SWEEs Ver.1.0

Operating Manual

Version 1.0.3

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1. Features of the probabilistic exposure evaluation model

This tool (SWEEs: integrated Score-based Workplace Exposure Estimating system) is an advanced exposure evaluation tool which estimates exposure concentration in workplaces. It probabilistically treats the confidence interval of predicted value and dispersion in exposure concentration inside and between workers in order to estimate the exposure concentration distribution. With the probabilistic prediction for exposure concentration, this tool can assist managers with implementing self-management for exposure and render higher cost-effectiveness than do qualitative and deterministic evaluations which make safe estimates.

This tool is made with Advanced REACH Tool (ART), developed in Europe, as the model. The input is exposure-related information, which describes the exposure condition of the worker, such as work type, substance form, steam pressure, and presence/absence of local exhaust ventilation. By inputting exposure-related information, a certain exposure scenario is set, and the corresponding exposure concentration distribution is estimated. Moreover, by inputting limited exposure data particular to individual managers, it is possible to make more accurate predictions of exposure concentration distribution (Figure 1-1).

For the target substance forms, this tool can handle liquids mist or steam. The definitions of mist and steam are as follows.

Table 1-1 Classification of substance forms

Substance form	Definition
Liquid mist	Floating fine particles of liquefied steam
Liquid steam	Vaporized liquid

Unlike the probabilistic exposure evaluation tools based on the conventional numerical model which uses emission amount from the source and air velocity, this tool estimates the exposure concentration based on the exposure-related information of the workplace and the regression equation for exposure concentration. As the modifying factors for the model used in this tool are the ones based on the exposure concentration and exposure-related information in Europe, investigation in workplaces in Japan is not sufficient. Also, it remains to examine and correct the values of the modifying factors and the terminology. For this reason, it is possible that the output results cannot directly be used as actual proof. Organization of exposure data in Japanese workplaces would make a probabilistic exposure evaluation model with better accuracy.

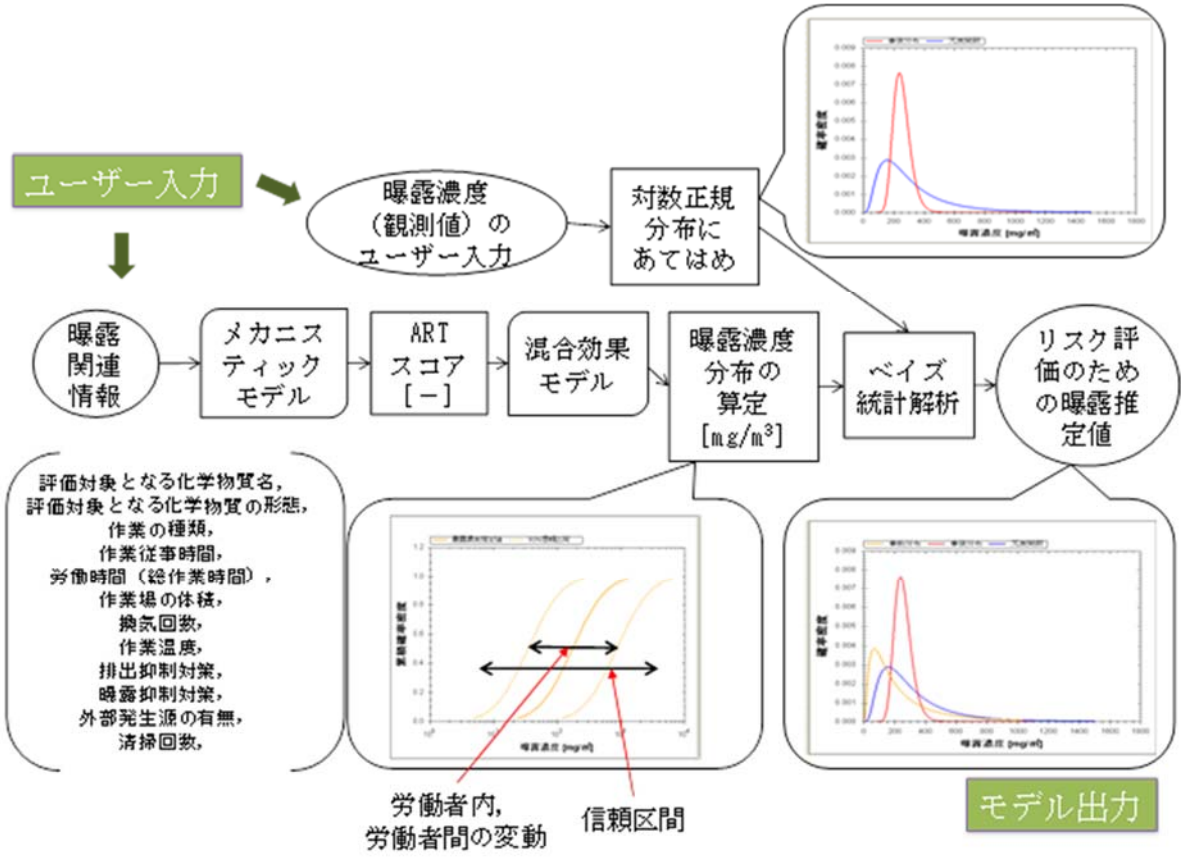


Figure 1-1 Input and output structure of SWEEs

Exposure-related information prepared in advance by the user

- Work procedure of the worker to be evaluated (labor duration and work duration)
- Name of substance handled, steam pressure, working temperature
- Map of the workplace and amount of ventilation
- Measured value of exposure concentration in the workplace (optional)

* This manual is written based on the following references: Fransman et al. (2010), Tielemans et al. (2011), Fransman et al.(2011), and Schinkel et al. (2011).

2. Program environment

2.1. Target OS

This software supports Windows7 and Windows 8.1. We do not provide performance guarantee for use with other OS. Also, the execution of this program requires Microsoft .Net Framework 3.5. Please install it if not yet installed.

2.2. Program start-up method

Start the program following the steps (1) - (2) shown below.

(1) Double-click SWEEs.exe (application) in the "SWEEs Ver.1.0" folder of CD.

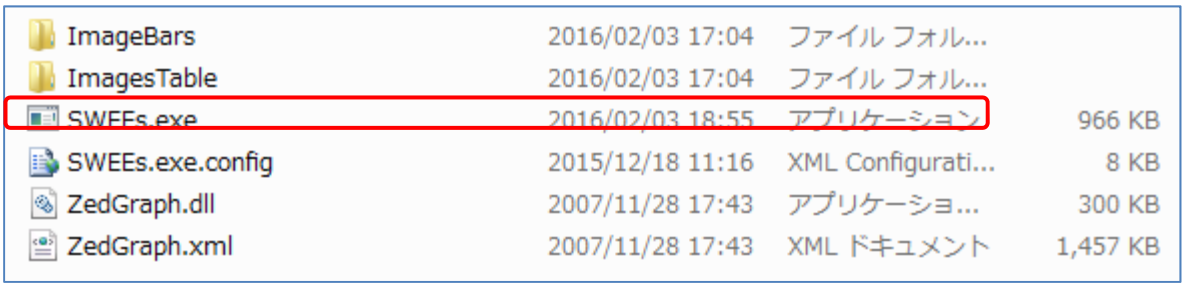


Figure 2-1 The folder structure of SWEEs Ver1.0 (with extensions)

※If the extensions are now shown, double-click SWEEs (application).

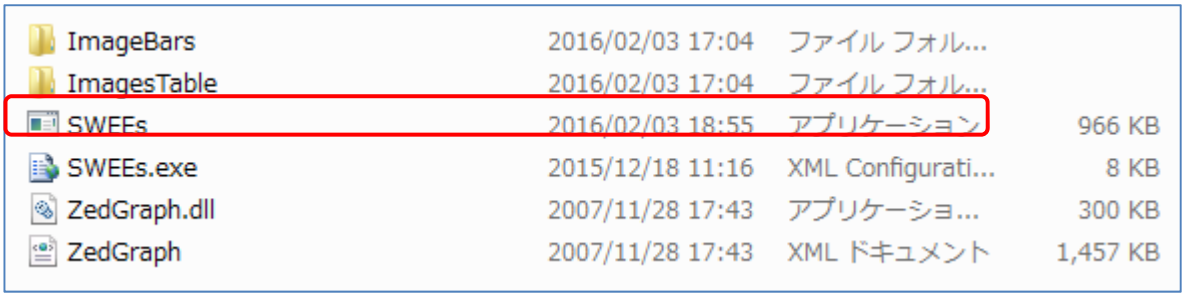


Figure 2-2 The folder structure of SWEEs Ver1.0 (without extensions)

(2) Check that the top screen of "SWEEs Ver1.0" starts.

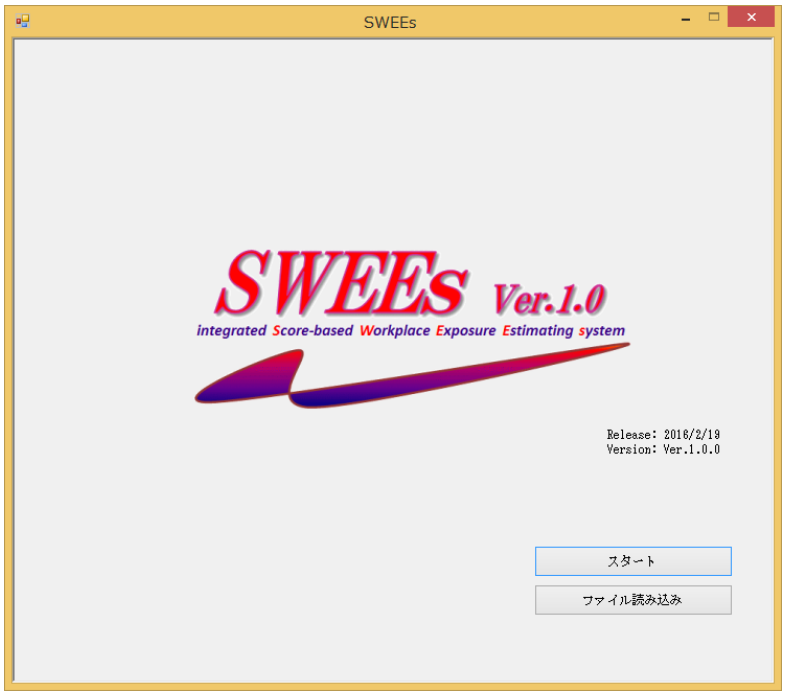


Figure 2-3 Top screen

2.3. Caution

This tool is normally displayed when the Windows screen size is 100 %, and the screen might be broken if the screen size is a different value. If the screen size is not 100 %, change the size to 100 % (below examples shows "small-100%" selected) in Control Panel > Display and start.

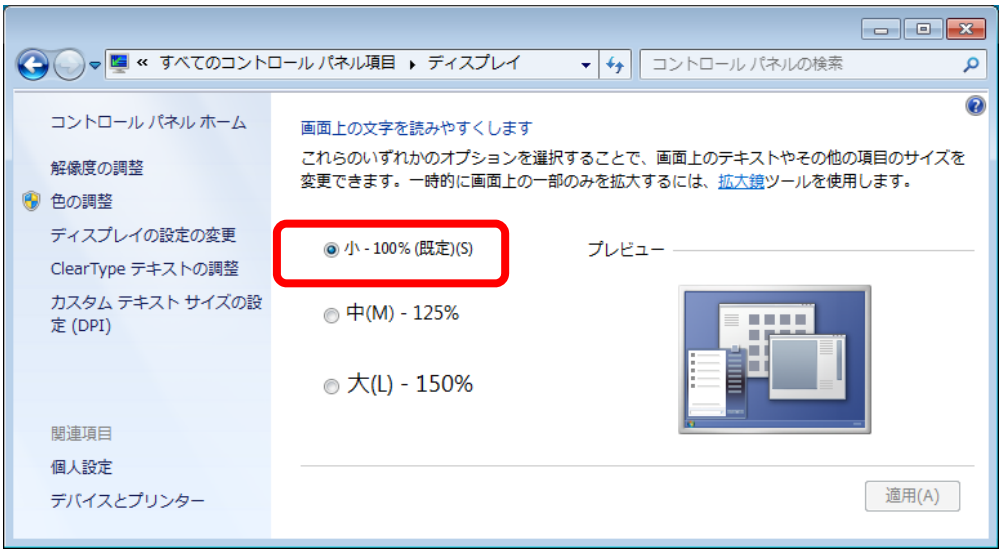


Figure 2-4-1 Display setting (Windows 7)

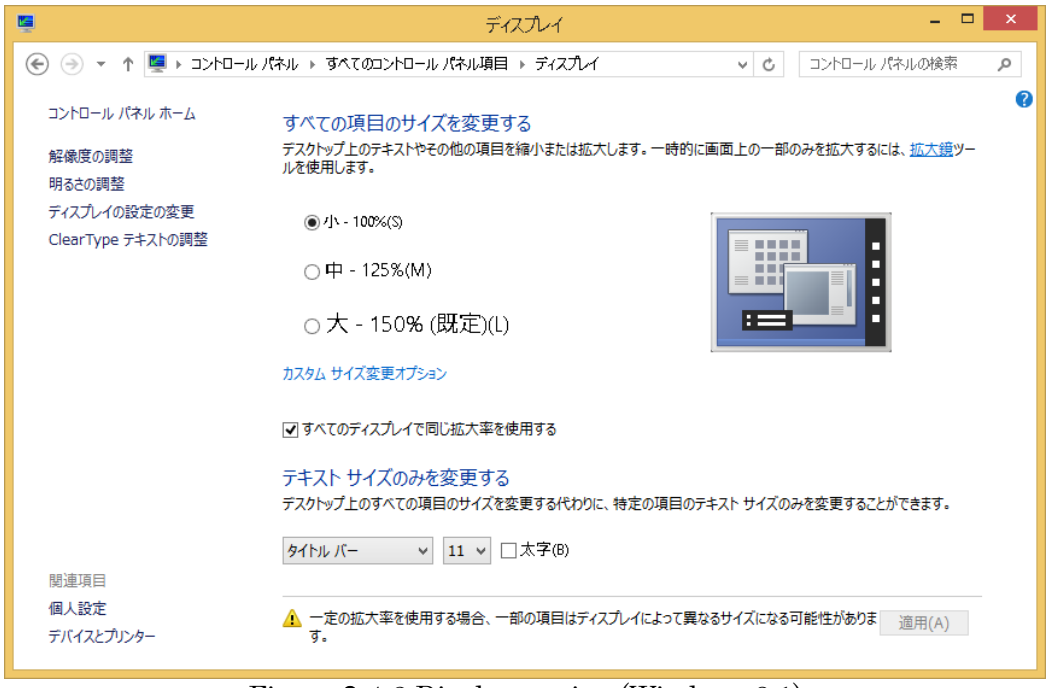
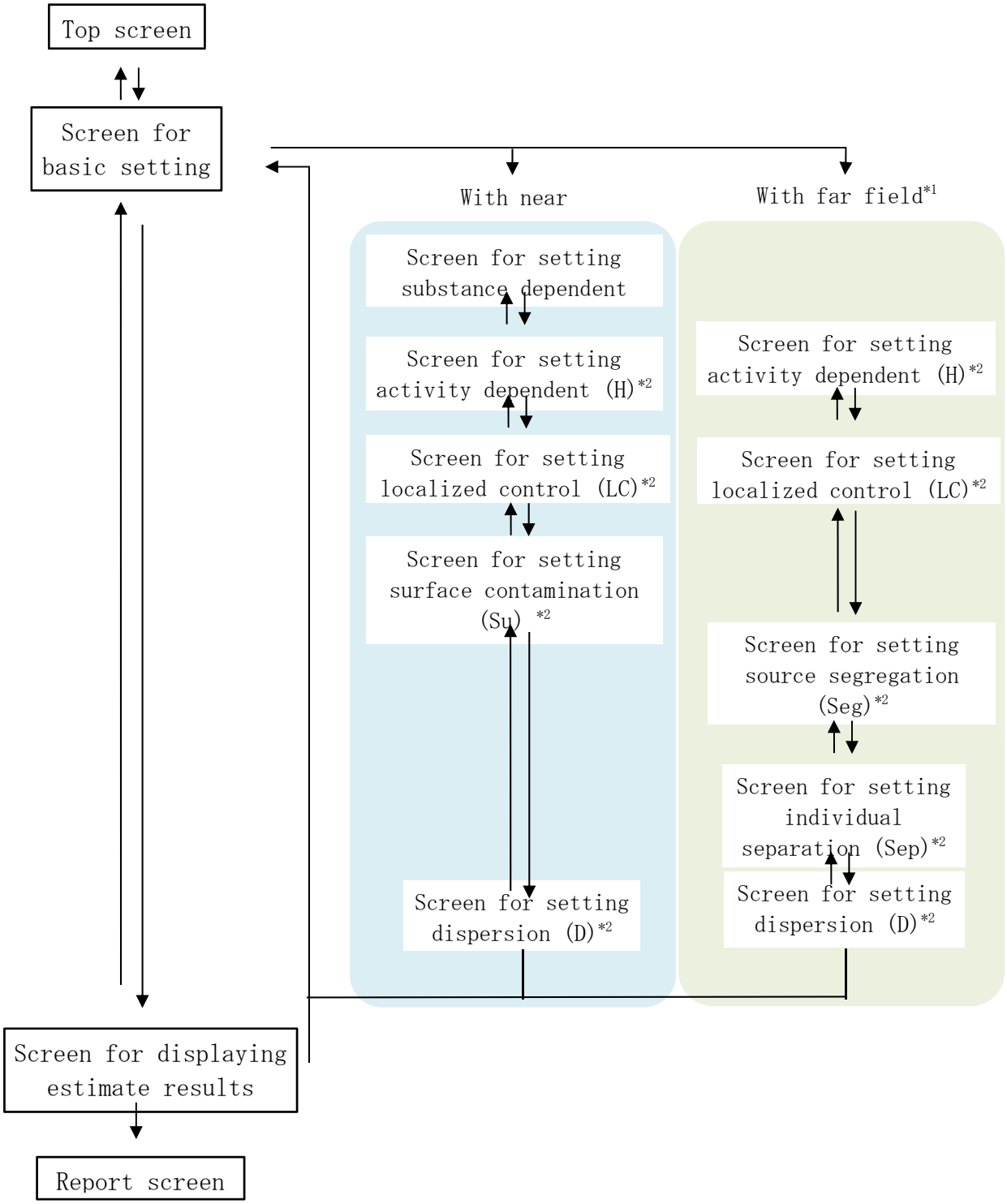


Figure 2-4-2 Display setting (Windows 8.1)

3. Overall structure of SWEEs



*1: Near field and far field (See Figure 3-1)

Near field (nf): Spatial region within 1 m from the worker's mouth in the vertical, horizontal and depth directions (8 m^3)

Far field (ff): Work space other than the near field

*2: Modifying factors of SWEEs: In SWEEs, the model coefficients are called the "modifying factors".

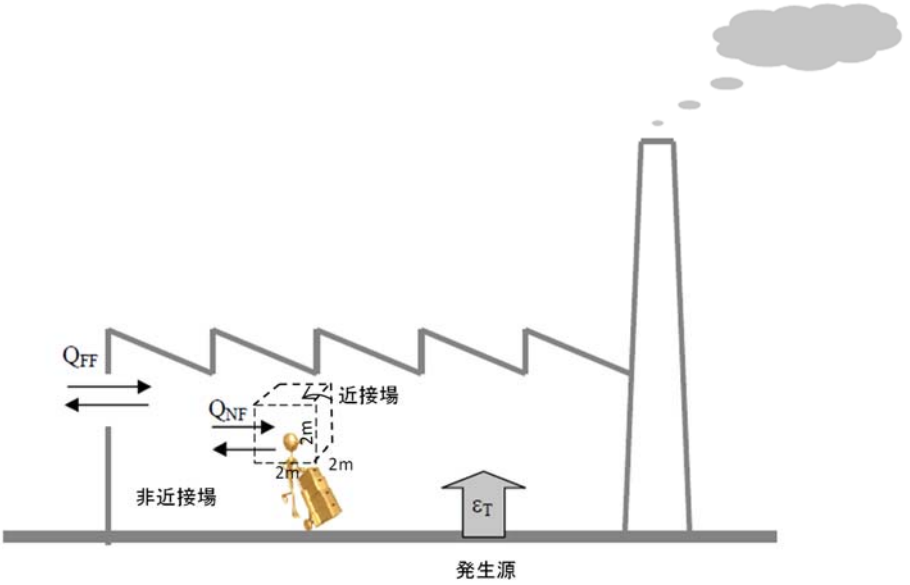


Figure 3-1 Near field and far field in this tool

4. Detailed description of operating screen

This chapter provides detailed descriptions of all the operating screens of SWEEs.

4.1. Top screen

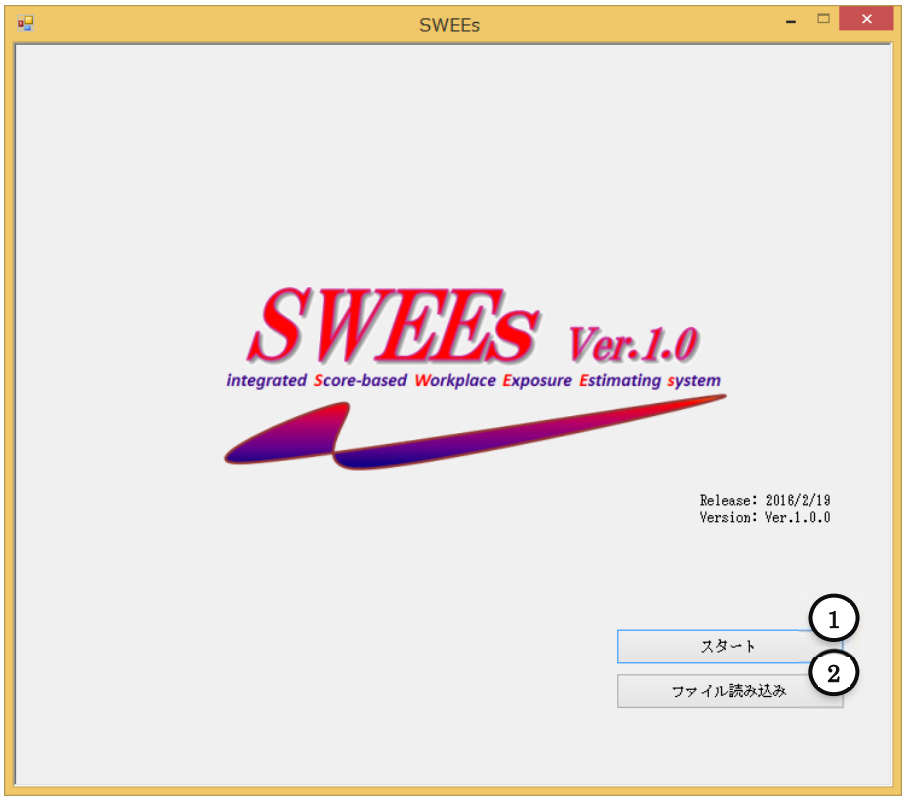


Figure 4-1 Top screen

ID	Item	Description
①	“Start” button	When clicked, it displays the screen for basic setting.
②	“Read file” button	It displays a file open dialog, use the information in the selected csv file to display screen for basic setting.

4.2. Screen for basic setting

Figure 4-2 Screen for basic setting

ID	Item	Description
①	“Name of analysis scenario” text box	Enter the name of analysis scenario. Arbitrary name of analysis scenario can be entered.
②	“Substance name” text box	Enter the substance name. Arbitrary substance name can be entered.
③	“Substance form” radio button	The current version, which selects liquid mist or liquid steam, cannot evaluate solid polish dust or solid dust.
④	“Setting” button for basic information	If clicked after entering name of analysis scenario and substance name and selecting substance form, input for the setting of working condition is enabled.
⑤	“Total work duration” text box	Enter the total work duration in minutes for the entered scenario.
⑥	“Work duration” text box for each task	Enter the work duration in minutes for tasks 1 - 4. If the modifying factors of near field for task 1 are not entered, entering time in the work duration text boxes 2 - 4 are disabled. Similarly, in order to enter the work duration for the next task, all input values for the previous task must be completed.
⑦	“Substance dependent (E)” text box	It displays the modifying factor value set in the screen for setting substance dependent (E).
⑧	“Activity dependent (H)” text box (for near field)	It displays the modifying factor value set in the screen for setting activity dependent (H).
⑨	“Localized control 1 (LC1)” text box (for near field)	It displays the modifying factor value set in the screen for setting localized control (LC).
⑩	“Localized control 2 (LC2)” text box (for near field)	If two local exhaust ventilation devices are set, it displays the modifying factor values in accordance with the second device type in the screen for setting localized control (LC).
⑪	“Surface contamination (Su)” text box	It displays the modifying factor value set in the screen for setting surface contamination (Su). The value of this item is common for near and far fields.
⑫	“Dispersion (D)” text box (for near field)	It displays the modifying factor value set in the screen for setting dispersion (D).
⑬	“Activity dependent (H)” text box (for far field)	It displays the value of the modifying factor set in the screen for setting activity dependent (H).
⑭	“Localized control 1 (LC1)” text box (for far field)	It displays the modifying factor value set in the screen for setting localized control (LC).
⑮	“Localized control 2 (LC2)” text box (for far field)	If two local exhaust ventilation devices are set, it displays the modifying factor values in accordance with the second device type in the screen for setting localized control (LC).
⑯	“source segregation (Seg)” text box (for far field)	It displays the value of the modifying factor set in the screen for setting source segregation (Seg).
⑰	“individual separation (Sep)” text box (for far field)	It displays the value of the modifying factor set in the screen for setting individual separation (Seg).
⑱	“Dispersion (D)” text box (for far field)	It displays the modifying factor value set in the screen for setting dispersion (D).
⑲	“Setting” button for modifying factors (for near field)	When clicked, it switches to the screen for setting the modifying factors for near field. For near field, it displays the screen for setting substance dependent (E). In order to enter values for the next task, all input values for the previous task must be completed. Similarly, if the task 2 (3) is not completely set, clicking the setting button is disabled for task 3 (4).
⑳	“Setting” button for modifying factors (for far field)	When clicked, it switches to the screen for setting the modifying factors for far field. For far field, it is set when there is a large source outside the 8 m^3 region around the worker's mouth. For far field, it displays the screen for setting activity dependent (H). If the modifying factors of near field for the same task are not set, clicking the setting button for far field is disabled. If the setting button is selectable, hovering the cursor over the button leads to a comment around the button, stating “For far field, it is set when there is a large source outside the 8 m^3 region around the worker's mouth.”
㉑	“Return” button	Clicking this button makes the system return to the top screen.
㉒	Status display	It displays the condition of the current setting. It highlights each status.
㉓	“Calculation” button	The system makes calculations based on the set modifying factors and displays the screen for estimation result.

※About modifying factors

Table 4-1 shows the characteristics and reasons for the assignment of the modifying factors in SWEEs.

Table 4-1 characteristics and reasons for the assignment of the modifying factors

Modifying factor	Abbreviation	Symbol	Information source	Characteristics (3-pattern classification)
Substance emission potential (Substance emission potential)	Substance dependent	*E*	"First principles" with respect to physiochemical properties	A. Takes a value common for near and far fields
Activity emission potential （Activity emission potential）	Activity dependent	*H*	Exposure data from calibration database, literature data, expert judgment	B. Takes a value different for near and far fields
Localized control （Localized control）	Localized control	*LC*	ECEL database* and expert elicitation workshop	B. Takes a value different for near and far fields
Source Segregation (Segregation)	Segregation	*Seg*	ECEL database*, expert judgment	C. Factor only for far field
Individual Separation (Separation)	Separation	*Sep*	ECEL database*, expert judgments	C. Factor only for far field
Surface contamination (Surface contamination)	Surface contamination	*Su*	Expert judgment	A. Common for near and far fields
Dispersion (Dispersion)	Dispersion	*D*	Simulation with two-component box model	B. Different for near and far fields

* Exposure Control Efficacy Library (ECEL) database is an evidence database with collection of efficacy of management strategies for inhalation exposure. The database contains the efficacy evaluations for management strategy for exposure based on 433 pieces of data extracted from 90 reviewed papers from the four important academic journals in occupational health (Annals of Occupational Hygiene, American Industrial Hygiene Association Journal, Applied Occupational and Environmental Hygiene, and Journal of Occupational and Environmental Hygiene) (Fransman et al. 2008).

Source: Fransman et al. 2010. Added "Characteristics"column to the table.

4.3. Screen for setting substance dependent (E)

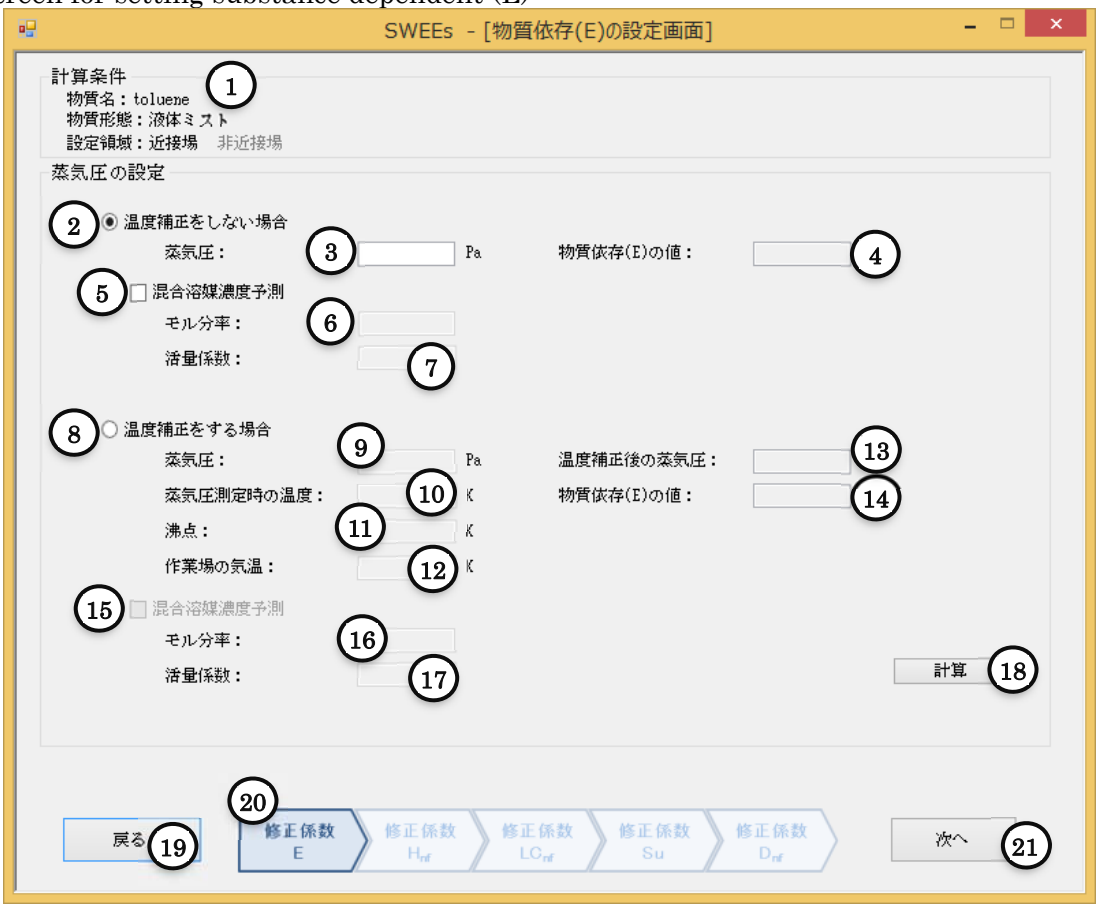


Figure 4-3 Screen for setting substance dependent (E)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Without temperature correction” radio button	Check when not making the temperature correction for steam pressure. If this button is checked, inputting to ③ Steam pressure becomes enabled.
③	“Steam pressure” text box	Enter the value for steam pressure.
④	“Substance dependent (E) value” text box	When clicking ⑫ Calculation button, it calculates the value of substance dependent from ③ Steam pressure and displays the value.
⑤	“Mixed solvent concentration estimate” check box	With ② “Without temperature correction” button checked, clicking this check box leads to a calculation of the substance dependent (E) based on molar fraction and activity coefficient.
⑥	“Molar fraction” text box	For calculating the substance dependent (E) with mixed solvent, enter the molar fraction.
⑦	“Activity coefficient” text box	For calculating the substance dependent (E) with mixed solvent, enter the activity coefficient.
⑧	“With temperature correction” radio button	Check when making the temperature correction for steam pressure. If this button is checked, inputting to ⑥ Steam pressure, ⑦ Temperature during steam pressure measurement, ⑧ Boiling point, and ⑨ Workplace temperature becomes enabled. After entering these values, clicking ⑫ Calculation button leads to displaying calculated results to ⑩ Steam pressure after temperature correction and ⑪ Substance dependent (E) value

⑨	“Steam pressure” text box	Enter the value for steam pressure.
⑩	“Temperature during steam pressure measurement” text box	Enter the temperature during steam pressure measurement.
⑪	“Boiling point” text box	Enter the boiling point of the target substance.
⑫	“Temperature in workplace” text box	Enter the temperature in workplace.
⑬	“Steam pressure after temperature correction” text box	When clicking ⑫ Calculation button, it calculates steam pressure after temperature correction and displays it.
⑭	“Substance dependent (E) value” text box	When clicking ⑫ Calculation button, it calculates the value of substance dependent (E) based on temperature correction and displays the value.
⑮	“Mixed solvent concentration estimate” check box	With ⑧ “With temperature correction” button checked, clicking this check box leads to a calculation of the substance dependent (E) based on molar fraction and activity coefficient.
⑯	“Molar fraction” text box	For calculating the substance dependent (E) with mixed solvent, enter the molar fraction.
⑰	“Activity coefficient” text box	For calculating the substance dependent (E) with mixed solvent, enter the activity coefficient.
⑱	“Calculation” button	It calculates the substance dependent (E). With ② “Without temperature correction” button checked, it calculates the substance dependent (E) based on the ③ Steam pressure. The calculation result is displayed in ④ Substance dependent (E) value. With ⑤ “With temperature correction” button checked, it calculates the steam pressure after temperature correction and the substance dependent (E) based on the values of -⑥ Steam pressure, ⑦Temperature during steam pressure measurement, ⑧ Boiling point, and ⑨ Temperature in workplace. The calculation results are displayed in ⑩ Steam pressure after temperature correction and ⑪ Substance dependent (E) value.
⑲	“Return” button	Returns to the screen for basic setting.
⑳	Status display	The current setting condition is displayed in the status bar. Near field is displayed in blue.
㉑	“Next” button	Moves onto the screen for setting activity dependent (H).

※Method for calculating the substance dependent (E)

The substance dependent (E: Substance dependent emission potential) is calculated from the substance's steam pressure P[Pa] (see below equation). Here, E=1 for p>30,000 [Pa] and E=3.33×10^{-4} for P<10[Pa].

$$E_i = \frac{p_i}{30{,}000}$$

In the case of toluene, for example, the steam pressure at 20℃ is 2,930 Pa (=22 mmHg). Using the above equation, the substance dependent (E) is calculated as (E)=2,930/30,000 =0.0977.

This indicates that the worker’s exposure concentration is 0.0977 times lower than that in the case of handling substance with steam pressure of 30,000 ［Pa］.

Also, in the case of a mixture, the steam pressure of substance i in the mixture, $P_{i,mix}$, can be calculated based on the molar fraction χ_i and the activity coefficient γ_i. The activity coefficient of the substance is calculated using the xIUNIFAC[*1] model (below equation).

$$p_{i,mix} = \gamma_i \times \chi_i \times p_i$$

In the case of a mixture, the substance dependent emission potential (E_i) can be calculated by the below equation.

$$E_i = \frac{p_{i,mix}}{30{,}000}$$

※1. Reference for the xIUNIFAC model
Randhol, P. and Engelien H.K. (2000) xlUNIFAC, a Computer Program for Calculation of Liquid Activity Coefficients Using the UNIFAC Model.

※About temperature correction for steam pressure
When the substance's steam pressure during work is not known, the substance's steam pressure P_i (T) at temperature T is calculated by the Clausius-Clapeyron equation.

$$p_i(T) = p_i \cdot \exp\left\{-\frac{\triangle H_v}{R}\left(\frac{1}{T_p}-\frac{1}{T}\right)\right\}$$

Here, P_i: Steam pressure of substance i at temperature T_p
R: Gas constant 8.314[J/K・mol]
$\triangle H_v$: Enthalpy of vaporization

$$\triangle H_v = R \cdot \ln\frac{p_2}{101325}\frac{1}{\left(\frac{1}{T_2}-\frac{1}{T_B}\right)}$$

Here, P_2: Steam pressure at temperature T_2
T_B : Boiling point of substance i

4.4. Screen for setting liquid mist for activity dependent (H)

4.4.1. Spraying liquid

Figure 4-4 Screen for setting liquid mist for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Spraying liquid”, the “Screen for work subtype” is displayed as shown in Figure 4-4.
③	Work subtype “Surface spraying” radio button	Select this for the work subtype of “Surface spraying”.
④	Work subtype “Space spraying” radio button	Select this for the work subtype of “Space spraying”.
⑤	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Spray speed User input：0.1～3 Spray direction User input：0.3～3 Spray technique User input：1～3 Spray region User input：1～10
⑥	“Score setting” radio button	This is selectable if ③ is selected. The modifying factor for activity dependent (H) is the product of the scores corresponding to the selectable parts.
⑦	“Score setting” radio button	This is selectable if ④ is selected. The modifying factor for activity dependent (H) is the score corresponding to the selectable part.

⑧	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑨	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.4.2. Handling with open surface or reservoir

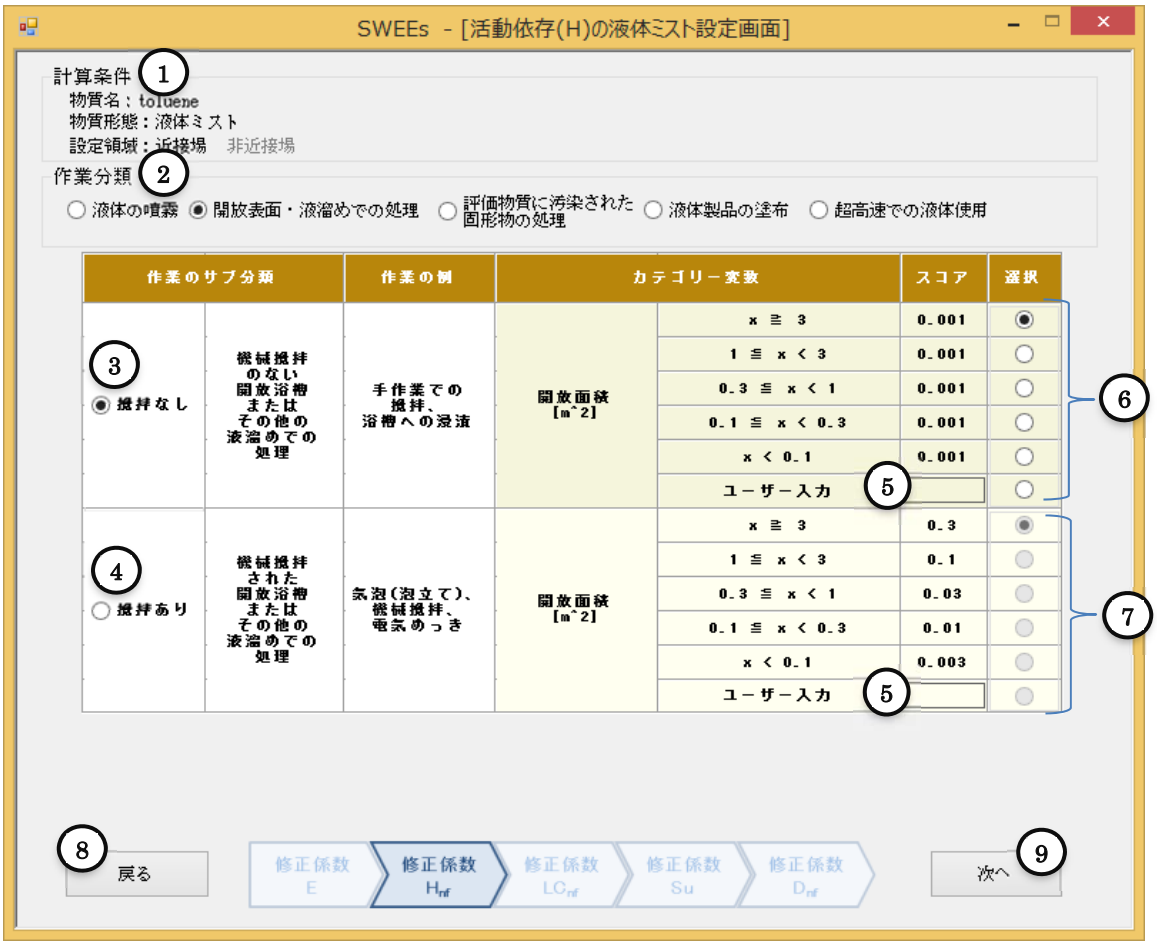


Figure 4-5 Screen for setting liquid mist for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Handling with open surface or reservoir”, the “Screen for work subtype” is displayed as shown in Figure 4-5.
③	Work subtype “Without stirring” radio button	Select this for the work subtype of “Without stirring”.
④	Work subtype “With stirring” radio button	Select this for the work subtype of “With stirring”.
⑤	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Without stirring Open area User input: 0.001-0.3 With stirring Open area User input: 0.001-0.3

⑥	“Score setting” radio button	This is selectable if ③ is selected. The modifying factor for activity dependent (H) is the corresponding score.
⑦	“Score setting” radio button	This is selectable if ④ is selected. The modifying factor for activity dependent (H) is the corresponding score.
⑧	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑨	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.4.3. Handling solid substance contaminated with evaluated substance

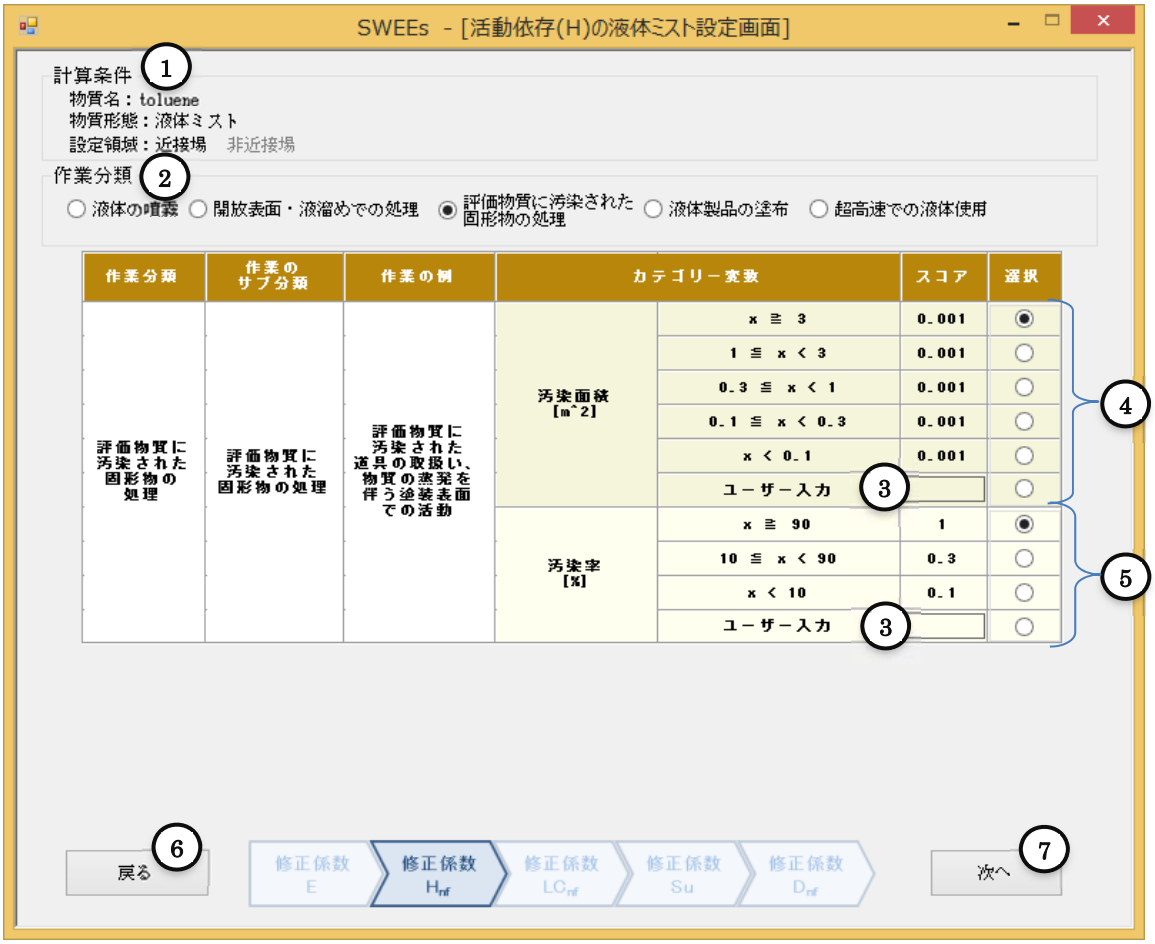


Figure 4-6 Screen for setting liquid mist for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Handling solid substance contaminated by evaluated substance*1”, the “Screen for work subtype” is displayed as shown in Figure 4-6.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Contamination area User input: 0.001～0.3 Contamination rate User input: 0.1～1
④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores for ③ Contamination area*2 and ④ Contamination rate*3.

⑤	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores for ③ Contamination area*2 and ④ Contamination rate*3.
⑥	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑦	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

(Note on table)*1: Evaluated substance: the substance selected in the conditions for calculation and evaluated by SWEEs. In this example, it is toluene.
*2: Contamination area: Surface area of the solid substance
*3: Contamination rate: Rate of the evaluated substance attached to the surface of the solid substance.

4.4.4. Application of liquid product

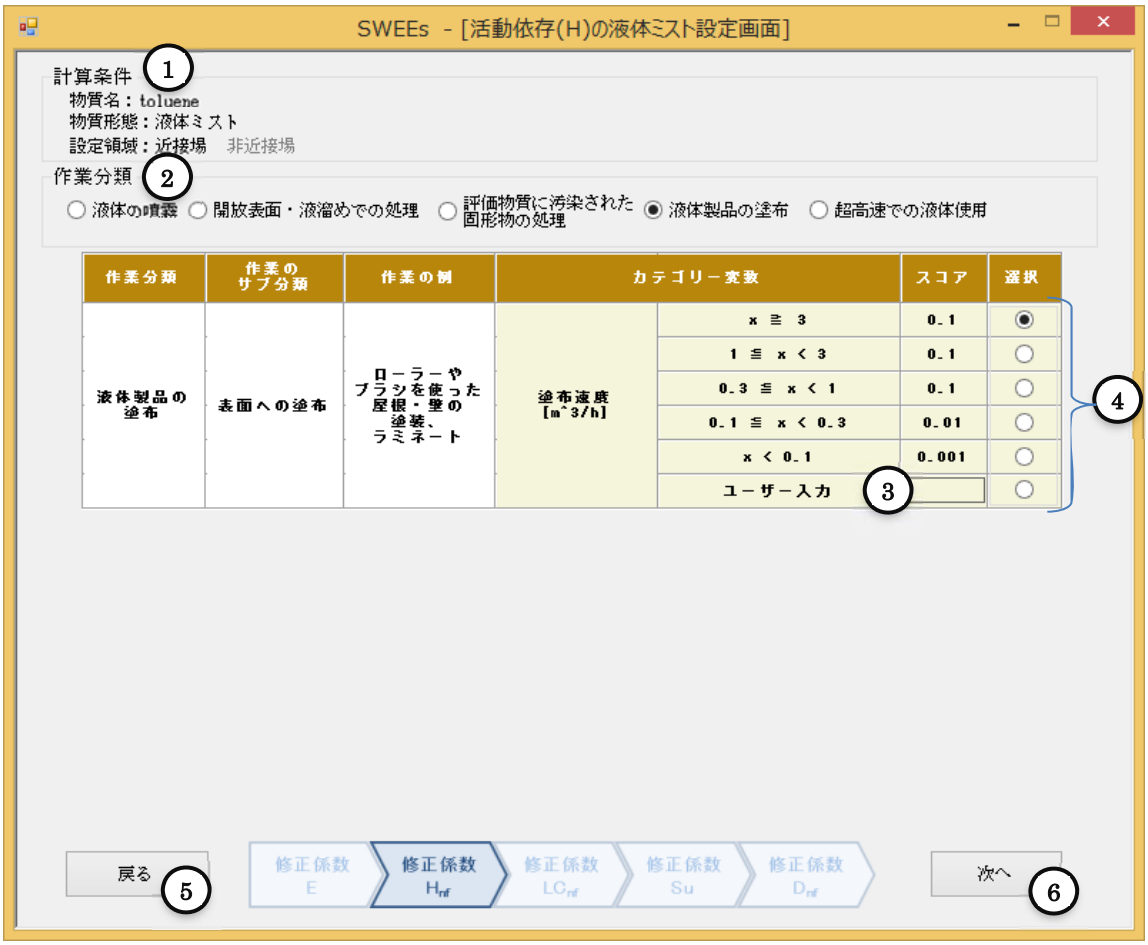


Figure 4-7 Screen for setting liquid mist for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Application of liquid product”, the “Screen for work subtype” is displayed as shown in Figure 4-7.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Application speed User input : 0.001～0.3

④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the score corresponding to the selected item.
⑤	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑥	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.4.5. Ultrafast liquid use

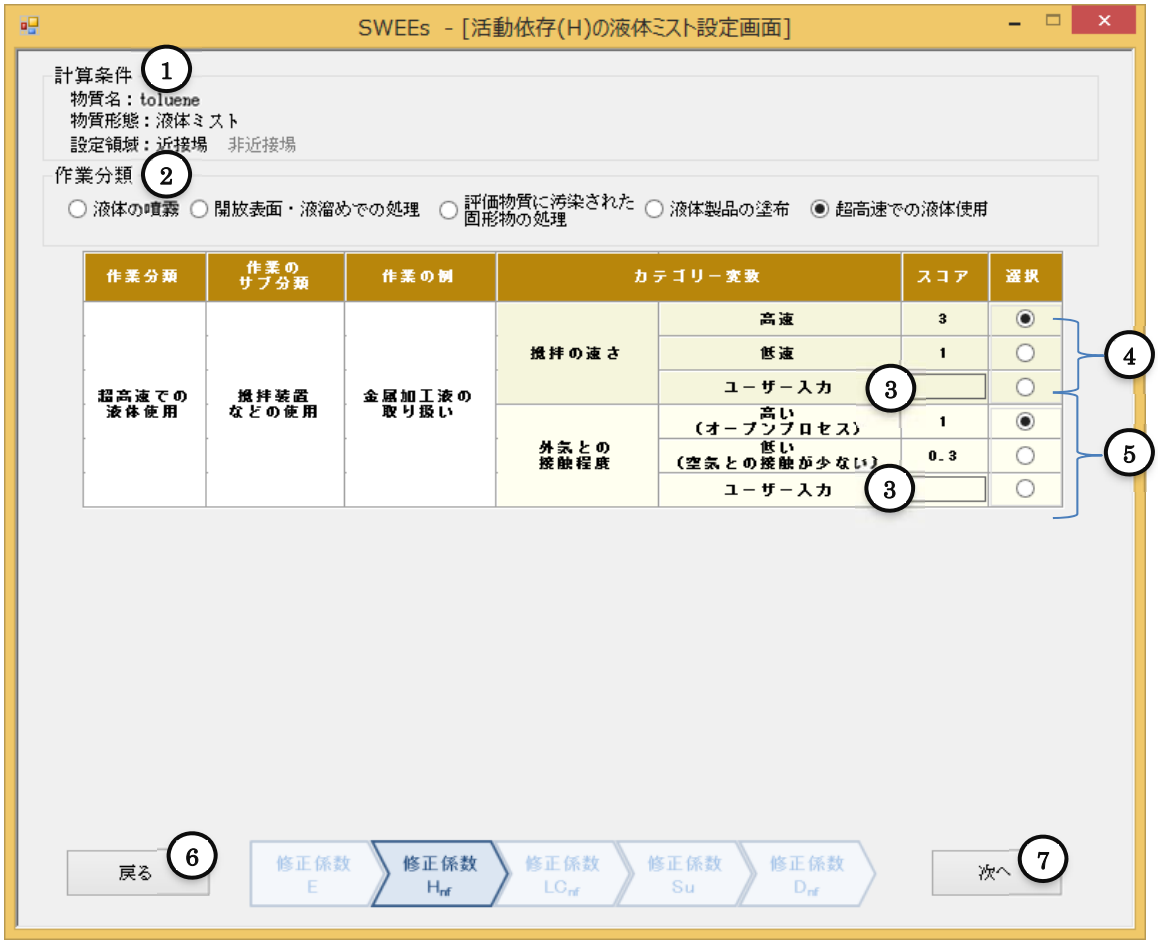


Figure 4-8 Screen for setting liquid mist for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Ultrafast liquid use”, the “Screen for work subtype” is displayed as shown in Figure 4-8.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Stirring speed User input: 1～3 Degree of contact with air User input：0.3～1
④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③Stirring speed* and ④ Degree of contact with air.

⑤	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③Stirring speed* and ④ Degree of contact with air.
⑥	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑦	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

(Note on table)* Stirring speed: Stirring speed of the stirring device.

4.5. Screen for setting liquid steam for activity dependent (H)

4.5.1. Spraying liquid

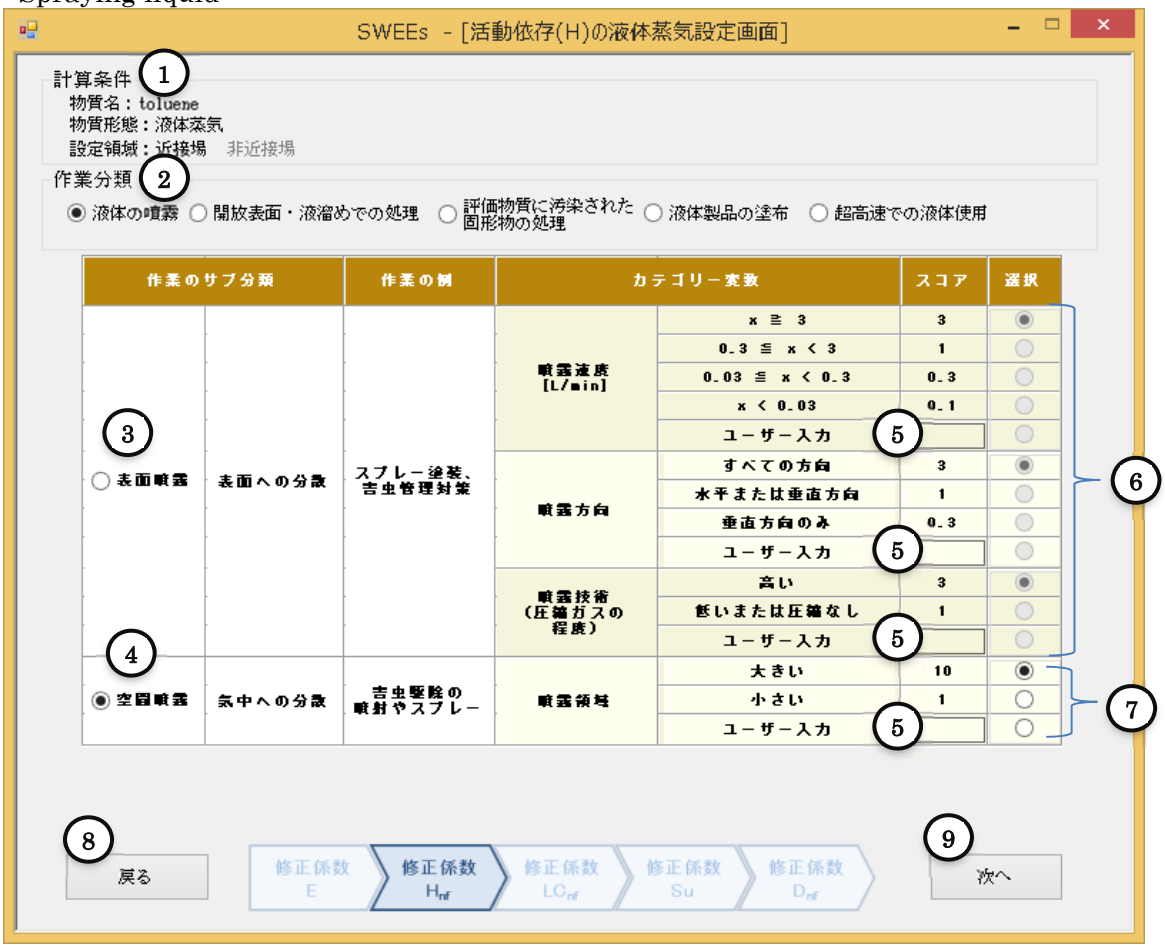


Figure 4-9 Screen for setting liquid steam for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Spraying liquid”, the “Screen for work subtype” is displayed as shown in Figure 4-9.
③	Work subtype “Surface spraying” radio button	Select this for the work subtype of “Surface spraying”.
④	Work subtype “Space spraying” radio button	Select this for the work subtype of “Space spraying”.
⑤	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Spray speed User input：0.1～3 Spray direction User input：0.3～3 Spray technique User input：1～3 Spray region User input：1～10
⑥	“Score setting” radio button	This is selectable if ③ is selected. The modifying factor for activity dependent (H) is the product of the scores corresponding to the selectable parts.
⑦	“Score setting” radio button	This is selectable if ④ is selected. The modifying factor for activity dependent (H) is the score corresponding to the selectable part.

⑧	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑨	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.5.2. Handling with open surface or reservoir

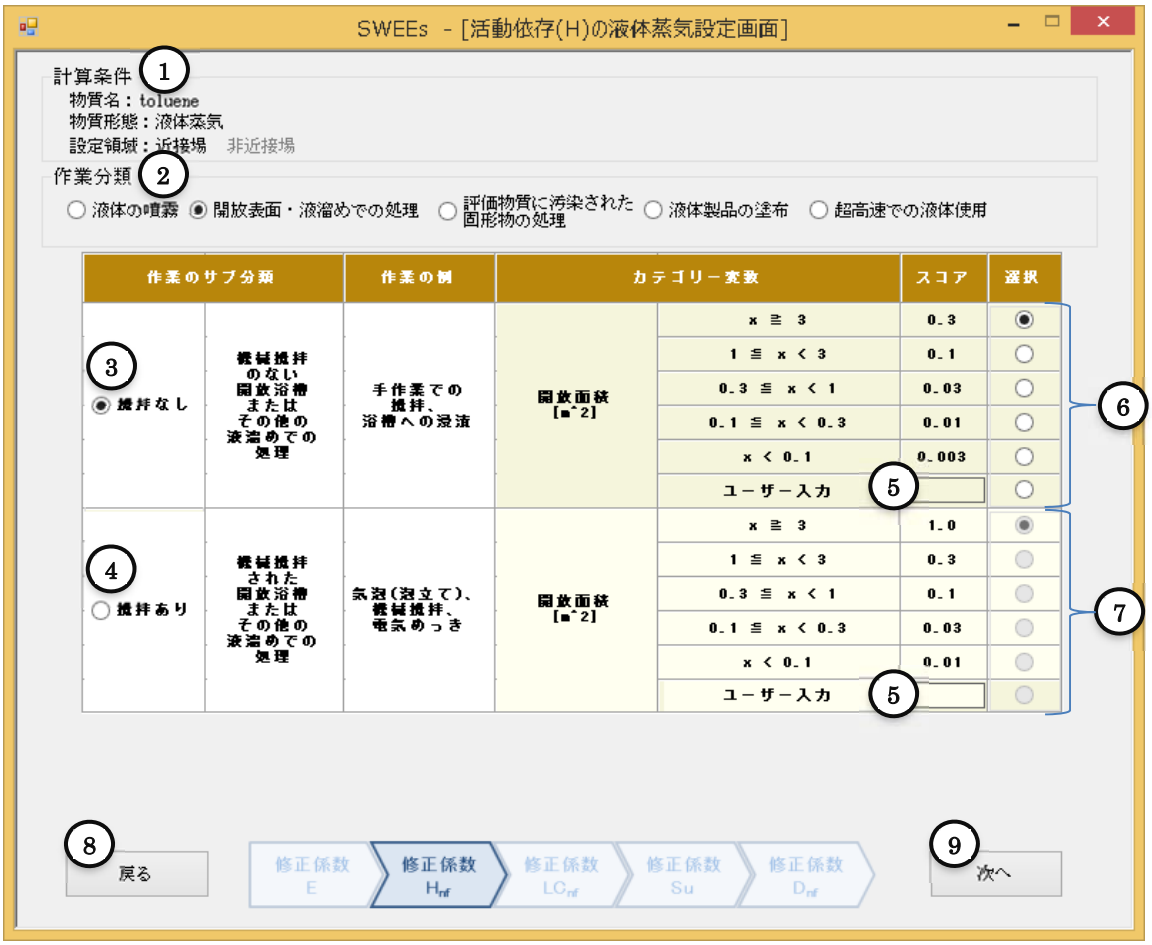


Figure 4-10 Screen for setting liquid steam for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Handling with open surface or reservoir”, the “Screen for work subtype” is displayed as shown in Figure 4-10.
③	Work subtype “No affected substance” radio button	Select this for the work subtype of “No affected substance”.
④	Work subtype “Stirring surface” radio button	Select this for the work subtype of “Stirring surface”.
⑤	“User input” text box	If the user wishes to enter a score value, the user enters in this text box. The ranges of input values are as follows. Without stirring Open area User input: 0.001～0.03 With stirring Open area User input: 0.003～1
⑥	“Score setting” radio button	This is selectable if ③ is selected. The modifying factor for activity dependent

		(H) is the corresponding score.
⑦	“Score setting” radio button	This is selectable if ④ is selected. The modifying factor for activity dependent (H) is the corresponding score.
⑧	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑨	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.5.3. Handling solid substance contaminated with evaluated substance

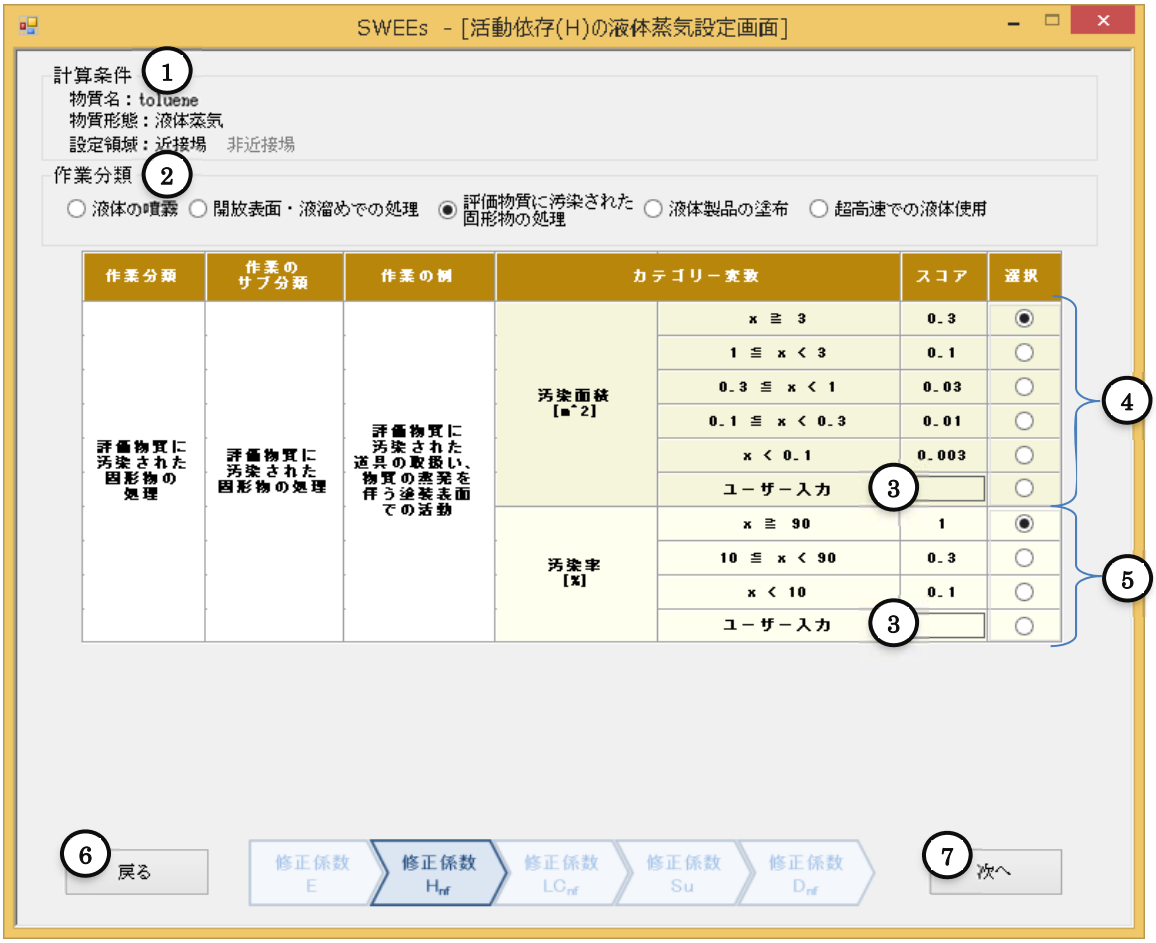


Figure 4-11 Screen for setting liquid steam for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Handling of solid contaminated by evaluated substance”, the “Screen for work subtype” is displayed as shown in Figure 4-11.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Contamination area User input: 0.003～1 Contamination rate User input: 0.1～1

④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③ and ④.
⑤	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③ and ④.
⑥	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑦	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.5.4. Application of liquid product

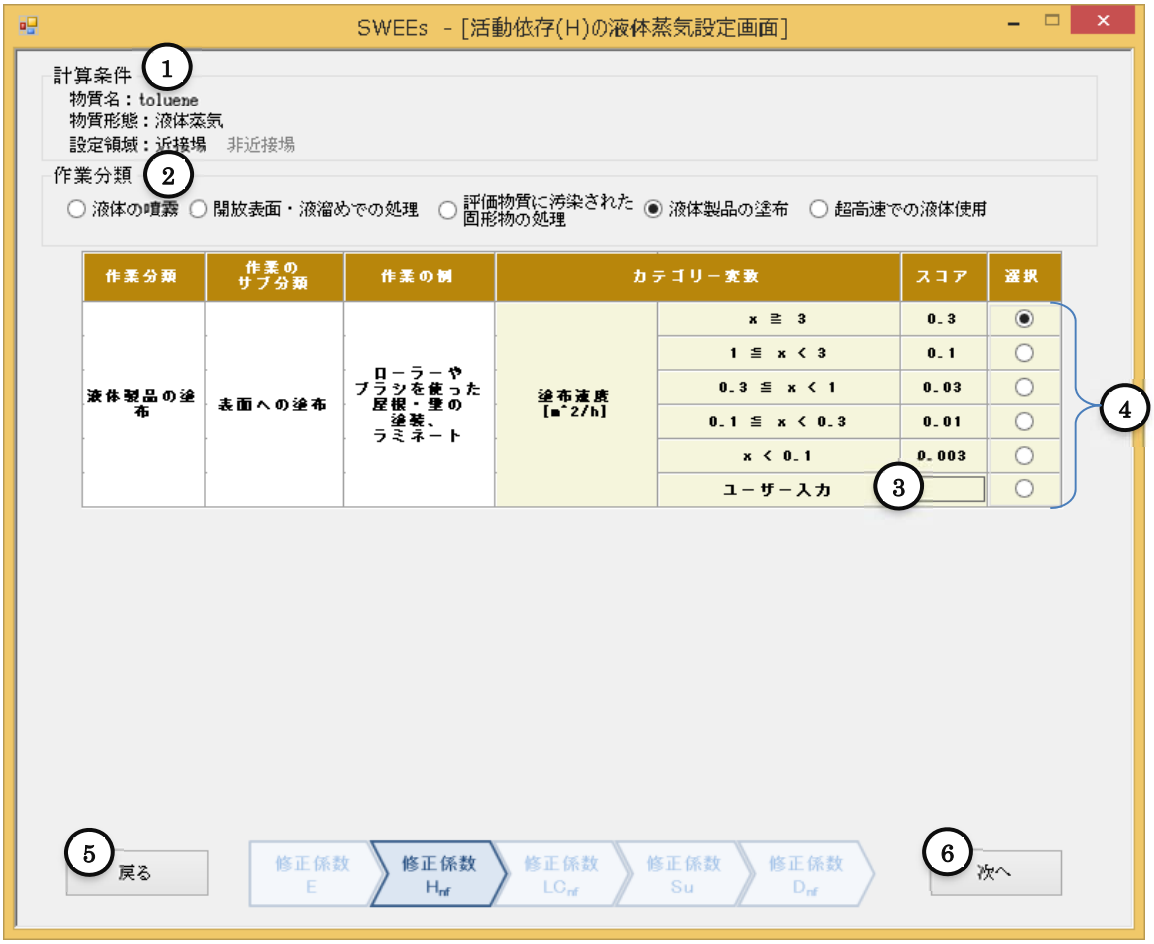


Figure 4-12 Screen for setting liquid steam for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Application of liquid product”, the “Screen for work subtype” is displayed as shown in Figure 4-12.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The range of input value is as follows. Application speed User input：0.001～0.3
④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the score corresponding to the selected item.

⑤	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑥	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.5.5. Ultrafast liquid use

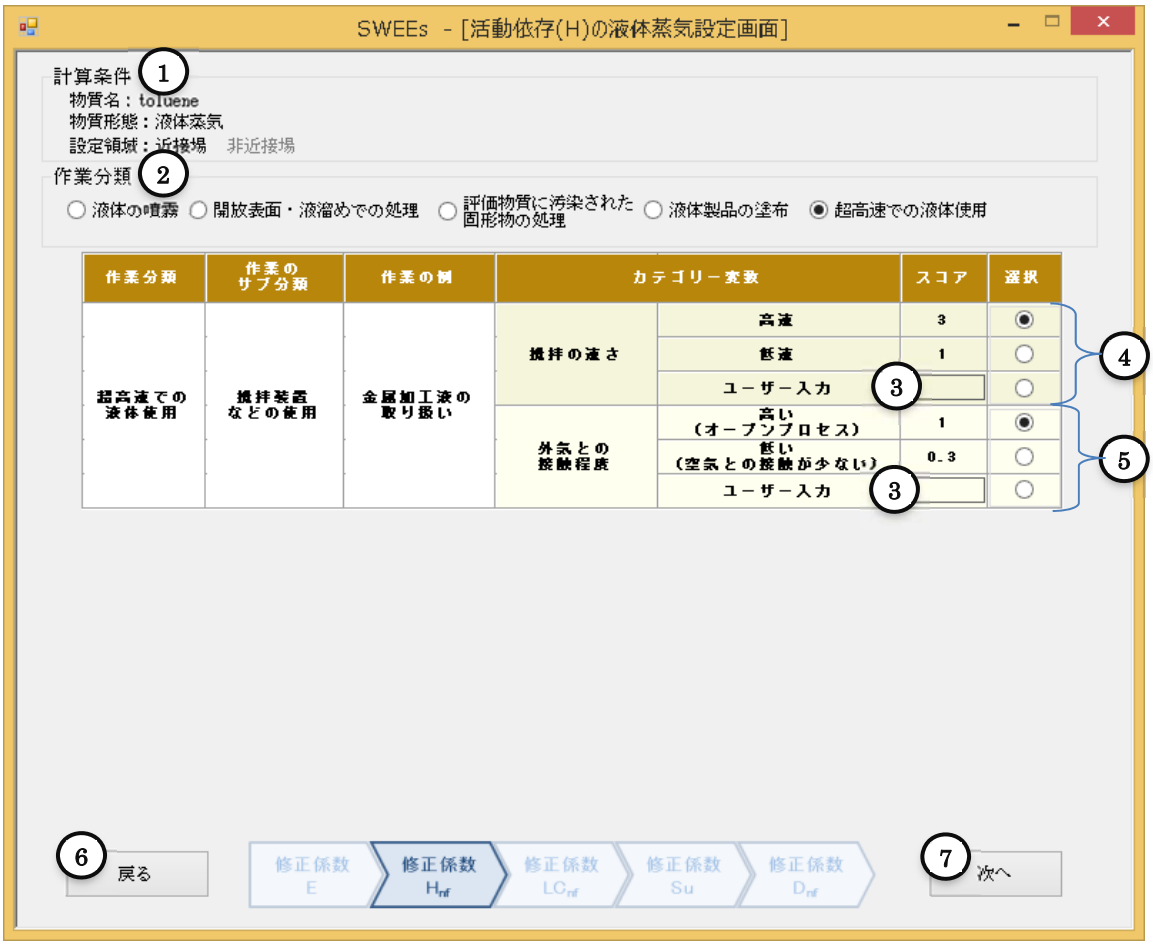


Figure 4-13 Screen for setting liquid steam for activity dependent (H)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Work type” radio button	Select the applicable work type from the available work types. When selecting “Ultrafast liquid use”, the “Screen for work subtype” is displayed as shown in Figure 4-13.
③	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. Stirring speed User input: 1～3 Degree of contact with air User input : 0.3～1
④	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③ and ④.
⑤	“Score setting” radio button	Select one that applies. The modifying factor for activity dependent (H) is the product of the scores corresponding to ③ and ④.

⑥	“Return” button	The modifying factor for activity dependent (H) is not set, and the system returns to the screen for setting substance dependent (E).
⑦	“Next” button	The modifying factor for activity dependent (H) is set, and the system moves on to the screen for setting localized control (LC).

4.6. Screen for setting localized control (LC)

Figure 4-14 Screen for setting localized control (LC)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	LC1 radio button	Select one that applies. The modifying factor for LC1 is the score corresponding to the selected item. Default is set without provision.
③	LC2 radio button	In case of two local exhaust ventilation devices, select one that applies. The modifying factor for LC2 is the score corresponding to the selected item. Default is set without provision.
④	“User input” text box	If the user wishes to enter a score value, the user enters it in this text box. The ranges of input values are as follows. User input 1: 0.0001～1 User input 2: 0.0001～1
⑤	“Return” button	The modifying factor for localized control (LC) is not set, and the system returns to the screen for setting activity dependent (H).
⑥	“Next” button	The modifying factor for localized control (LC) is set, and the system moves on to the screen for setting surface contamination (Su).

(Note on table) Refer to Table　5-1(p.44) for classification of localized control.

4.7. Screen for setting surface contamination (Su) (for near field)

Figure 4-15 Screen for setting surface contamination (Su)

ID	Item	Description
①	"Conditions for calculation"	It displays the conditions for calculation set in the screen for basic setting.
②	"User input" text box	If the user wishes to enter a score value, the user enters it in this text box. The range of input value is as follows. User input: 0～0.01
③	"Score setting" radio button	Select one that applies. The modifying factor for surface contamination (Su) is the score corresponding to the selected item. The default is set without surface contamination.
④	"Return" button	The modifying factor for surface contamination (Su) is not set, and the system returns to the screen for setting localized control (LC).
⑤	"Next" button	The modifying factor for surface contamination (Su) is set, and the system moves on to the screen for setting dispersion (D).

4.8. Screen for setting dispersion (D)

To the modifying factor (Dnf) related to dispersion in near field, the score corresponding to short-time exposure is assigned if the work duration of the task is 60 minutes or below, and long-time exposure if the work duration is longer than 60 minutes. For this reason, screen with different score is displayed depending on the work duration entered in the basic setting.

4.8.1. If the work duration is 60 minutes or below

Figure 4-16 Screen for setting dispersion (D) (If the work duration is 60 minutes or below)

ID	Item	Description
①	"Conditions for calculation"	It displays the conditions for calculation set in the screen for basic setting.
②	"Number of ventilations per hour [ACH]" radio button	Select the number of ventilations per hour. The column of the selected radio button is displayed in blue. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects (1.4 in the above figure) The default is 3 times.
③	"Volume of workplace [m^3]" radio button	Select the value that is closest to the volume of workplace. The row of the selected radio button is displayed in blue. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects. The default is 300m^3.
④	"Return" button	The modifying factor for dispersion (D) is not set, and the system moves on to the screen for setting surface contamination (Su).
⑤	"Set" button	The modifying factor for dispersion (D) is set, and the system moves to the screen for basic setting.

4.8.2. If the work duration is more than 60 minutes

Figure 4-17 Screen for setting the dispersion (D) (If the work duration is more than 60 minutes)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“Number of ventilations per hour [ACH]” radio button	Select the number of ventilations per hour. The column of the selected radio button is displayed in blue. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects (36 in the above figure) The default is 3 times.
③	“Volume of workplace [m^3]” radio button	Select the value that is closest to the volume of workplace. The row of the selected radio button is displayed in blue. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects. The default is 300m^3.
④	“Return” button	The modifying factor for dispersion (D) is not set, and the system returns on to the screen for setting the surface contamination (Su).
⑤	“Set” button	The modifying factor for dispersion (D) is set, and the system moves to the screen for basic setting.

4.9. Screen for setting segregation (Seg) (for far field)

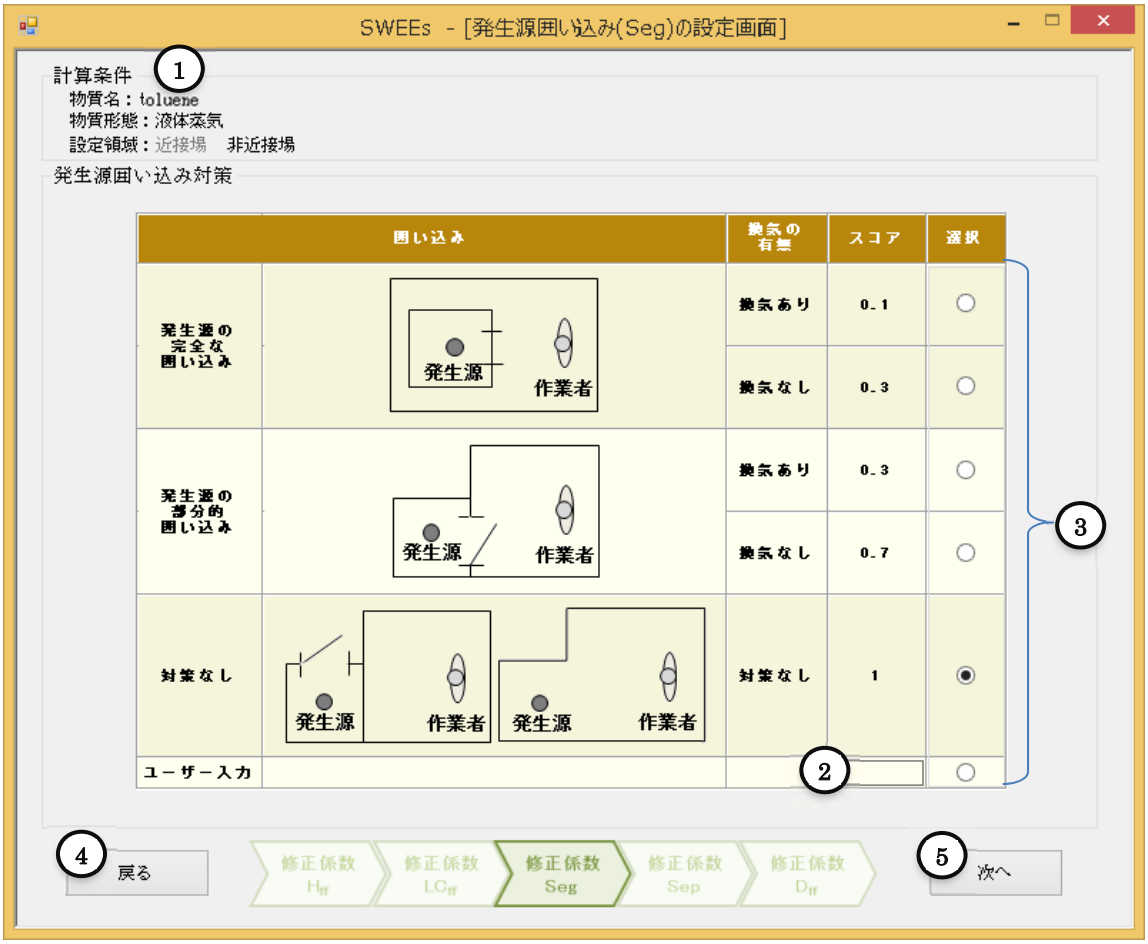


Figure 4-18 Screen for setting segregation (Seg)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“User input” text box	If the user wishes to enter the score value, the user enters in this text box. The range of input value is as follows. User input: 0.1～1
③	“Score setting” radio button	Select one that applies. The selected score is the modifying factor for segregation (Seg). Default is set to "No localized controls".
④	“Return” button	The modifying factor for segregation (Seg) is not set, and the system returns to the screen for setting the localized control (LC).
⑤	“Next” button	The modifying factor for segregation (Seg) is set, and the system moves on to the screen for setting the separation (Sep).

4.10. Screen for setting the separation (Sep) (for far field)

Figure 4-19 Screen for setting the separation (Sep)

ID	Item	Description
①	“Conditions for calculation”	It displays the conditions for calculation set in the screen for basic setting.
②	“User input” text box	If the user wishes to enter the score value, the user enters in this text box. The range of input value is as follows. Spray speed User input：0.1～1
③	“Score setting” radio button	Select one that applies. The selected score is the modifying factor for separation (Sep). Default is set to "No localized controls".
④	“Return” button	The modifying factor for separation (Sep) is not set, and the system returns to the screen for setting segregation (Seg).
⑤	“Next” button	The modifying factor for separation (Sep) is set, and the system moves on to the screen for setting the dispersion (D).

4.11. Screen for setting the dispersion (D) for far field

To the modifying factor (Dff) related to dispersion in far field, the score corresponding to short exposure is assigned if the work duration of the task is 60 minutes or below, and long exposure if the work duration is longer than 60 minutes. For this reason, screen with different score is displayed depending on the work duration entered in the basic setting.

4.11.1. If the work duration is 60 minutes or less

Figure 4-20 Screen for setting the dispersion (D) (If the work duration is 60 minutes or less)

ID	Item	Description
①	"Conditions for calculation"	It displays the conditions for calculation set in the screen for basic setting.
②	"Number of ventilations per hour [ACH]" radio button	Select the number of ventilations per hour. The column of the selected radio button is displayed in green. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects (7 in the above figure) The default is 3 times.
③	"Volume of workplace [m^3]" radio button	Select the value that is closest to the volume of workplace. The row of the selected radio button is displayed in green. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects. The default is 300m^3.
④	"Return" button	The modifying factor for dispersion (D) is not set, and the system returns on to the screen for setting the separation (Sep).
⑤	"Set" button	The modifying factor for dispersion (D) is set, and the system moves to the screen for basic setting.

4.11.2. If the work duration is more than 60 minutes

Figure 4-21 Screen for setting the dispersion (D) (If the work duration is more than 60 minutes)

ID	Item	Description
①	"Conditions for calculation"	It displays the conditions for calculation set in the screen for basic setting.
②	"Number of ventilations per hour [ACH]" radio button	Select the number of ventilations per hour. The column of the selected radio button is displayed in green. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects (35 in the above figure) The default is 3 times.
③	"Volume of workplace [m^3]" radio button	Select the value that is closest to the volume of workplace. The row of the selected radio button is displayed in green. The modifying factor for dispersion (D) is the value in the cell where the column in ② and the row in ③ intersects. The default is 300m^3.
④	"Return" button	The modifying factor for dispersion (D) is not set, and the system returns on to the screen for setting the separation (Sep).
⑤	"Set" button	The modifying factor for dispersion (D) is set, and the system moves to the screen for basic setting.

4.12. Screen for displaying estimate results

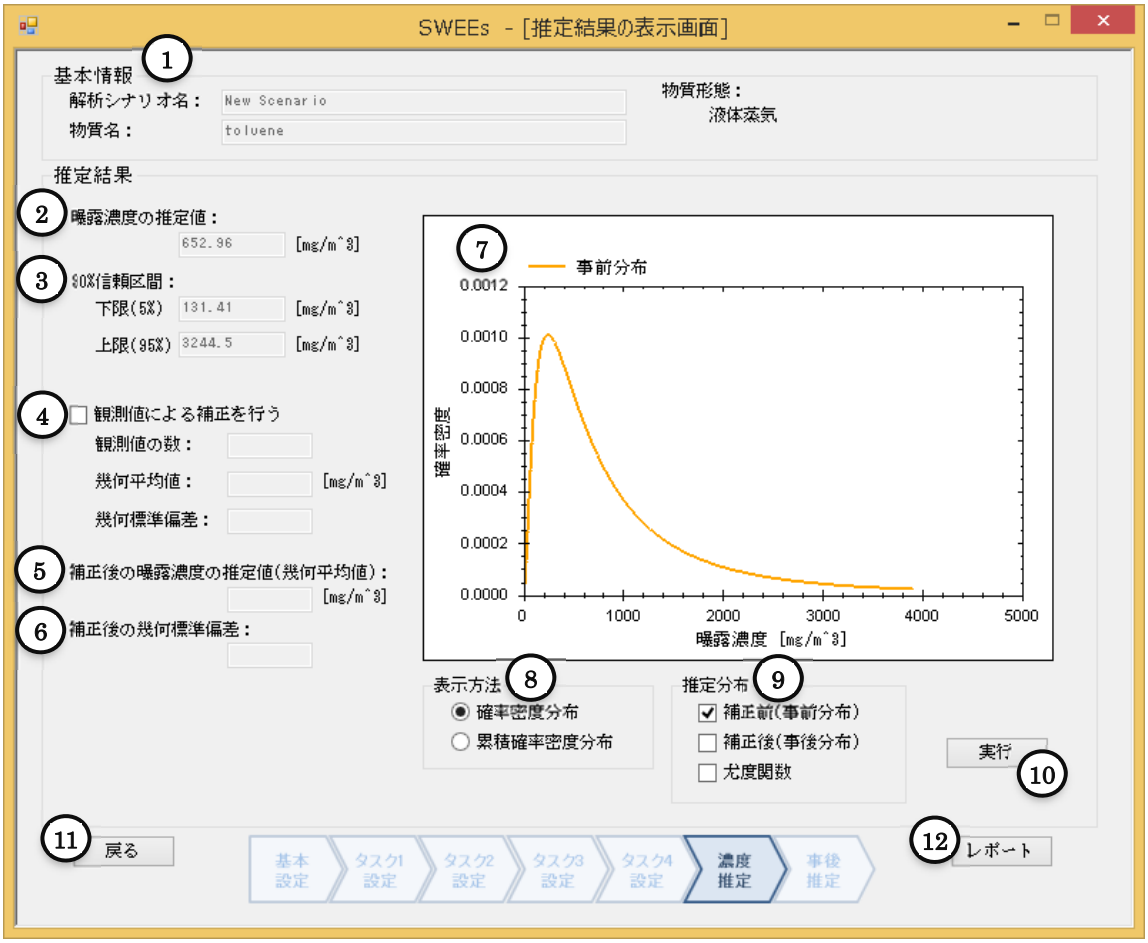


Figure 4-22 Screen for displaying estimate results

ID	Item	Description
①	Basic information	As basic information, it displays the name of analysis scenario, substance name, and substance form. It displays the above information as entered in the screen for basic setting.
②	“Exposure concentration estimate” text box	It displays the exposure concentration estimate calculated based on each modifying factor displayed in the screen for basic setting. This indicates the geometric mean of the prior distribution.
③	“90 % confidence interval” text box	It displays the lower (5 %) and upper (95 %) limits of the 90 % confidence interval of the exposure concentration estimate.
④	“Correct by measurements” check box	Checking this check box enables the input into the observed data. When entering the observed data and clicking ⑩ Execute button, the system calculated the corrected values for exposure concentration estimate and geometric standard deviation and display them in ⑤ and ⑥. Also, if ⑨ “After correction (posterior distribution)” in Estimated distribution section is checked, the graph of posterior distribution is displayed. As observed data, enter the number of observed values, geometric mean [mg/m^3], and geometric standard deviation. Refer to p.60 for geometric mean and geometric standard deviation of observed data.

ID	Item	Description
⑤	“Corrected exposure concentration estimate (geometric mean)” text box	It displays the geometric mean (geometric standard deviation) of the corrected exposure concentration.
⑥	“Corrected geometric standard deviation” text box	After checking ④ and entering observed data, click ⑩ Execute button, and the corresponding value is displayed.
⑦	Graph of exposure concentration distribution	It displays the probability distributions before and after the correction. For the display method, selection of probability density distribution or cumulative probability density distribution is available in ⑧. It is also possible to superimpose the distributions checked in ⑨. Controls such as expanding and shrinking of the graph are possible by mouse.
⑧	“Display method” radio button	Select probability density distribution or accumulated probability density distribution. The graph is displayed in the selected form.
⑨	“Estimated distribution” check box	It displays the graph of the checked distributions (prior distribution, posterior distribution, and/or likelihood function) When changing ⑧Display method or ⑨ Estimated distribution, clicking ⑩ Execute button will display the corresponding graph.
⑩	“Execute” button	It executes the graphing display. When clicking ④ and entering the observed data or changing ⑧Display method or ⑨ Estimated distribution, clicking ⑩ Execute button will update the content of the graph.
⑪	“Return” button	Returns to the screen for basic setting.
⑫	“Report” button	The system moves on to the report screen.

4.13. Report screen

This screen enlists the input and output values. Here, modifying factors for near field are in blue, those for far field are in green, and those for both fields are in white. Also, in each display item, when the number of letters are too many and cannot be displayed in the grid, reduced letters which still carry the meaning will be displayed.

Figure 4-23 Report screen

ID	Item	Description
①	Basic information	As basic information, it displays the name of analysis scenario, substance name, and substance form. It displays the above information as entered in the screen for basic setting.
②	Work conditions	As work conditions, total work duration and work durations of tasks 1- 4 are displayed. It displays the values as entered in the screen for basic setting.
③	Activity dependent (H)	It displays the items set in the screen for setting the activity dependent (H). In particular, work type, work subtype, category variables, and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed. ※In each display item, when the number of letters to be displayed are too many and cannot be displayed in the grid, reduced letters which still carry the meaning will be displayed.
④	Substance dependent (E)	It displays the items set in the screen for setting the substance dependent (E). In particular, the following are displayed: presence/absence of steam pressure correction, measured steam pressure [Pa], temperature during measurement [K], boiling point [K], temperature in workplace [K], steam pressure after correction [Pa], and scores. If there are inputs to multiple tasks, the content of each task is displayed.
⑤	Localized control (LC)	It displays the items set in the screen for setting the localized control (LC). In particular, category variables and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed. If there are inputs to multiple tasks, the content of each task is displayed.
⑥	Surface contamination (Su)	It displays the items set in the screen for setting the surface contamination (Su). In particular, categories and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed. This item is a modifying factor common for near and far fields.
⑦	Dispersion (D)	It displays the items set in the screen for setting the dispersion (D). In particular, number of ventilations [1/h], volume of room [m^3], and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed.
⑧	Segregation (Seg)	It displays the items set in the screen for setting segregation (Seg). In particular, category variables and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed.
⑨	Separation (Sep)	It displays the items set in the screen for setting the separation (Sep). In particular, category variables and scores are displayed. If there are inputs to multiple tasks, the content of each task is displayed. This is item is only for setting modifying factors for far field.
⑩	“csv output” button	It outputs the items on the report screen (excluding graph information) in csv format. This csv file can be loaded by clicking the “Read file” button on the top screen.
⑪	“Print” button	It prints the content of the report screen. When printing, two pages will be printed: one for the input items and the other for the estimate results. ※ When printing, the format needs to be set to A4 landscape.
⑫	Exposure concentration estimate	It displays the following values calculated in the display screen for estimate results: information for prior distribution (exposure concentration estimate [mg/m^3], 90 % confidence interval, geometric standard deviation, ART score[*1], and $\ln\alpha$[*2]).
⑬	Correction by observed values	If there is input to any of the observed data item (number of observed values, geometric mean, geometric standard deviation) in the display screen for estimate results, these values will be displayed. If there is no input, the values for the number of observed values, geometric mean, and geometric standard deviation will be 0. In this screen, double-clicking either of the number of observed values, geometric mean, and geometric standard deviation will display a dialog for setting the observed data, enabling the input of each value. After enter the values, click the “Set” button, and the values will be reflected on the report screen, and the system will calculate and display the corrected exposure concentration estimate and corrected geometric standard deviation and display the posterior distribution graph.

ID	Item	Description
⑭	Corrected exposure concentration estimate (geometric mean)	In the case of entering values for correction by observed values, the system makes a posterior estimation and displays the corrected values for exposure concentration estimate and geometric standard deviation.
⑮	Corrected geometric standard deviation	In the case of entering values for correction by observed values, the system makes a posterior estimation and displays the corrected values for exposure concentration estimate and geometric standard deviation.
⑯	Graph	It displays the graph according to ⑰ estimated distribution and ⑱ display method. Refer to "※Displayed content of graph" for the content of graph based on selection pattern.
⑰	"Estimated distribution" check box	Select the content to be displayed in the graph. If checking prior distribution, the prior distribution will be displayed. The same applies to posterior distribution and likelihood function. However, selection of prior distribution as well as cumulative probability density distribution in the display method will lead to display of 2-dimensional probabilistic exposure concentration distribution.
⑱	"Display method" radio button	Select the graph display method from probability density distribution and cumulative probability density distribution.

(Note on table) *1: ART score: Value correlated to individual exposure concentration This can be obtained by interpreting the exposure-related information in the score basis.

*2: Lnα: Intersection of ART score and the mixed effect model which expresses the regression equation for individual exposure concentration.

※ Displayed content of graph

(A) Display method: Probability density distribution

a-1) Estimated distribution: Prior distribution

Displays the probability density distribution of prior distribution.

a-2) Estimated distribution: Prior distribution and posterior distribution

Displays the probability density distributions of prior and posterior distributions.

a-3) Estimated distribution: Prior distribution, posterior distribution, and likelihood function

Displays the probability density distributions of prior and posterior distributions and likelihood function.

a-4) Estimated distribution: No selection

Graphs does not show anything.

(b) Display method: Cumulative probability density distribution

b-1) Estimated distribution: Prior distribution

It displays the 2-dimensional probabilistic exposure concentration distribution and its 90 % confidence interval graph for the prior distribution.

b-2) Estimated distribution: Prior distribution and posterior distribution

Displays the cumulative probability density distributions of prior and posterior distributions.

b-3) Estimated distribution: Prior distribution, posterior distribution, and likelihood function

Displays the cumulative probability density distributions of prior and posterior distributions and likelihood function.

b-4)Estimated distribution: If nothing is selected, the graph does not show anything.

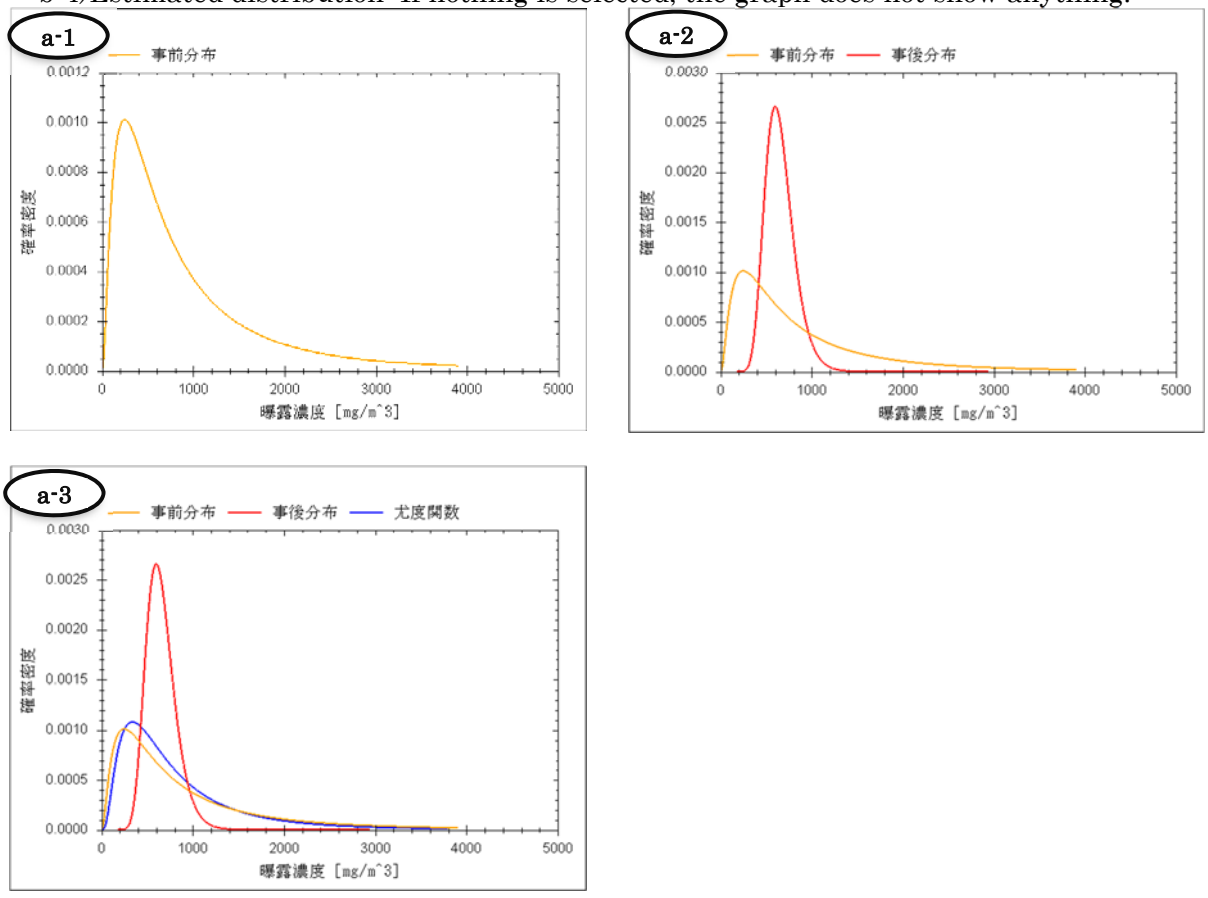


Figure 4-24 Example of graph for Display method: Probability density distribution

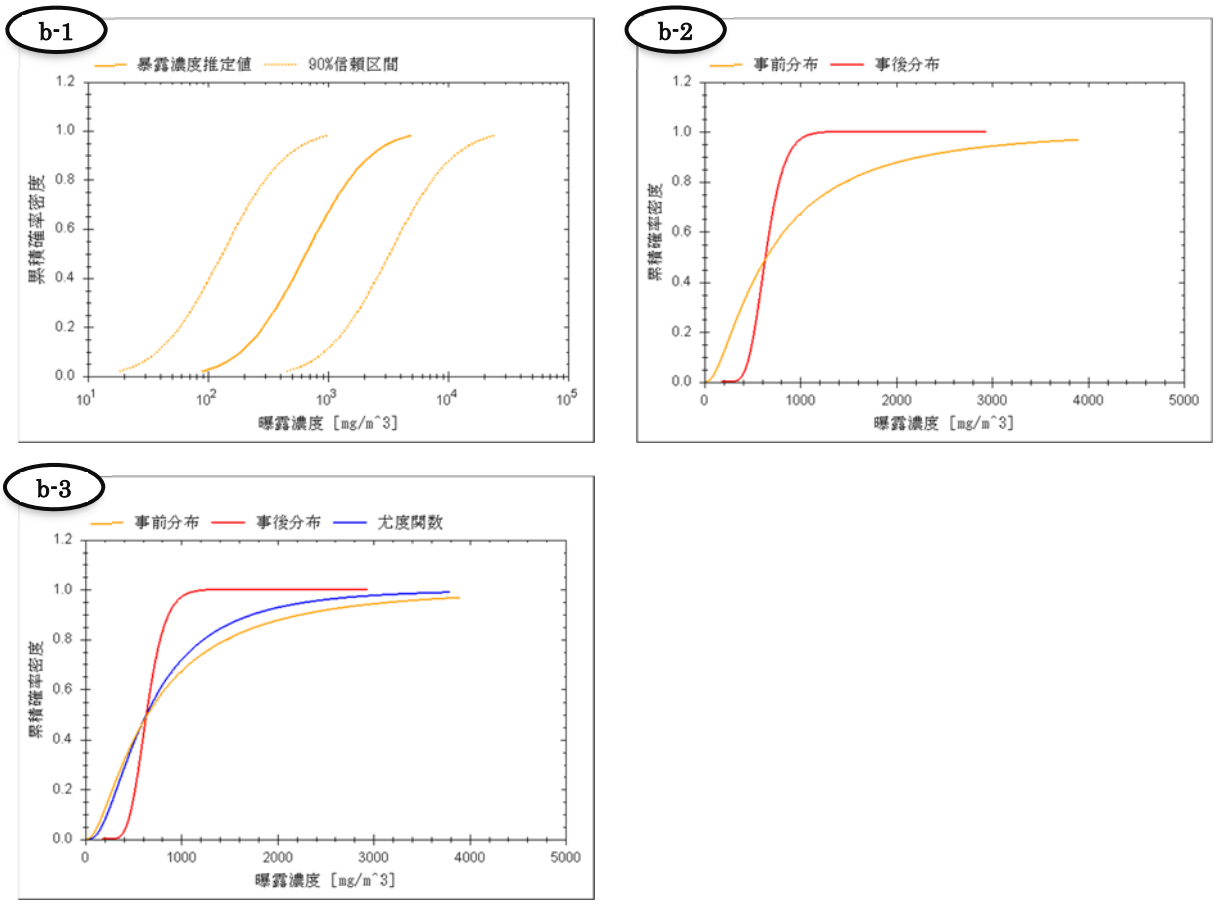


Figure 4-25 Example of graph for Display method: Cumulative probability density distribution

4.14. Screen for setting observed data

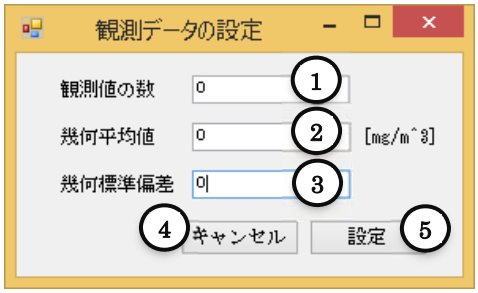


Figure 4-26 Screen for setting observed data

ID	Item	Description
①	“Number of observed values” text box	Enter the number of observed values.
②	“Geometric mean” text box	Enter the geometric mean of the observed data.
③	“Geometric standard deviation” text box	Enter the geometric standard deviation of the observed data.
④	“Cancel” button	The set values are canceled.
⑤	“Set” button	The modified values for the number of observed values, geometric mean, and geometric standard deviation will be set.

4.15. csv file output

The items to be outputted to csv file are as follows. Also, if there is no value in an item (e.g. Entering values only for task 1 and not for tasks 2 - 4), the output will be "-" (hyphen) for that item. In the output items, if there is no value for observed data and posterior distribution estimate, the output in the csv file will be 0.

Output item:
・Name of analysis scenario
・Substance name
・Substance form
・Total work duration
・Work duration
・Substance dependent (E) information
・Activity dependent (H) information
・Localized control 1 (LC1) information
・Localized control 2 (LC2) information
・Segregation (Seg) information
・Separation (Sep) information
・Surface contamination (Su) information
・Dispersion (D) information
・Prior distribution estimate (estimate concentration, 90 % confidence interval lower limit, 90 % confidence interval upper limit, geometric mean, ART score, and lnα)
・Observed data (geometric mean, geometric standard deviation, number of observed values)
・Posterior distribution (exposure concentration estimate, geometric standard deviation)

The csv file images are shown below. Also, in the below figures the comments on the right after "#" are only for explanation purpose and will not be outputted in the actual csv files.

#Basic setting # Basic Setting
Analysis scenario, Substance name, Substance form # Recorded items
Scenario1, toluene, liquid steam

#Work conditions # work conditions (work duration)
Total work duration, Task 1 duration, Task 2 duration, task 3 duration, Task 4 duration #Recorded items
480, 17, 5, -, -

#Substance dependent (E) # Modifying factor for substance dependent
Task No, Steam pressure correction, Measured steam pressure [Pa], Temperature during measurement [K], Boiling point [K], Temperature in workplace [K], Steam pressure after correction [Pa], Mixed solvent, Molar fraction, Activity coefficient, Score
1, Absent, 2930, -, -, -, -, Absent, -, -, 0.097667
2, Present, 2930, 293, 384, 308, 6069, Absent, -, -, 0.2023
3, -, -, -, -, -, -, -, -, -, -
4, -, -, -, -, -, -, -, -, -, -

#Activity dependent (H) # Modifying factor for activity dependent
Task No, Work type (nf), Work subtype, Category variable 1, Category variable 2, Work type (ff), Work subtype, Category variable 1, Category variable 2, Score # Recorded items
1, Spraying liquid, Surface spraying, Spray speed [L/min], x ≧ 3, 3, Handling of contaminated solid substance, -, Contamination area[㎡], x ≧ 3, 0.3 # Values related to task 1
, , Surface spraying, Spray direction, Horizontal or vertical, 1, , -, Contamination rate[%], x ≧ 90, 1
, , Surface spraying, Spray technique, High, 3, , -, -, -, -
2, Handling of contaminated solid substance, -, Contamination area[㎡], x ≧ 3, 0.3, -, -, -, -, - # Values related to task 2
, , -, Contamination rate[%], x ≧ 90, 1, , -, -, -, -
, , -, -, -, -, , -, -, -, -
3, -, -, -, -, -, -, -, -, -, - # Values related to task 3
, , -, -, -, -, , -, -, -, -
, , -, -, -, -, , -, -, -, -
4, -, -, -, -, -, -, -, -, -, - # Values related to task 4
, , -, -, -, -, , -, -, -, -
, , -, -, -, -, , -, -, -, -

#Localized control (LC) # Modifying factor for localized control
Task No., LC, Category variable (nf), Score, Category variable (ff), Score # Recorded items
1, LC1, Other booth-type hood, 0.1, Other booth-type hood, 0.1 # Values related to task 1
, LC2, No localized controls, 1, No localized controls, 1
2, LC1, Other booth-type hood, 0.1, -, - # Values related to task 2
, LC2, No localized controls, 1, -, -
3, LC1, -, -, -, - # Values related to task 3
, LC2, -, -, -, -
4, LC1, -, -, -, - # Values related to task 4
, LC2, -, -, -, -

#Segregation (SEG) # Modifying factor for segregation
Task No., Category variable 1, Category variable 2, Score # Recorded items
1, No localized controls, No localized controls, 1 # Values related to task 1
2, -, -, - # Values related to task 2
3, -, -, - # Values related to task 3
4, -, -, - # Values related to task 4

#Separation (SEP) # Modifying factor for separation
Task No., Category variable 1, Category variable 2, Score
1, No localized controls, No localized controls, 1 # Values related to task 1
2, -, -, - # Values related to task 2
3, -, -, - # Values related to task 3
4, -, -, - # Values related to task 4

#Surface contamination (SU) # Modifying factor for surface contamination
Task No., Category, Score
1, Monitoring once or more per month, Prevention of contaminant leak by sampling and periodic cleaning, 0 # Values related to task 1
2, Default (No cleaning habit, No protective clothing, No entire closure), 0.01 # Values related to task 2
3, -, - # Values related to task 3
4, -, - # Values related to task 4

#Prior distribution estimate # Result of prior distribution estimate
Estimate concentration[mg/m^3], 90% confidence interval lower limit (5%), 90% confidence interval upper limit (95%), geometric standard deviation, ART score, $\ln \alpha$
171.99, 34.613, 854.61, 2.65, 0.0044602, 10.56

#Observed data # Observed data
Geometric mean[mg/m^3], Geometric standard deviation, Number of observed values
255, 2, 10

#Posterior distribution estimate # Result of posterior distribution estimate
Exposure concentration estimate [mg/m^3], Geometric standard deviation
250, 21, 1.2384

5. Operating Guide for SWEEs

This chapter describes the operating methods of SWEEs.

This part shows the method for estimating the exposure concentration for a worker (defined as worker A) who handles toluene in the work conditions and management method described in the next page.

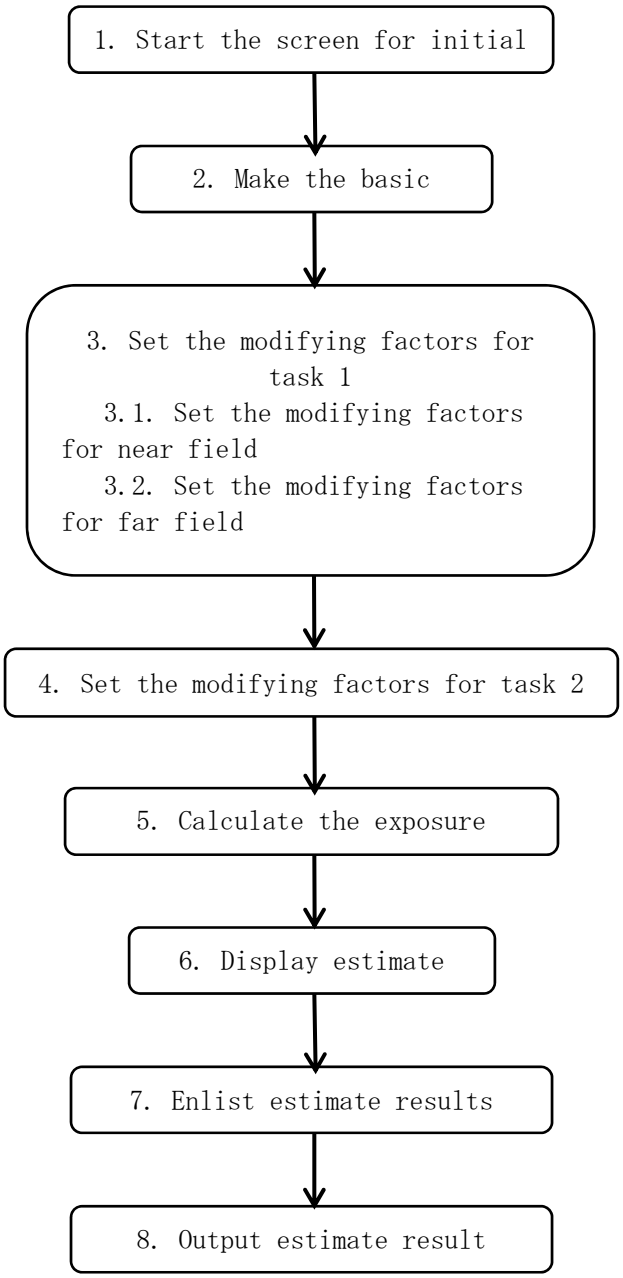
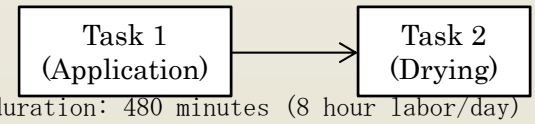


Figure 5-1 Flow of the entire system

Work example

Work content of worker A who handles toluene



Daily labor duration: 480 minutes (8 hour labor/day)

Volume of workplace: 500 m^3

Number of total ventilations: 3 times/hour

<Work conditions of task 1>

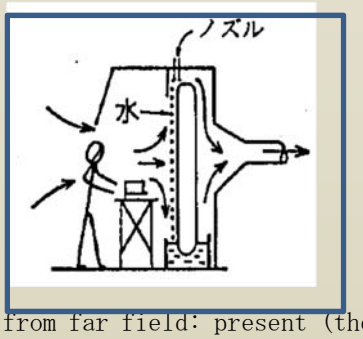
Work duration: 17 minutes

Work temperature: 20 ℃ (steam pressure of toluene at 20℃: 2,930 [Pa])

Substance form: liquid (steam)

Work activity: Application by spray, spray speed (3.0 [L/min] or higher), horizontal spray, use of new spraying device.

Presence/absence of localized control and device type: installation of booth-type local exhaust ventilation



Presence/absence of exposure from far field: present (the material in machine drying in task 2 is close by. It is enclosed by a separate booth-type local exhaust ventilation)

Presence/absence of surface contamination: absent

<Work conditions of task 2>

Work duration: 5 minutes

Work temperature: 35 ℃

Work activity: Drying work (surface area 3m^2 or more, machine/hand dry of applied material with contamination rate 90% or higher)

Presence/absence of localized control and device type: installation of booth-type local exhaust ventilation

Presence/absence of exposure from far field: absent

Presence/absence of surface contamination: present (no cleaning habit)

5.1. Start the top screen

Start the “top screen” following “2. Method for program installation”.

Push the “Start” button to move to the screen for basic setting.

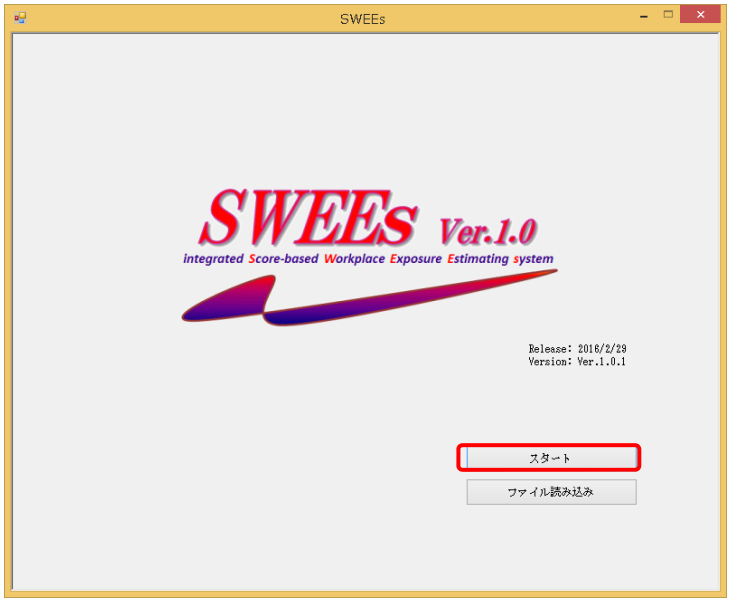


Figure 5-2 Top screen

5.2. Make the basic setting

In the screen for basic setting, enter the name of analysis scenario, substance name, substance form, and work duration.

In the basic information section, enter “Scenario1” in name of analysis scenario and “toluene” in substance name.

The items can also be entered in Japanese; for example, “シナリオ１” and “トルエン”.

Select “Liquid steam” for substance form in the “Liquid mist/Liquid steam section”.

Push the “Set” button in the top-right corner of the screen.

※Dot not enter comma (“,”) in for the name of analysis scenario and substance name. If commas are entered, they will be replaced by under bars (“_”) before proceeding.

Figure 5-3 Screen for basic setting: Setting basic information

Here, liquid steam refers to vaporized liquid and liquid mist to floating fine particles of liquefied steam.

Total work duration in “Setting of work conditions” section, work duration of “Task 1”, and “Set” button become available. Enter the daily total labor duration “480” minutes in the total work duration and “17” minutes in the work duration of task 1.

Figure 5-4 Screen for basic setting: Setting work conditions of task 1

As shown above, the setting of name of analysis scenario, substance name, substance form, and exposure time for task 1 is completed. In case of multiple tasks, complete the setting of modifying factors for task 1 before proceeding to the setting of work conditions of the next task.

5.3. Set the modifying factors for task 1

5.3.1. Set the modifying factors for near field

Next, set the modifying factors for task 1.

Push the “Set” button for near field of task 1.

Figure 5-5 Screen for basic setting: Setting modifying factors of task 1

Here, near field in SWEEs refers to the spatial region within 1 m from the worker's mouth in the vertical, horizontal and depth directions (8 m^3) and far field (ff) to the space other than the near field.

5.3.1.1. Substance emission potential (E)

Moves on to the screen for setting the substance dependent (E). For task 1 the work temperature is same as the temperature during steam pressure measurement, so there is no need for temperature correction for steam pressure. Thus, select “Without temperature correction” radio button.

Enter substance’s steam pressure [Pa].

Here, enter the steam pressure of toluene at 20℃, “2930” [Pa], and push the “Calculate” button. The substance dependent (E) is entered.

Figure 5-6 Modifying factors: Substance emission potential (E) (Setting steam pressure)

Push “Next” at the bottom of the screen.

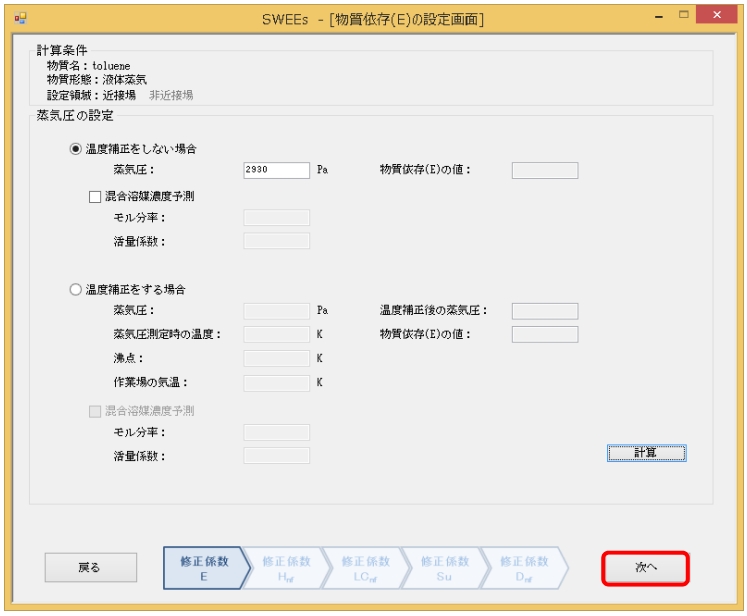


Figure 5-7 Modifying factors: Substance emission potential (E) (Setting completed)

5.3.1.2. Activity emission potential (H_{nf})

Moves onto the screen for setting Activity emission potential (H_{nf}) (screen for setting the activity dependent (H) of liquid steam).

First, select the category applicable for the work content of task 1 from the following categories: ①"Spraying liquid", ②"Handling with open surface or reservoir", ③"Handling of solid substance contaminated by evaluated substance", ④"Application of liquid product", and ⑤"Ultrafast liquid use". In this example, the work activity of task 1 is "application by spraying", so select "Spraying liquid", and the screen for work subtype corresponding to "Spraying liquid" is displayed.

Figure 5-8 Modifying factors: Activity emission potential (H_{nf}) (selection of work activity)

Next, set the work subtype applicable for the work content of task 1 and category variable.

In this example, according to the work content, select "Surface spraying" for work subtype, "≧3L/min" for spray speed, "Horizontal or Vertical" for spray direction, and "High" for spray technique.

Figure 5-9 Modifying factors: Setting activity emission potential (H_{nf})

As shown above, the activity emission potential (H_{nf}) of near field for task 1 is set.

Push “Next” at the bottom of the screen.

5.3.1.3. Localized control (LC_{nf})

Moves on to the screen for setting the localized control (LC_{nf}).

Select presence/absence of localized control for task 1, and according to the type of local exhaust ventilation, set the localized control (LC_{nf}) in near field.

In this case, there is one booth-type local exhaust ventilation of type other than draft chamber, horizontal/downward laminar flow booth, glove bag, or glove box, so set “Booth-type hood” → “Other booth-type hood (0.1)” for LC1, and “No localized controls (1)” for lC2.

Figure 5-10 Modifying factors: Setting localized control (LC_{nf})

Also, up to two localized controls can be set. In case of setting two types, select the type of local exhaust ventilation applicable for LC2. Refer to Table 5-1 (p.51) for classification of localized control.

As shown above, the localized control (LC_{nf}) for task 1 is set. Push “Next” at the bottom of the screen.

Table 5-1 Categories of localized control

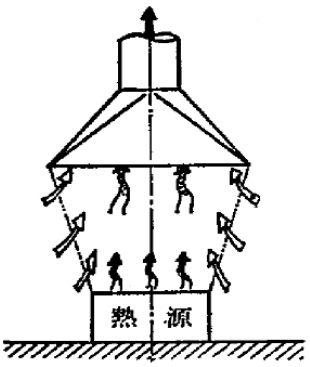
Type of provision		Description	Item
Control technology		Technology for controlling the generation of organic solvent in the room air (other than local exhaust ventilation)	**Wetting method:** Moisturize or apply water before or during the work to control the solvent.
			Knockdown method: Moisturize or apply water after the work to control the solvent.
Enclosure		Seal the emission of organic solvent near the source and enclose. (Figure 5-11)	Install a cover on machines, open parts of container to enclose the organic solvent. There are three levels: low-, medium-, and high-levels.
Local exhaust ventilation	**Receiving hood**	It sucks organic solvent from the source with constant air flow (Figure 5-12)	**Canopy hood:** A self-standing hood suspended above the source like a canopy. This is used when there is vapor flow by thermal buoyancy and contaminant flow in a particular direction.
			Other receiving hood: It creates a constant air flow and sucks the diffusing organic solvent. It takes a form of grinder, circle, or rectangular.
	Capturing hood	It creates air flow and sucks organic solvent (Figure 5-13)	**Fixed capturing hood:** A fixed capturing hood, and suction region and ventilation rate depend on the work.
			Movable capturing hood: A movable capturing hood with which the worker can effectively collect organic solvent.
			On-tool extraction capturing hood: A hood in which the work device and the hood are integrated.
	Booth-type hood:	The source is almost completely enclosed in the hood, and organic solvent is effectively sucked (Figure 5-14)	**Draft chamber:** This has a sliding door on the booth-type opening surface, and the work can insert tools or hands to work.
			Horizontal/downward laminar flow booth: This makes air flow in either horizontal or downward direction and sucks from the booth wall or ventilation plate between the ceiling and floor.
			Glove bag (No ventilation, ventilation or negative pressure): A large plastic bag which covers the work device.
			Glove box (low-, medium-, and high-spec): Closed container designed to allow only hands inside in order for work with blocked outside air. The sides of the box are directly connected to gloves.
			Other booth-type hood: It surrounds the source, as it is normally opened for work. The worker stand on the opened surface, inhales clean air from behind, and work facing inside.
	Other systems	Local exhaust ventilation of type other than the above	**Other local exhaust ventilation:** Hood system of type other than the above.
Steam collection system			Collection system which stores gasoline and volatile liquid substance as liquids and gas as gaseous substance and does not allow them out to the environment. The stored substances are reused.

(a)Low level

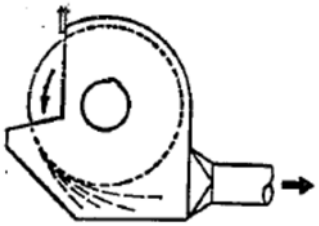
(b) Medium level

(c)High level

Figure 5-11 Enclosure system

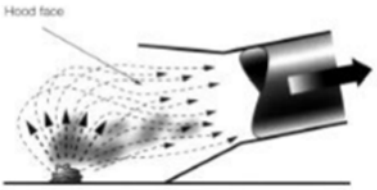


(A) Canopy hood



(b) Other receiving hood (grinder-type)

Figure 5-12 Receiving hood

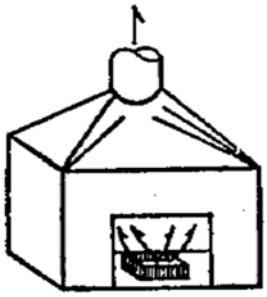


(a)Fixed capturing hood hood

(b)Movable capturing hood

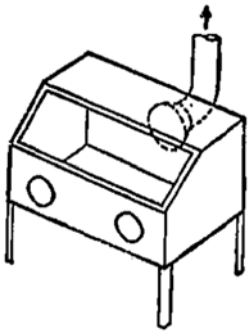
(c)On-tool extraction capturing

Figure 5-13 Capturing hood



(a)Draft chamber

(b)Horizontal/downward laminar flow booth



(c)Glove box

Figure 5-14 Booth-type hood

5.3.1.4. Surface contamination (Su)

Moves on to the screen for setting the surface contamination (Su).

Since there is no surface contamination in this example, select “No surface contamination”.

Figure 5-15 Modifying factors: Setting surface contamination (Su)

As shown above, the modifying factors for surface contamination (Su) are set. Push “Next” at the bottom of the screen.

5.3.1.5. Dispersion (D_{nf})

Moves on to the screen for setting the dispersion (D). To the modifying factor (D_{nf}), the score corresponding to short exposure is assigned if the work duration of the task is 60 minutes or below, and long exposure if the work duration is longer than 60 minutes. For this reason, screen with different score is displayed depending on the work duration entered in the basic setting.

In this example, the work duration is 17 minutes, so the scores for short-term exposure are displayed. According to the conditions of workplace, enter “3 times” [ACH] for number of ventilations per hour and “300” [m^3] for volume of room.

Figure 5-16Modifying factors: Setting dispersion (D_{nf})

Push “Set” at the bottom of the screen. As shown above, the inputting of modifying factors of near field for task 1 is completed. Push “Next” at the bottom of the screen.

Moves to the screen for basic setting.

Check that the modifying factors of near field for task 1 are displayed and that the “Set” button is selectable.

Figure 5-17 Checking the modifying factors on the screen for basic setting (task 1, near field)

5.3.2. Set the modifying factors for far field

Set the modifying factors of far field for task 1.

Push “Set” in the column of far field for task 1.

Figure 5-18 Screen for basic setting: Setting of far field for task 1

5.3.2.1. Activity emission potential (H_{ff})

Moves onto the screen for setting liquid steam activity dependent (H). According to the work content of this example, select the same item applicable for the work content of near field for task 2. Since the work activity of near field for task 2 involves drying paints, select “Handling of solid substance contaminated by evaluated substance” from the work activity categories. Also, select “≧3m^2” for contamination area and “≧90%” for contamination rate.

Figure 5-19 Modifying factors: Setting activity emission potential (H_{ff})

Push “Next” at the bottom of the screen.

5.3.2.2. Localized control (LC_{ff})

It displays the screen for setting the localized control (LC). In this example, it is the same local exhaust ventilation as of near field for task 1, so select “Other booth-type hood” for LC1 and “No localized controls” for LC2. Also, up to two localized controls can be set. In case of setting two types, select the type of local exhaust ventilation applicable for LC2. Refer to Table 5-1 (p.13) for classification of localized control.

Figure 5-20 Modifying factors: Setting localized control (LC_{ff})

Push “Next” at the bottom of the screen.

5.3.2.3. Segregation (Seg)

It displays the screen for setting segregation (Seg). In this example, the source in task 2 enclosed in a booth-type local exhaust ventilation different from that for task 1, and there is entire ventilation. So, select “Partial enclosure of the source” and “ventilation” (0.3).

Figure 5-21 Modifying factors: Setting segregation (Seg)

Push “Next” at the bottom of the screen.

5.3.2.4. Separation (Sep)

Moves to the screen for setting the separation (Sep). In this example, since there is not enclosure that separates the worker from the source, select “No localized controls” (1).

Figure 5-22 Modifying factors: Setting the separation (Sep)

Next, push “Next” at the bottom of the screen.

5.3.2.5. Dispersion (D_{ff})

Moves on to the screen for setting the dispersion (D).

The modifying factors for dispersion differ for near and far fields. According to the work duration entered in the basic setting, the list of the scores is displayed.

In this example, the work duration is 17 minutes, so the modifying factors for short-term exposure are displayed. According to the work conditions, enter “3 times” [ACH] for number of ventilations per hour and “300” [m^3] for volume of room.

Figure 5-23 Modifying factors: Setting the dispersion (D_{ff})

Push “Set” at the bottom of the screen.

As shown above, dispersion (D_{ff}) is set, and the inputting of all the modifying factors for task 1 is completed.

Moves to the screen for basic setting. Check that the modifying factors for task 1 are displayed and that the “Set” buttons in the columns of work duration and near field for task 2 are selectable.

5.4. Set the modifying factors for task 2

Enter the modifying factors for task 2.

Enter “5” minutes for work duration of task 2.

Figure 5-24 Screen for basic setting: Setting work duration of task 2

Since, there is not exposure from far field in task 2, set the modifying factors of only near field.

Push the “Set” button for near field of task 2.

Figure 5-25 Screen for basic setting: Setting modifying factors of task 2

5.4.1. Substance emission potential (E)

Since the work temperature of task 2 is 35 ℃, temperature correction of steam pressure is necessary. Select the “With temperature correction” radio button. Enter the following items before pushing “Calculate” button: steam pressure of toluene at 20℃ (steam pressure before correction) “2930” [Pa], temperature during steam pressure measurement “293” [K] (20℃), boiling point of toluene “384” [K] (110.6℃), and work temperature “308” [K] (35℃) .The steam pressure after temperature correction and substance dependent (E) is entered.

Figure 5-26 Modifying factors: Temperature correction of substance emission potential (E)

Push “Next” at the bottom of the screen.

5.4.2. Activity emission potential (H_{nf})

Moves onto the screen for setting liquid steam activity dependent (H).

Since the work activity for task 2 involves drying paints, select “Handling of solid substance contaminated by evaluated substance” from the work activity categories. Also, select “≧3m²” for contamination area and “≧90%” for contamination rate.

Figure 5-27 Modifying factors: Setting activity emission potential (H_{nf})

Push “Next” at the bottom of the screen.

5.4.3. Localized control (LC_{nf})

Moves on to the screen for setting localized control (LC).

Since a local exhaust ventilation of same type as in task 1 is used, set “Booth-type hood” →”Other booth-type hood (0.1)” for LC1 and “No localized controls (1)” for LC2.

Refer to Table 5-1 (p.13) for classification of localized control.

Push “Next” at the bottom of the screen.

5.4.4. Surface contamination (Su)

Moves on to the screen for setting surface contamination.

Since the workplace in this example does not have a cleaning habit, select “No cleaning habit, No protective clothing, No entire closure.”

Figure 5-28 Modifying factors: Setting surface contamination (Su)

Push “Next” at the bottom of the screen.

5.4.5. Dispersion (D)

Moves on to the screen for setting the dispersion (D). Similar to task 1, enter “3 times” [ACH] for number of ventilations per hour and “300” [m³] for volume of room.

Figure **5-29** Modifying factors: Setting dispersion (D_{nf})

As shown above, the inputting of all the modifying factors for task 2 is completed. Push “Set” at the bottom of the screen.

Moves to the screen for basic setting.

5.5. Calculate the exposure concentration

This displays the exposure concentration estimate and probability density distributions of exposure concentration. Check that the total work duration, work durations of task 1 and task 2, and the modifying factors are entered in the screen for basic setting, and push the “Calculate” button at the bottom of the screen.

Figure 5-30 Calculation of exposure concentration

5.6. Display estimate results

Moves to the screen for displaying estimate results. The estimate results are displayed in “Exposure concentration estimate” and “90 % confidence interval”. This values refer to, respectively, the geometric mean of exposure concentration for works with same work scenario (same work condition and management methods), and the 90 % confidence interval which indicates the accuracy of the estimate made by SWEEs. This indicates that the exposure concentration at the workplace is in the range of 34-855[mg/m^3] with the probability of 90 %.

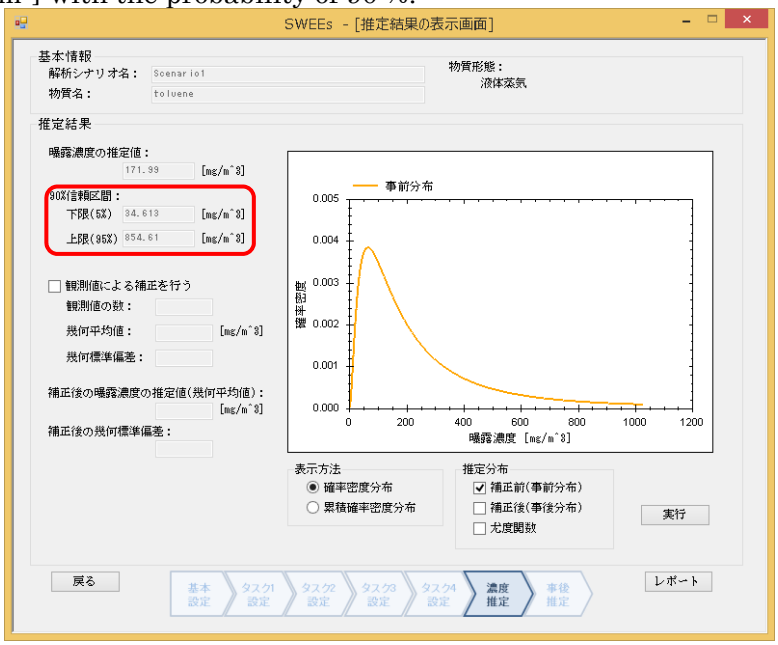


Figure 5-31 Calculation of exposure concentration

5.6.1. Display prior distribution graph

On the right side of the screen, the probability density distribution graph for exposure concentration estimate is shown in orange curve. This distribution is called the “prior distribution”.

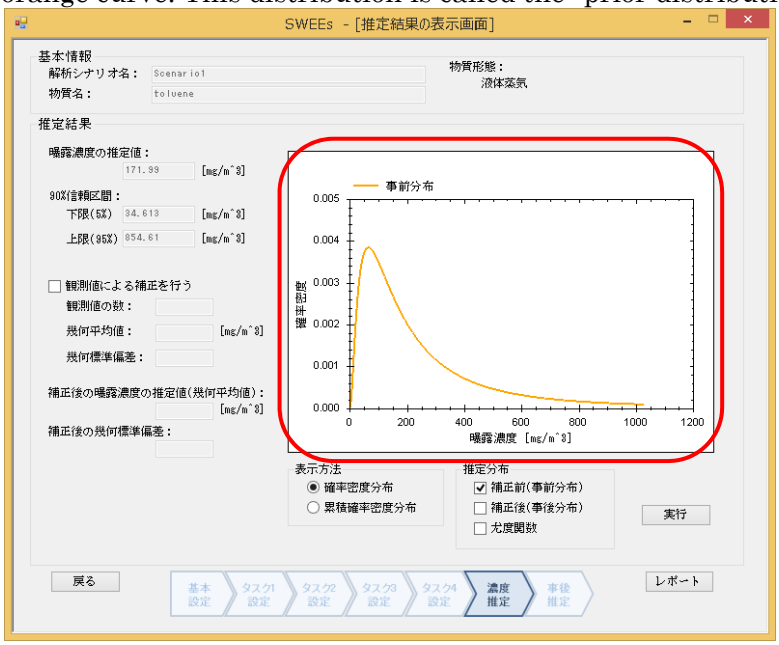


Figure 5-32 Display of prior distribution

※If the graph's scale does not match the screen, right-click the mouse and select "Set Scale to Default" to adjust.

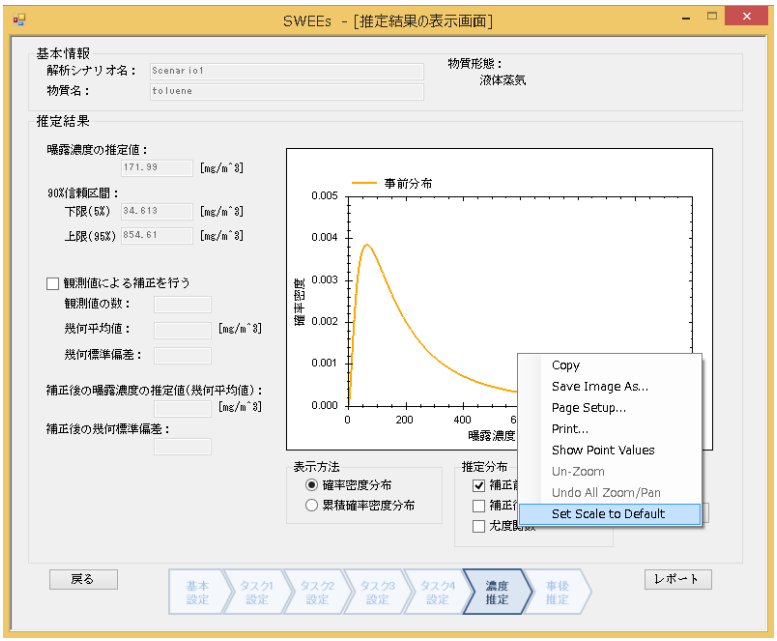


Figure 5-33 Adjusting the graph

5.6.2. Bayes update

This uses the observed values from the workplaces to update the estimates and estimates the geometric mean and probability distribution after the correction.
The probability distribution after the correction is called the "posterior distribution". Selecting the "Correction by observed values" check box enables the selection of the text boxes in the observed data section. Also, un-check the check box for prior distribution at the bottom right and select the check box for posterior distribution. Next, enter the observed data. Enter "10" for number of observed values, "255" for geometric mean [mg/m^3], and "2.0" for geometric standard deviation, and push the "Execute" button.

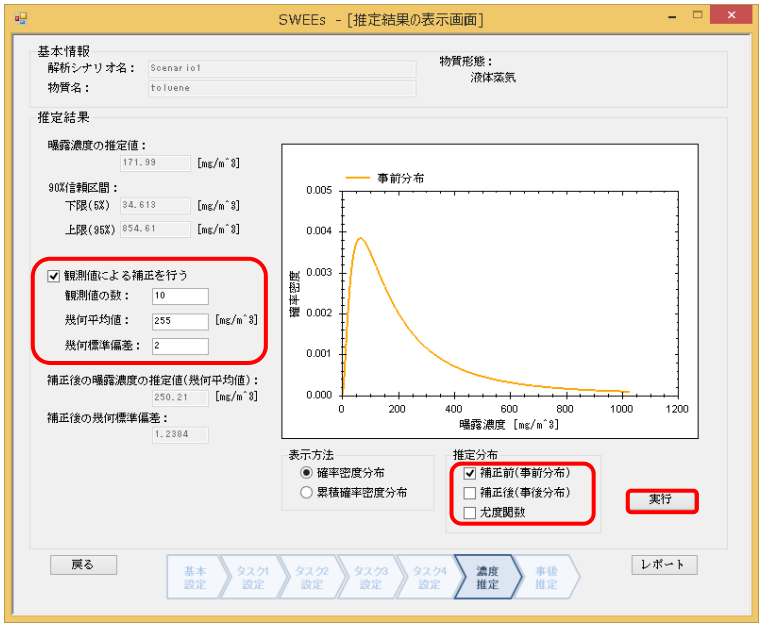


Figure 5-34 Bayes update by observed data

※Method for geometric mean and geometric standard deviation of observed values.

Geometric mean $\bar{x}$ of observed values x_1, x_2, ・・・・x_n

$$\bar{x} = \sqrt[n]{x_1 \cdot x_2 \cdots x_n}$$

In Excel, use geomean () function to find geomean (x_1, x_2, ・・・・x_n).

Also, geometric standard deviation of observed values x_1, x_2・・・・x_n

Let y_i=lnx_i

$$\exp\left(\sqrt{\frac{(y_1-\bar{y})^2+(y_2-\bar{y})^2+\cdots+(y_n-\bar{y})^2}{n}}\right)$$

In Excel, use stdev( ) function to find stdev (y_1, y_2, ・・・・y_n), and enter the output value into exp( ), which calculates the geometric standard deviation of the observed values.

5.6.3. Display posterior distribution

The posterior probability density distribution of exposure concentration is the red curve, and the distribution of observed data is displayed in blue as the likelihood function.

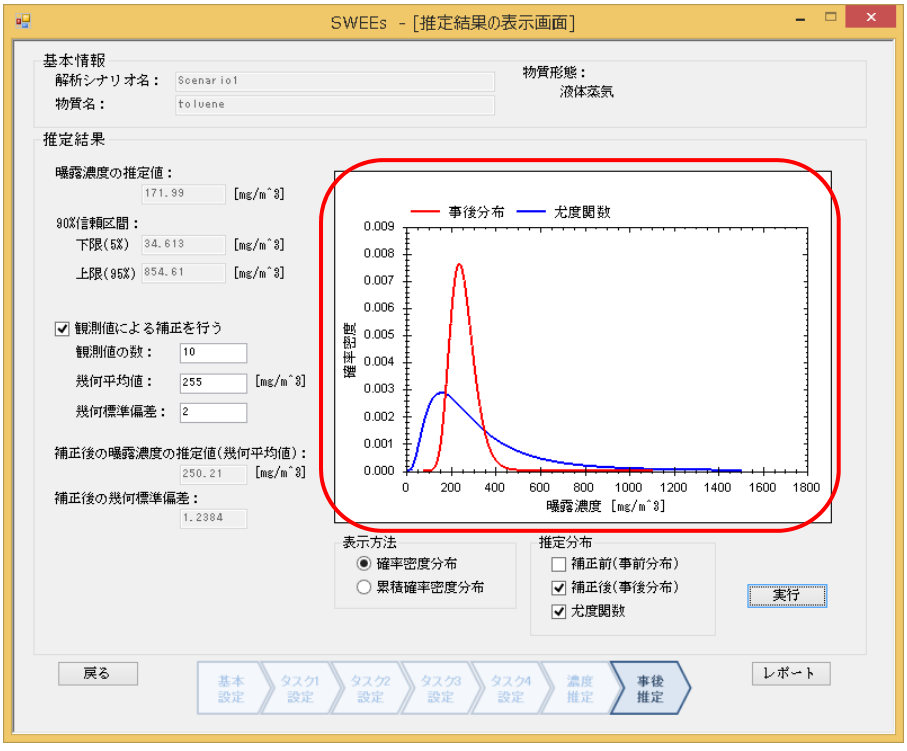


Figure 5-35 Display of posterior distribution

5.6.4. Superimpose prior and posterior distributions

Check “Before correction (prior distribution)” check box in the “estimated distribution” section and push “Execute”.

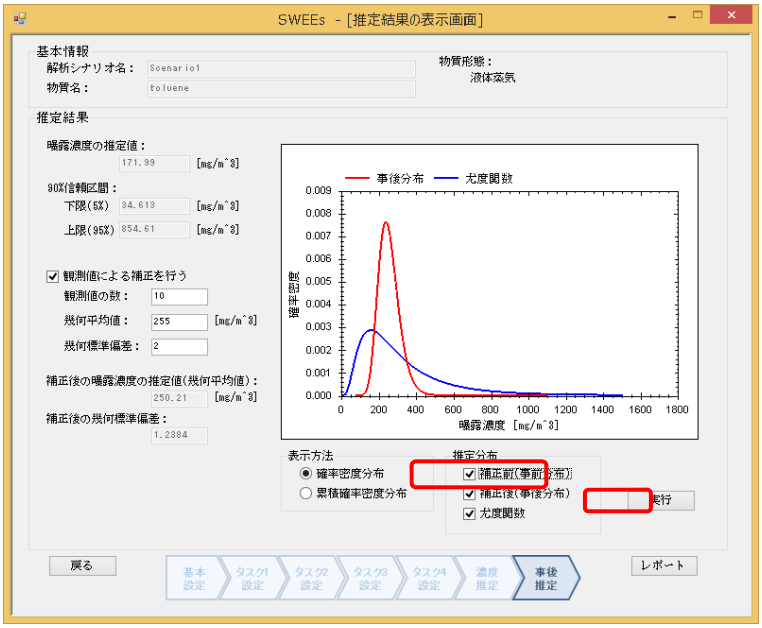


Figure 5-36 Superimposing prior and posterior distributions

The superimposed graphs of prior and posterior probability density distributions are displayed with appropriate scale.

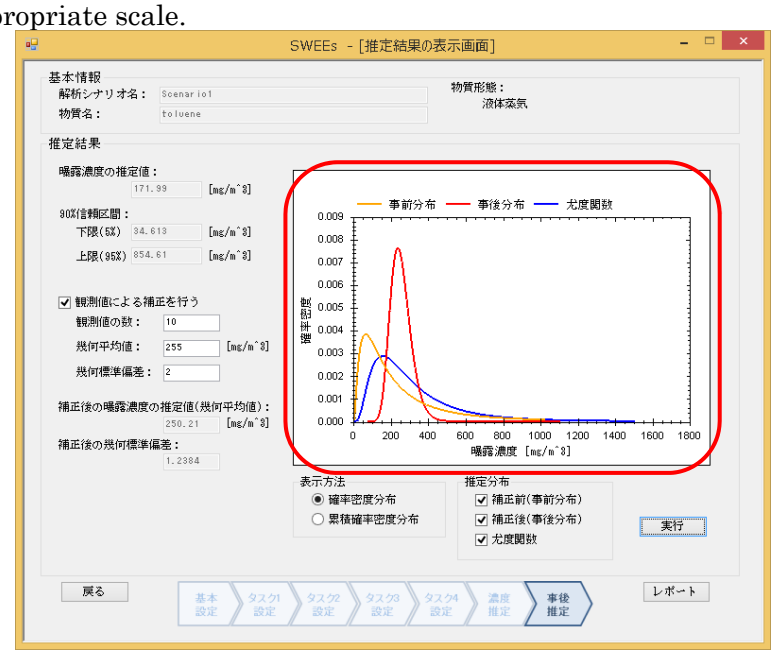


Figure 5-37 Display of superimposed prior and posterior distributions

5.6.5. Display cumulative probability density distribution

From “Display method”, select “Cumulative probability density distribution” and push “Execute”.

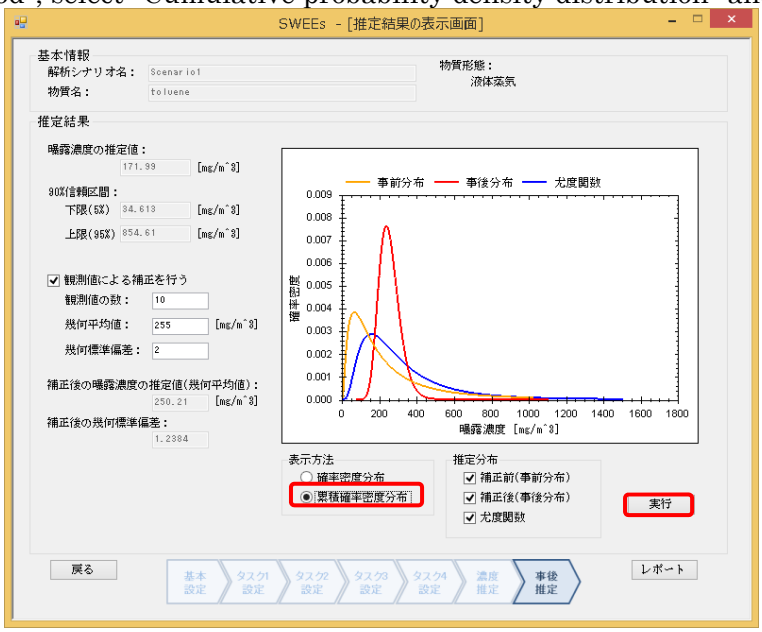


Figure 5-38 Display of cumulative probability density distribution

The superimposed graphs of prior and posterior cumulative probability density distributions and likelihood function are displayed with appropriate scale.

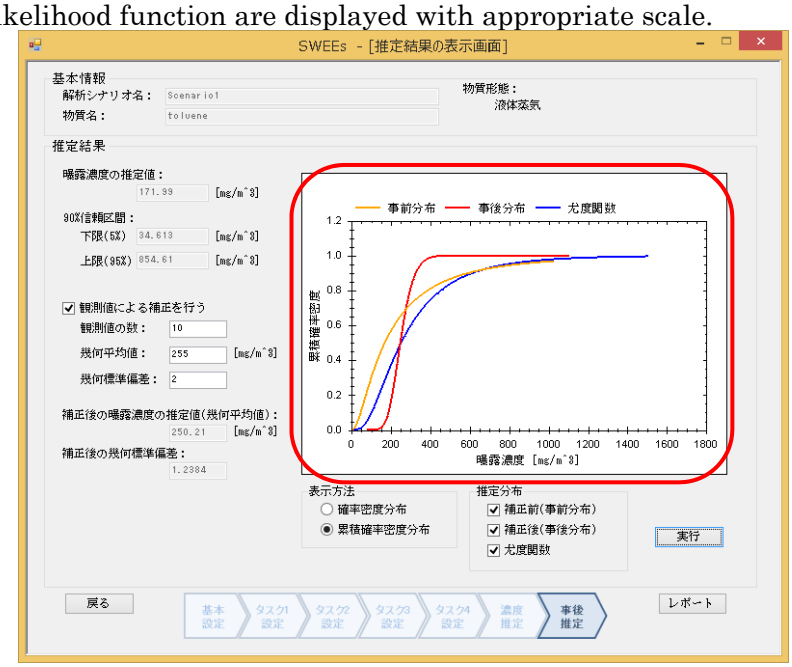


Figure 5-39 Display of superimposed graphs of prior and posterior cumulative probability density distributions and likelihood function

5.7. Enlist estimate results

5.7.1. Display the input and estimated values.

Push “Report” at the bottom of the screen.

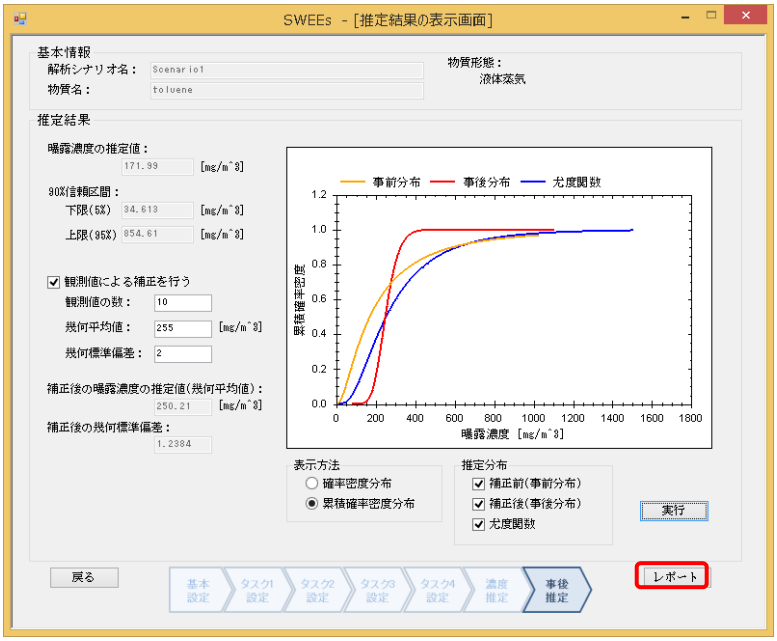


Figure 5-40 Output of estimate result report

The system moves on to the report screen.

In the report screen, the list of the input information is displayed.

Figure 5-41 Report display of input information

Move down the scroll bar on the right to show the estimate results by SWEEs.

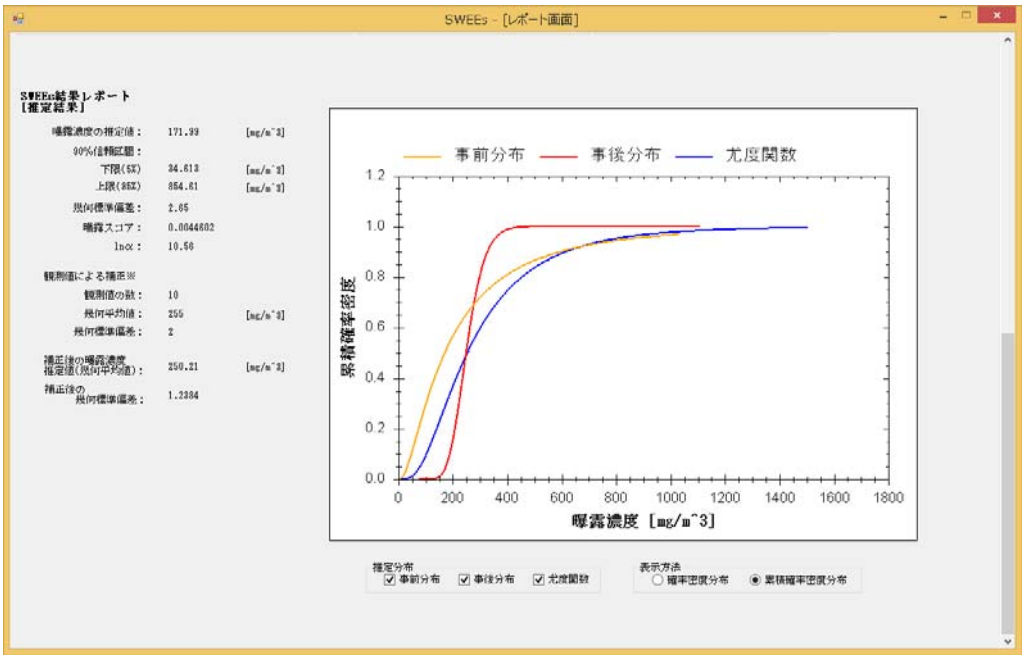


Figure 5-42 Display of estimate result report

5.7.2. Correct observed values

In “Correction by observed values”, double-click the value of either the number of observed values, geometric mean, or geometric standard deviation Screen for setting the observed data pops up.

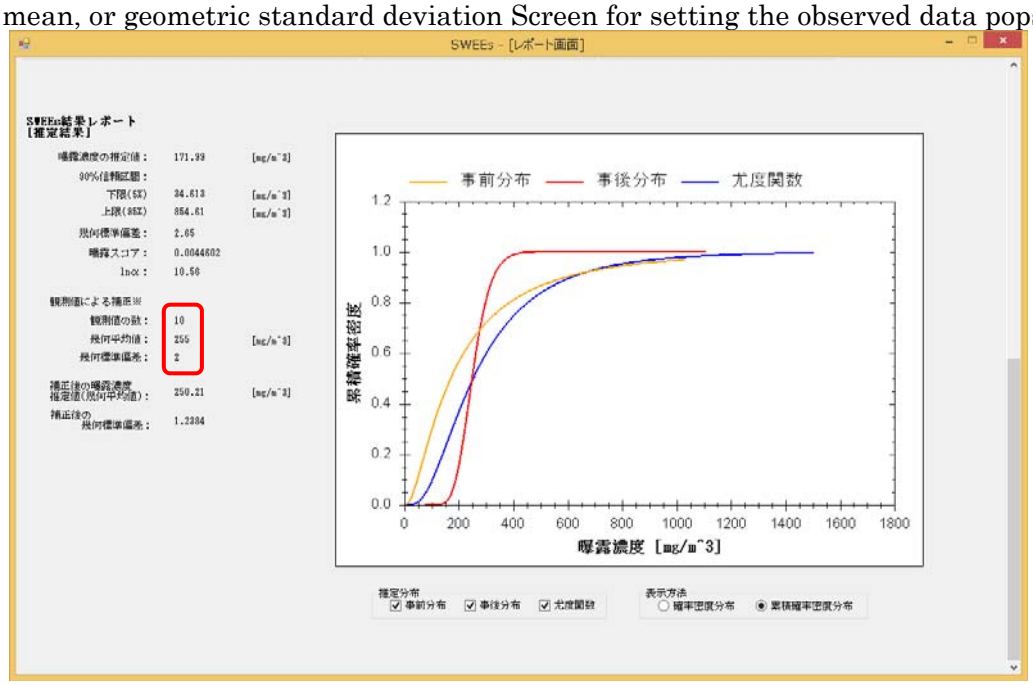


Figure 5-43 Display of estimate result report

In the setting of observed data, change the number of observed values from “10” to “15”, geometric mean from “255” to “230”, and geometric standard deviation from “2” to “3”, and push the “Set” button.

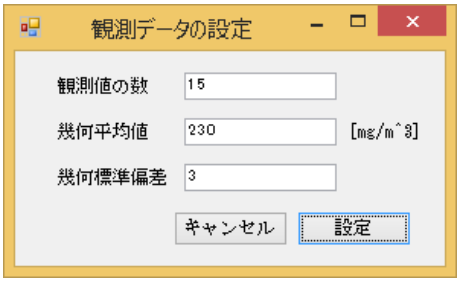


Figure 5-44 Screen for setting observed data

The values set for the observed data are reflected in the probability density distribution graph on the right.

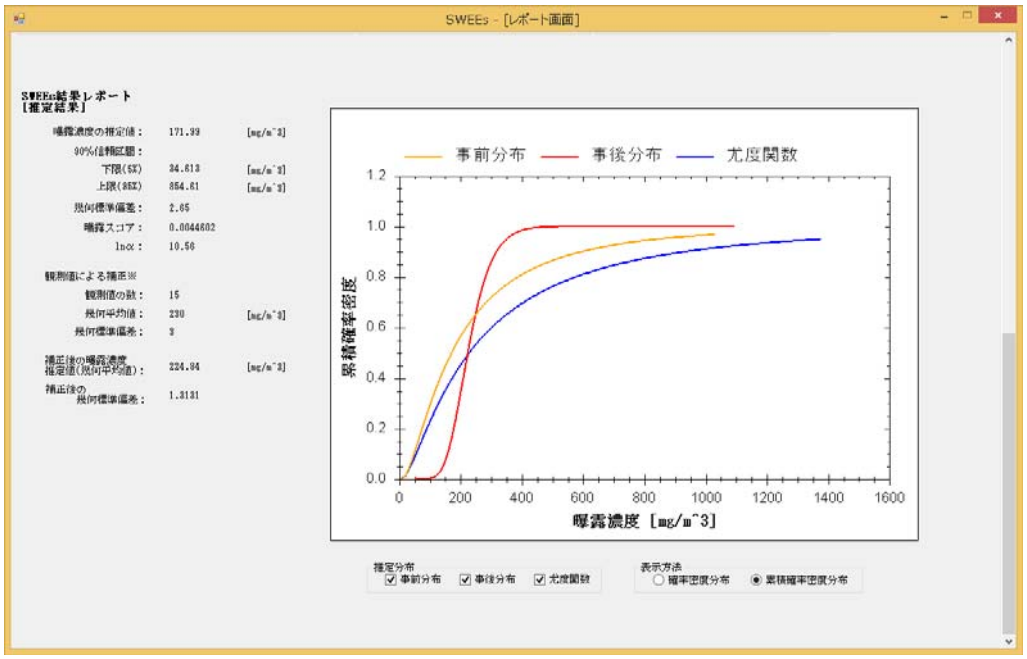


Figure 5-45 Update of observed data

5.8. Output estimate result report

Scroll up to the top of the screen and push the “csv output” button in the right bottom corner. A file selection dialog for saving pops up.

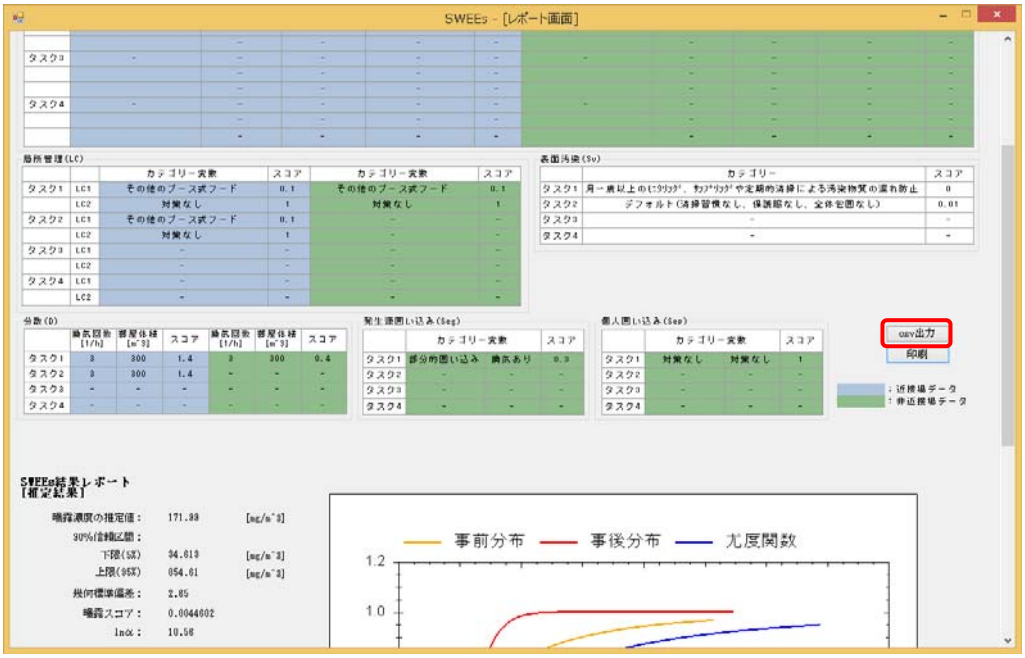


Figure 5-46 File output in csv format

In the file selection dialog, enter the file name to be saved.

It outputs the items on the report screen (excluding graph information) in csv format. The output csv file can be loaded by clicking the “Read file” button on the top screen.

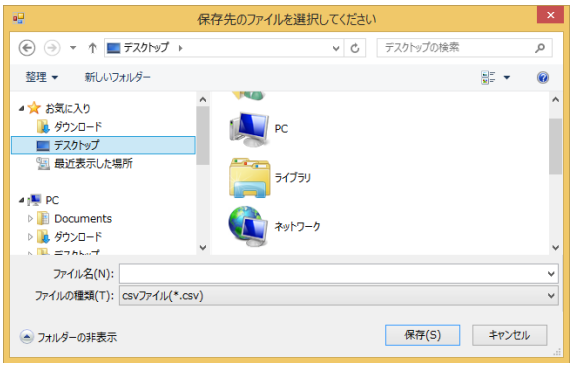


Figure 5-47 Saving the csv file

5.9. Print the estimate result report

Push the “Print” button in the right bottom corner of the screen.

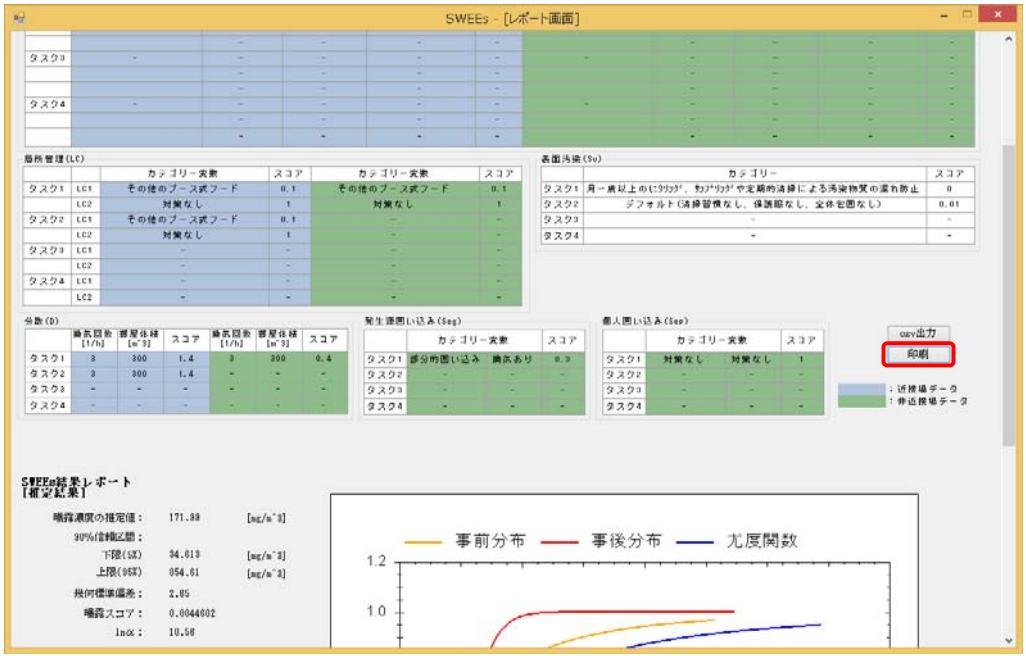


Figure 5-48 Printing the file

A page setting dialog as below is displayed. Set the printing orientation to “Horizontal” and push the OK button. The items displayed on the report screen are printed.

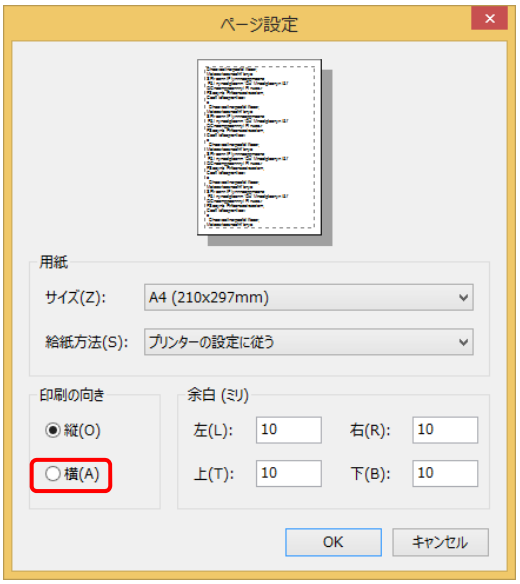


Figure 5-49 Page setting dialog

6. Acknowledgment

This tool is part of the accomplishment in the 2012 New LRI First Assigned Tasks by Japan Chemical Industry Association (general incorporated association). We hereby express our gratitude.

7. References

1.Fransman, W., Cherrie, J., vanTongeren, M., Schneider, T., Tischer, M., Schinkel, J., Marquart, H., Warren, N., Kromhout, H. and Tielemans, E. (2010) Development of a mechanistic model for the Advanced REACH Tool (ART) －Version 1.0 －, TNO report V9009.

2.Fransman, W., Tongeren, M.V., Cherrie, J.W., Tischer, M., Schneider, T., Schinkel, J., Kromhout, H., Warren, N., Goede, H. and Tielemans, E. (2011) Advanced Reach Tool (ART): Development of the Mechanistic Model, *Annals of Occupational Hygiene,* 55 (9), 957-979.

3.Schinkel, J., Warren, N., Fransman, W., vanTongeren, M., McDonnell, P., Voogd, E., Cherrie, J.W., Tischer, M., Kromhout, H. and Tielemans, E. (2011) Advanced REACH Tool (ART): Calibration of the mechanistic model, *Journal of Environmental Monitoring*, 13, 1374-1382.

4.Tielemans, E., Warren, N., Fransman, W., vanTongeren, M., McNally, K., Tischer, M., Ritchie, P., Kromhout, H., Schinkel, J., Schneider, T and Cherrie, J.W. (2011) Advanced REACH Tool (ART): Overview of Version 1.0 and Research Needs, *Annals of Occupational Hygiene*, 55 (9), 949–956.

5. Randhol, P. and Engelien H.K. (2000) xlUNIFAC, a Computer Program for Calculation of Liquid Activity Coefficients Using the UNIFAC Model.

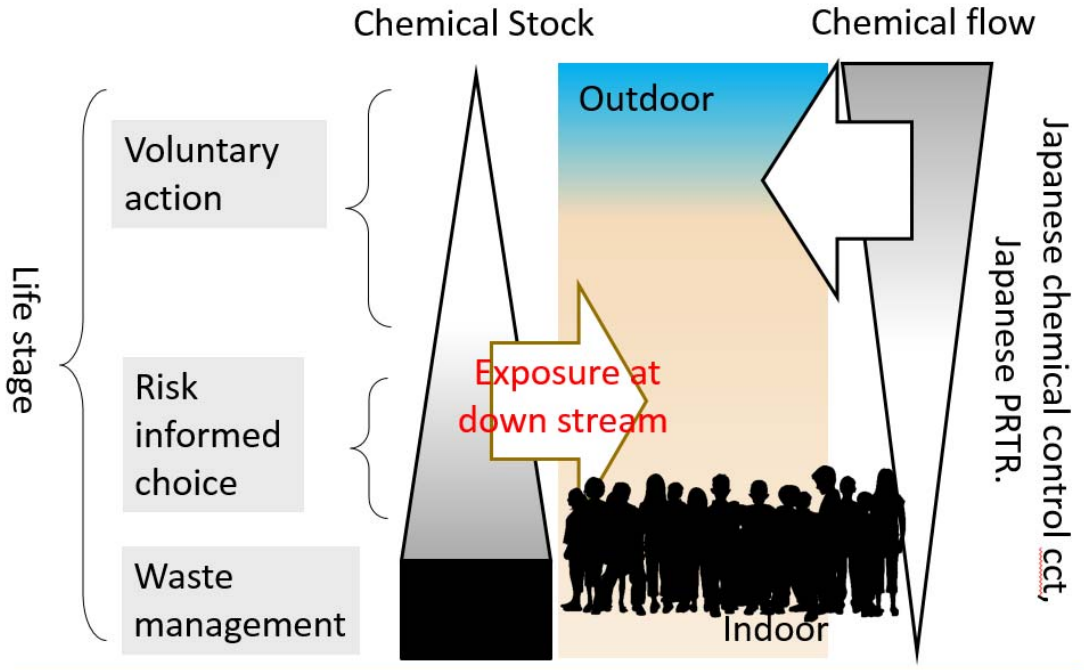
8. Appendix

Occupational Exposure Assessment for Industrial Sector Voluntary Risk Management

Graduate School of Engineering, Osaka U., Japan
Sustainability design on-site research center, Osaka U., Japan

1

Chemical risk assessment in Japan



2

There are many models, however, downstream users are not well examined.

Screening analysis :
Rapid estimation with a limited dataset.

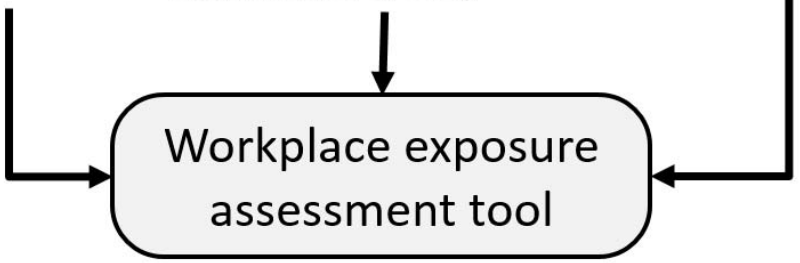
Specific object analysis :
Detailed estimation to evaluate the necessity of carrying out management options.

The central concept of this screening analysis is to integrate three finding types into one instrument:

Models:
Indoor exposure model, Bayesian update method.

Observations:
Observations at workplace(environment, human blood, etc.)

Knowledge:
Expert judgement, findings obtained in real workplace.

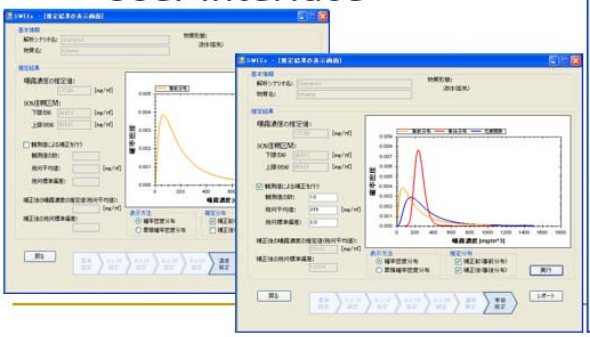


integrated Score-based Workplace Exposure Estimating system

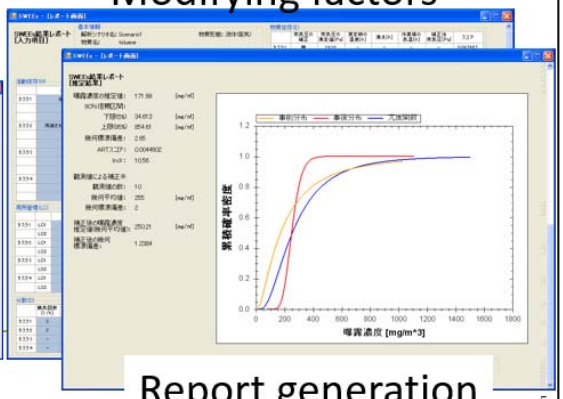
SWEEs Ver.1.0β
Integrated Score-based Workplace Exposure Estimating system

User interface

Modifying factors



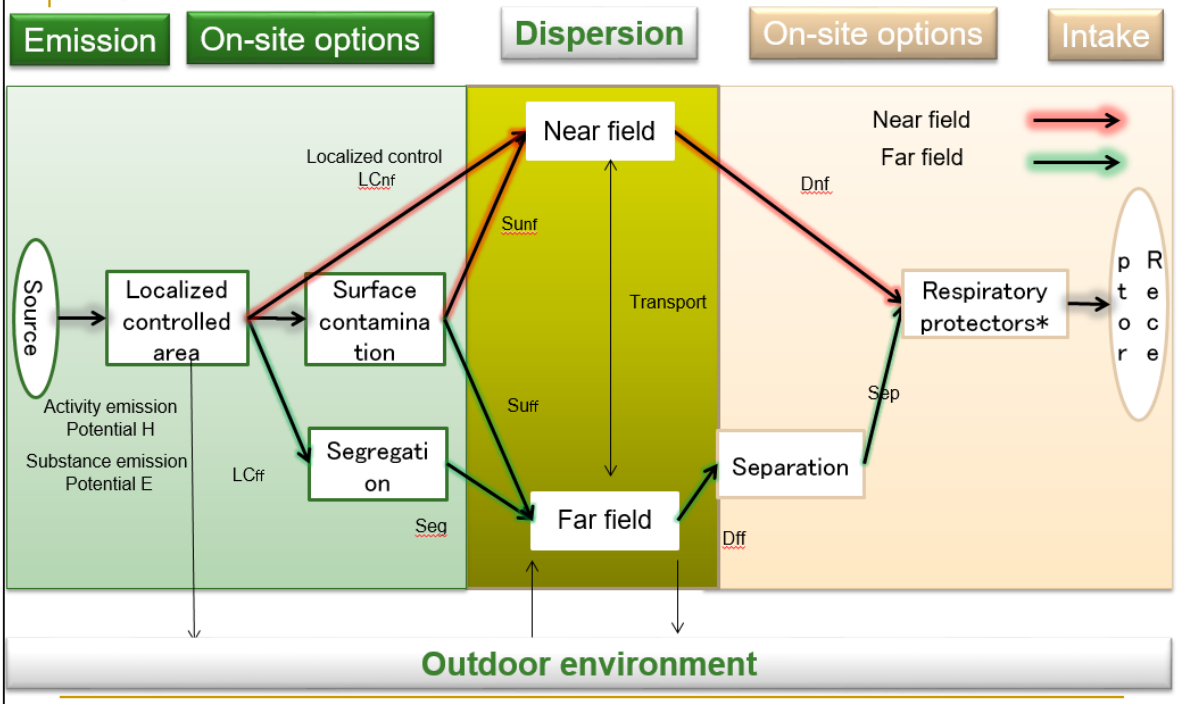
Estimation and updates



Report generation

5

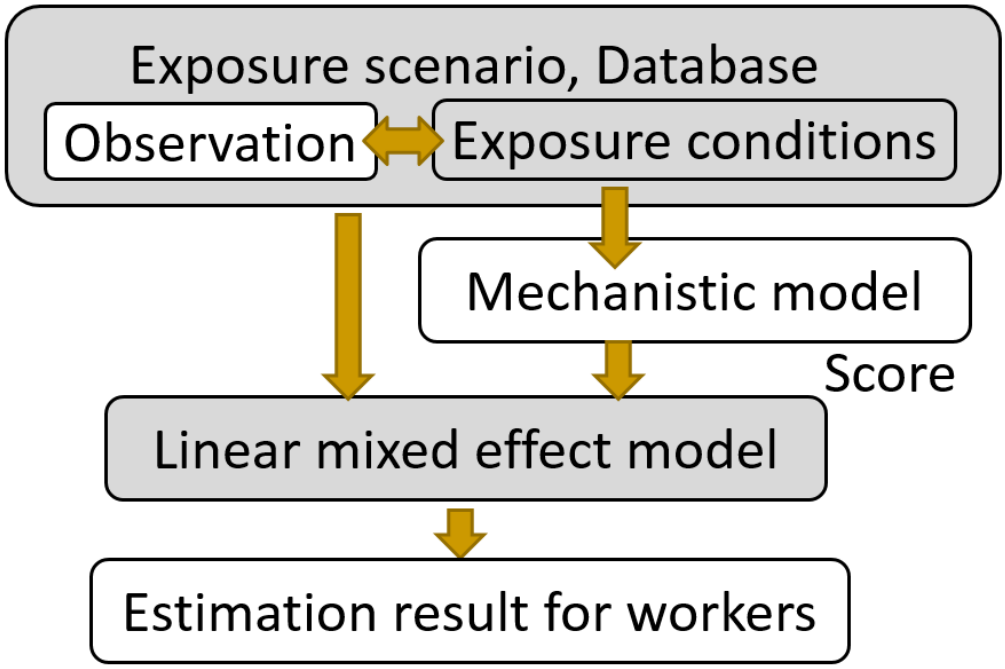
Exposure scenario in ART for downstream users



*ART version1.0, this is not included.

6

SWEES Structure



7

Mechanistic model

Total exposure Score C_t

$$C_t = \frac{1}{t_{total}} \sum_{tasks} \{t_{exposure} \times (C_{nf} + C_{ff} + Su)\}$$

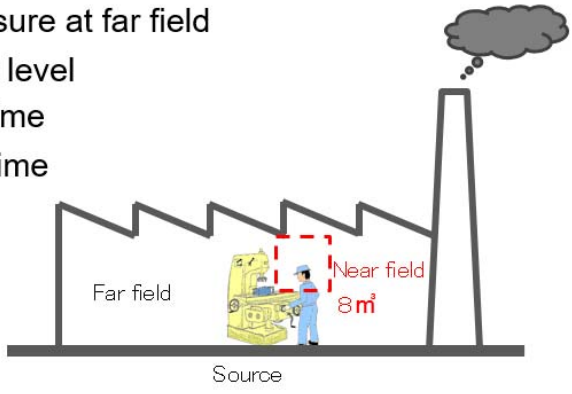
C_{nf} : personnel exposure at near field

C_{ff} : personnel exposure at far field

Su : surface pollution level

$t_{exposure}$: exposure time

t_{total}: total working time



8

Mechanistic model … continues

Near field C_{nf}

$$C_{nf} = \left(E_{nf} \times H_{nf} \times LC_{nf1} \times LC_{nf2}\right) \times D_{nf}$$

E_{nf} : modifying factor for emission potential (near field)

H_{nf} : modifying factor for activity dependence(near field)

LC_{nf1} : modifying factor for local management

LC_{nf2} : modifying factor for local management

D_{nf} : modifying factor for dilution (near field)

Similarly, the far field exposure concentration is calculated. C_{ff}

9

Modifying factor data sources

Modifying factor	symbol	Sources
Substance dependent potential	*E*	Physicochemical properties of chemical substance
Activity dependent potential	*H*	Exposure data used for calibration. Expert judgement
Local control	*LC*	ECEL database*, expert meeting
Segregation	*Seg*	ECEL database*, expert judgement
Separation	*Sep*	ECEL database*, expert judgement
Surface pollution	*Su*	Expert judgement
Dispersion	*D*	2 box model simulation results

*ECEL (Exposure Control Efficacy Library) Database comprised of (Annals of Occupational Hygiene, American Industrial Hygiene Association Journal, Applied Occupational and Environmental Hygiene, Journal of Occupational and Environmental Hygiene) .90 referred papers and 433 datasets. (Fransman et al. 2008).

10

Linear mixed effect model considers…

Variation among enterprises, facilities, tasks, and workers.

$$\ln(Y_{ijk}) = \ln(\alpha) + \ln(C_t) + \delta_i + c_{ij} + \varepsilon_{ijk}$$

Y_{ijk} : chemical exposure level of *i*-th scenario, *j-th enterprise*, *k*-th observation

$\ln(\alpha)$: intercept

δ_i : random effect of *i*-th scenario

c_{ij} : random effect of *i*-th scenario and *j*-th enterprise

ε_{ijk} : error

※Schinkel et al.(2011):
observation data : 2056, ln(α)=10.56

11

Fin