ingestion summed over all radionuclides*', '*Dose from inhalation outdoors summed over all radionuclides*' and '*Annual effective dose from external exposure outdoors*' for area A in opened MS Excel sheet. Repeat for Area B.

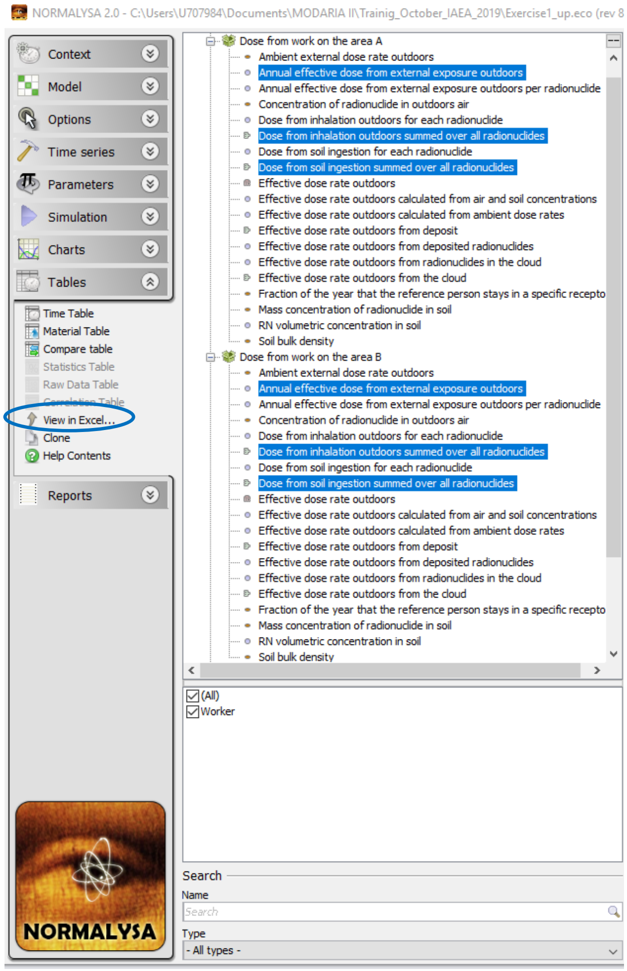

FIG 23. Selecting the needed intermediate dose calculations results for export to MS Excel to calculate “Dose per area” end-point.

Calculating doses per radionuclide (for Area B)

To obtain dose per radionuclide (Sr-90 and Cs-137) summed over all pathways for the “Area B”, we are interested in following parameters: ‘*Annual effective dose from external exposure outdoors per radionuclide*’, ‘*Dose from inhalation outdoors for each radionuclide*’ and ‘*Dose from ingestion of soil for each radionuclide*’ for the respective sub-system.

The following operations need to be carried to accomplish the above task:

1. Choose need output parameters from the tree with simulation results.
2. Make sure that both Sr-90 and Cs-137 are selected (FIG 24) !
3. Carry out steps 2-3 described in previous paragraph.

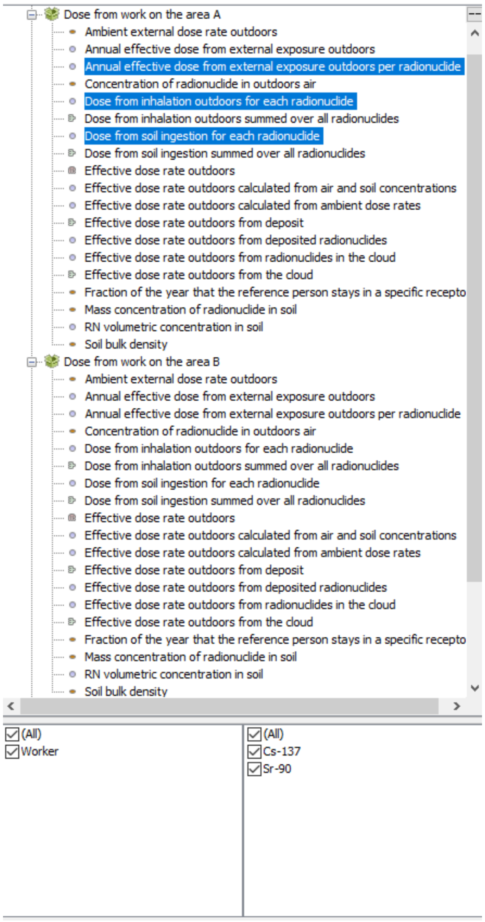

FIG 24. Selecting the needed intermediate dose calculations results for export to MS Excel to calculate “Dose per radionuclide (Area B)” end-point.

5. Results of exercise

This section lists simulation results in table format for exercise cross-checking purposes.

5.1 Total annual effective dose

Total dose summed over all pathways and all radionuclides shall be 2.72 E-04 Sv/year.

5.2 Doses for different exposure pathways

Doses for different exposure pathway summed over all radionuclide are shown below in Table 5. It can be seen from this table that the main exposure pathway is external exposure.

Table 5. Annual effective doses per pathway summed over all radionuclide for Exercise 1.

Pathways	Dose, Sv/year
Soil ingestion	5.70E-07
Inhalation outdoors	1.77E-08
External exposure outdoors	2.71E-04

5.3 Doses per area A and B

Doses per Area A and per Area B summed over all pathways and radionuclides are shown below in Table 6.

Table 6. Doses per Area A and per Area B calculated in Exercise 1.

Area	Dose, Sv/year
Area A	8.86E-05
Area B	1.83E-04

Total dose from occupancy outdoors is higher in the Area B compared to Area A due to higher radionuclide (in particular Cs-137) activity concentration in topsoil layer.

5.4 Doses per radionuclide in Area B

Doses formed by Cs-137 and Sr-90 through all exposure pathways in Area B are shown below in Table 7. It can be seen that exposure dose is dominated by Cs-137, as this radionuclide contributes mostly to the external exposure pathway, which is dominant pathway.

Table 7. Doses formed by Cs-137 and Sr-90 in Area B calculated in Exercise 1.

Radionuclide	Dose, Sv/year
Cs-137	1.82E-04
Sr-90	1.44E-06

6. Exercise for independent work

Estimate what will be the total annual effective dose through all pathways received by reference individual for the scenario assuming that he spends 25% of his working time in Area A, and 5% of his work time – in Area B.