

IVIVE Simulation Examples

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May 30, 2025

If you have not already read the *Introduction to the ToCS App* vignette, it is highly recommended to do so to get a general idea of the app's layout and obtain a detailed description of common user inputs across all output modules. Users should also review the ToCS README file to setup ToCS if they have not accessed the app yet. This vignette assumes that you have access the ToCS app GUI already.

Introduction

This vignette provides three examples that use the ToCS app to generate oral equivalent doses (OEDs) by in vitro in vivo extrapolation (IVIVE), each example with different parameters selected. Two of the three examples also incorporate chemical exposure data to generate bioactivity exposure ratios for chemical prioritization. To begin, open the app by using any of the methods described in the README file. You have correctly accessed the app if your screen looks like the image below.

Toxicokinetic Chemical Simulator (ToCS)

General ParametersModel SpecificationsCompound SelectionAdvanced (Optional) ParametersRun Simulation

INSTRUCTIONS

Fill out the prompts on each of the above tabs moving left to right. Then, click the 'Run Simulation' tab to run the simulation or reset all selections.

ToCS provides four toxicokinetic (TK) outputs: 1) Concentration-time profiles, which returns chemical concentrations in bodily compartments over time, 2) Steady state (SS) concentrations, which returns SS concentrations in bodily compartments from an oral infusion, 3) In vitro in vivo extrapolation (IVIVE), which returns oral equivalent doses to in vitro bioactive concentrations, 4) Parameter calculations, which returns elimination rates, volumes of distribution, tissue to unbound plasma partition coefficients, half-lives, and total plasma clearances.

This application uses the U.S. EPA's R package 'httk'. For more information on 'httk', refer to <https://doi.org/10.18637/jss.v079.i04> and/or <https://cran.r-project.org/web/packages/httk>

For additional guidance on ToCS, please refer to the vignettes (<https://github.com/KristenWindoloski/ToCS/tree/main/vignettes>). To report issues or suggestions for improvement, visit <https://github.com/KristenWindoloski/ToCS/issues>.

OUTPUT

Select the desired output.

Select

Must not be equal to Select.

SPECIES

Select the species to analyze.

Select

Must not be equal to Select.

The opening interface to the ToCS app.

Example 1

Let's say we want to perform IVIVE for eight chemicals that we have bioactivity data for. Since the IVIVE produces an OED for each bioactive concentration, assume that we want to transform the nominal bioactivity data to a free concentration in vitro. When the solution is outputted, we want the 5th dose quantile human plasma OED calculated from the pbtk model. Assume that we also have chemical exposure estimates for all eight chemicals.

General Parameters Tab

Since we want to perform IVIVE, we select the *In vitro in vivo extrapolation (IVIVE)* option under the drop down menu from the *Output* card. Then under the *Species* card, we select *Human* for the first drop down. Thus, the completed *General Parameters* tab should look like the image below.

Toxicokinetic Chemical Simulator (ToCS)

General Parameters

Model Specifications

Compound Selection

Advanced (Optional) Parameters

Run Simulation

INSTRUCTIONS

Fill out the prompts on each of the above tabs moving left to right. Then, click the 'Run Simulation' tab to run the simulation or reset all selections.

ToCS provides four toxicokinetic (TK) outputs: 1) Concentration-time profiles, which returns chemical concentrations in bodily compartments over time, 2) Steady state (SS) concentrations, which returns SS concentrations in bodily compartments from an oral infusion, 3) In vitro in vivo extrapolation (IVIVE), which returns oral equivalent doses to in vitro bioactive concentrations, 4) Parameter calculations, which returns elimination rates, volumes of distribution, tissue to unbound plasma partition coefficients, half-lives, and total plasma clearances.

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OUTPUT

Select the desired output.

In vitro in vivo extrapolation (IVIVE) ▾

SPECIES

Select the species to analyze.

Human ▾

The completed General Parameters tab for example 1.

Model Specifications Tab

There are several user choices to be made under the *Model* card. Since we want to use the pbtk model for IVIVE, we select *pbtk* for the first drop down. For the second drop down we select *No* and decide to not make compounds with only in silico generated parameters for hepatic clearance or fraction unbound in plasma available for this example. Then, the third drop down menu asks the user whether they want to return a single OED per compound (a selected quantile) or all OED samples per compound. Since we only want the 5th OED quantile (95th steady state concentration quantile), we select *Only return a specified dose quantile (default)*. This prompts the appearance of an additional numeric input box where we want to enter the desired steady state concentration

quantile. Since we want the 95th steady state concentration quantile (5th OED quantile), we leave the input as *0.95*. Under the *Dosing* card, we see that there are no user specifications to be made for this module. Thus, the completed *Model Specifications* tab should look like the image below.

Toxicokinetic Chemical Simulator (ToCS) General Parameters **Model Specifications** Compound Selection Advanced (Optional) Parameters Run Simulation

MODEL

Select the model to simulate. If a species other than 'Human' is selected, '3compartmentss' must be chosen.

pbtk

Select whether to use in silico generated parameters for compounds with missing in vitro data. These parameters will not overwrite existing in vitro data, and it will expand the number of compounds available.

No, do not load in silico parameters

Select whether to return all oral equivalent dose (OED) samples for each compound or a selected quantile.

Only return a specified dose quantile (default)

Enter the steady state concentration quantile (as a decimal) to be used in the OED calculation. Selecting the 95th concentration quantile will output the 5th OED quantile.

0.95

DOSING

No options for this category.

The completed model specifications tab for example 1 showing the model card.

Compound Selection Tab

Different from the other modules and vignettes, the first drop down menu under the *Preloaded Compounds* card has the user select a set of assumptions to implement regarding in vitro and in vivo bioactivity as well as metabolic clearance. The user can select from the following options:

- NULL:
 - Default assumptions applied (listed below) or customizable in the Advanced Parameters tab
 - Restrictive metabolic clearance (protein binding taken into account in liver clearance)
 - Treats the total specified concentration or tissue as bioactive in vivo
 - Treats the nominal concentration in vitro as bioactive
- Honda1:
 - Restrictive metabolic clearance (protein binding taken into account in liver clearance)
 - Treats the unbound (free) venous plasma concentration in vivo as bioactive
 - Treats the unbound (free) concentration in vitro as bioactive
- Honda2:
 - Restrictive metabolic clearance (protein binding taken into account in liver clearance)
 - Treats the unbound (free) venous plasma concentration in vivo as bioactive
 - Treats the nominal concentration in vitro as bioactive
- Honda3:
 - Restrictive metabolic clearance (protein binding taken into account in liver clearance)

- Treats the total venous plasma concentration in vivo as bioactive
- Treats the nominal concentration in vitro as bioactive
- Honda4:
 - Non-restrictive metabolic clearance (protein binding not taken into account in liver clearance)
 - Treats the total specified tissue concentration in vivo as bioactive
 - Treats the nominal concentration in vitro as bioactive

For more details, see the EPA's htk documentation and/or the following publication

<https://doi.org/10.1371/journal.pone.0217564> (<https://doi.org/10.1371/journal.pone.0217564>). Since we want to use the unbound (free) concentration in vitro as bioactive instead of the nominal concentration, we select the *Honda1* assumption for the first drop down menu. We then keep the second drop menu in the *Preloaded Compounds* card on *Choose from all available chemicals*. Then, the box below asks for the user to specify the fraction fetal bovine serum. We apply the assumption that it is 0.1 for the bioactivity assays for our desired compounds and leave the box at 0.1. Another box below also appears and contains a list of preloaded compounds that we can select from. We search for the eight compounds that we would like to simulate and see that they are all present in the preloaded list. Thus, we select those compounds. On the *Uploaded Data* card on the right of the interface, there are three datasets that can be uploaded. The first one is if we need to upload any physical-chemical data for compounds we want to simulate that are not available under the preloaded compounds list. However, we do not need to upload anything here because all of the compounds we wanted were already available. The second spot to upload a file is required for IVIVE simulations. Here, we must upload a CSV file with bioactive concentrations (uM units) for each compound selected to simulate. Therefore, we upload the following csv table. Note that the table must have the following exact format.

A csv file with bioactivity data for all eight chemicals. All values were calculated as the 5th percentile of AC50s (active calls only) for each compound, where the list of AC50s was taken from the cHTS assay database from ICE.

ChemicalName	CAS	BioactiveConcentration
Acetamiprid	135410-20-7	7.35400
2,4-db	94-82-6	13.46000
Acephate	30560-19-1	0.05875
Acetochlor	34256-82-1	1.34800
Alachlor	15972-60-8	1.61700
Aldicarb	116-06-3	0.09300
Ametryn	834-12-8	1.08200
Amitraz	33089-61-1	27.49000

The third spot to upload a CSV file is for chemical exposure estimates, which is optional. Uploading this data will allow the user to visualize these exposure estimates against the model-outputted OEDs as well as a generate bioactivity exposure ratios, which can guide chemical prioritization for potential risk. Suppose we have the following exposure data file:

A csv file with exposure data (mg/kg BW/day) for all eight chemicals. These exposure estimates were gathered from the EPA CompTox Dashboard. NHANES estimates were used if available. Otherwise, the EPA's SEEM3 model predictions were used.

ChemicalName	CAS	Upper	Median	Lower
Acetamiprid	135410-20-7	2.39e-04	5.99e-07	NA
2,4-db	94-82-6	1.29e-04	1.31e-06	NA
Acephate	30560-19-1	1.40e-06	3.37e-07	4.79e-08
Acetochlor	34256-82-1	2.00e-07	4.93e-08	4.74e-09
Alachlor	15972-60-8	1.40e-06	2.7e-07	NA
Aldicarb	116-06-3	2.39e-03	3.03e-06	NA
Ametryn	834-12-8	1.43e-03	2.23e-06	NA
Amitraz	33089-61-1	9.77e-04	1.24e-06	NA

For help with exposure file formatting, please refer to the *Introduction to ToCS* vignette and/or the *Exposure Data File Folder* under the left-side *Instructions* card on the interface. Following the selection of the compounds to simulate as well as uploading bioactivity and exposure data files, the completed *Compound Selection* page should look like the image below.

Toxicokinetic Chemical Simulator (ToCS)
General Parameters
Model Specifications
Compound Selection
Advanced (Optional) Parameters
Run Simulation

INSTRUCTIONS

Click on the appropriate link(s) below to download guidance on how to upload data under the 'Uploaded Data' card. Follow the 'Instructions' document in the downloaded folder to correctly format the file you want to upload.

[Uploaded Physical-Chemical Data File Folder](#)

[Bioactivity Data File Folder](#)

[Exposure Data File Folder](#)

PRELOADED COMPOUNDS

Select an IVIVE assumption to implement. For any input nominal bioactive concentration in vitro, the Honda1 assumption is recommended. Leave on 'NULL' if no assumptions are to be applied. See the 'IVIVE Simulation Examples' vignette for the description of the below assumption categories.

Honda1

Select the types of compounds you want to simulate.

Choose from all available chemicals

Enter the volume fraction of fetal bovine serum used in the in vitro assay.

0.1

Select any preloaded compounds. Search through the list by clicking on the box and scrolling or typing in a name. The list may not show all available compounds. Click on a compound to select it. You may select multiple.

94-82-6, 2,4-db
30560-19-1, Acephate
135410-20-7, Acetamiprid
34256-82-1, Acetochlor
15972-60-8, Alachlor
116-06-3, Aldicarb
834-12-8, Ametryn
33089-61-1, Amitraz

UPLOADED DATA

Upload a CSV file of physical and chemical data for compounds not in the preloaded list (if desired). Download the 'Uploaded Physical-Chemical Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... No file selected

Upload a CSV file with in vitro bioactive concentrations (uM units) for all selected compounds. Download the 'Bioactivity Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... SampleBioData_8Che

Upload complete

Upload a CSV file of exposure data for all selected compounds (optional). Download the 'Exposure Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... SampleExpData_8Ch

Upload complete

The completed compound selection tab for example 1.

Advanced (Optional) Parameters Tab

We will leave all options on this tab at their default values and proceed to the final *Run Simulation* tab. The *Advanced Parameters* tab should look like the image below.

Toxicokinetic Chemical Simulator (ToCS)
General Parameters
Model Specifications
Compound Selection
Advanced (Optional) Parameters
Run Simulation

MODEL CONDITIONS

Enter the number of Monte Carlo samples generated for each compound.

1000

Select whether to adjust the chemical fraction unbound in presence of plasma proteins for lipid binding.

Yes, adjust the fraction of unbound plasma (default)

Select whether to use regressions when calculating partition coefficients.

Use regressions (default)

Enter the p-value threshold for the in vitro intrinsic hepatic clearance rate where clearance assay results with p-values above this threshold are set to zero.

0.05

Enter the minimum acceptable chemical fraction unbound in presence of plasma proteins. All values below this will be set to this value.

0.0001

MODEL SOLVER

No options for this category.

BIOAVAILABILITY

Enter a default value for the Caco-2 apical-to-basal membrane permeability (denoted Caco2.Pab, 10^{-6} cm/s).

1.6

Select whether to use the Caco2.Pab value set above to estimate F_{abs} (the in vivo measured fraction of an oral dose absorbed from the gut lumen into the gut) if bioavailability data is unavailable.

Use the Caco2.Pab value selected above (default)

Select whether to use the Caco2.Pab value set above to calculate F_{gut} (the in vivo measured fraction of an oral dose that passes gut metabolism and clearance) if bioavailability data is unavailable.

Use the Caco2.Pab value selected above (default)

Select whether to overwrite in vivo F_{abs} and F_{gut} data (if available).

Do not overwrite in vivo values (default)

Select whether to keep F_{abs} and F_{gut} at 100% availability (which overwrites all other bioavailability parameter settings)

OUTPUT SPECIFICATION

Select the dose output units from either mg/kg BW/day (mgpkgpd) (default) or umol/kg BW/day (umolpkgpd).

mgpkgpd

The completed advanced parameters tab for example 1.

Run Simulation Tab

Now that all user parameter selections have been made and all compounds appear under the *Select Compounds* card, we click the *Run Simulation* button. Once the simulation is complete, the user's interface should look like the image below. The first tab shows a table of the OED for each compound. The table is available for download by the user if the user clicks the *Download Table 1* button. The user is also able to download all of the simulation parameters and chemical information used in the simulation by clicking the *Download OED Simulation Parameters* tab.

TOXICOKINETIC CHEMICAL SIMULATOR (TOCS)

General Parameters

Model Specifications

Compound Selection

Advanced (Optional) Parameters

Run Simulation

ACTIONS

Click on the 'Run Simulation' button when all information has been entered.

Run Simulation

Click on the button below to reset your session. This will clear all selections and any uploaded data, and is recommended to be done every time a new simulation is run.

Reset Session

☐ Check the box to display plots with a log10 scale y-axis.

SELECTED COMPOUNDS

Selected_Compounds

2,4-db

Acephate

Acetamiprid

Acetochlor

Alachlor

Aldicarb

Ametryn

Amitraz

RESULTS

Oral Equivalent Dose Table

Download Table 1

Download OED Simulation Parameters

Show 10 entries

Search:

	CompoundName	CAS	OED
1	2,4-db	94-82-6	0.003257
2	Acephate	30560-19-1	0.005198
3	Acetamiprid	135410-20-7	0.286
4	Acetochlor	34256-82-1	0.6619
5	Alachlor	15972-60-8	0.3133
6	Aldicarb	116-06-3	0.006385
7	Ametryn	834-12-8	0.005925
8	Amitraz	33089-61-1	0.004481

Showing 1 to 8 of 8 entries

Table 1: Table of the IVIVE oral equivalent doses (OED) (mg/kgpday) for each selected compound.

Oral Equivalent Dose Plot

Bioactivity Exposure Ratio Table

Previous 1 Next

The completed run simulation tab for example 1 showing the expanded OED table tab.

The image below is the completed OED plot tab, which shows the OED (in blue) for the selected quantile for each compound plotted in ascending order. The plot also shows the exposure data estimates (in pink) from the uploaded exposure data file next to each respective chemical so users can compare the oral equivalent dose needed for bioactivity and the exposure estimate. The plot shown below uses a linear y-axis, but as we can see, this makes it challenging to visually see the difference between the smaller OEDs as well as the distribution for the exposure estimates.

RESULTS

Oral Equivalent Dose Plot

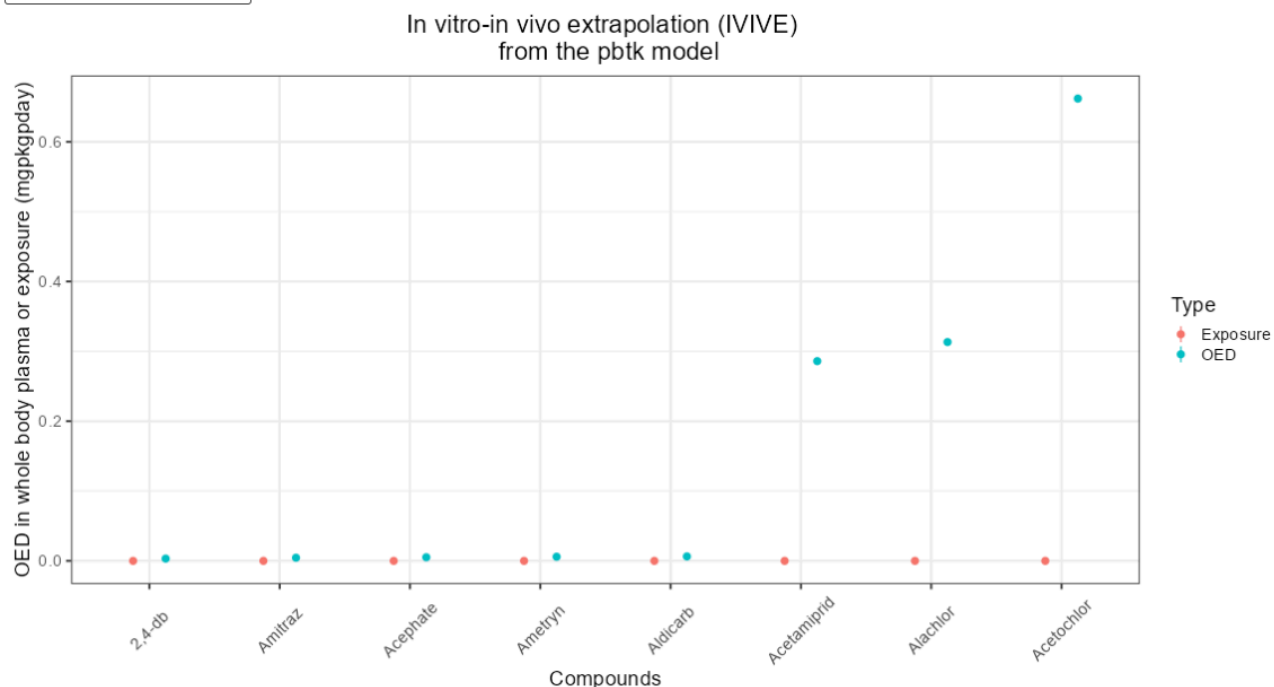
[Download Figure 1](#)

Figure 1: Plot of the estimated oral equivalent dose (OED) for each selected compound (blue) and user-uploaded exposure estimates (red). Compounds are arranged in ascending order of their OED values. Exposure estimates are shown as a distribution if more than one exposure estimate was provided for each compound. The purple dot represents the median exposure either uploaded by the user or calculated within the program. If the user only uploaded one exposure value for a compound, then the purple dot represents that value.

The completed run simulation tab for example 1 showing the expanded OED plot tab where the plot has a linear scale y-axis.

Therefore, we can click the box under the *Actions* card to change the scale of the y-axis to a log10 scale. That then results in the image shown below, which allows the user to view the differences in magnitudes of all OEDs and exposure estimates. Two chemicals have three exposure estimates available (lower, median, and upper), which is clearly seen by the median pink dot with bars extending in both directions, while the remaining chemicals only have two exposure estimates uploaded (median and upper). Those chemicals show a pink dot which represents the median exposure and one bar which reaches the upper exposure limit. The user can download either the linear or log10 scale plot by clicking the *Download Figure 1* button.

RESULTS

Oral Equivalent Dose Plot

Download Figure 1

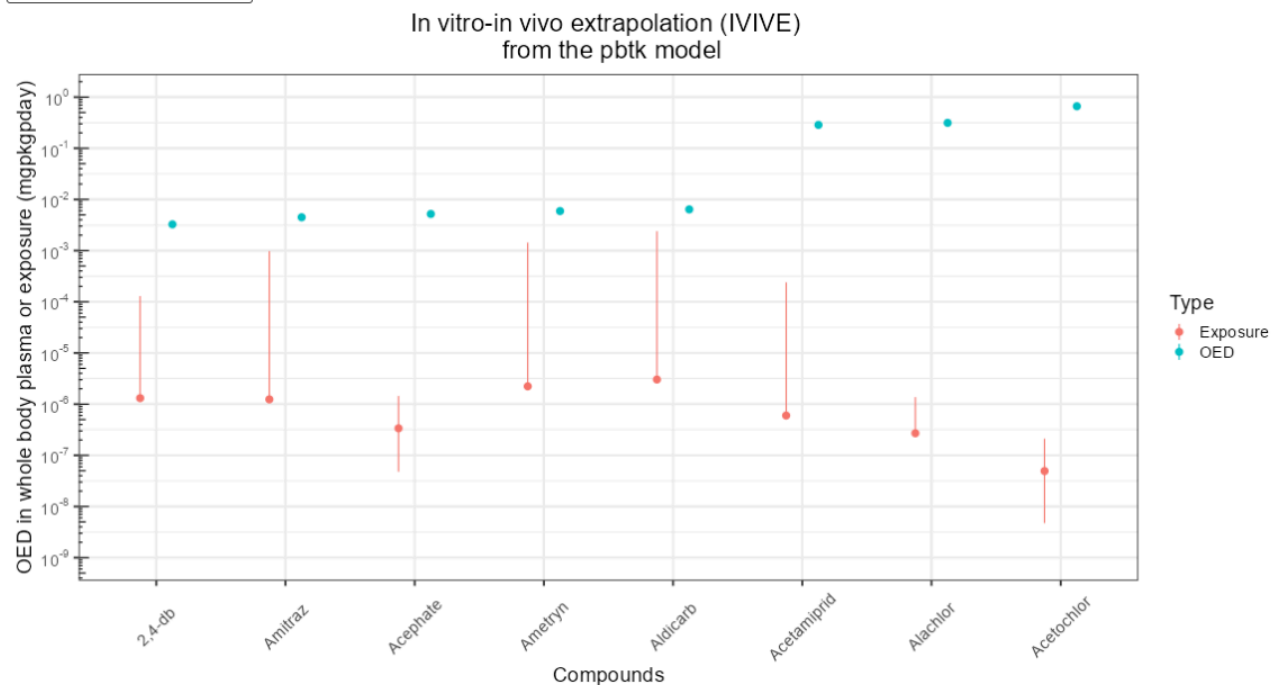
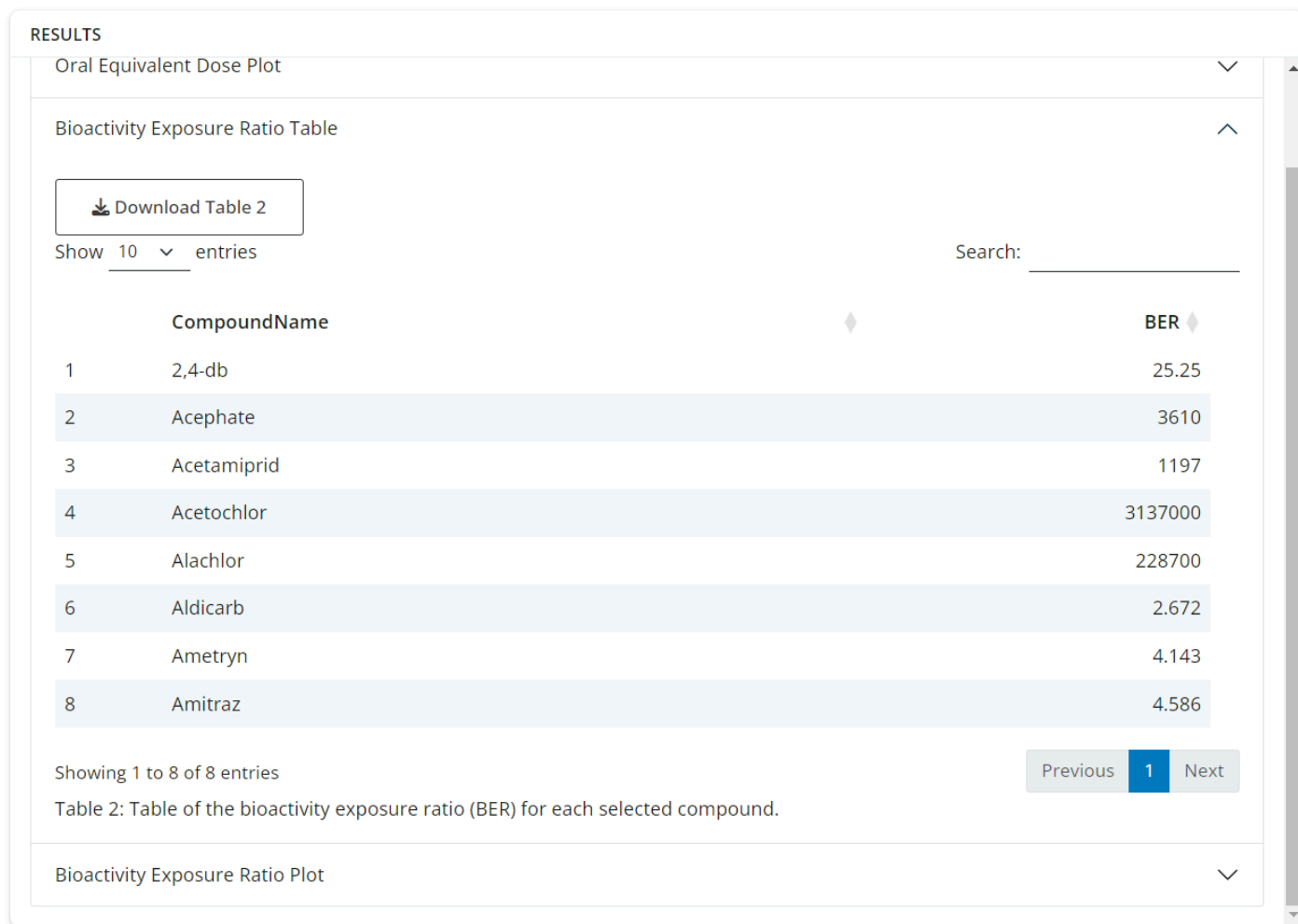


Figure 1: Plot of the estimated oral equivalent dose (OED) for each selected compound (blue) and user-uploaded exposure estimates (red). Compounds are arranged in ascending order of their OED values. Exposure estimates are shown as a distribution if more than one exposure estimate was provided for each compound. The purple dot represents the median exposure either uploaded by the user or calculated within the program. If the user only uploaded one exposure value for a compound, then the purple dot represents that value.

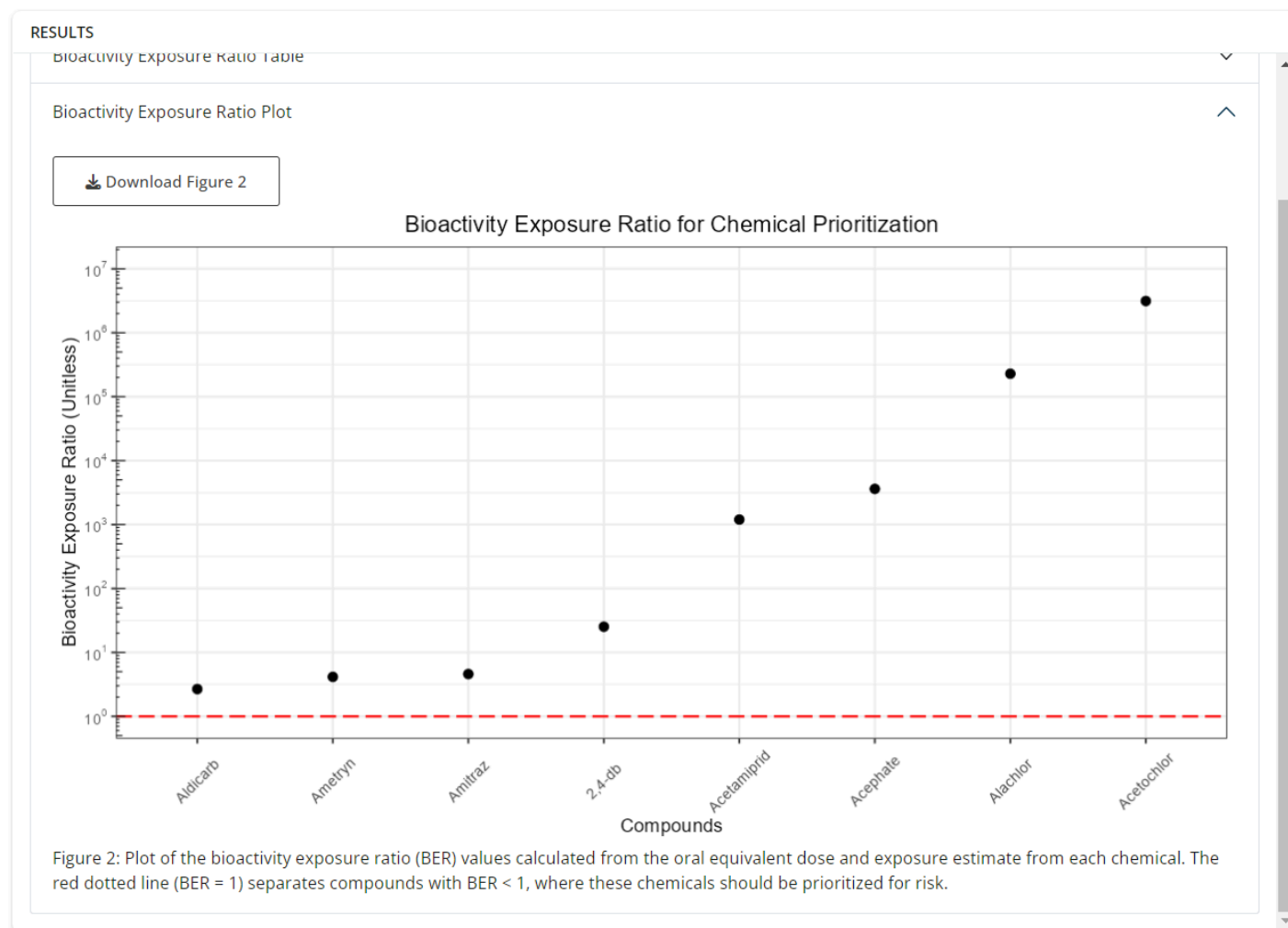
The completed run simulation tab for example 1 showing the expanded OED plot tab where the plot has a log10 scale y-axis.

The image below shows the bioactivity exposure ratio (BER) table output for the calculated OEDs and uploaded exposure estimates. This is computed as the OED divided by the upper exposure estimate. As with Table 1, users can download this table by clicking the "Download Table 2" button.



The completed run simulation tab for example 1 showing the expanded bioactivity exposure ratio (BER) table tab.

The final output for the IVIVE module is given below and shows a plot of the BER for each chemical. The red dotted line on the plot indicates the threshold for chemical prioritization (BER = 1), where any chemicals that fall below that threshold should be prioritized for further assessment. In this simulation though, all BERs are greater than one. As with the previous plot, the user has the opportunity to download this plot by clicking the “Download Figure 2” button above the plot.



The completed run simulation tab for example 1 showing the expanded BER plot tab where the plot has a log10 scale y-axis.

If we wanted to run another simulation, we would click the *Reset Session* button under the *Actions* button, which would clear all parameter inputs and simulations and return the interface to the *General Parameters* tab.

Example 2

Let's say we want to perform human IVIVE for ten chemicals that we have bioactivity data for. Assume that we want to use the nominal plasma in vitro bioactivity data as the bioactive concentration instead of the free concentration in vitro, and we want to use restrictive clearance. When the solution is outputted, suppose that we want to view all generated plasma OED samples calculated from the 3compartmentss model. Also suppose that we have chemical exposure estimates for all ten chemicals and would like to use them for this analysis.

General Parameters Tab

Since we want to perform IVIVE, we select the *In vitro in vivo extrapolation (IVIVE)* option under the drop down menu from the *Output* card. Then under the *Species* card, we select *Human* for the first drop down. Thus, the completed *General Parameters* tab should look like the image below.

INSTRUCTIONS

Fill out the prompts on each of the above tabs moving left to right. Then, click the 'Run Simulation' tab to run the simulation or reset all selections.

ToCS provides four toxicokinetic (TK) outputs: 1) Concentration-time profiles, which returns chemical concentrations in bodily compartments over time, 2) Steady state (SS) concentrations, which returns SS concentrations in bodily compartments from an oral infusion, 3) In vitro in vivo extrapolation (IVIVE), which returns oral equivalent doses to in vitro bioactive concentrations, 4) Parameter calculations, which returns elimination rates, volumes of distribution, tissue to unbound plasma partition coefficients, half-lives, and total plasma clearances.

This application uses the U.S. EPA's R package 'httk'. For more information on 'httk', refer to <https://doi.org/10.18637/jss.v079.i04> and/or <https://cran.r-project.org/web/packages/httk>

For additional guidance on ToCS, please refer to the vignettes (<https://github.com/KristenWindolowski/ToCS/tree/main/vignettes>). To report issues or suggestions for improvement, visit <https://github.com/KristenWindolowski/ToCS/issues>.

OUTPUT

Select the desired output.

In vitro in vivo extrapolation (IVIVE) ▾

SPECIES

Select the species to analyze.

Human ▾

The completed General Parameters tab for example 2.

Model Specifications Tab

Under the *Model* card, we select *3compartmentss* for the first drop down. For the second drop down, we select *Yes* and decide to make compounds with only in silico generated parameters (hepatic clearance, fraction unbound in plasma) also available for this example. Then, the third drop down menu asks the user whether they want to return a single OED per compound (a selected quantile) or all OED samples per compound. Since we want to output all generated OED samples, we select *Return all OED samples (will also return the 5th dose quantile)*. Under the *Dosing* card, there are no options to select from. Thus, the completed *Model Specifications* tab should look like the image below.

MODEL

Select the model to simulate. If a species other than 'Human' is selected, '3compartments' must be chosen.

3compartments

Select whether to use in silico generated parameters for compounds with missing in vitro data. These parameters will not overwrite existing in vitro data, and it will expand the number of compounds available.

Yes, load in silico parameters

Select whether to return all oral equivalent dose (OED) samples for each compound or a selected quantile.

Return all OED samples (will also return the 5th dose quantile)

DOSING

No options for this category.

The completed model specifications tab for example 2.

Compound Selection Tab

As with the first example, the first drop down menu under the *Preloaded Compounds* card has the user select a set of simulations assumptions to implement. See example 1 above for descriptions of the assumptions. Since we want to use the nominal concentration in vitro as bioactive and restrictive clearance (protein binding taking into account in liver clearance), we select NULL for the first drop down menu (note that we could have also selected Honda3 for the same result). We keep the second drop menu in the *Preloaded Compounds* card on *Choose from all available chemicals* and then the box below contains a list of preloaded compounds that we can select from. We search for the ten compounds we want to simulate and see that they are all present in the preloaded list. Thus, we select those compounds. Under the *Uploaded Data* card, we ignore the first file selection option since all compounds to simulate were found in the preloaded compounds list. Then for the second file selection option, we are required to upload a CSV file with bioactivity data in it for each selected compound. Therefore, we upload the following csv table. The csv file must have the exact format as the table below.

A csv file with bioactivity data for all ten chemicals. All values were calculated as the 5th percentile of AC50s (active calls only) for each compound, where the list of AC50s was taken from the cHTS assay database from ICE. Abamectin did not have any AC50s, so one was entered to fill the data set.

ChemicalName	CAS	BioactiveConcentration
Acetamiprid	135410-20-7	7.35400
2,4-db	94-82-6	13.46000

ChemicalName	CAS	BioactiveConcentration
Acephate	30560-19-1	0.05875
Abamectin	71751-41-2	1.00000
Acetochlor	34256-82-1	1.34800
Alachlor	15972-60-8	1.61700
Aldicarb	116-06-3	0.09300
Ametryn	834-12-8	1.08200
Amitraz	33089-61-1	27.49000
Atrazine	1912-24-9	1.30200

For formatting instructions, please either download the *Bioactivity Data File Folder* on the left side of the page or consult the *Introduction to ToCS* vignette. The final file upload option under the *Uploaded Data* card provides the user the opportunity to upload chemical exposure data. Thus, we upload the following CSV file:

A csv file with exposure estimate data (mg/kg BW/day) for all ten chemicals. These exposure estimates were gathered from the EPA CompTox Dashboard. NHANES estimates were used if available. Otherwise, the EPA's SEEM3 and SEEM2 model predictions were used.

ChemicalName	CAS	Upper	Median	Lower
Acetamiprid	135410-20-7	2.39e-04	5.99e-07	NA
2,4-db	94-82-6	1.29e-04	1.31e-06	NA
Acephate	30560-19-1	1.40e-06	3.37e-07	4.79e-08
Acetochlor	34256-82-1	2.00e-07	4.93e-08	4.74e-09
Alachlor	15972-60-8	1.40e-06	2.7e-07	NA
Aldicarb	116-06-3	2.39e-03	3.03e-06	NA
Ametryn	834-12-8	1.43e-03	2.23e-06	NA
Amitraz	33089-61-1	9.77e-04	1.24e-06	NA

ChemicalName	CAS	Upper	Median	Lower
Abamectin	71751-41-2	1.24e-05	4.17e-08	NA
Atrazine	1912-24-9	4.00e-07	5.76e-08	2.81e-09

For more details on the format of this file, please review the *Introduction to ToCS* vignette and/or the Exposure Data File Folder below the upload area in the interface. The completed *Compound Selection* tab should look like the images below.

Toxicokinetic Chemical Simulator (ToCS)
General Parameters
Model Specifications
Compound Selection
Advanced (Optional) Parameters
Run Simulation

INSTRUCTIONS

Click on the appropriate link(s) below to download guidance on how to upload data under the 'Uploaded Data' card. Follow the 'Instructions' document in the downloaded folder to correctly format the file you want to upload.

[Uploaded Physical-Chemical Data File Folder](#)

[Bioactivity Data File Folder](#)

[Exposure Data File Folder](#)

PRELOADED COMPOUNDS

Select an IVIVE assumption to implement. For any input nominal bioactive concentration in vitro, the Honda1 assumption is recommended. Leave on 'NULL' if no assumptions are to be applied. See the 'IVIVE Simulation Examples' vignette for the description of the below assumption categories.

NULL

Select the types of compounds you want to simulate.

Choose from all available chemicals

Select any preloaded compounds. Search through the list by clicking on the box and scrolling or typing in a name. The list may not show all available compounds. Click on a compound to select it. You may select multiple.

94-82-6, 2,4-db
71751-41-2, Abamectin
30560-19-1, Acephate
135410-20-7, Acetamiprid
34256-82-1, Acetochlor
15972-60-8, Alachlor
116-06-3, Aldicarb
834-12-8, Ametryn
33089-61-1, Amitraz
1912-24-9, Atrazine

UPLOADED DATA

Upload a CSV file of physical and chemical data for compounds not in the preloaded list (if desired). Download the 'Uploaded Physical-Chemical Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse...
No file selected

Upload a CSV file with in vitro bioactive concentrations (uM units) for all selected compounds. Download the 'Bioactivity Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse...
SampleBioData_10Cl
Upload complete

Upload a CSV file of exposure data for all selected compounds (optional). Download the 'Exposure Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse...
SampleExpData_10Cl
Upload complete

The completed compound selection tab for example 2.

Advanced (Optional) Parameters Tab

To speed up the computation time of the program, let's change the number of Monte Carlo samples generated for each compound (under the *Model Conditions* card) from 1000 to 500. Also, since we want to output the plasma OED, we keep the second drop down menu as *plasma* under the '*Output Specification* card. Thus, the completed *Advanced Parameters* tab should look like the image below.

MODEL CONDITIONS

Enter the number of Monte Carlo samples generated for each compound.

Select which chemical concentration is treated as bioactive in vivo.

Select whether protein binding is taken into account in liver clearance.

Select whether to adjust the chemical fraction unbound in presence of plasma proteins for lipid binding.

Select whether to use regressions when calculating partition coefficients.

Enter the p-value threshold for the in vitro intrinsic hepatic clearance rate where clearance assay results with p-values above this threshold are set to zero.

MODEL SOLVER

No options for this category.

BIOAVAILABILITY

Select whether to use the Caco2.Pab value set above to estimate F_{abs} (the in vivo measured fraction of an oral dose absorbed from the gut lumen into the gut) if bioavailability data is unavailable.

Select whether to use the Caco2.Pab value set above to calculate F_{gut} (the in vivo measured fraction of an oral dose that passes gut metabolism and clearance) if bioavailability data is unavailable.

Select whether to overwrite in vivo F_{abs} and F_{gut} data (if available).

Select whether to keep F_{abs} and F_{gut} at 100% availability (which overwrites all other bioavailability parameter settings above).

OUTPUT SPECIFICATION

Select the dose output units from either mg/kg BW/day (mgpkpday) (default) or umol/kg BW/day (umolpkpday).

Select the output concentration type.

Select a tissue you want the output concentration in. Leave on 'NULL' if the whole body concentration is desired.

The completed advanced parameters tab for example 2.

Run Simulation Tab

Now that all user parameter selections have been made and all compounds appear under the *Select Compounds* card, we click the *Run Simulation* button. Once the simulation is complete, the user's interface should look like the image below. The first tab shows a table of all generated OEDs for each compound (based on different steady state concentrations obtained from Monte Carlo simulations). The first row of the table contains the 5th quantile plasma OED, and then the rows below indicate the sample number and corresponding plasma OED from that sample. The user can view the various pages of samples by clicking the *Next* button at the bottom of the table. The table is available for download by the user if the user clicks the *Download Table 1* button. The user is also able to download all of the simulation parameters and chemical information used in the simulation by clicking the *Download OED Simulation Parameters* tab.

ACTIONS

Click on the 'Run Simulation' button when all information has been entered.

Run Simulation

Click on the button below to reset your session. This will clear all selections and any uploaded data, and is recommended to be done every time a new simulation is run.

Reset Session

☐ Check the box to display plots with a log10 scale y-axis.

SELECTED COMPOUNDS

Selected_Compounds

2,4-db

Abamectin

Acephate

Acetamiprid

Acetochlor

Alachlor

Aldicarb

Ametryn

Amitraz

Atrazine

RESULTS

Oral Equivalent Dose Table

Download Table 1 Download OED Simulation Parameters

Show 10 entries Search:

	2,4-db	Abamectin	Acephate	Acetamiprid	Acetochlor	Alachlor	Aldicarb	Ametryn	Amitraz	Atrazine
OED_5	0.00821	0.05295	0.003954	0.3721	1.4	0.7174	0.005155	0.01097	0.3913	0.014
Samples										
1	0.07899	0.7032	0.03679	3.427	18.24	1.132	0.0331	0.2383	8.243	0.097
2	0.02598	0.4325	0.009741	1.236	16.18	5.166	0.01098	0.01616	1.871	0.037
3	0.08012	0.4179	0.03164	2.547	1.784	2.682	0.02864	0.01648	3.653	0.086
4	0.006524	0.8591	0.01308	1.463	6.812	7.08	0.003727	0.155	3.056	0.013
5	0.02461	0.2286	0.02597	2.074	2.642	3.96	0.01284	0.01631	1.456	0.037
6	0.01675	0.1444	0.005954	0.2856	7.415	1.219	0.01976	0.04372	10.99	0.025
7	0.01722	0.125	0.01746	1.228	5.502	2.756	0.0075	0.08015	43.79	0.025
8	0.04574	0.2073	0.03181	1.966	4.259	2.066	0.0133	0.0537	0.832	0.057

Showing 1 to 10 of 502 entries

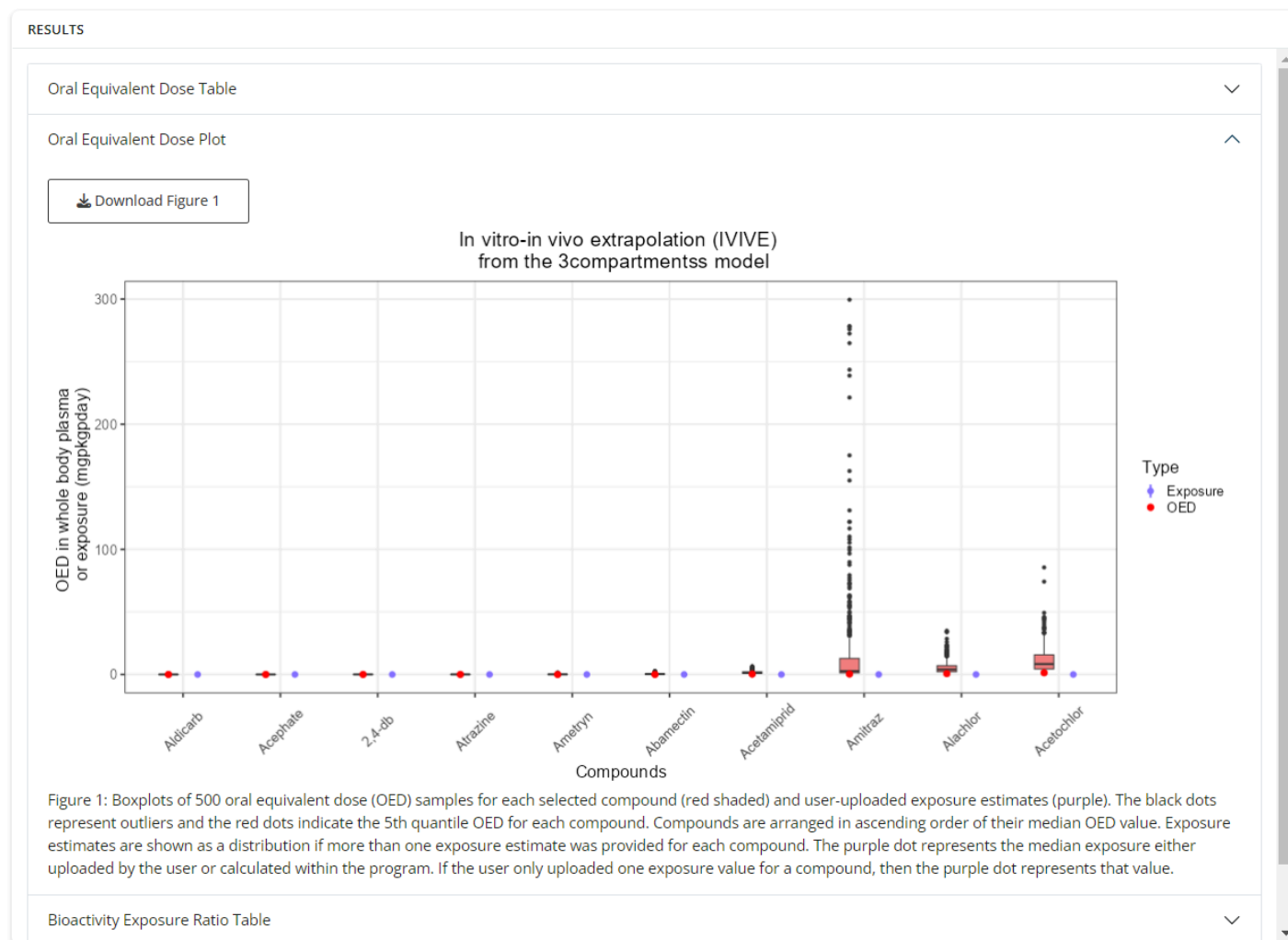
Previous 1 2 3 4 5 ... 51 Next

Table 1: Table of 500 IVIVE oral equivalent dose (OED) samples (mgpkgs/day) for each selected compound. OED_5 represents the 5th OED quantile (using the 95th quantile steady state concentration).

Oral Equivalent Dose Plot

The completed run simulation tab for example 2 showing the expanded OED table tab.

The image below is the completed OED plot tab, which shows boxplots describing the distribution of all OED samples for each simulated compound with line ranges of exposure estimate distributions (in purple) next to each chemical (though they look like singular points due to the linear y-axis). The black dots are outlying samples, and the large red dots represent the 5th quantile OED from the OED table in the previous drop down tab. The plot shown below uses a linear y-axis, but as we can see, this makes it challenging to visually see the distribution of OED samples and all exposure estimates.



The completed run simulation tab for example 2 showing the expanded OED plot tab where the OED plot has a linear scale y-axis and showcases the OED distributions against the chemical exposure estimate distributions.

Therefore, we can click the box under the *Actions* card to change the scale of the y-axis to a log10 scale. That then results in the image shown below, which allows the user to clearly view and compare the OED sample distributions and exposure estimates of all compounds. The description of the exposure estimates is the same as in example 1. The user can download either the linear or log10 scale plot by clicking the *Download Figure 1* button.

RESULTS

Oral Equivalent Dose Table

Oral Equivalent Dose Plot

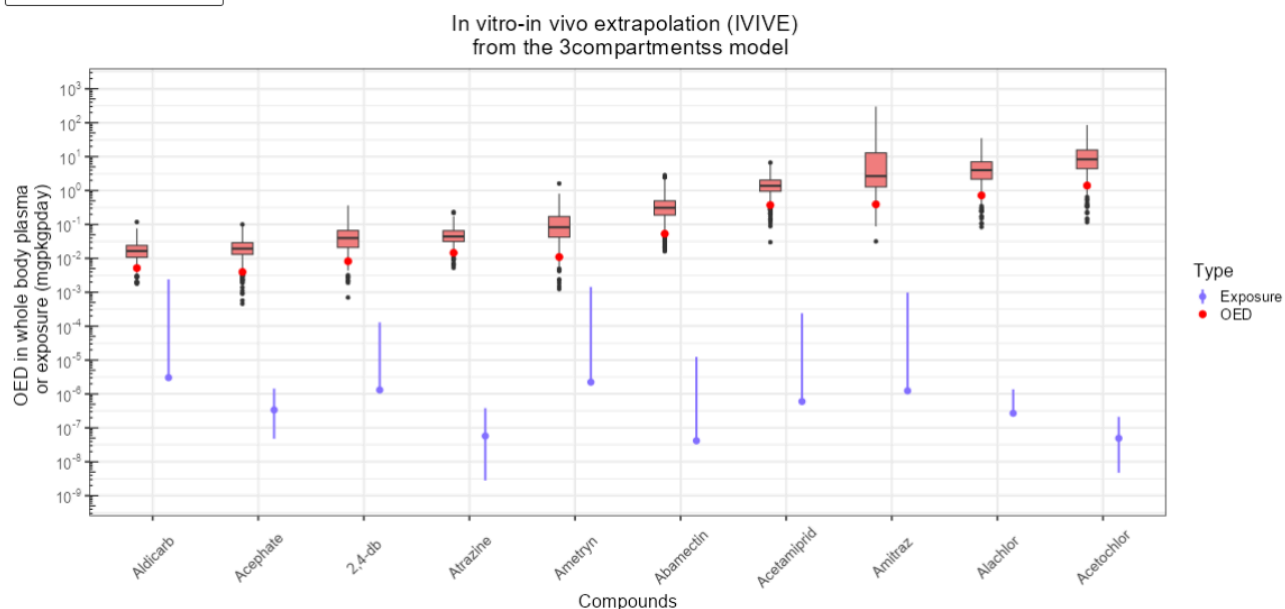
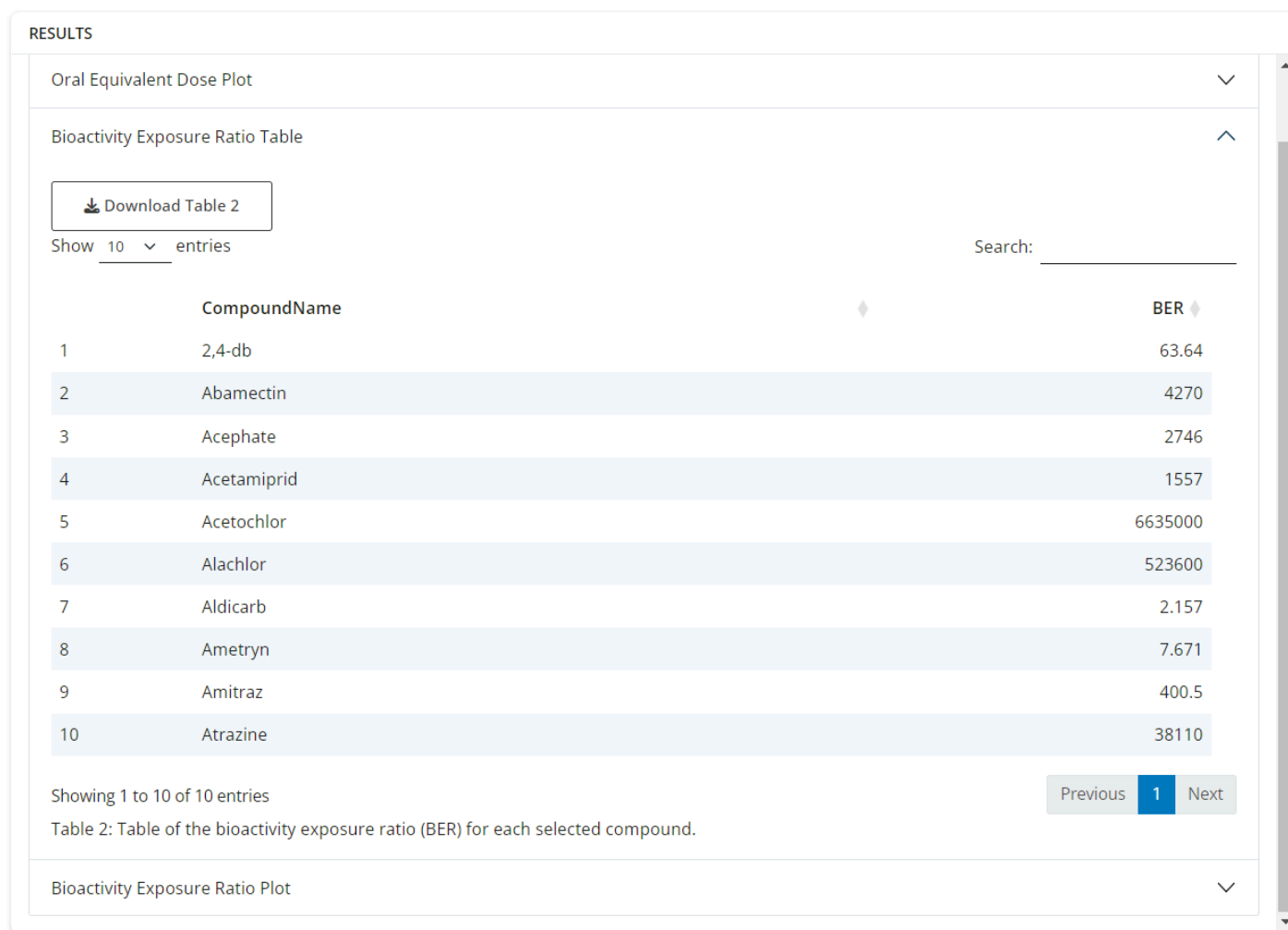
[Download Figure 1](#)

Figure 1: Boxplots of 500 oral equivalent dose (OED) samples for each selected compound (red shaded) and user-uploaded exposure estimates (purple). The black dots represent outliers and the red dots indicate the 5th quantile OED for each compound. Compounds are arranged in ascending order of their median OED value. Exposure estimates are shown as a distribution if more than one exposure estimate was provided for each compound. The purple dot represents the median exposure either uploaded by the user or calculated within the program. If the user only uploaded one exposure value for a compound, then the purple dot represents that value.

Bioactivity Exposure Ratio Table

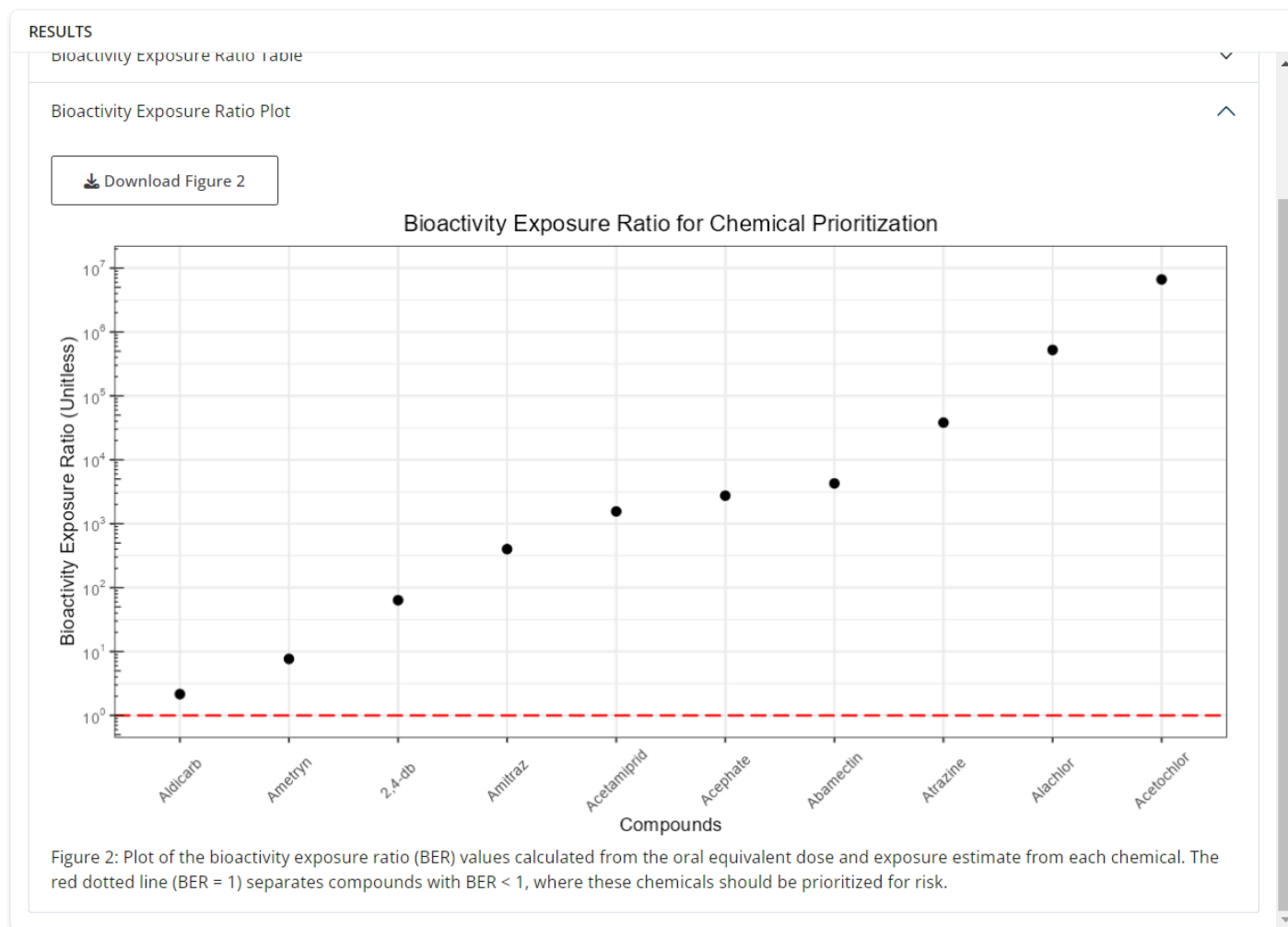
The completed run simulation tab for example 2 showing the expanded OED plot tab where the plot has a log10 scale y-axis.

The table below shows the calculated bioactivity exposure ratios (BERs) for the chemicals included in the simulation with exposure data. The BER was calculated as the quotient of the 5th quantile OED (red dot from the OED plot) and the upper exposure estimate data point. Users can download the table by clicking the *Download Table 2* button above the table.



The completed run simulation tab for example 2 showing the expanded BER table tab.

The image below shows the final output of the IVIVE module which is a plot of the bioactivity exposure ratio (BER) for each chemical. As we can see from the plot, all BERs in this simulation are > 1 (visually seen by the dotted red line), so they are not considered a risk with the current data used in the simulation. However, the user may want to use a different threshold for determining risk. Users can download this plot by clicking the *Download Figure 2* button above the plot.



The completed run simulation tab for example 2 showing the expanded BER plot tab where the plot has a log10 scale y-axis.

If we wanted to run another simulation, we would click the *Reset Session* button under the *Actions* button, which would clear all parameter inputs and simulations and return the interface to the *General Parameters* tab.

Example 3

Let's say that we want to perform human IVIVE to obtain 10th quantile liver OEDs using the 3compartment model. We will use the nominal bioactivity data for the eight compounds used in example 1, and want to include restrictive clearance in the model. We will not upload chemical exposure data for this example.

General Parameters Tab

Since we want to perform IVIVE, we select the *In vitro in vivo extrapolation (IVIVE)* option under the drop down menu from the *Output* card. Then under the *Species* card, we select *Human* for the first drop down. Thus, the completed *General Parameters* tab should look like the image below.

INSTRUCTIONS

Fill out the prompts on each of the above tabs moving left to right. Then, click the 'Run Simulation' tab to run the simulation or reset all selections.

ToCS provides four toxicokinetic (TK) outputs: 1) Concentration-time profiles, which returns chemical concentrations in bodily compartments over time, 2) Steady state (SS) concentrations, which returns SS concentrations in bodily compartments from an oral infusion, 3) In vitro in vivo extrapolation (IVIVE), which returns oral equivalent doses to in vitro bioactive concentrations, 4) Parameter calculations, which returns elimination rates, volumes of distribution, tissue to unbound plasma partition coefficients, half-lives, and total plasma clearances.

This application uses the U.S. EPA's R package 'httk'. For more information on 'httk', refer to <https://doi.org/10.18637/jss.v079.i04> and/or <https://cran.r-project.org/web/packages/httk>

For additional guidance on ToCS, please refer to the vignettes (<https://github.com/KristenWindoloski/ToCS/tree/main/vignettes>). To report issues or suggestions for improvement, visit <https://github.com/KristenWindoloski/ToCS/issues>.

OUTPUT

Select the desired output.

In vitro in vivo extrapolation (IVIVE) ▾

SPECIES

Select the species to analyze.

Human ▾

The completed General Parameters tab for example 3.

Model Specifications Tab

Under the *Model* card, we select *3compartment* for the first drop down. For the second drop down, we select *No* and decide to make compounds with only in vitro data available for this example. Then, the third drop down menu asks the user whether they want to return a single OED per compound (a selected quantile) or all OED samples per compound. Since we want to output the 10th quantile OED, we select *Only return a specified dose quantile (default)*. This results in the appearance of another input box. In this final box under the *Model* card, we enter the steady state concentration quantile that we desire to use in our OED calculation (0.90). This will return the 10th quantile OED in the simulation results. Under the *Dosing* card, there are no options to select from. Thus, the completed *Model Specifications* tab should look like the image below.

MODEL

Select the model to simulate. If a species other than 'Human' is selected, '3compartmentss' must be chosen.

3compartment

Select whether to use in silico generated parameters for compounds with missing in vitro data. These parameters will not overwrite existing in vitro data, and it will expand the number of compounds available.

No, do not load in silico parameters

Select whether to return all oral equivalent dose (OED) samples for each compound or a selected quantile.

Only return a specified dose quantile (default)

Enter the steady state concentration quantile (as a decimal) to be used in the OED calculation. Selecting the 95th concentration quantile will output the 5th OED quantile.

0.9

DOSING

No options for this category.

The completed model specifications tab for example 3.

Compound Selection Tab

As with the first example, the first drop down menu under the *Preloaded Compounds* card has the user select a set of simulations assumptions to implement. See example 1 for descriptions of the assumptions. As with example 2, we will select NULL for the first drop down menu since we wanted to use 1) the nominal in vitro concentration as bioactive, 2) restrictive clearance, and 3) liver tissue as bioactive in vivo. We keep the second drop menu in the *Preloaded Compounds* card on *Choose from all available chemicals* and then in the box below that, there's a list of preloaded compounds that we can select from. We search for the eight compounds that we want to select and see that they are all present in the preloaded list. Thus, we select those compounds. Under the *Uploaded Data* card, we ignore the first file upload option since all of the compounds we want to simulate are available under the preloaded list in the middle column. The second file upload for bioactivity data is required, and so we upload the following csv table of bioactive concentrations for all compounds:

A csv file with bioactivity data for all eight chemicals. All values were calculated as the 5th percentile of AC50s (active calls only) for each compound, where the list of AC50s was taken from the cHTS assay database from ICE.

ChemicalName	CAS	BioactiveConcentration
Acetamiprid	135410-20-7	7.35400
2,4-db	94-82-6	13.46000
Acephate	30560-19-1	0.05875

ChemicalName	CAS	BioactiveConcentration
Acetochlor	34256-82-1	1.34800
Alachlor	15972-60-8	1.61700
Aldicarb	116-06-3	0.09300
Ametryn	834-12-8	1.08200
Amitraz	33089-61-1	27.49000

For formatting instructions, please either download the *Bioactivity Data File Folder* on the left side of the page or consult the *Introduction to ToCS* vignette. The final file upload option under the *Uploaded Data* card provides the user the opportunity to upload chemical exposure data. However, suppose that we do not have chemical exposure data to upload for this simulation. Therefore, we leave that blank. The completed *Compound Selection* tab should look like the images below.

Toxicokinetic Chemical Simulator (ToCS)
General Parameters
Model Specifications
Compound Selection
Advanced (Optional) Parameters
Run Simulation

INSTRUCTIONS

Click on the appropriate link(s) below to download guidance on how to upload data under the 'Uploaded Data' card. Follow the 'Instructions' document in the downloaded folder to correctly format the file you want to upload.

[Uploaded Physical-Chemical Data File Folder](#)

[Bioactivity Data File Folder](#)

[Exposure Data File Folder](#)

PRELOADED COMPOUNDS

Select an IVIVE assumption to implement. For any input nominal bioactive concentration in vitro, the Honda1 assumption is recommended. Leave on 'NULL' if no assumptions are to be applied. See the 'IVIVE Simulation Examples' vignette for the description of the below assumption categories.

NULL

Select the types of compounds you want to simulate.

Choose from all available chemicals

Select any preloaded compounds. Search through the list by clicking on the box and scrolling or typing in a name. The list may not show all available compounds. Click on a compound to select it. You may select multiple.

94-82-6, 2,4-db
30560-19-1, Acephate
135410-20-7, Acetamiprid
34256-82-1, Acetochlor
15972-60-8, Alachlor
116-06-3, Aldicarb
834-12-8, Ametryn
33089-61-1, Amitraz

UPLOADED DATA

Upload a CSV file of physical and chemical data for compounds not in the preloaded list (if desired). Download the 'Uploaded Physical-Chemical Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... No file selected

Upload a CSV file with in vitro bioactive concentrations (uM units) for all selected compounds. Download the 'Bioactivity Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... SampleBioData_8Che

Upload complete

Upload a CSV file of exposure data for all selected compounds (optional). Download the 'Exposure Data File Folder' under the 'Instructions' card for file formatting instructions.

Browse... No file selected

The completed compound selection tab for example 3.

Advanced (Optional) Parameters Tab

Since we want to output the plasma OED in the liver, we select *plasma* under the second drop down menu in the *Output Specification* card specifying the output concentration type. Then, we select *liver* under the third drop down menu since we want the liver OED. No changes to other parameters on this page should be made for this example. Thus, the completed *Advanced Parameters* tab should look like the image below.

Toxicokinetic Chemical Simulator (ToCS)

General Parameters

Model Specifications

Compound Selection

Advanced (Optional) Parameters

Run Simulation

MODEL CONDITIONS

Enter the number of Monte Carlo samples generated for each compound.

Select whether protein binding is taken into account in liver clearance.

Select whether to adjust the chemical fraction unbound in presence of plasma proteins for lipid binding.

Select whether to use regressions when calculating partition coefficients.

Enter the p-value threshold for the in vitro intrinsic hepatic clearance rate where clearance assay results with p-values above this threshold are set to zero.

Enter the minimum acceptable chemical fraction unbound in presence of plasma proteins. All values below this will be set to this value.

MODEL SOLVER

No options for this category.

BIOAVAILABILITY

Enter a default value for the Caco-2 apical-to-basal membrane permeability (denoted Caco2.Pab, 10^{-6} cm/s).

Select whether to use the Caco2.Pab value set above to estimate F_{abs} (the in vivo measured fraction of an oral dose absorbed from the gut lumen into the gut) if bioavailability data is unavailable.

Select whether to use the Caco2.Pab value set above to calculate F_{gut} (the in vivo measured fraction of an oral dose that passes gut metabolism and clearance) if bioavailability data is unavailable.

Select whether to overwrite in vivo F_{abs} and F_{gut} data (if available).

Select whether to keep F_{abs} and F_{gut} at 100% availability (which overwrites all other bioavailability parameter settings).

OUTPUT SPECIFICATION

Select the dose output units from either mg/kg BW/day (mgpkgsday) (default) or umol/kg BW/day (umolpkgsday).

Select the output concentration type.

Select a tissue you want the output concentration in. Leave on 'NULL' if the whole body concentration is desired.

The completed advanced parameters tab for example 3.

Run Simulation Tab

Now that all user parameter selections have been made and all compounds appear under the *Select Compounds* card, we click the *Run Simulation* button. Once the simulation is complete, the user's interface should look like the image below. The first tab shows a table of the OED for each compound. The table is available for download by the user if the user clicks the *Download Table 1* button. The user is also able to download all of the simulation parameters and chemical information used in the simulation by clicking the *Download OED Simulation Parameters* tab.

ACTIONS

Click on the 'Run Simulation' button when all information has been entered.

Run Simulation

Click on the button below to reset your session. This will clear all selections and any uploaded data, and is recommended to be done every time a new simulation is run.

Reset Session

☐ Check the box to display plots with a log10 scale y-axis.

SELECTED COMPOUNDS

Selected_Compounds

2,4-db

Acephate

Acetamidiprid

Acetochlor

Alachlor

Aldicarb

Ametryn

Amitraz

RESULTS

Oral Equivalent Dose Table

Download Table 1 Download OED Simulation Parameters

Show 10 entries Search:

	CompoundName	CAS	OED
1	2,4-db	94-82-6	0.02099
2	Acephate	30560-19-1	0.0004554
3	Acetamidiprid	135410-20-7	0.02996
4	Acetochlor	34256-82-1	0.006264
5	Alachlor	15972-60-8	0.006047
6	Aldicarb	116-06-3	0.0005376
7	Ametryn	834-12-8	0.009288
8	Amitraz	33089-61-1	0.3419

Showing 1 to 8 of 8 entries

Table 1: Table of the IVIVE oral equivalent doses (OED) (mgpkpday) for each selected compound.

Oral Equivalent Dose Plot

Bioactivity Exposure Ratio Table

Bioactivity Exposure Ratio Plot

The completed run simulation tab for example 3 showing the expanded OED table tab.

The image below is the completed OED plot tab, which shows a plot of the 10th quantile OEDs using the liver steady state concentration for OED calculation. The plot shown below uses a linear y-axis, but as we can see, this makes it challenging to visually notice the magnitude of smaller OEDs.

RESULTS

Oral Equivalent Dose Table

Oral Equivalent Dose Plot

Download Figure 1

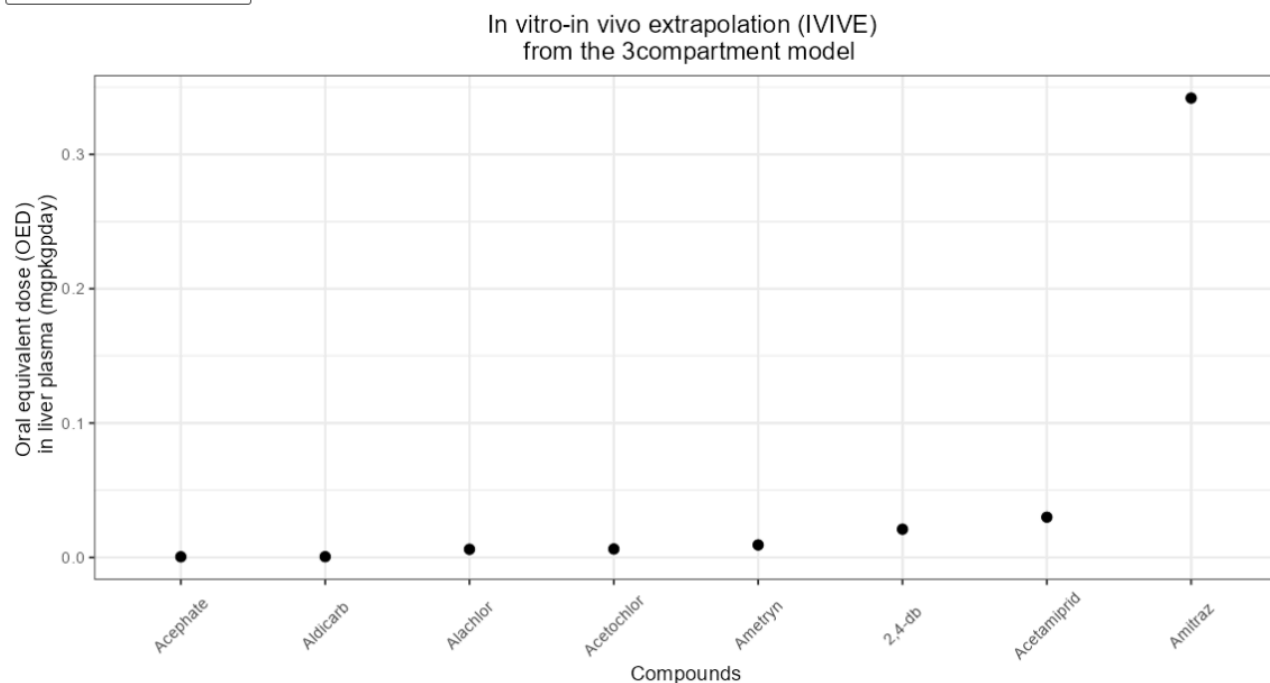


Figure 1: Plot of the estimated oral equivalent dose (OED) for each selected compound. Compounds are arranged in ascending order of their OED values.

The completed run simulation tab for example 3 showing the expanded OED plot tab where the plot has a linear scale y-axis.

Therefore, we can click the box under the *Actions* card to change the scale of the y-axis to a log10 scale. That then results in the image shown below, which allows the user to view the differences in magnitudes of all OEDs. The user can download either the linear or log10 scale plot by clicking the *Download Figure 1* button.

RESULTS

Oral Equivalent Dose Table

Oral Equivalent Dose Plot

Download Figure 1

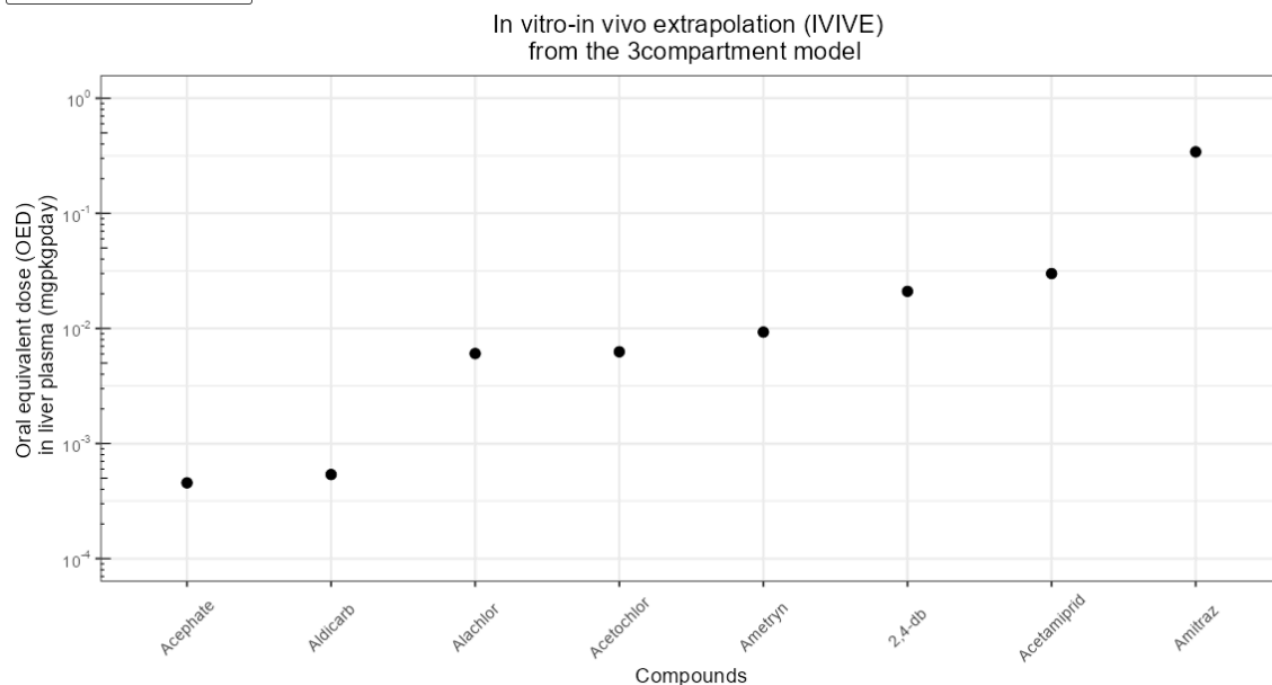


Figure 1: Plot of the estimated oral equivalent dose (OED) for each selected compound. Compounds are arranged in ascending order of their OED values.

The completed run simulation tab for example 3 showing the expanded OED plot tab where the plot has a log10 scale y-axis.

The final two tabs on the IVIVE module exhibit the bioactivity exposure ratio (BER), if applicable for the simulation. Since no chemical exposure data was uploaded under the *Compound Selection* tab, no BERs were calculated for this simulation. If the user wanted to calculate BERs for this simulation, they would need to upload chemical exposure under the previous tab.

RESULTS

Oral Equivalent Dose Table



Oral Equivalent Dose Plot



Bioactivity Exposure Ratio Table



Chemical exposure data was not uploaded under the 'Compound Selection' tab, so the bioactivity exposure ratio (BER) cannot be calculated. If the BER is desired, please upload exposure data on the 'Compound Selection' tab under the 'Output Specification' card.

Bioactivity Exposure Ratio Plot



Chemical exposure data was not uploaded under the 'Compound Selection' tab, so the bioactivity exposure ratio (BER) cannot be calculated. If the BER is desired, please upload exposure data on the 'Compound Selection' tab under the 'Output Specification' card.

The completed run simulation tab for example 3 showing the expanded BER table and plot tabs, which notifies the user that the calculations were not computed due to lack of exposure data.

If we wanted to run another simulation, we would click the *Reset Session* button under the *Actions* button, which would clear all parameter inputs and simulations and return the interface to the *General Parameters* tab.