Exposure Assessment Tools From the American Industrial Hygiene Association: A Short Review With Examples

Presentation prepared by:

Thomas W. Armstrong, CIH, PhD, FAIHA

TWA8HR Occupational Hygiene Consulting, LLC,
Bangor, Maine, United States.
twa8hr@gmail.com

Introduction

Software tools developed in the American Industrial Hygiene Association's Exposure Assessment Strategies Committee provide ways to evaluate data and model occupational/consumer exposure scenarios. The tools are free and most are VBA and macro enhanced MS Excel spreadsheets. We will look at the list of available tools and brief descriptions of them. Then, we will look at four (IH Mod, ODHMod, IH Skinperm, Dermal Risk Assessment Model) in more detail, with examples of their use for chemical exposures and oxygen deficiency hazards.

Available at: *bit.ly/3QSjTbv*

(AIHA Risk Assessment Tools)

Most of the tools are macro and VBA enhanced MS Excel spreadsheets.

You will need to be able to download and install an Excel Macro Enabled spreadsheet, that has the ".XLSM" file extension.

In many government agencies and companies, you may need organizational permission and assistance from your computer support personnel.

QR Code to access the AIHA Risk Assessment Tools

Outline of the tools part 1 (first 5 of 9)

1. **IH Exposure Scenario Tool** guides evaluation of the workplace, specific scenarios and agents(s), key determinants of exposure and the type of engineering controls.
2. **Structured Deterministic Model (SDM 2.0)** is a deterministic model that provides point estimates of the 95th percentile airborne concentrations as a predictor of inhalation exposure to chemicals. It applies to pure, or relatively pure, volatile and semi-volatile chemicals and chemical mixtures (Checklist #1) and fibers, particulates and aerosols (Checklist #2) Requires: ap identified work few minutes us subjective prof
3. **IH Stat** is a goodness of fit
4. **IHSTAT B** using a Bayesia Bayesian engir AIHA exposure
5. **IH Mod** is a estimating air concentration exposures. IH Mod 2.0 additionally provides native in MS Excel Monte Carlo Simulation. This tool has a separate HELP file.

Given the number of tools and limited time, I will give just quick overviews of functionality for most of these. They have HELP screens or files available. If you are interested, further details on any of these tools are available with the tools themselves. I will discuss the four in **RED** in more detail. Write to me after the talk if you wish to see more details on the others that I briefly cover in the Supplemental Materials at the end of this slide set.

Outline of the Tools part 2 (6 to 9)

6. **ODHMod** is a Microsoft® Excel workbook for predicting the oxygen content trends in environments where inert gas releases may lead to asphyxiation risks. ODHMODTM uses a Near Field-Far Field approach and estimates the oxygen concentration percent by volume and as mmHg partial pressure over time in the two zones. ODHMod has many built-in examples.
7. **IH SkinPerm** is an Excel application for estimating the dermal uptake or evaporation of dermally deposited agents. Four dermal absorption scenarios can be simulated including estimates of dermal uptake from air. This tool has a separate HELP file.
8. **Dermal Risk Assessment Model (DRAM)** provides a systematic screening evaluation of the relative risks of dermal exposure to a material and may be especially useful for the purposes of prioritizing additional analysis for specific materials or scenarios
9. Toxico-kinetic Extended Shift OEL Adjustment is an MS Excel spreadsheet that implements the Hickey and Reist toxico-kinetic approach to adjust OELs for extended and unusual work shifts, as published by Armstrong et al. The spreadsheet has four tabs: 1. known half-life, 2. unknown half-life, 3. documentation and 4. examples.

What goes on in mathematical modeling of exposures?

Exposure
= function of

Intensity
- Quantity of material
- Its physical-chemical properties
- Build-up/Dilution/Removal/Decay

Duration

Frequency

But also consider
Uncertainty &
Variability

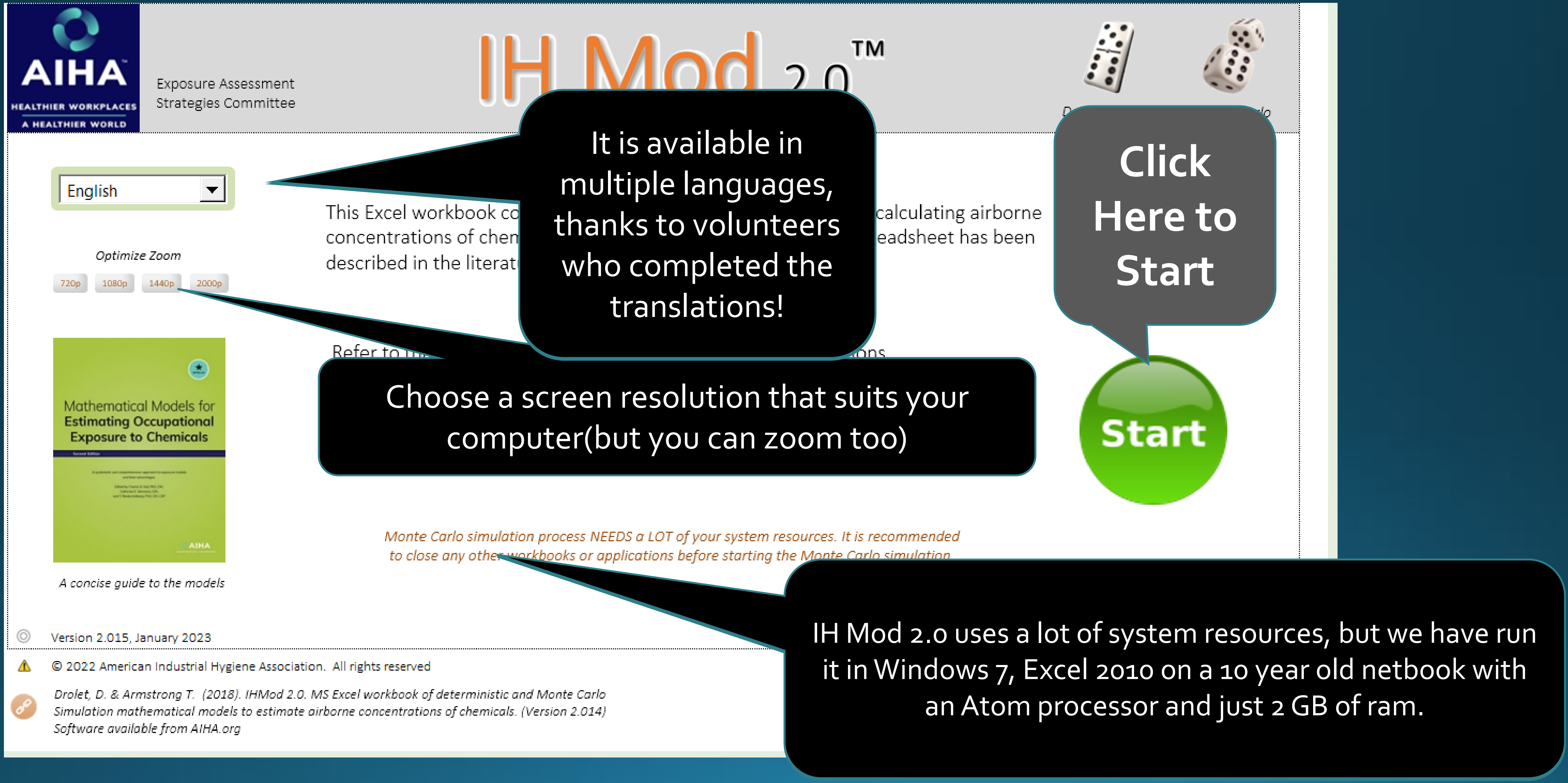
IH Mod 2.0 mathematical models to estimate air concentrations

- IH Mod 2.0 includes Monte Carlo Simulation to evaluate parameter uncertainty and variability in the deterministic models given in IH Mod 1.0, ***in Excel***, with no other software needed!
  - The calculations are set to give the 5^{th}, 25^{th}, median, 75^{th} and 95^{th} percentiles of the results distribution and this is not user configurable.
  - MCS calculations can be very useful where you have a possible range of values for certain model parameters, such as a minimum and maximum for the ventilation rate, or a minimum, most probable and maximum for the contaminant generation rate, or a log-normal distribution of air velocity.
- The Concentration vs Time (or TWA vs Time) curves at the given percentiles can provide new insights into time and variability patterns of the air contamination.
- "What if we increase ventilation" and similar control questions can be evaluated by changing the parameter value and running the model again.

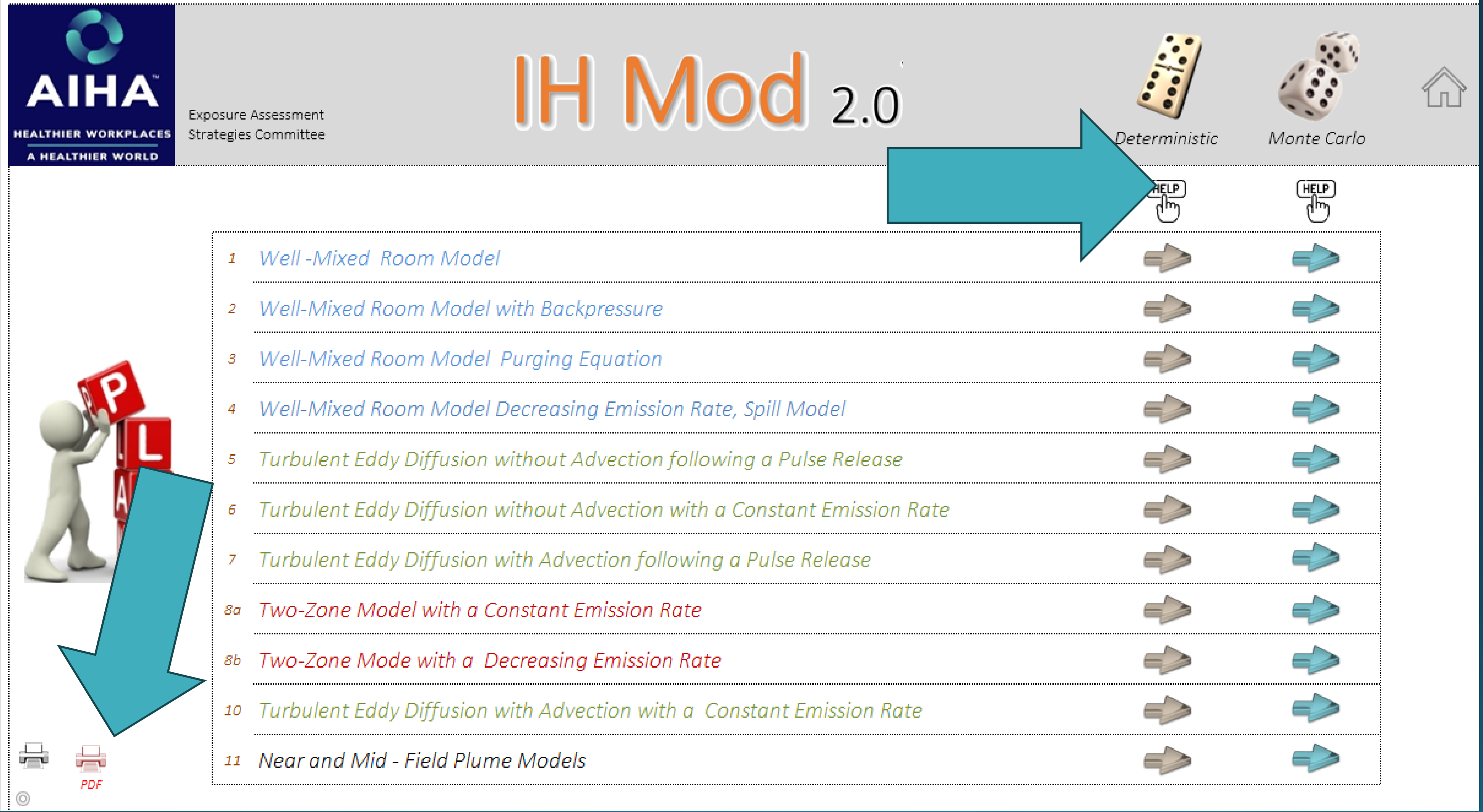
What is Monte Carlo Simulation

- The Monte Carlo Method was invented, based on game theory, by John von Neumann and Stanislaw Ulam during World War II to improve decision making under uncertain conditions
- The Monte Carlo method is a computerized mathematical technique
- Input factors are defined as statistical distributions
- The software randomly selects a value from each input distribution, calculates results, and sets them aside
- The software then selects a different random set, calculates, sets the result aside, and repeats over and over again
- At the end of the specified iterations, the software compiles and presents the statistical analysis of all the results

This is what you first see (after disclaimer)



These are the models included in IH Mod 2.0



The Two Zone Constant Generation MCS Version

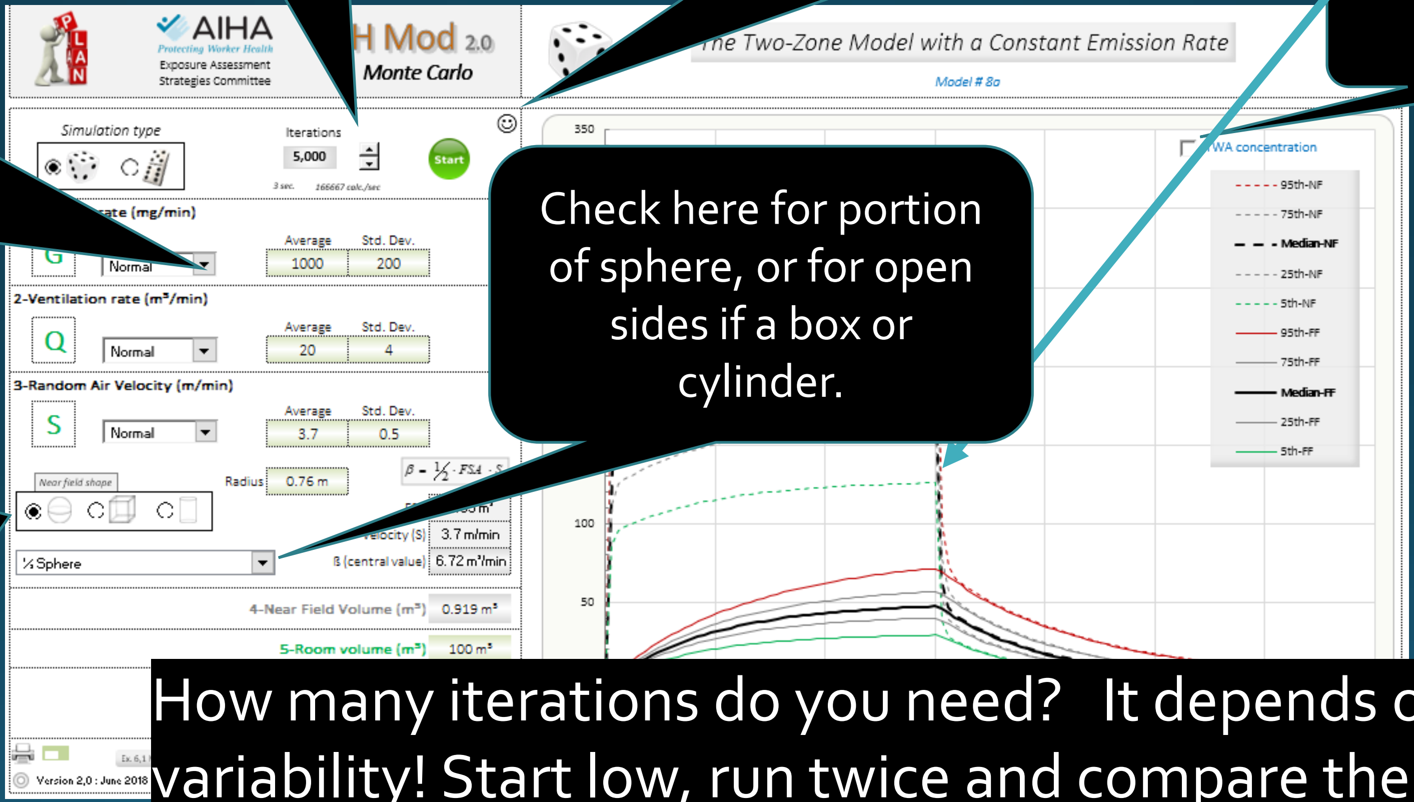
Choose the distribution type and set the parameters.

The normal distribution is truncated to avoid zero and negative values

Set the number of iterations.

Smile = good to go!
Frown = parameters, etc. not quite right!

Show graph for TWA or C vs T



Check here for portion of sphere, or for open sides if a box or cylinder.

Here you define the Near Field shape and how much of it is open to air exchange. The spreadsheet then calculates **Beta,** using S and FSA, The room Far Field Volume adjusts too.

How many iterations do you need? It depends on parameter variability! Start low, run twice and compare the results. If quite divergent, increase the iterations until you have satisfactory “stability” from run to run.

ODHMOD

Oxygen Deficiency Hazard Predictive Modelling

The spreadsheet is the product of research by
Elena Stefana and Filippo Marciano,
with additional Excel development by Daniel Drolet

UNIVERSITÀ DEGLI STUDI DI BRESCIA unibs.it

Department of Mechanical and Industrial Engineering

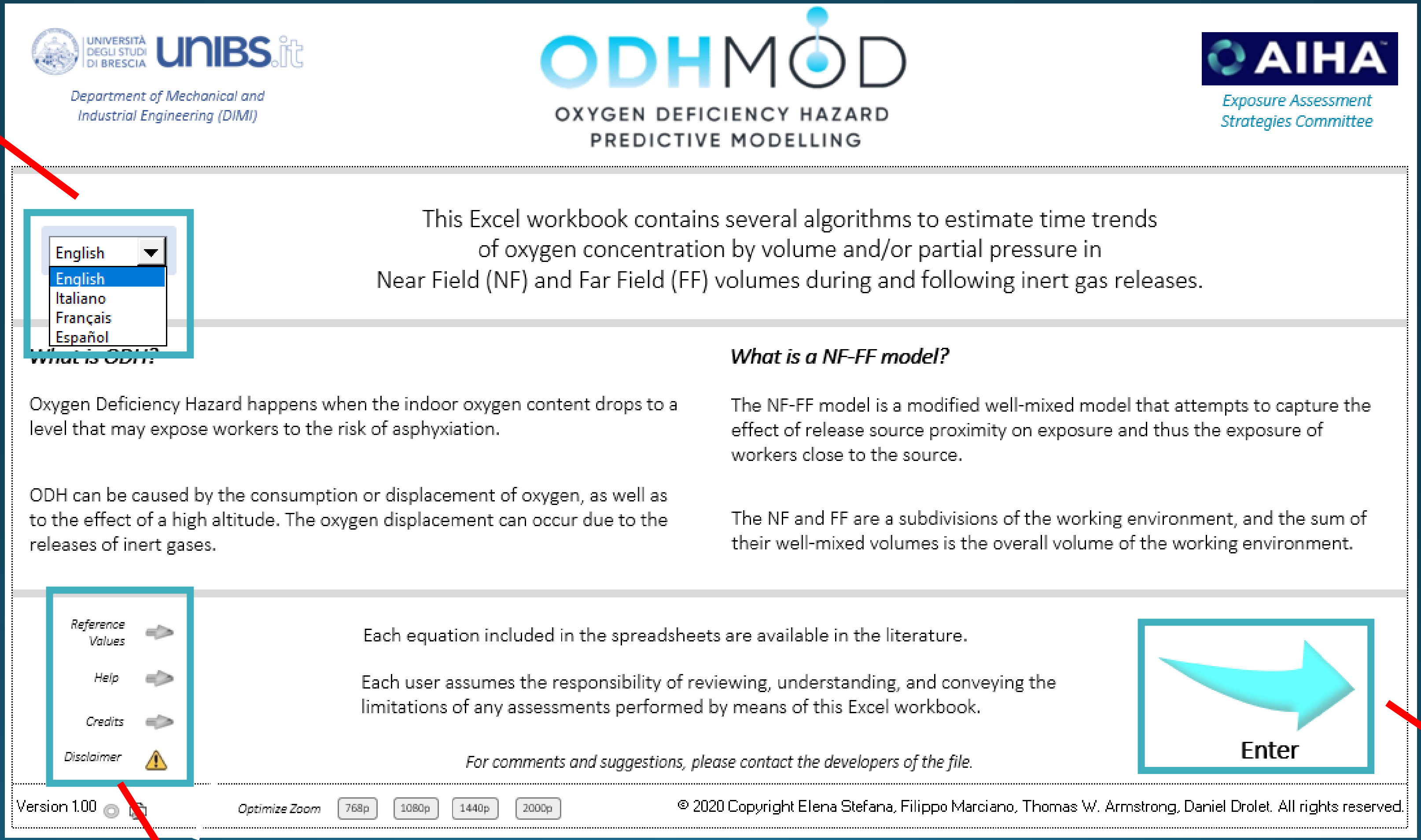
AIHA

Exposure Assessment Strategies Committee

ODHMOD

- Disclaimer
- Introductory page
- Information page
- Help page
- Credits
- **Model sheet**
- Calculation sheet
- Example sheets

To select the language in the entire tool (with the exception of Disclaimer)



To consult other sheets of the tool

To go to the Model sheet and run simulations

ODHMod includes a table of reference values

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ODHMOD
OXYGEN DEFICIENCY HAZARD PREDICTIVE MODELLING

Oxygen % and PP

In the literature there is no consensus on a safe Threshold Limit Value for the oxygen content in terms of concentration by volume and/or partial pressure.

...er, useful information and recommendations can be derived from the ranges reported in the table below.

Sources

O_2 concentration by volume (*at atmospheric pressure and at sea level*) From	to	O_2 partial pressure (*Atmospheric pressure equal* 101.325 kPa) From	to	Symptoms and physiological effects (*for individuals at rest or however seated ones*)	Action!
21 %	18 %	160 mmHg 21.3 kPa	137 mmHg 18.2 kPa	No symptoms in healthy adults.	Monitoring
18 %	15 %	137 mmHg 18.2 kPa	114 mmHg 15.2 kPa	Decreased ability to perform tasks; early symptoms in person with heart, lung or circulatory problems. Night vision reduced. Increased breathing volume. Accelerated heartbeat. Dizziness. Time required for novel tasks doubled. Loss of muscle control.	Monitoring and suggested measure adoption
15 %	12 %	114 mmHg 15.2 kPa	91.2 mmHg 12.2 kPa	Respiration deeper, pulse faster. Impaired and poor coordination. Impaired attention and thinking. Intermittent breathing. Rapid fatigue. Sudden changes in mood. Emotional upsets. Impaired judgment. Tunnel vision.	
12 %	10 %	91.2 mmHg 12.2 kPa	76 mmHg 10.1 kPa	Giddiness. Possibility of fainting. Very faulty judgment. Lips slightly blue. Loss of consciousness. Permanent brain damage. Possible damage to the heart. Very poor muscular coordination.	Required urgent measure and control adoption
10 %	8 %	76 mmHg 10.1 kPa	60.8 mmHg 8.11 kPa	Nausea, vomiting, unconsciousness, ashen face, fainting, mental failure. Inability to move.	
8 %	6 %	60.8 mmHg 8.11 kPa	45.6 mmHg 6.08 kPa	Spasmodic breathing. Convulsive movements. Death in 5 - 8 min. After 6 min 50 % of the persons exposed to ODH die and 50 % recover with treatment, 100 % of the persons exposed to ODH recover with treatment in 4 - 5 min.	
6 %	0 %	45.6 mmHg 6.08 kPa	0 mmHg 0 kPa	Coma in 40 s, convulsion, respiration ceases, and death.	

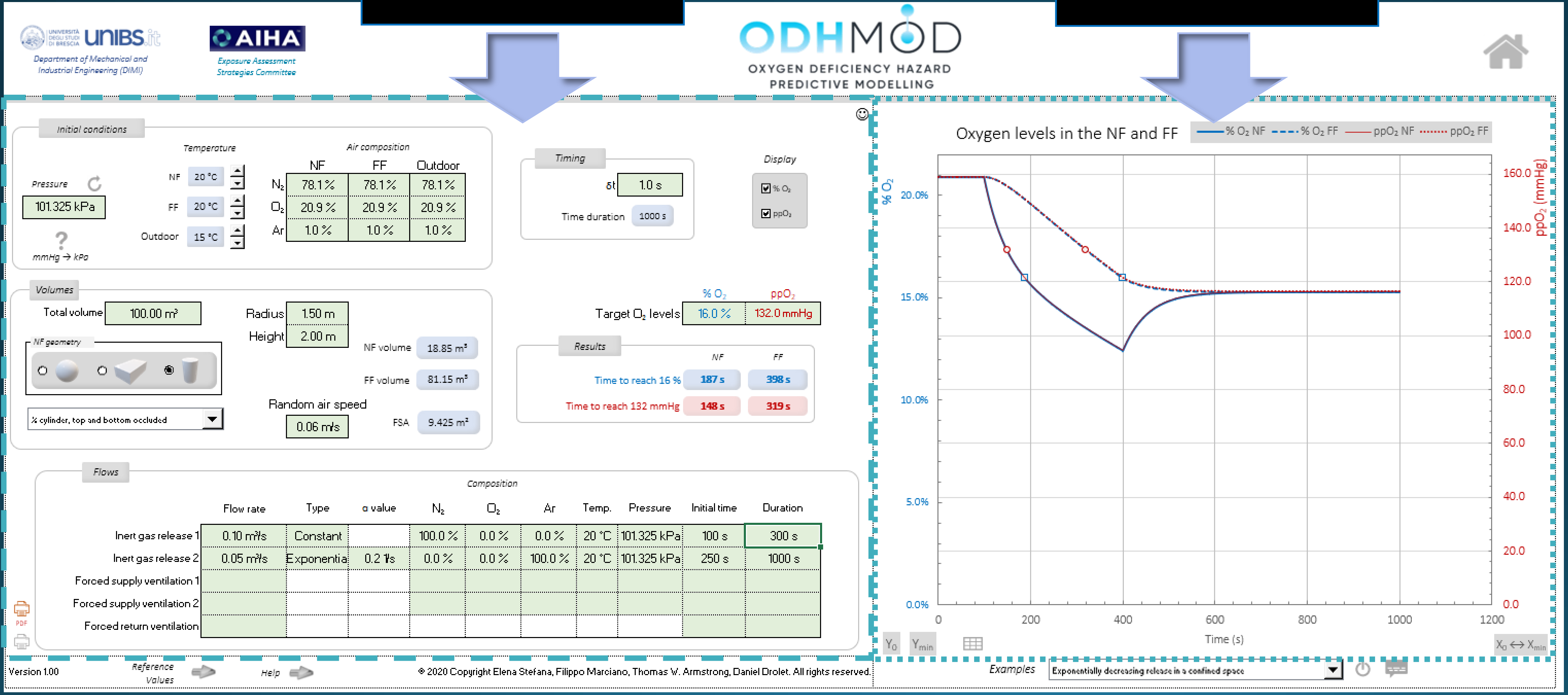
Version 1.02

This e-tool was done by Elena Stefana, Filippo Marciano, Thomas W. Armstrong and Daniel Drolet.

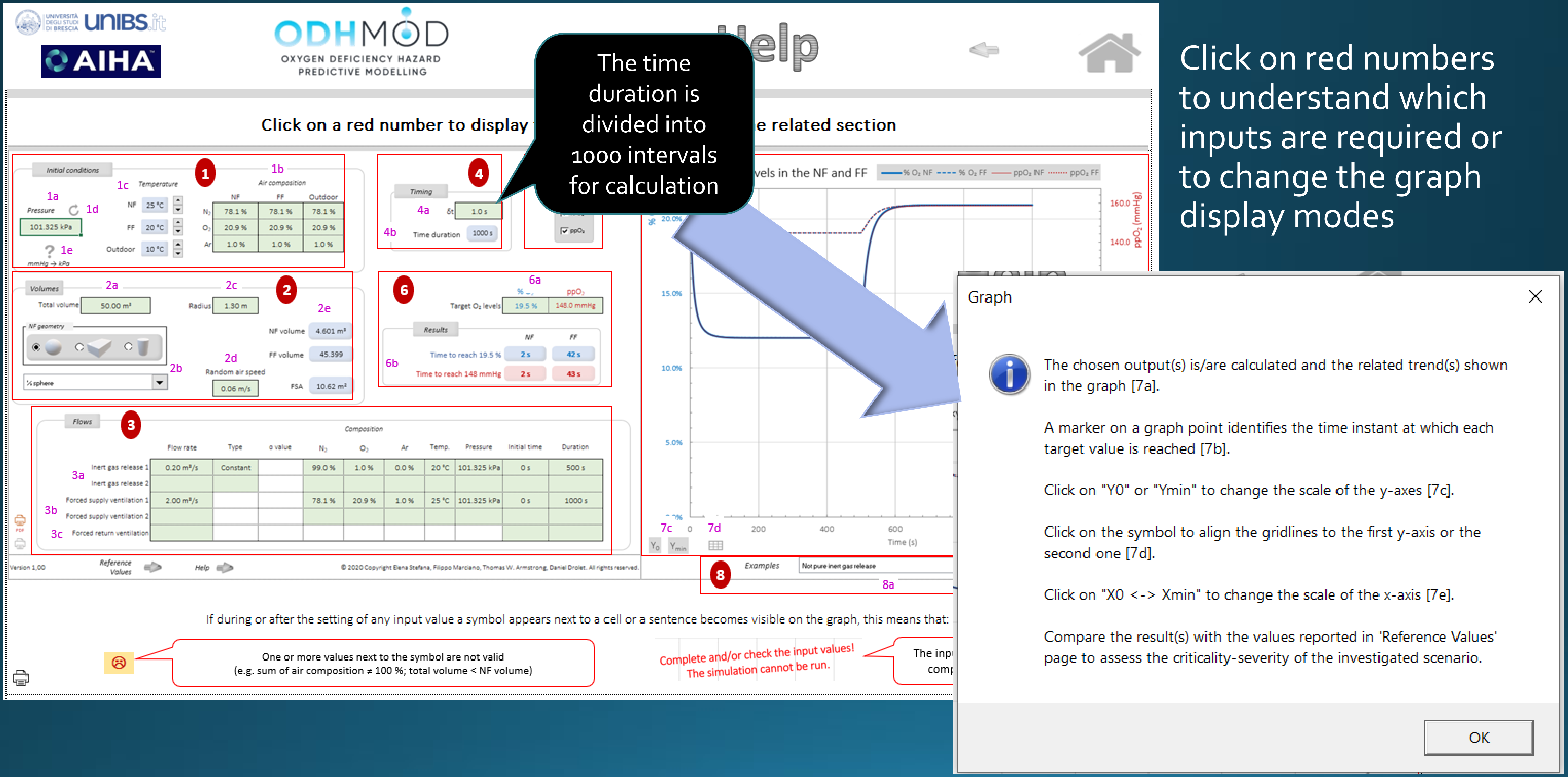
THE MODEL SHEET (1)

Inputs

Outputs



HELP PAGE



Click on red numbers to understand which inputs are required or to change the graph display modes

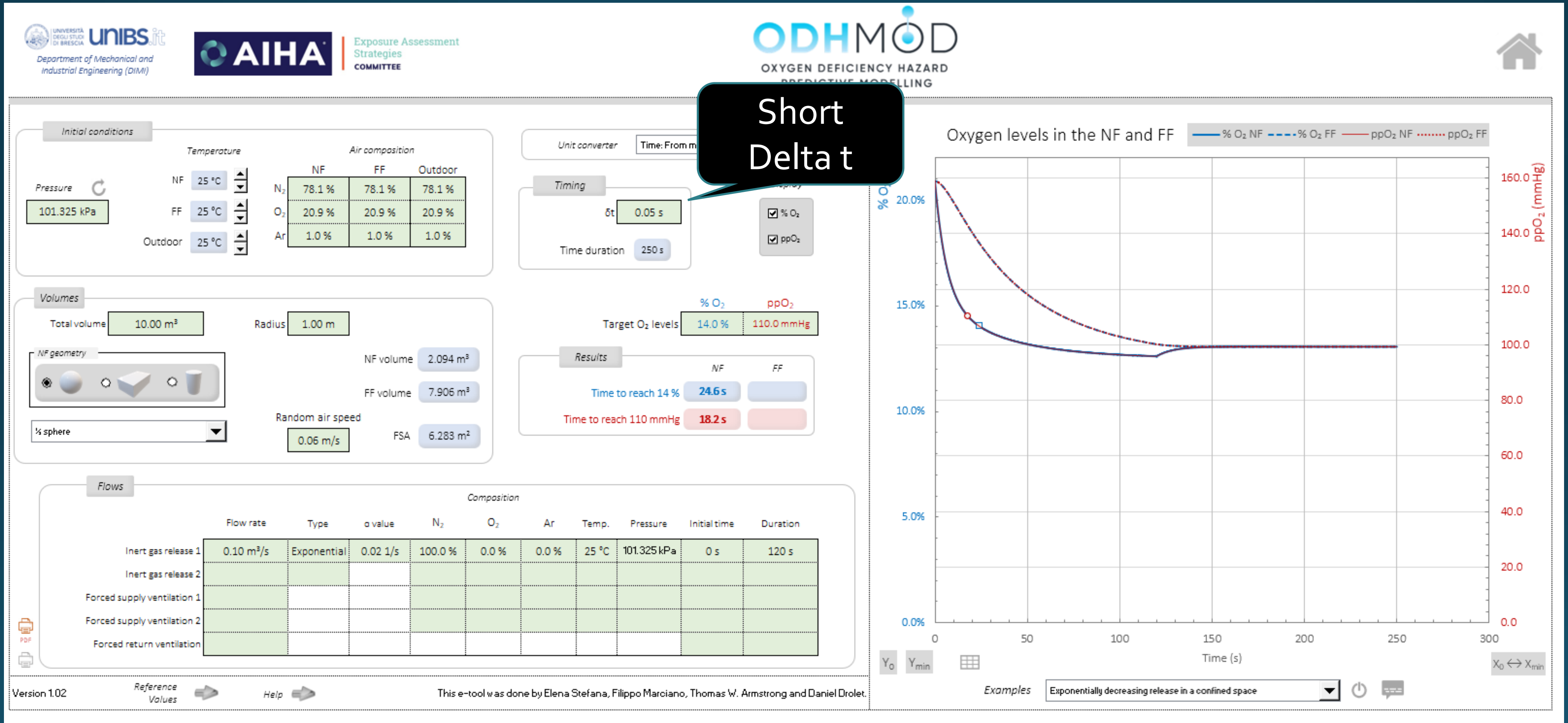
ODHMod includes these examples

Examples

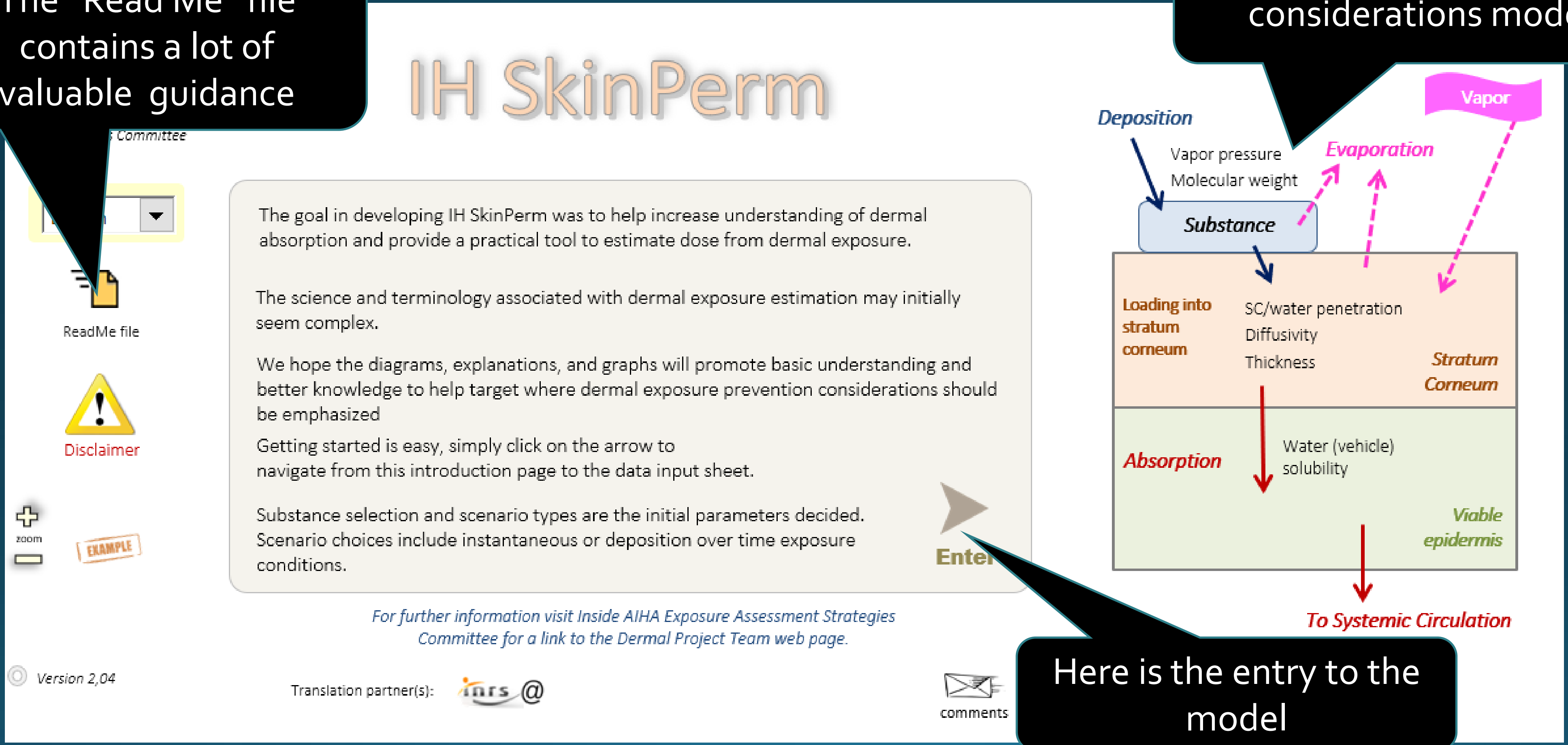
Simultaneous flows

- Simultaneous flows
- Pure release and ventilation airflows
- Two releases and no ventilation
- Not pure inert gas release
- Cold pure inert gas release
- Release and simultaneous ventilation airflows
- Cold flows in a large working environment
- Hot flows in a large working environment
- Pure release and no ventilation
- Pure release in a confined space
- Simultaneous flows (different timing)
- Exponentially decreasing simultaneous flows
- Exponentially decreasing release in a confined space

Example, exponentially decreasing release, confined space, no ventilation



IH SkinPerm program introduction screen



The "Read Me" file contains a lot of valuable guidance

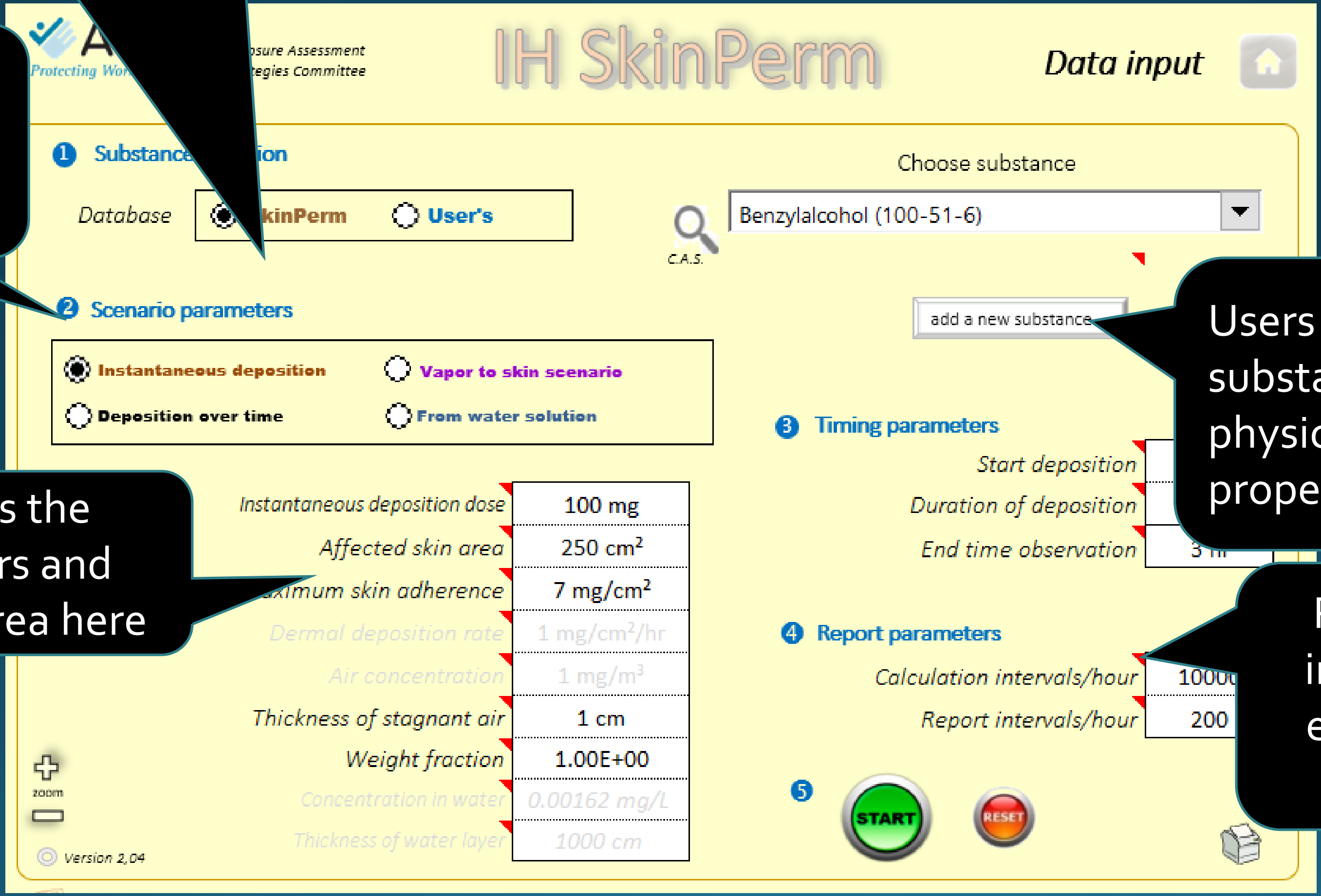
This figure shows the major considerations modeled

Here is the entry to the model

ata input screen

Many compounds of are in the database with all required physical chemical properties

Note four scenario variants can be modeled



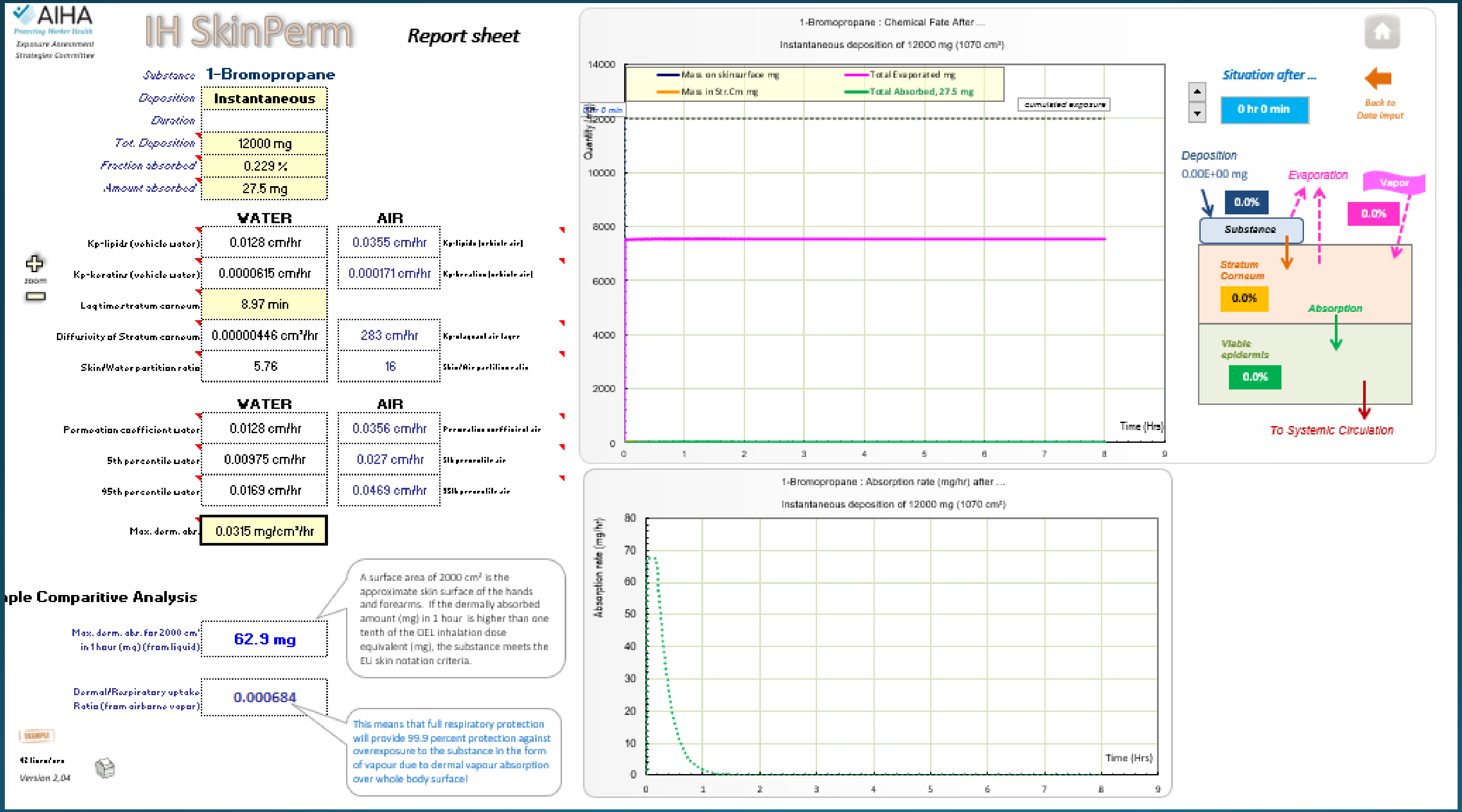
The user sets the loading factors and affected skin area here

Users can enter new substances if the necessary physical chemical properties are available

Red triangles indicate some explanation is available

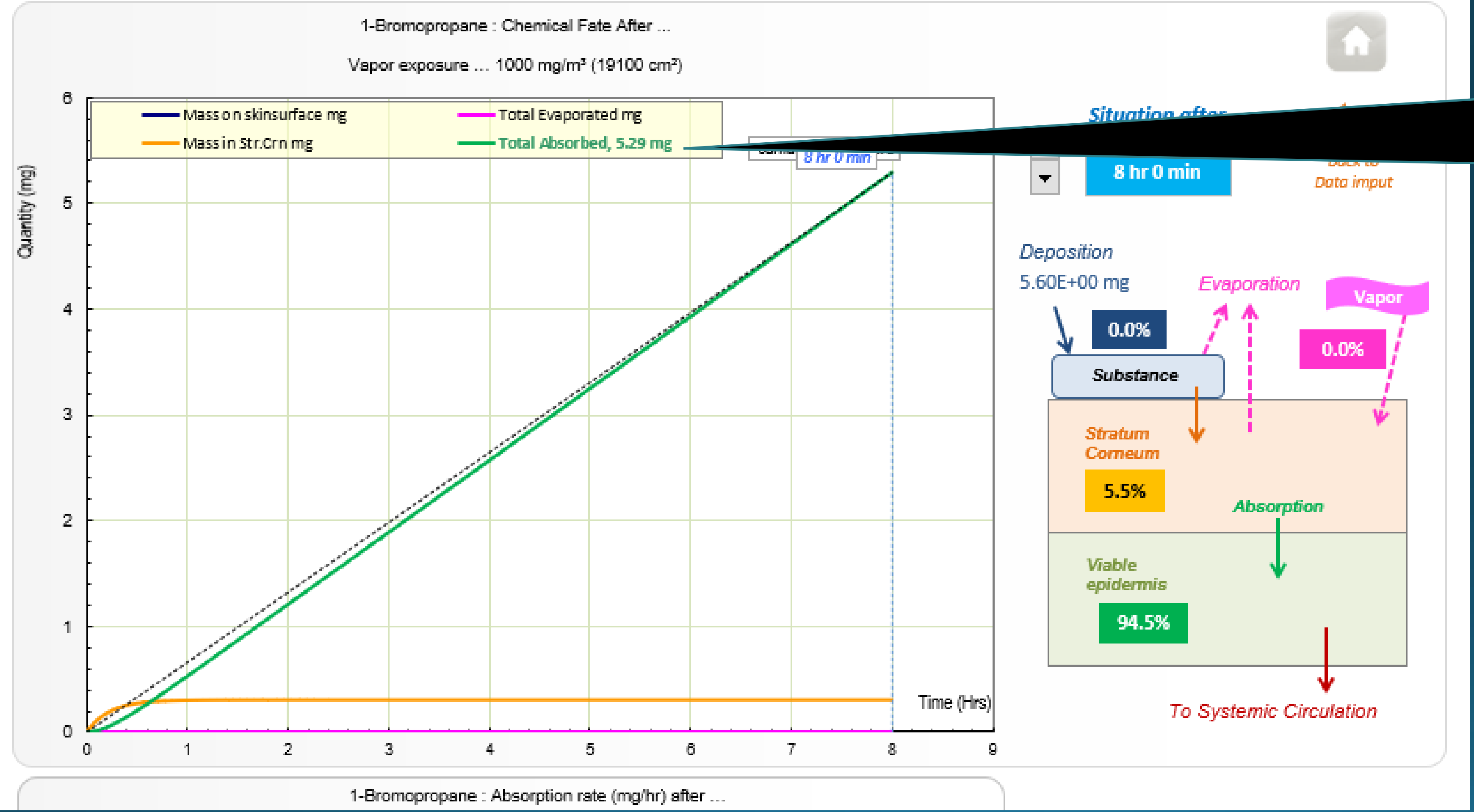
IH SkinPerm results screen.

What is shown varies with the initial scenario choice. This is for 1-BP splash exposure to both hands. Basically it all evaporates!



IH SkinPerm 1-Bromopropane air to skin

Full adult male skin surface (19100 cm2) and 1000 mg/M3 air concentration (200 ppm)



5.3 mg absorbed for 8 hours

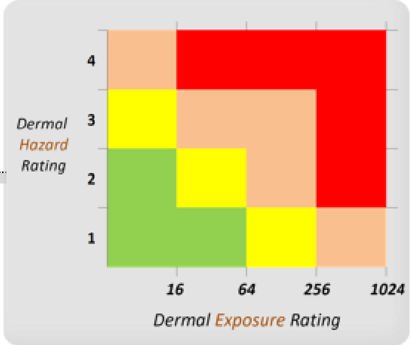
Dermal Risk Assessment Model

ESSI Exposure Science and Sustainability Institute

AIHA | Exposure Assessment Strategies COMMITTEE

DRAM

Dermal Risk Assessment Model



Adjust ZOOM

1440p

Select language

English

The Dermal Risk Assessment Model (DRAM) provides a systematic evaluation of the relative risks of dermal exposure to a material.

The tool uses information about the nature of the dermal toxicity and categorical choices for exposure factors such as dermal contact area, contact frequency, dermal retention time, dermal concentration/loading and dermal penetration potential.

The factors are used in an algorithm to estimate of the risk and plot it on risk grid. As such, understanding the tool's inputs and results can guide the user to decisions about controls or to more refined risk assessments.

This file has was created by Jennifer Sahmel, Susan F. Arnold, Daniel Drolet and Thomas W. Armstrong

Many members of the AIHA EAS Committee and the Dermal Project Team provided encouragement, ideas, and verification during the years of the spreadsheet development.
Those members deserving special mention include Josie Walton and Robert Roy.

Contributors

Disclaimer

Version: 1.00, February 2022

Deterministic input screen

ESSI Exposure Science and Sustainability Institute

AIHA | Exposure Assessment Strategies Committee

Deterministic Simulation

Assessment Summary Form

DRAM

Dermal Risk Assessment Model

Step 1 Dermal Hazard Rating

Rate with relative toxicity

Rate with GHS Code

3

- ○ 1- Reversible or very low skin or systemic toxicity
- ○ 2- Moderate but reversible skin or systemic toxicity
- ● 3- Irreversible/chronic skin or systemic toxicity or sensitization
- ○ 4- Life threatening skin or systemic toxicity or sensitization or severe corrosivity

Step 2 Dermal Exposure Rating

2.1 Dermal Contact Area

3

- ○ Unexpected/unlikely
- ● Contact possible to hands and forearms
- ○ Very small area of skin contact
- ○ Contact possible to significant area of skin

2.2 Dermal Concentration or Loading

1

- ● Negligible concentration of agent likely to contact or load onto the skin
- ○ Moderate concentration of agent likely to contact or load onto the skin
- ○ Low concentration of agent likely to contact or load onto the skin
- ○ High concentration of agent likely to contact or load onto the skin

2.3 Dermal Contact Frequency

3

- ○ Minimal contact with skin; one or two incidental contacts; contact during less than 5% of task
- ● Up to 50 incidental contacts with skin; contact during less than 50% of task
- ○ Up to 10 incidental contacts with skin; contact during less than 10% of task
- ○ Routine incidental contact with skin throughout shift; contact during 50-100% of task

2.4 Dermal Retention Time

3

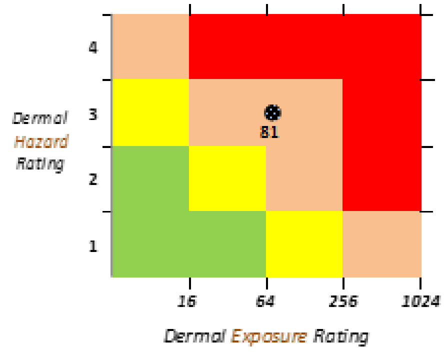
- ○ Amount transferred unlikely to remain on skin for any period of time (i.e., high volatility, dry and powdery)
- ○ Amount transferred may remain on skin for some time (i.e., some volatility or adherence to skin)
- ● Amount transferred is likely to remain on skin for a significant period of time (i.e., low volatility, high MW, sticky or consolidated on skin even if not visible)
- ○ Amount transferred very likely to remain on skin (i.e., substance not volatile, MW > 100, substance very likely to stick to skin)

2.5 Dermal Penetration Potential

3

- ○ Not likely (large, insoluble particles)
- ○ Low potential (small insoluble particle > 1 micron in size, or both poor lipid solubility and poor water solubility)
- ● Possible or slow (very small insoluble particles < 1 micron, or some lipid solubility and some water solubility, or marginal skin health)
- ○ Probable or likely (good lipid solubility and good water solubility, or poor skin health)

Step 3 Results



Exposure Rating = CA * C * CF * RT * PP = 81

Reset

Category "Orange"
High risk

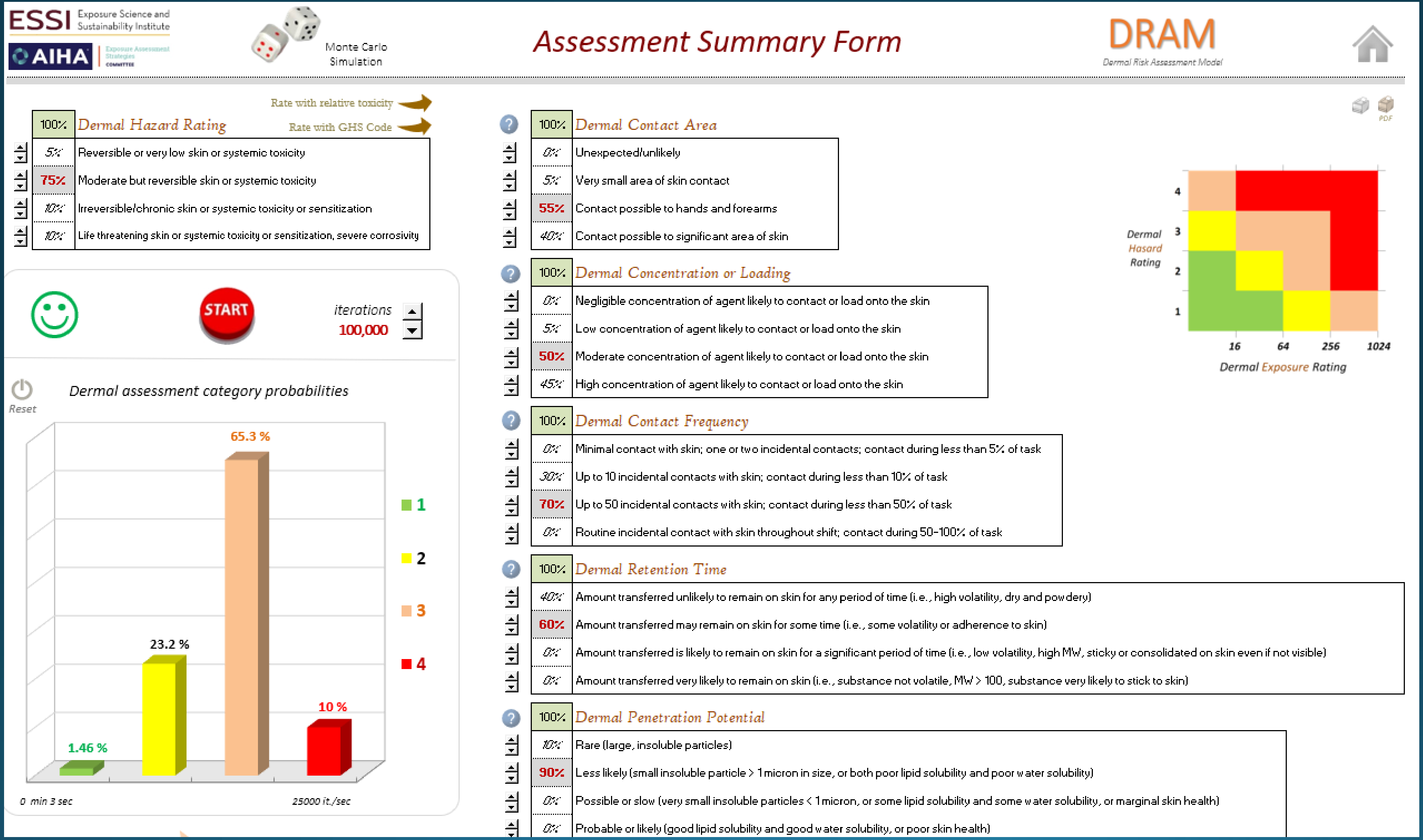
PDF

Version: 1.00, February 2022

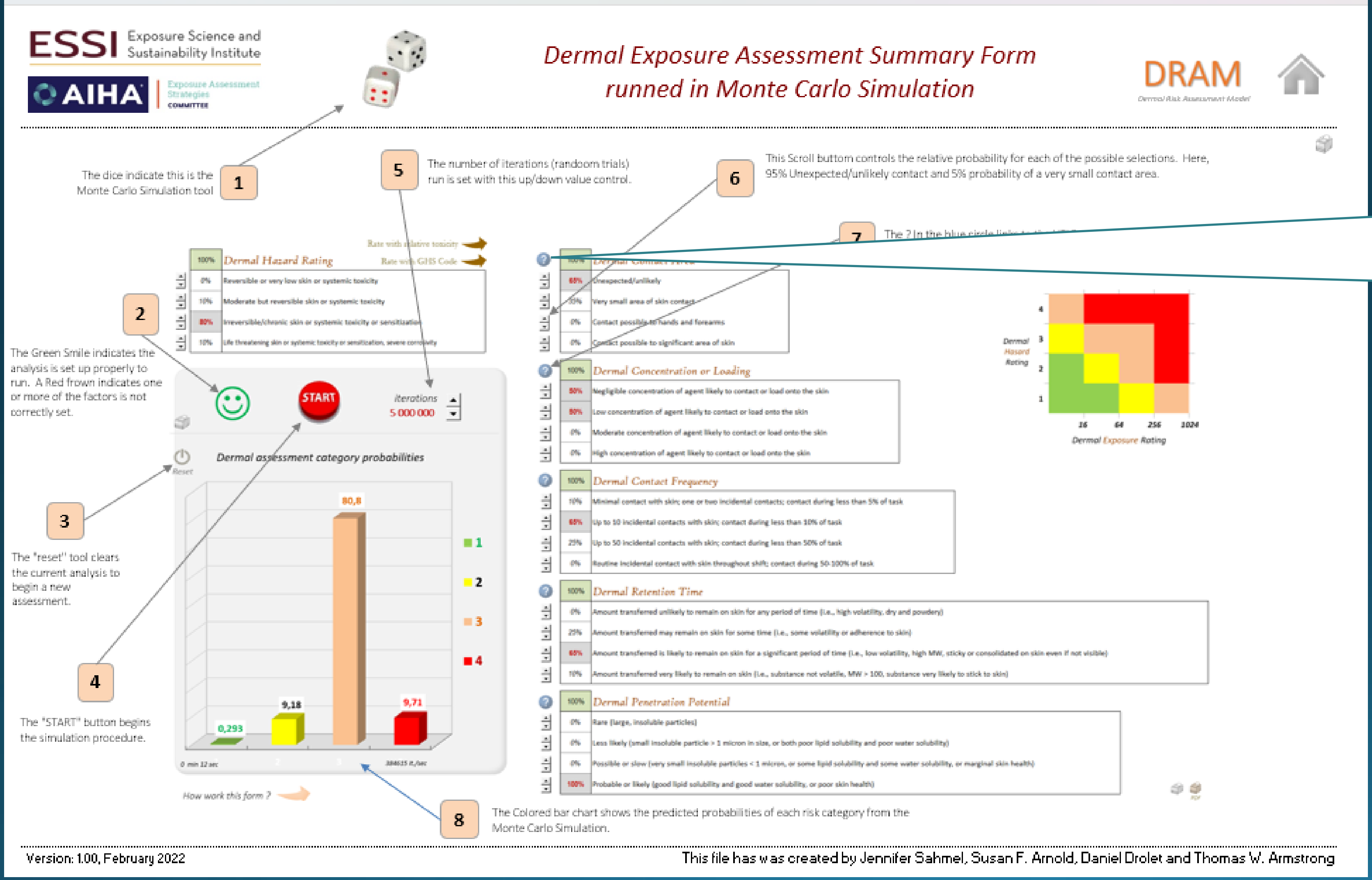
How work this form ?

This file has was created by Jennifer Sahmel, Susan F. Arnold, Daniel Drolet and Thomas W. Armstrong

Monte Carlo Simulation input screen



This is the MCS HELP Screen (First Level)



Each of the factors with a ? has an additional information screen

In Summary

The tools reviewed are freeware, are openly available and provide easy to use approaches to important aspects of the exposure assessment process

- Scenario definition and documentation of key exposure determinants
- Qualitative evaluation via judgement heuristics
- Statistical evaluation of survey data
- Modeling of dermal uptake including from air
- Either deterministic or MCS simulation of air concentrations with multiple algorithms can be useful for occupational or downstream user scenario evaluation

The AIHA EASC team involved in developing tools welcomes collaboration on their further development and for translations of the multi-lingual tools

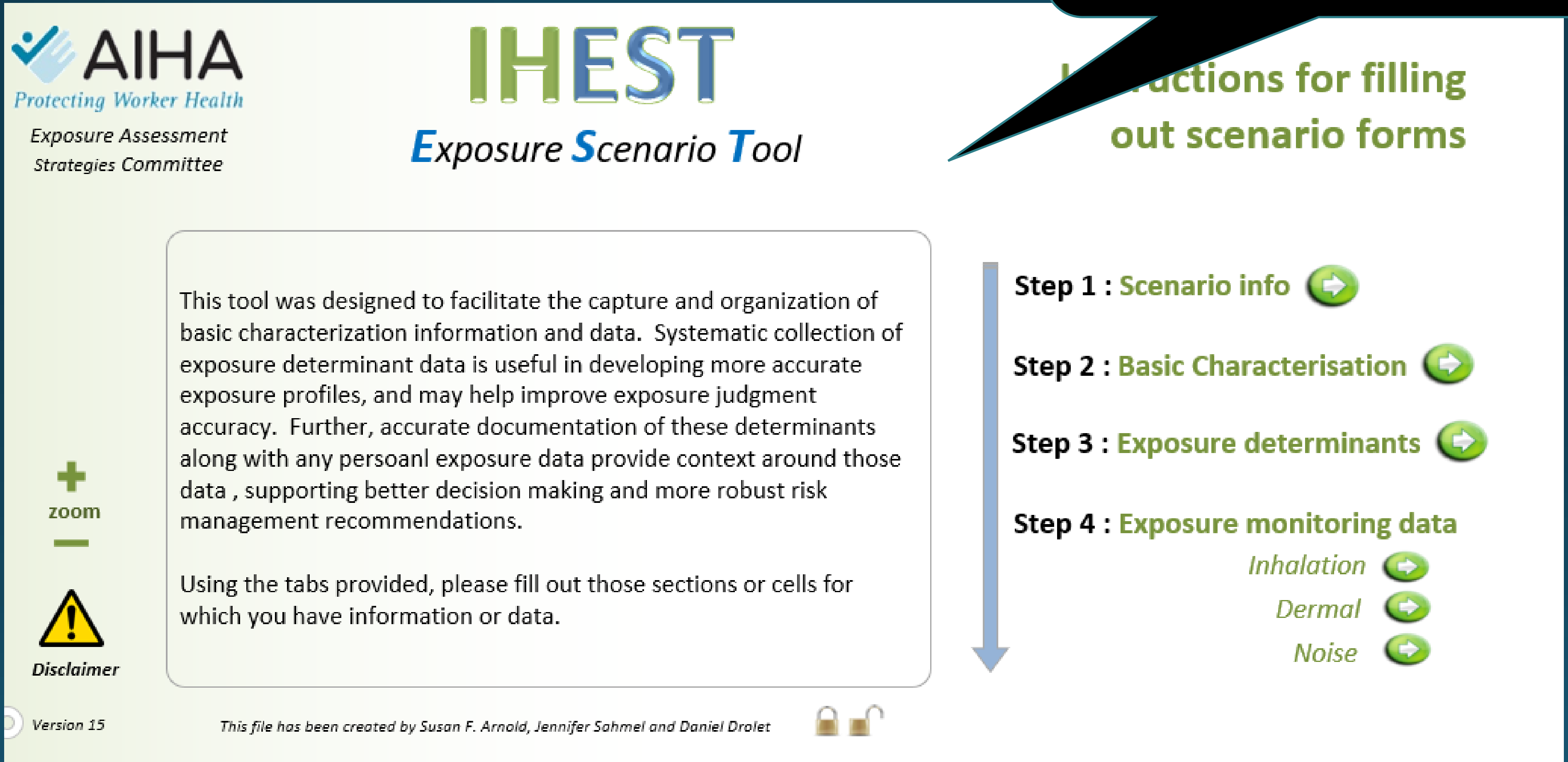
Supplemental Materials

Blando Dry Cleaning Scenario Preparatory Calculations

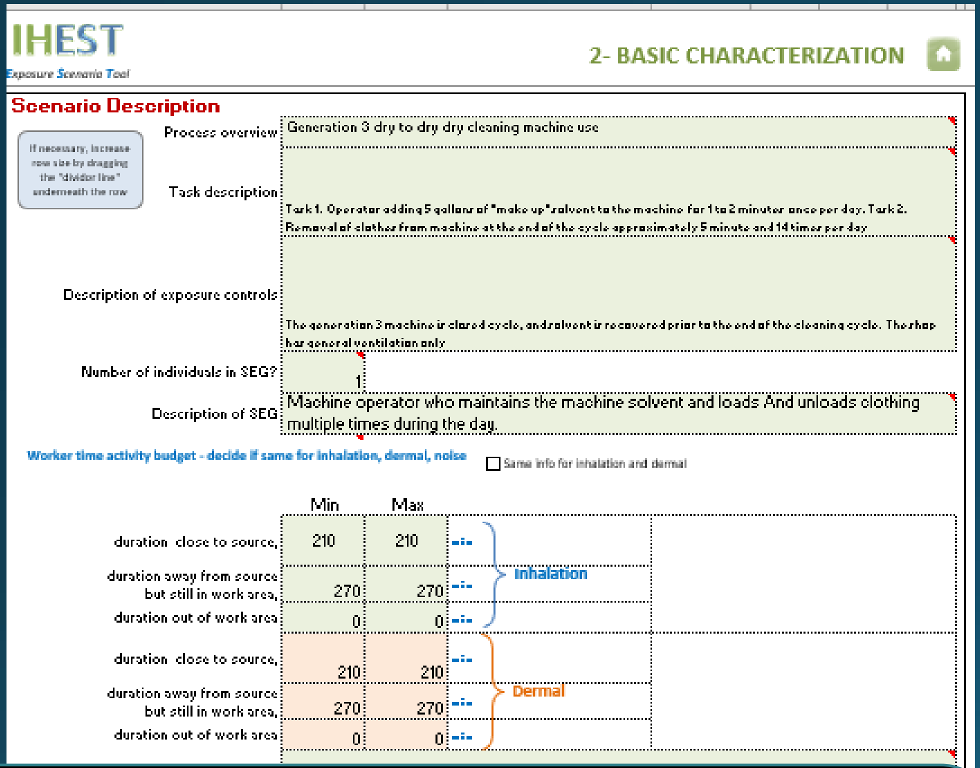
- Residual solvent vapor concentration in drum, 10,000 to 43,000 mg/M^3. (US EPA report). Saturation concentration is approximately 730,000 mg/M^3
- Typical dry cleaning machine drum volume 0.24 to 0.64 M^3 (US EPA Report)
- 1-BP mass in drum, 2414 to 27,699 mg Calculated
- Unloaded over about 5 minutes, the "generation rate" is 483 to 5538 mg/minute Calculated
- S is set as the commonly used value from Baldwin and Maynard , *Ann Occup Hyg. 1998 Jul;42(5):303-13*, the source for the often used 3.6 m/min, GSD 1.96.

IHEST Opening Screen

This tool helps structure and document the basic characterization of an exposure scenario.



IHEST Basic Characterization



IHEST
Exposure Scenario Tool
2- BASIC CHARACTERIZATION

Scenario Description

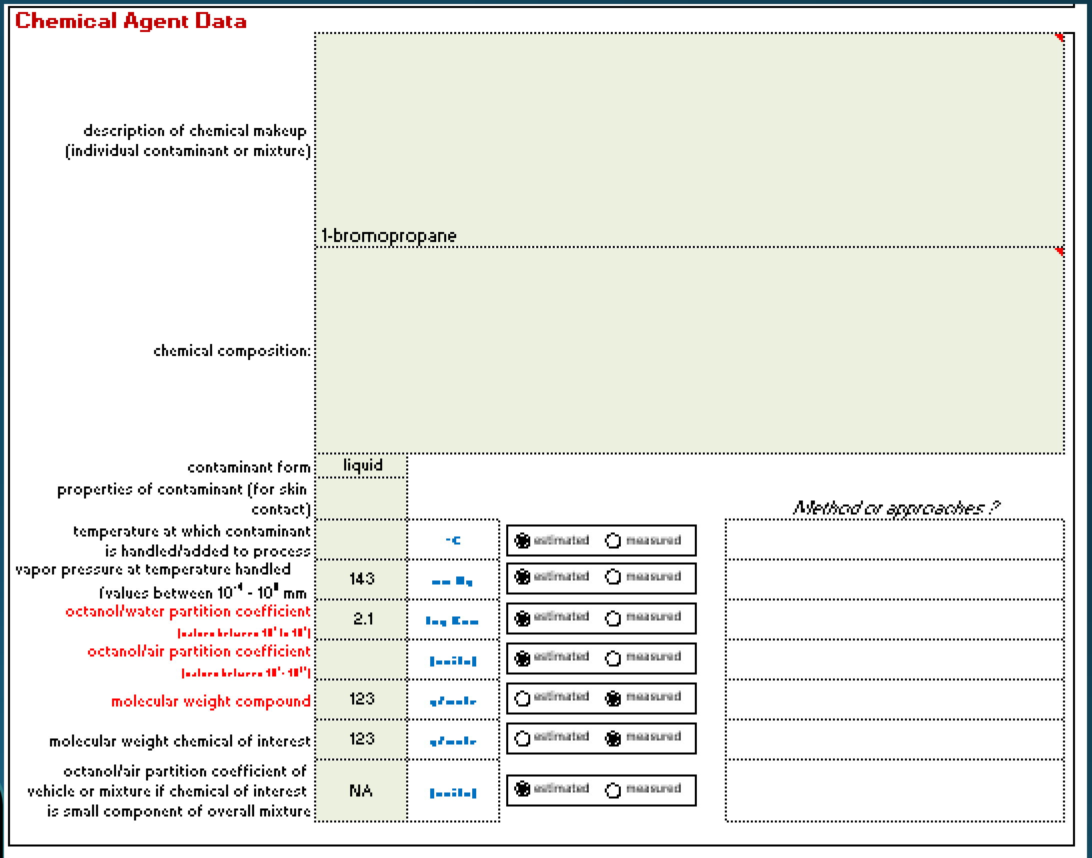
If necessary, increase row size by dragging the "divider line" underneath the row

Process overview	Generation 3 dry to dry dry cleaning machine use
Task description	Task 1. Operator adding 5 gallons of "make up" solvent to the machine for 1 to 2 minutes once per day. Task 2. Removal of clothes from machine at the end of the cycle approximately 5 minute and 14 times per day
Description of exposure controls	The generation 3 machine is closed cycle, and solvent is recovered prior to the end of the cleaning cycle. The shop has general ventilation only
Number of individuals in SEG?	1
Description of SEG	Machine operator who maintains the machine solvent and loads And unloads clothing multiple times during the day.

Worker time activity budget - decide if same for inhalation, dermal, noise

☐ Same info for inhalation and dermal

	Min	Max		
duration close to source,	210	210		Inhalation
duration away from source but still in work area,	270	270		Inhalation
duration out of work area	0	0		Inhalation
duration close to source,	210	210		Dermal
duration away from source but still in work area,	270	270		Dermal
duration out of work area	0	0		Dermal



Chemical Agent Data

description of chemical makeup (individual contaminant or mixture)	1-bromopropane			
chemical composition:				
contaminant form	liquid			
properties of contaminant (for skin contact)				Method or approaches ?
temperature at which contaminant is handled/added to process		°C	◉ estimated ○ measured	
vapor pressure at temperature handled (values between 10^{-4} - 10^{3} mm	143		◉ estimated ○ measured	
octanol/water partition coefficient	2.1		◉ estimated ○ measured	
octanol/air partition coefficient			◉ estimated ○ measured	
molecular weight compound	123		○ estimated ◉ measured	
molecular weight chemical of interest	123		○ estimated ◉ measured	
octanol/air partition coefficient of vehicle or mixture if chemical of interest is small component of overall mixture	NA		◉ estimated ○ measured	

After a little experience, this tool is quick and efficient and the information is very useful for designing a survey or other estimation technique such as mathematical modeling

IHEST Exposure Determinant Data

IHEST
Exposure Scenario Tool

3- EXPOSURE DETERMINANT D

	average?	Minimum	Maximum			Mini
Ventilation rate		4.6	88	m³/min	Local air velocity *(at 1meter from source)*	

Physical Layout Data

Room layout description *(e.g. spacious, occluded areas or confined areas?)*

280 cubic meter dry cleaning shop. Task 1 Generation rate for solvent addition based on sat
concentration and 5 gal displaced volume from machine. Task 2 generation rate based on US E
Generation 3 residual concentration in dry cleaning machine drum. 5 gallons equals 19,000 ml a
968326 mg/M3. From EPA EPA Document# 740-R1-5001
February 2016 , residual solvent concentration in the drum ranges from 2000 to 8600 ppm (10000
mg/M3)

Generation rate	18393	mg/min	Chemical usage rate *(as applicable)*	24	
Number of Sources:	1				

	Width	Length	Height		Surface
Room dimensions				meter	0.0 m²

DERMAL

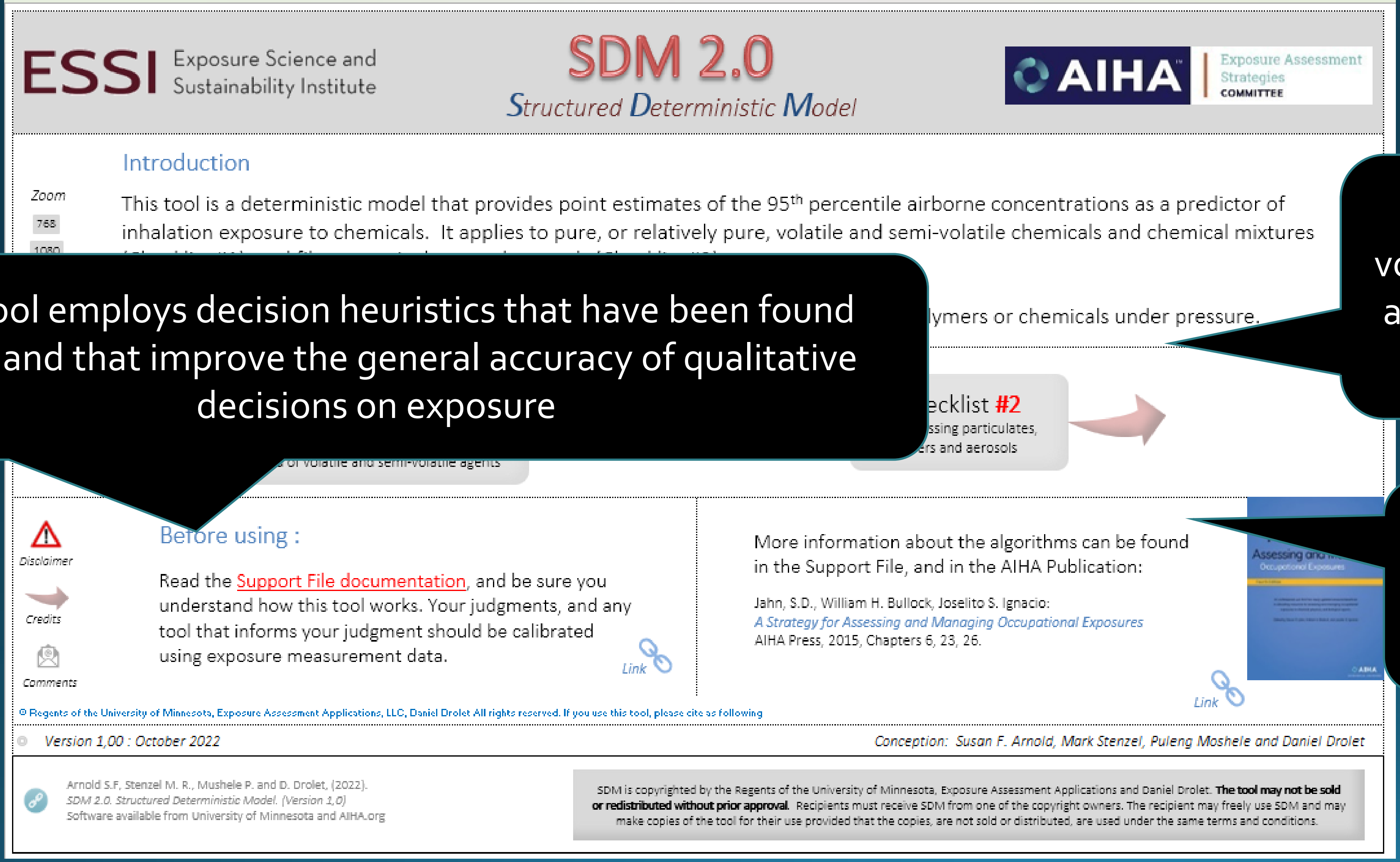
Exposed body surface areas

- None
- Total body
- Head
- Legs
- Trunk (includes neck)
- Fingertips
- Palm and fingers
- Hands
- ForeArms
- Arms

Duration/Intensity of dermal contact	splash
Frequency of dermal contact	intermittent
Dermal retention time	Unlikely (volatile, very dry, large particulate)
Concentration of chemical of interest in mixture	high (50-100%)

These may all be key factors in a qualitative judgement guided assessment or in designing a survey or may be used to guide model and input parameter selection

Structured Deterministic Model SDM 2.0

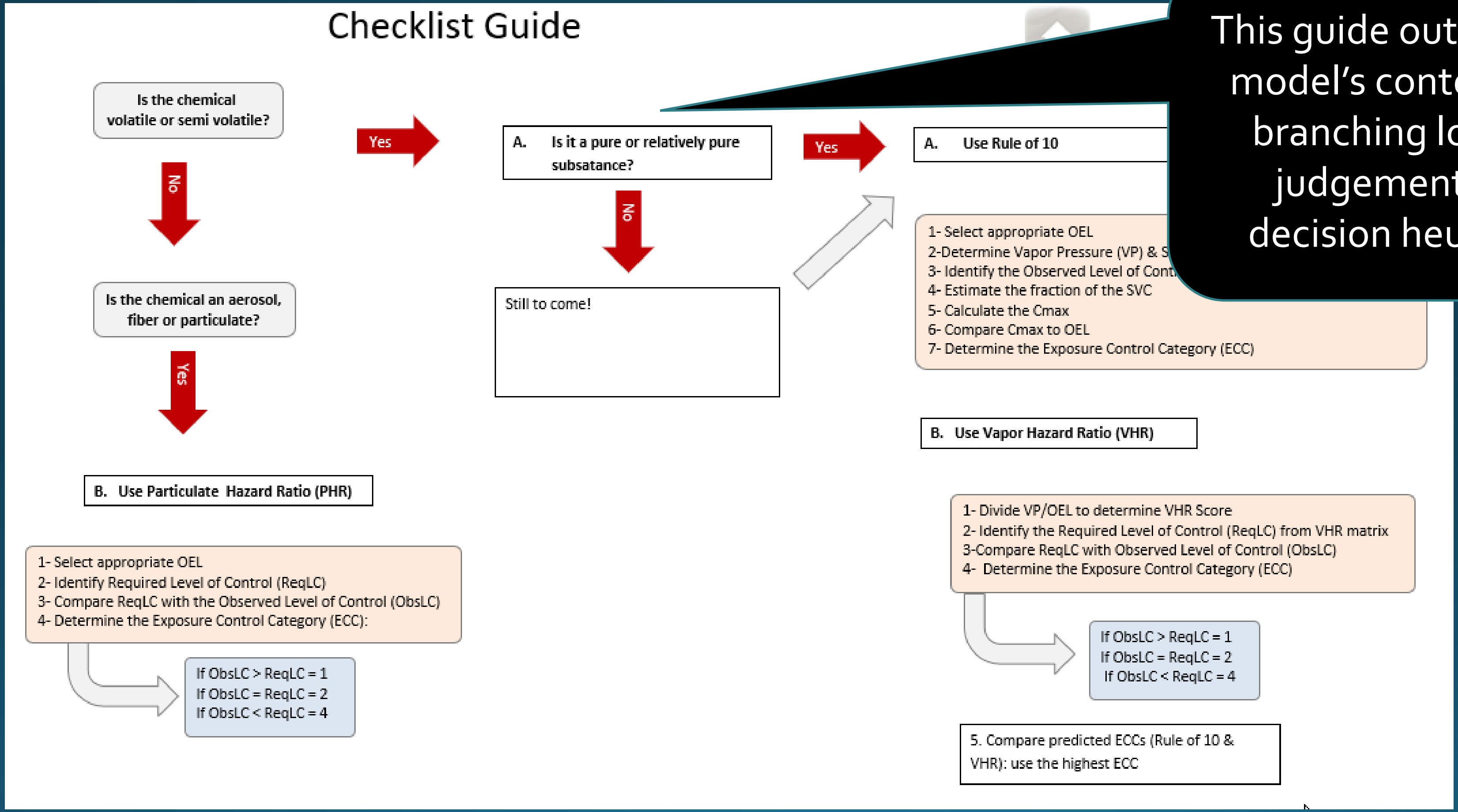


This tool employs decision heuristics that have been found useful and that improve the general accuracy of qualitative decisions on exposure

The user can assess volatile or semi-volatile agents or particulates, fibers or aerosols

It is always important to understand a tool before using it!

Qualitative Exposure Assessment Tool Checklist Guide



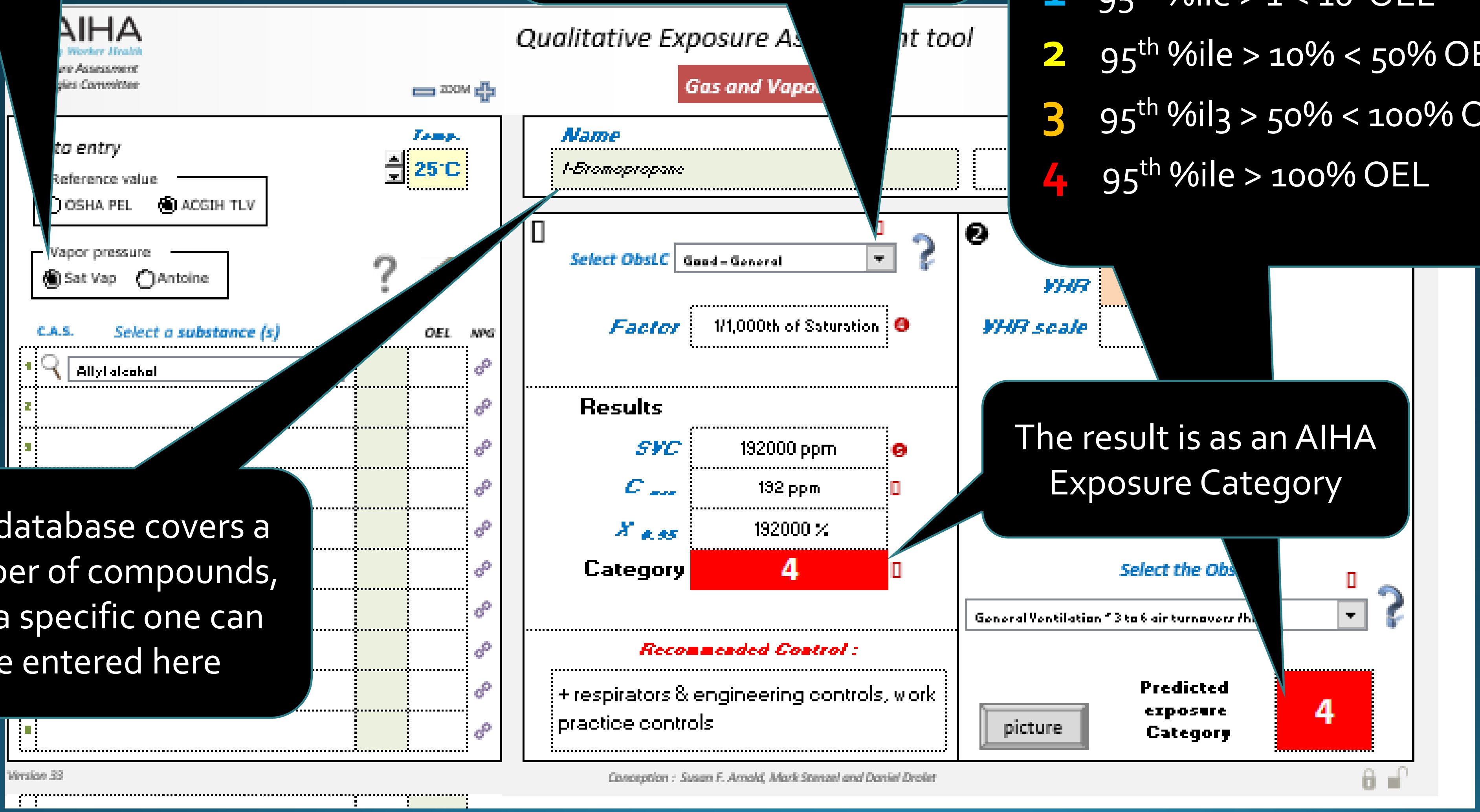
This guide outlines the model's content and branching logic of judgement and decision heuristics

Q… e Exposure Assessment Tool
Ga… s and Vapo…

Vapor pressure is a key determinant

A key piece is the expected or observed level of control

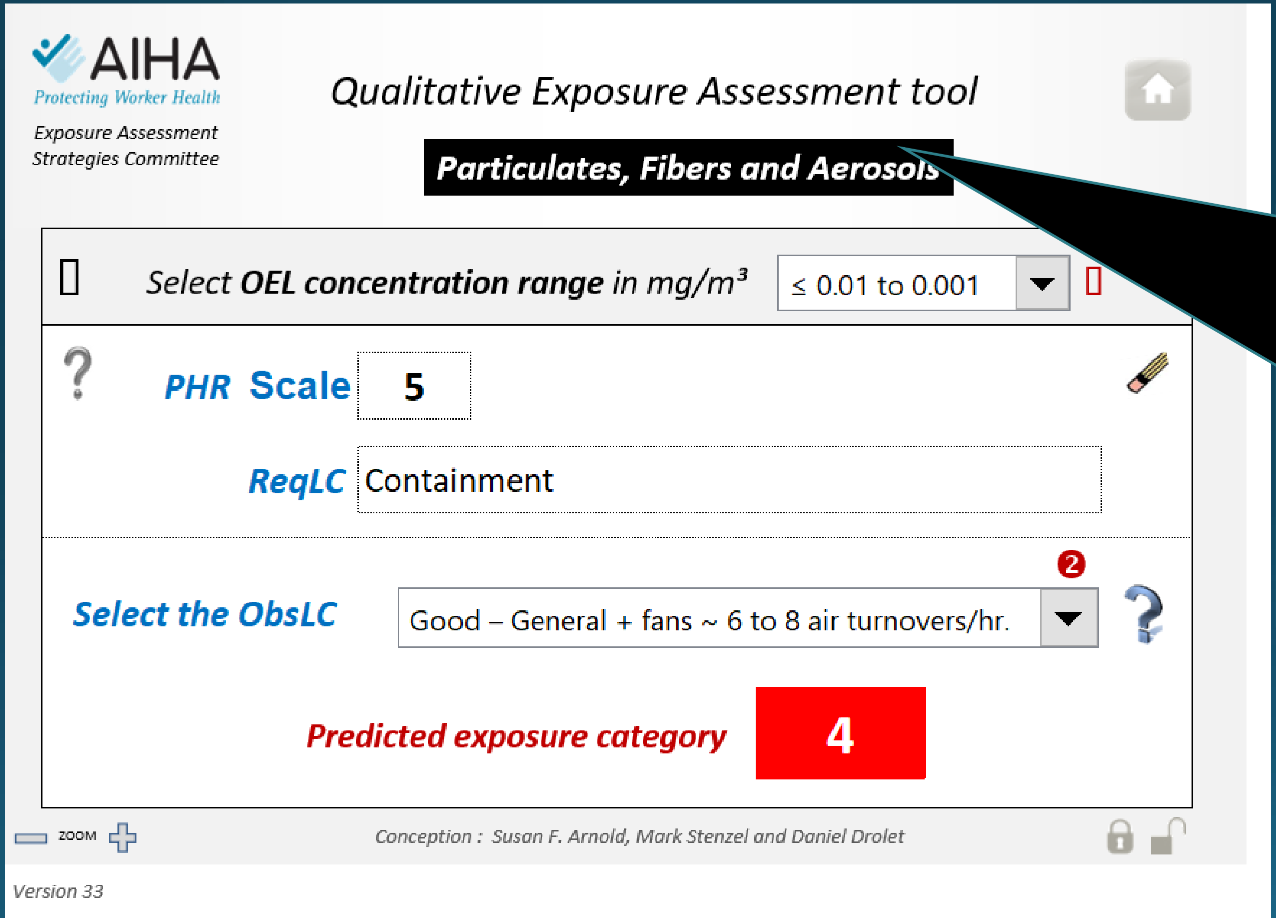
0	95^{th} %ile < 1% OEL
1	95^{th} %ile > 1 < 10 OEL
2	95^{th} %ile > 10% < 50% OEL
3	95^{th} %il3 > 50% < 100% OEL
4	95^{th} %ile > 100% OEL



The database covers a number of compounds, but a specific one can be entered here

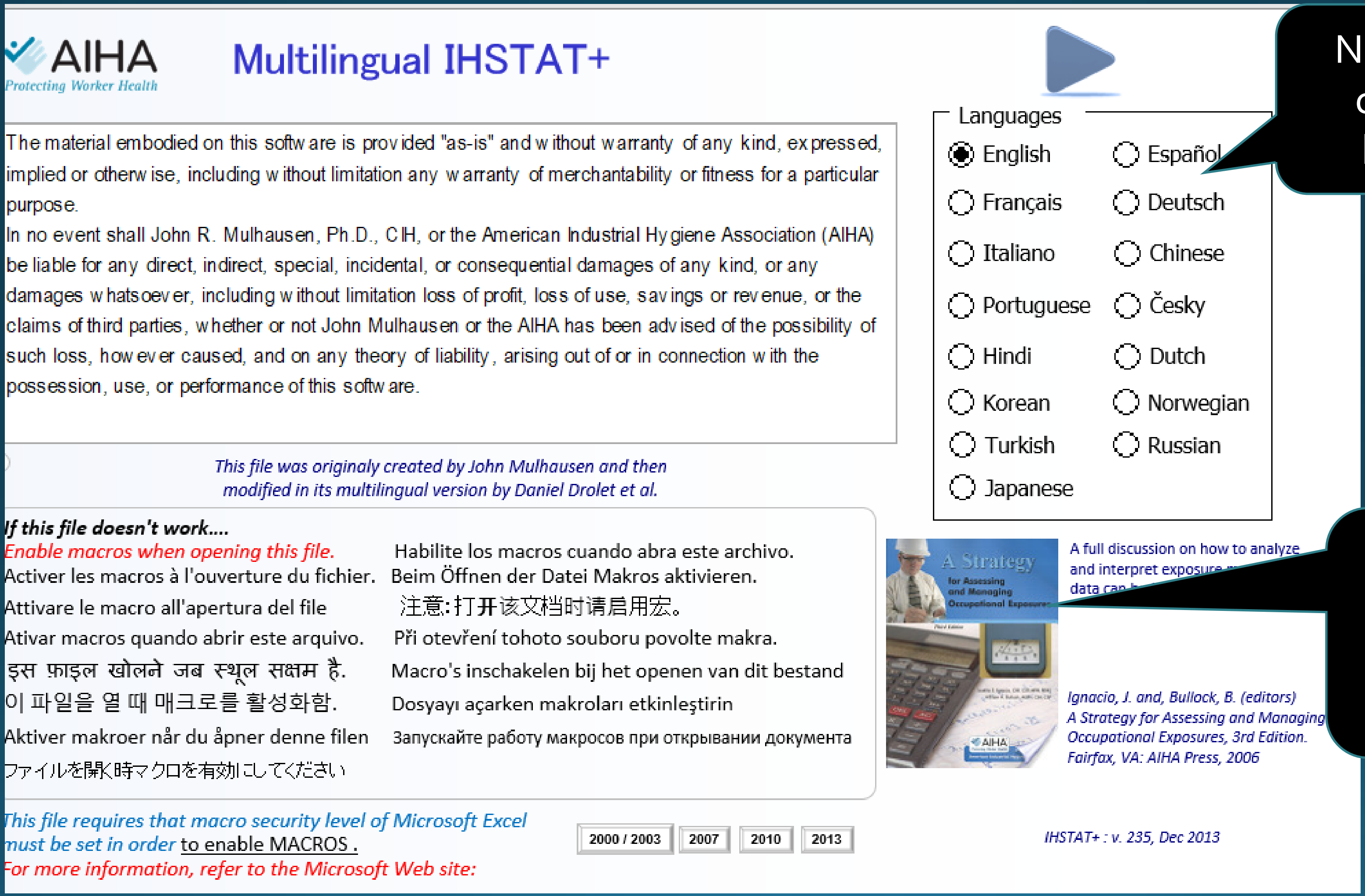
The result is as an AIHA Exposure Category

Qualitative Exposure Assessment Tool
Particulates, Fibers and Aerosols



These tools must not be used without a good understanding of the strengths and limitations of the heuristics and of the terminology

IH Stat – the Opening Screen

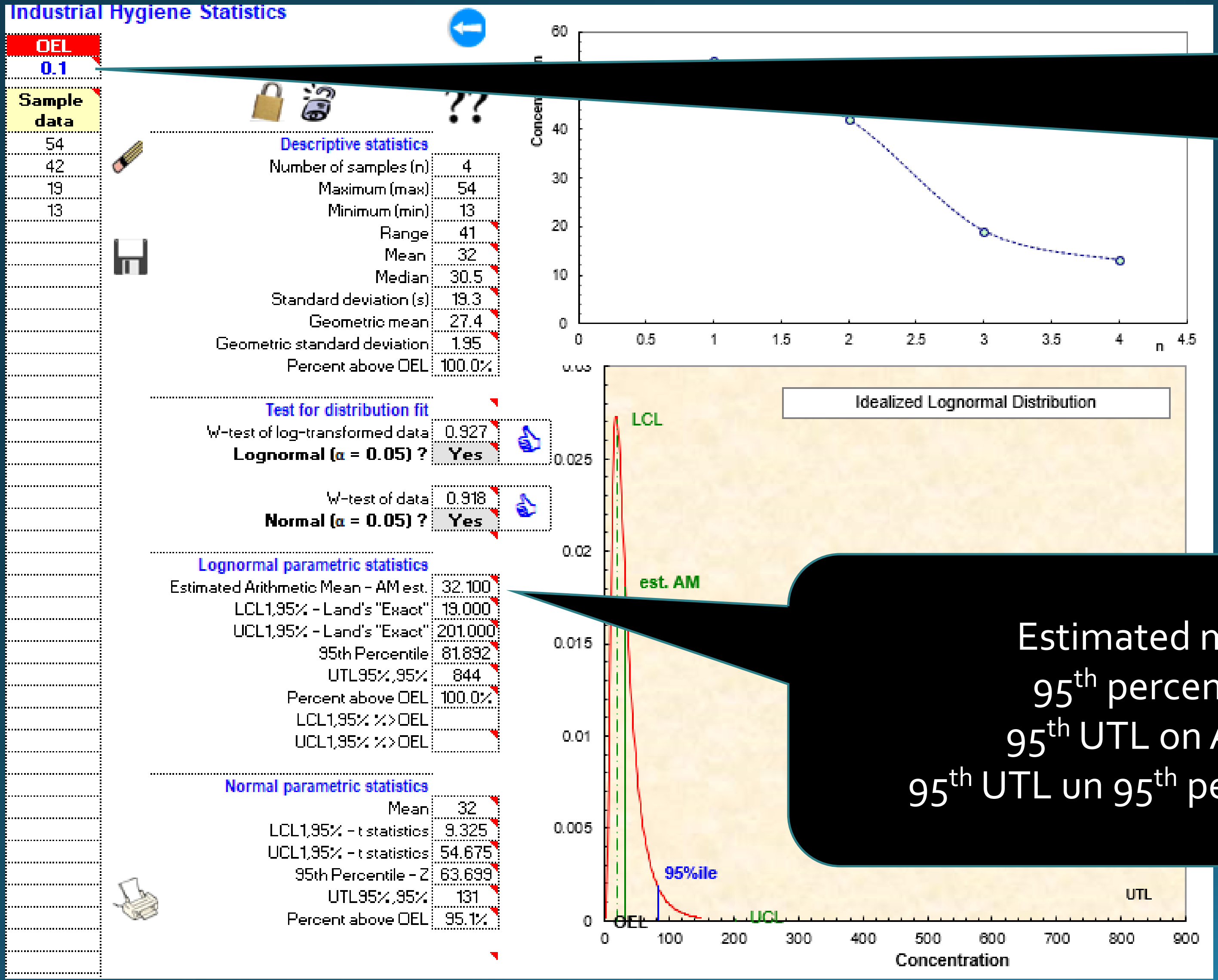


Now with 15 choices of language

The program uses MACROS which must be enabled

This book gives more information on the statistical techniques and more.

IH Stat Analysis – Data From Blando 2010 Shop A C



The user sets the OEL and enters the data (up to n=200)

Various parameters are calculated and shown graphically

Estimated mean 32 ppm (161 mg/M3)
95th percentile 82 ppm (412 mg/M3)
95th UTL on AM 201 ppm (1011 mg/M3)
95th UTL un 95th percentile 844 ppm (4245 mg/M3)

IHSTAT Bayes

This is a bit more complicated than just a simple EXCEL file: you need to download the 2 files, launch the installer (setup) and follow the instructions. Once installed, the tool itself is an EXCEL file within the installation folder (take care to remember it during installation), open it to use the tool.

LOTs of “help” information and an on-line forum are available

Toxico-kinetic Extended Shift OEL Adjustment Spreadsheet

Spreadsheet Documentation and Explanations

This workbook has some section protected against inadvertent modification that would lead to incorrect calculations   Password = mahl

WARNING: The "UnknownT_half (MAHL) sheet IS NOT PASSWORD PROTECTED. Current versions of Solver do not run in protected worksheets

Do not change any calculation cells. Cells you may safely use to enter the shift data and starter value half life are highlighted green

This spreadsheet is "freeware" and is offered as is without any warranties expressed or implied. The user of this spreadsheet assumes responsibility for understanding its correct use. It is suggested the user become familiar with the exposure limit adjustment concepts, as decribned in Verma, Dave K., 2000. Adjustment of Occupaqtional Exposure Limits for Unusual Work Schedules. . Am. Ind. Hyg. Assoc. J. 61:367-374.

Also, see "Application of occupational exposure limits to unusual work schedulesJ. L. S. Hickey and P.C. Reist, AIHAJ, V.38, 1977"

The equation used (following Eide's nomenclature) is:

$$Fp = \frac{\left(1-e^{-kt_{1n}}\right)\left(1-e^{-k(t_{1n}+t_{2n})n}\right)\left(1-e^{-kT_s}\right)\left(1-e^{-k(t_{1s}+t_{2s})}\right)}{\left(1-e^{-kt_{1s}}\right)\left(1-e^{-k(t_{1s}+t_{2s})m}\right)\left(1-e^{-kT_n}\right)\left(1-e^{-k(t_{1n}+t_{2n})}\right)}$$

where:

	Name as used in Excel formulas: For MAHL		For Known T1/2
Fp = the pharmacokinetic reduction factor	F_p		F_pk
k = the biologic elimination rate = (ln 2)/$T_{1/2}$, where $T_{1/2}$ = the biologic half-life	k_2	and	k_2k
t_{1n} = the length of the standard work day (8 hours)	t_1n		t_1n
t_{2n} = the length of the standard recovery period (16 hours)	t_2n		t_2n
$t_{1n}+t_{2n}$ = the length of the standard day (24 hours)	lsd		lsd
T_n = the length of the standard week (seven days or 168 hours)	T_n		T_n
n = number of days in standard work week (5)	Nwds		Nwds
t_{1s} = length of the extended shift work day (in hours)	t_1s		t_1sk
t_{2s} = length of the rest period between extended shift work days (in hours)	t_2s		t_2sk
t_{1s} + t_{2s} = length of the extended shift "day" (usually, but not always 24 hours)	SpD		SpDk
T_s = total length of the periodic work cycle [the number of days worked and days in the rest period (in hours)]	T_s		T_sk
m = the number of "days" per work "week" in the extended shift work schedule	Swds		Swdsk

In Excel, complex equations are easier to set up if broken into "pieces", with the "pieces" then assembled.
Otherwise, the levels of parentheses to control the order of the calculations can be difficult to enter correctly.
This spreadsheet thus breaks the equation into 8 "pieces" (Terms A to H below)
These terms draw upon "Named" cells from the worksheets "UnknownT_half (MAHL)" and "Known T_half". Refer to Excel "HELP" for
Refer to Excel "HELP" for instructions and conventions for Named cells and ranges

For Unknown T_half (MAHL)	For Known T_Half T_half

Toxico-kinetic Extended Shift OEL Adjustment

The spreadsheet has tabs for Known half-life, Unknown Half-life, Documentation, Examples
The tab shown below is the UNKNOWN HALF-LIFE calculation

This worksheet calculates a pharmacokinetic model based reduction factor to use to adjust OELS for extended workshifts and workweeks,
... when the biologic half life is unknown or uncertain.
This spreadsheet will calculate the extended shift adjustment factor (Fp) for:
An unknown or uncertain biologic half-life. It provides the MAXIMUM adjustment needed
(presuming worst case half-life!) for a given shift schedule.
"Fp" is the multiplier to use with the TWA 8 hour TLV (or PEL, WEEL, etc.) to yield an extended shift limit.

Enter "Extended Shift" information in the green cells	
length of new (special) shift, hours	**10**
length of new (special) rest period, hours	**14**
length of special "day" hours	**24**
number of "days" in special "work week"	**5**
number of days in full cycle	**7**
Enter an initial value* (1 to 100) biologic (T1/2), hours	**50**

*** this is to give Solver a starting point. DO NOT use 0 or negative numbers!**

MAHL - Maximum Adjustment Half Life
Result

Fp =	**0.81**	**At T 1/2 =**	**50 Hours**

Target cell

Use SOLVER from the Excel menu to find this value!(Excel 2010 Data, Data Analysis, Solver, Older Excel Tools, Solver)
NOTE 1: set the biologic half life (Cell G16) to a value in the range of 1 to 100 *before* running Solver)
This helps assure Solver will converge to a real solution.
Note 2: A biologic half-life (T 1/2) that is greater than a working lifetime makes no sense
and is thus a "constraint" in Solver so that T1/2 is < 350000

When you open Solver a pop-up window like shown in the workbook "Spreadsheet Documentation" below will appear.
The yellow cell in the MAHL box above is "named" Fp_MAHL, and is the "Set Target Cell" for SOLVER.
That will be in the Solver Pop-up window. Solver will AUTOMATICALLY (when the "Solve" button is pushed)
find the T 1/2 (Named cell T_2) to MINIMIZE Fp_MAHL. That T 1/2 will be used to calculate the Fp_MAHL,

IHMod 2.0, Welding Fume Example

Scenario

- A worker is welding mild steel outdoors with limited mobility. The worker is continuously welding every 2 minutes using a E7018 rod that contains 1-5% manganese. According to Jenkins (2003), 10% of the welding consumables vaporize, with 10% of that airborne (the remainder condenses in the welding pool). Each welding rod is about 0.15 pounds.

What is worker's airborne exposure to manganese from vaporized welding fumes?

Jenkins NT (2003) Chemistry of airborne particles from metallurgical processing Doctoral thesis Massachusetts Institute of Technology.

Model Selection

- Which model do you choose?
  - Near field plume model
  - Two-zone model
  - Well mixed room model
  - Eddy diffusion model
- Deterministic or probabilistic approach?
  - Deterministic
  - Probabilistic

Calculations

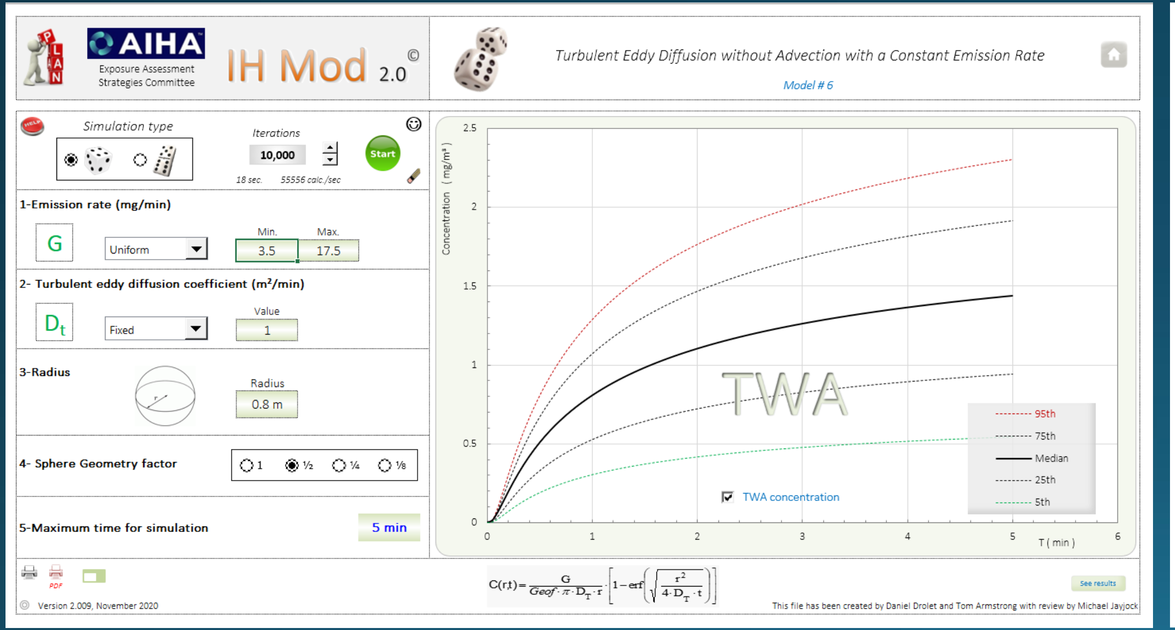
1. Calculate amount of manganese emitted over time (mg/min)
   - Rod (lb) × 454 (g/lb) × 1000 (mg/g) × Mn (%) × air (%) ÷ time (min)
   - 0.15 lb × 454 (g/lb) × 1000 (mg/g) × 0.01–0.05 × 0.01 ÷ 2 min = **3.5–17.5 mg/min**
2. Determine NF geometry and distance (x, y, z)
   - Assume welding at arm's length = **0.8 m**
3. Determine eddy diffusion coefficient
   - From literature or professional judgement = **0.1 or 1 m^2/min**
4. Determine time (min)
   - Assume task duration = **2 min**

Initial Model Choice

Turbulent Eddy Diffusion Without Advection and Constant Emissions

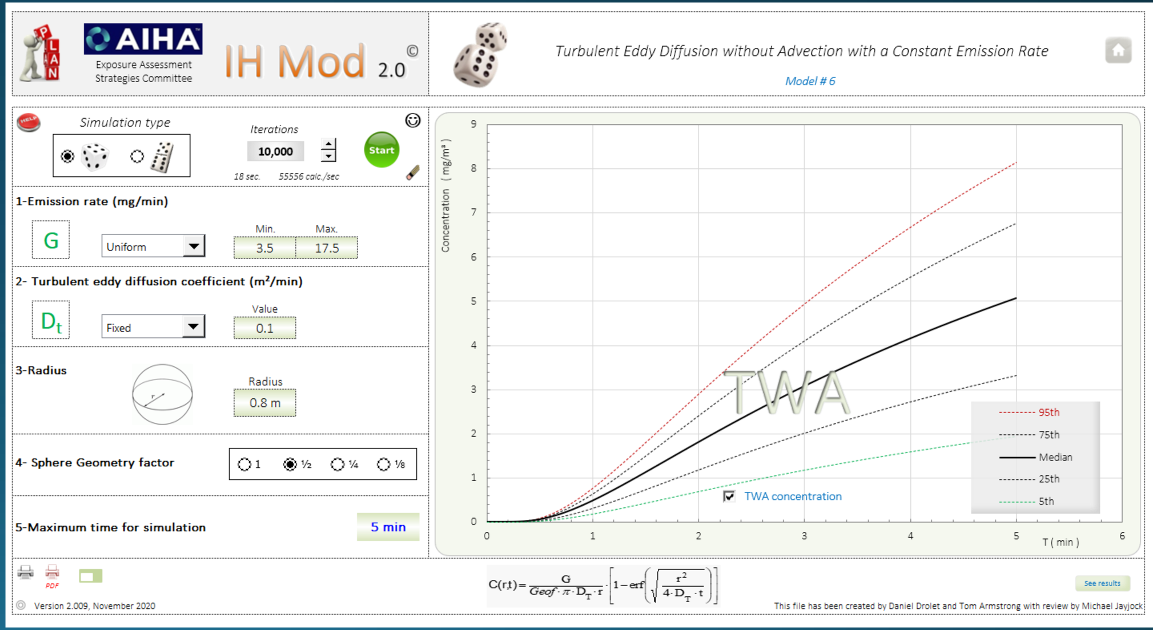
Dt 1, Hemisphere r 0.8 m
TWA 2 min
Median = 1.1mg/m^3
95th %ile = 1.8 mg/m^3

Median C 1 min = 1.8, and at 2 min 2.2



Dt 0.1, Hemisphere r 0.8 m
TWA 2 min
Median = 1.8 mg/m^3
95th %ile = 2.9 mg/m^3

Median C 1 min = 1.6, and at 2 min 4.5



Note the "rise time" of the air concentration. Even Dt 1 looks a bit "slow" compared to welding plume exposures I have seen.

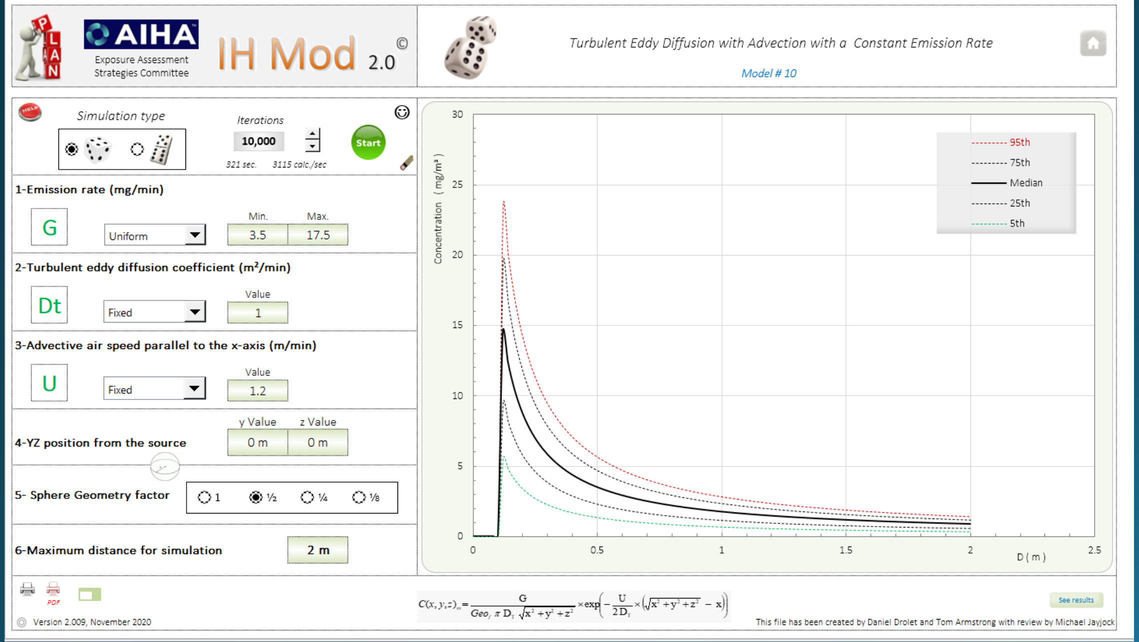
Second Model Choice

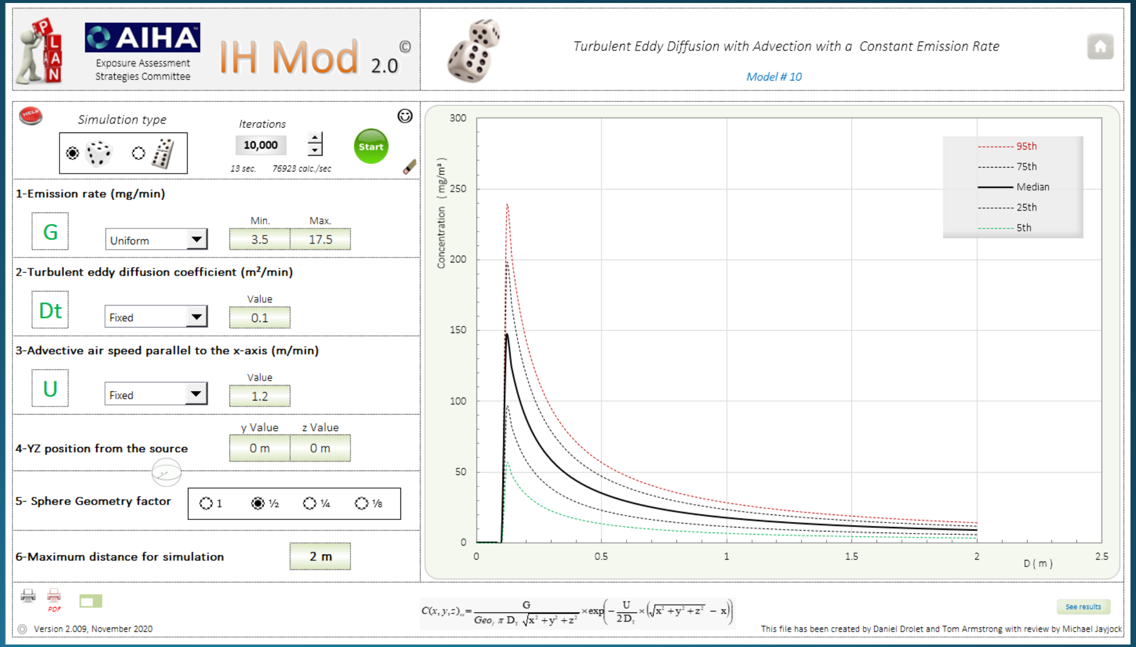
Turbulent Eddy Diffusion With Advection and Constant Emissions Scenario revision:

Add low air movement advection, 25% of “12 feet per minute” based on my judgement for this illustration = 1.2 m/min

Dt 1
Hemisphere r 0.8 m
Median = 2.1 mg/m^3
95th %ile = 3.5 mg/m^3

Dt 0.1
Hemisphere r 0.8 m
Median = 22 mg/m^3
95th %ile = 35 mg/m^3





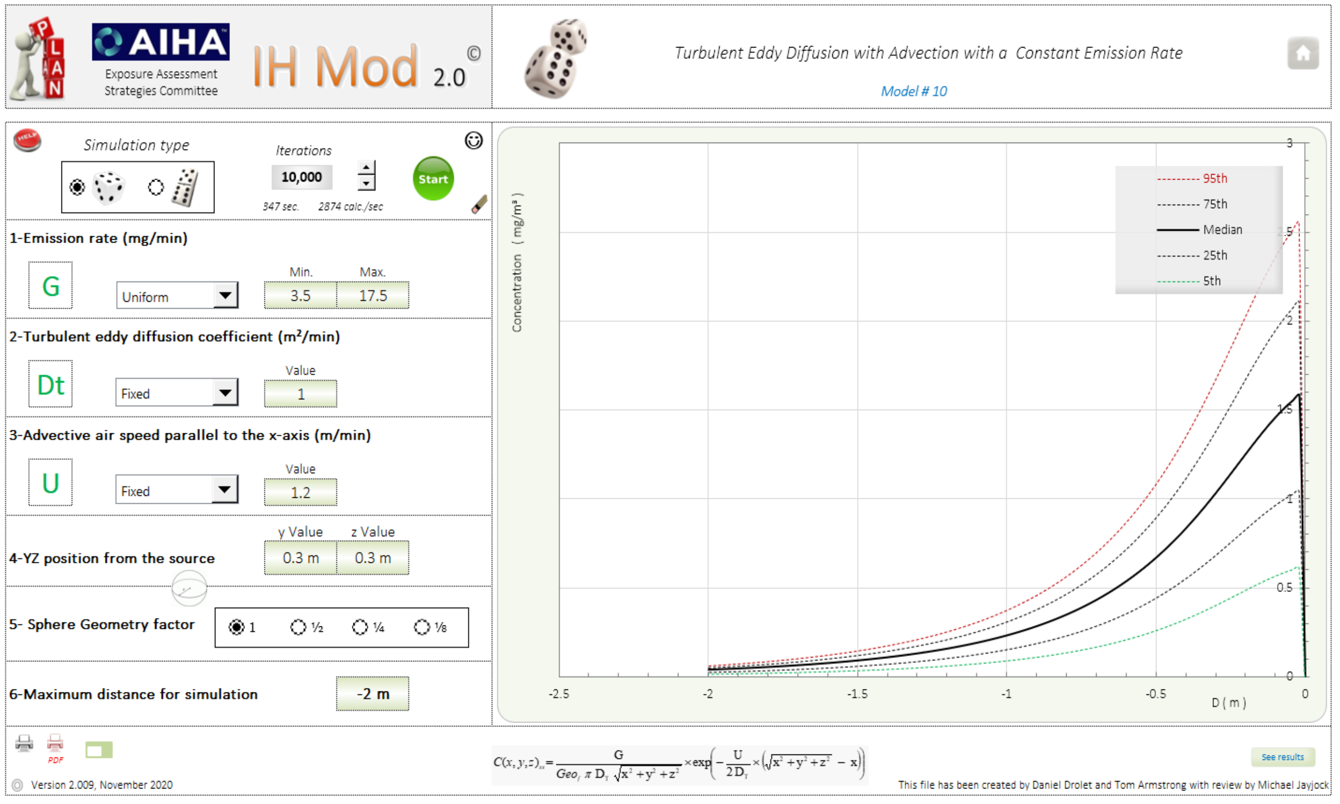
Third Model Choice

Turbulent Eddy Diffusion With Advection and Constant Emissions

The welder is a bit off-axis Y, Z and UPWIND (-X) with respect to the advective airflow direction direction

Dt 1
Hemisphere
At -0.8 meters
Median = 0.35 mg/m³
95th %ile = 0.56 mg/m³

Intuitively, if we have observed welding, this makes a lot of sense. We know a bit of directional airflow and positioning can make a big difference, both good and bad



A FEW ADDITIONAL RESOURCES…

- www.IHMod.org
- New book, Chris Keil, Editor, AIHA Press, “A Case-Based Introduction to Modeling Occupational Inhalation Exposures to Chemicals”
- Older book, new edition in development, AIHA Press, “Mathematical Models for Estimating Occupational Exposure to Chemicals, 2nd edition”