

Virtual Product-Process Design Lab
for
Formulation design and verification

Tutorials

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1. General information

These tutorials introduce the user to the new work-flow of the software 'The virtual Product-Process Design Laboratory' (virtual PPD-lab) for formulation design and verification. The work-flow can be used in different modes:

- the user can perform virtual experiments, searching databases, checking the miscibility of solvents, verifying the solubility of an Active Ingredient or an additive in a single solvent or solvent mixture;
- the user can design a solvent mixture;
- the user can design a formulated product.

All the above characteristics of the work-flow are highlighted here through two tutorials:

1. tutorial 1: the main features of the software are shown.
 - a) database search
 - b) LLE miscibility check
 - c) mixture design
 - d) choose AI and check AI solubility
 - e) choose additive and check additive solubility
2. tutorial 2: an insect repellent formulation is designed.

Notes for the installation of the virtual PPD-lab can be found in Appendix A. The manual for the use of the new work-flow for formulation design is also available.

1. Tutorial 1

1.a) Database search

1.a.1 Target

A list of alcohols and esters which show total miscibility with water has to be identified.

1.a.2 Solution

This problem can be solved in two ways: searching databases or using Computer Aided Molecular Design (CAMD) techniques. The virtual PPD-lab contains databases which can be screened to find a list of suitable candidates; on the other side, from the virtual PPD-lab the software ICAS can be accessed, where the user can use ProCAMD (Harper, 2000), for the Computer Aided Molecular Design. In this tutorial we highlight the use of the virtual PPD-lab, while for the use of ProCAMD the user can refer to ICAS Documentation (2001).

1.a.3 Solution with the virtual PPD-lab

Step 1. The user has to access the databases from the ‘Solvent mixture design’ task (Figure 1). Here the list of databases is shown. Solvents are divided in categories according to the water solubility (water soluble, water insoluble), the type of solvent (alcohol, ester,...) and the solvent application in formulated products (paints, sunscreens,...).

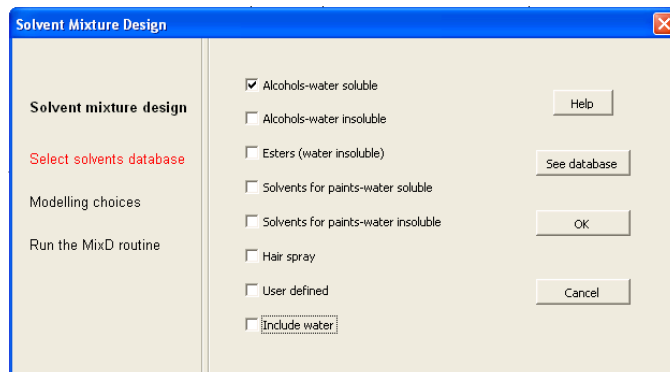


Figure 1. The list of databases of the formulation design work-flow in the virtual PPD-lab.

Step 2. The user has to select a database matching the targets (esters and alcohols which show complete miscibility with water). Esters are well known to be water insoluble (large immiscibility gaps with water), as underlined in the above dialog box. On the other side, alcohols can be totally miscible with water. As shown in Figure 1, the software contains a database of water soluble alcohols, shown in Table 1. The user has to select this single database.

Table 1. Water soluble alcohols and some of their properties from the formulation work-flow database.

n°	Name	Formula	CAS n°	Smile	Mw	ρ (Kg/l)	...
1	methanol	CH ₄ O	000067-56-1	OC	32.04	0.7861	
2	ethanol	C ₂ H ₆ O	000064-17-5	OCC	46.07	0.8040	
3	1-propanol	C ₃ H ₈ O	000071-23-8	OCCC	60.09	0.8016	
4	2-propanol	C ₃ H ₈ O	000067-63-0	OC(C)C	60.09	0.7825	
5	allyl alcohol	C ₃ H ₆ O	000107-18-6	C=CCO	58.08	0.9337	

Several databases can be chosen at the same time, for a maximum total amount of 300 solvents. Water can be added, and the user can also introduce his/her own database choosing the option ‘user defined’.

Databases can be accessed with the option ‘see database’ (only one database at the time has to be selected). When the user accesses the database, a full description of the properties included together with the units of measure are reported.

Note that in the virtual PPD-lab all the properties and therefore all the calculations performed also later in the tutorials (solubility included) are at a fixed temperature of 300 K.

1.b) LLE miscibility check

1.b.1 Target

Given the list of water soluble alcohols of Table 1, identify the compounds which are miscible with each others. This involves the screening of the liquid-liquid equilibrium (LLE) of all the binary combinations of the alcohols in Table 1.

1.b.2 Solution

This task can be solved into different ways: the user can use the algorithm contained in the virtual PPD-lab, or the user can access ICAS and perform the ‘Organic LLE’ calculations. In this tutorial we highlight the use of the virtual PPD-lab, while for the use of ICAS for the LLE calculations the user can refer to ICAS Documentation (2001).

1.b.3 Solution with the virtual PPD-lab

Step 1. The user has to select the database of water soluble alcohols from the dialog box shown in Figure 1.

Step 2. The user is then directed to another dialog box (Figure 2), which reports the information about the models employed in the algorithm. For the LLE miscibility check the UNIFAC model is employed, with the LLE parameter table.

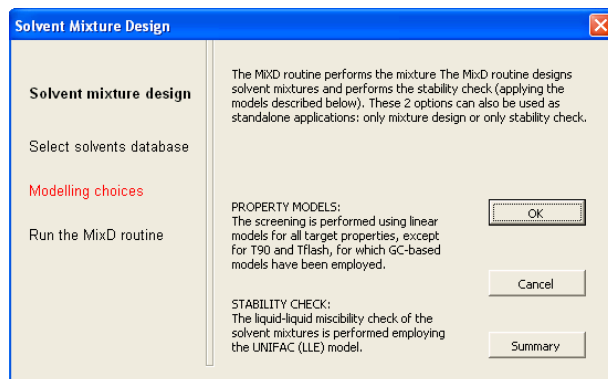


Figure 2. The information dialog box in the solvent mixture design task.

The user has to select the ‘Ok’ command button to proceed in the design.

Step 3. The user is redirected to the MixD dialog box (Figure 3).

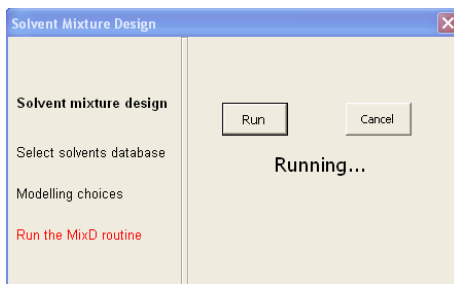


Figure 3. The dialog box from which the user can launch the mixture design routine.

Here the user has to launch the MixD routine, which performs both the mixture design (find the binary solvent mixtures matching some a priori defined targets) and the stability check of solvent mixtures. In this part of the tutorial we are not interested in the first option (mixture design), but only in the stability check. Since constraints have not been fixed, the routine will return all the possible binary combinations of the solvents in Table 1, and the information about their stability.

Step 4. Results are displayed as shown in Figure 4.

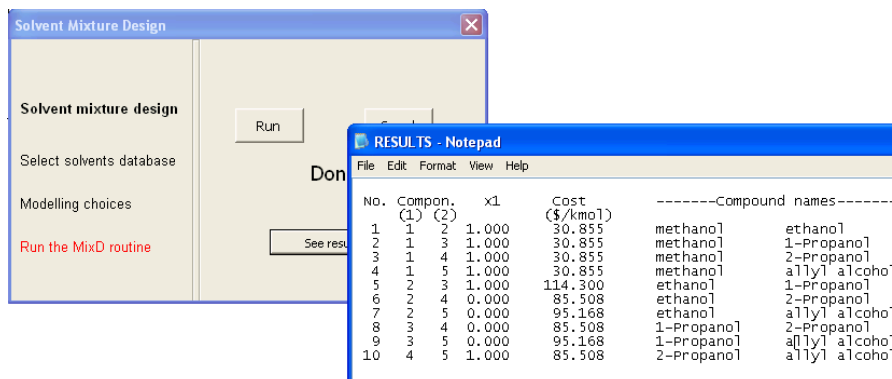


Figure 4. Results of the mixture design routine are displayed.

Table 2 summarizes the results: all the possible binary combinations between the 5 alcohols of Table 1, and the information about the stability. All the mixtures are one liquid phase (all the alcohols combinations are totally miscible between each other).

The UNIFAC (LLE) decomposition of the alcohols of Table 1 is reported in Appendix B (Table B1).

Table 2. All possible binary combinations between the solvents of Table 1.

Mixture n°	Components n°	Components names	Stability information
	(1) (2)		
1	1 2	methanol + ethanol	total miscibility
2	1 3	methanol +1-propanol	total miscibility
3	1 4	methanol + 2-propanol	total miscibility
4	1 5	methanol + allyl alcohol	total miscibility
5	2 3	ethanol + 1-propanol	total miscibility
6	2 4	ethanol + 2-propanol	total miscibility
7	2 5	ethanol + allyl alcohol	total miscibility
8	3 4	1-propanol + 2-propanol	total miscibility
9	3 5	1-propanol + allyl alcohol	total miscibility
10	4 5	2-propanol + allyl alcohol	total miscibility

1.c) Mixture design

1.c.1 Target

Identify the solvent mixtures of Table 2 which match the following a priori defined performance criteria (user needs):

- the mixture should not be toxic,
- the mixture should be sprayed from a nozzle.

1.c.2 Solution

In order to solve the above mixture design problem, the following steps need to be performed:

- translate the performance criteria into physicochemical properties (target properties);
- set constraints on the target properties;
- employ a mixture design algorithm to design mixtures matching the constraints.

Therefore, the performance criteria given in §1.c.1 have to be translated into physicochemical properties (the target properties). The translation process follows:

- the toxicity can be related to the toxicity parameter LC_{50} , which is the lethal aqueous concentration which causes the 50% of mortality in a fathead minnow population;
- the spray-ability is related to the dynamic viscosity η and molar volume V_m .

Then, constraints have to be applied on the variables LC_{50} , η and V_m :

$$0.5 \leq -\log(LC_{50}) \leq 1.2 \quad \text{mol/l} \quad (1)$$

$$\eta \leq 2.0 \quad \text{cP} \quad (2)$$

$$60.0 \leq V_m \leq 80.0 \quad \text{l/kmol} \quad (3)$$

The next step is to employ a mixture design algorithm to design the solvent mixtures matching the above targets. Eden et al. (2003) proposed a graphical method to find the solution to a mixture design problem. Here, we propose the use of the Mixture Design routine (Conte et al., 2010) which is implemented in the virtual PPD-lab.

1.c.3 Solution with the virtual PPD-lab

Step 1. The user needs to access the ‘Problem Definition’ task (Figure 5). Since the objective of the design is not a particular product but just a solvent mixture, the user should choose ‘other’ in the options listed, and name the case study ‘tutorial 1’, for instance.

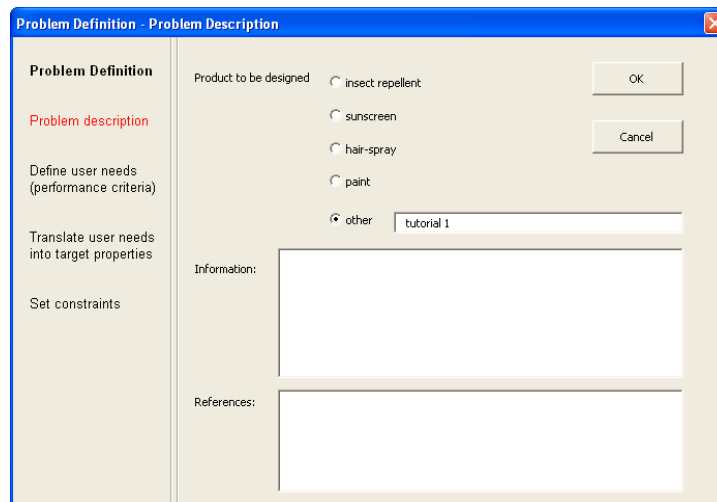


Figure 5. General dialog box for the problem definition.

Step 2. The user has to introduce the performance criteria given during the target definition (§1.c.1), to document the specific case study (Figure 6).

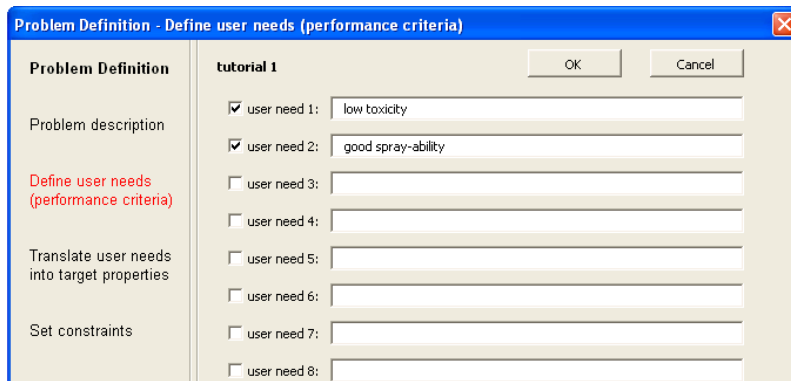


Figure 6. The user defines the performance criteria for the mixture to design. The description of the criteria is just qualitative, for documentation.

Step 3. The user needs to translate the performance criteria need into physicochemical properties (the target properties, §1.c.2), as shown in Figure 7.

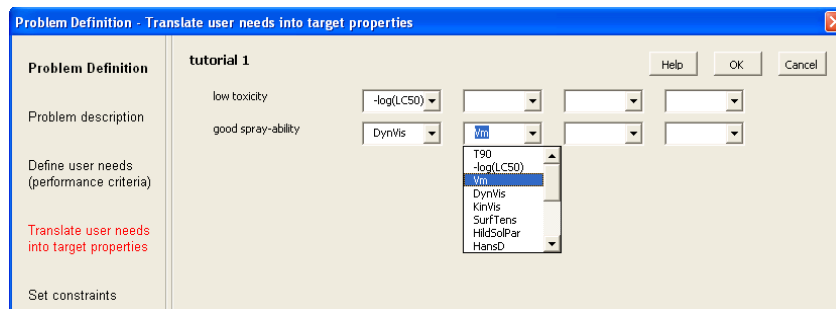


Figure 7. The translation from performance criteria to physical and chemical properties.

The Help in Figure 7 contains a description of the target properties to choose within (i. e., DynVisc = dynamic viscosity η).

Step 4. The user needs to introduce the constraints (§1.c.2) on the target properties as shown in Figure 8.

The problem definition is now concluded.

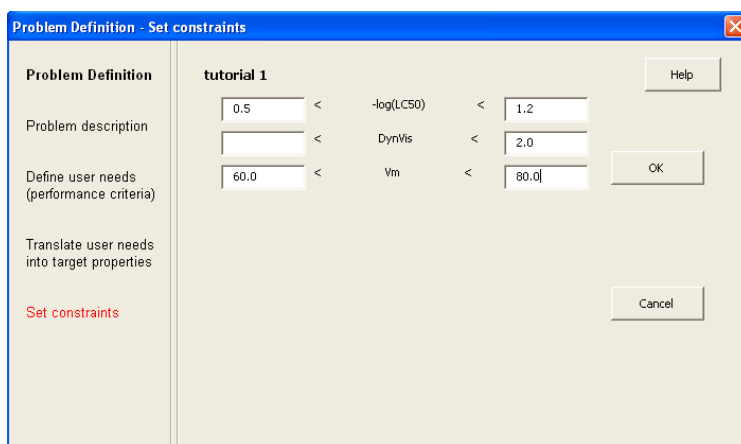


Figure 8. The user sets the constraints on the target properties.
The Help gives the unit of measure for the constraints.

Step 5. The next step is to run the Mixture Design routine. The user has to follow the same steps given in §1.a and §1.b: from the ‘Solvent mixture design’ task, select the solvent database (water soluble alcohols) and run the MixD algorithm. Results from the MixD routine are summarized in Table 3.

Table 3. Solvent mixtures matching the a priori defined constraints given in §1.c.2. The mixtures numbers refer to the mixtures previously listed in Table 2. The mixtures matching the targets are 8, while 2 mixtures have been rejected.

Mix n°	Comp. n° (1) (2)	Names	x_1	Cost (\$/kmol)	$-\log(LC_{50})$ (mol/l)	η (cP)	V_m (l/kmol)	stability
2	1 3	methanol +1-propanol	0.437	134.24	0.91	1.35	60.00	total miscibility
3	1 4	methanol + 2-propanol	0.466	60.04	0.81	1.35	60.00	total miscibility
4	1 5	methanol + allyl alcohol	0.103	88.56	0.92	1.54	60.00	total miscibility
5	2 3	ethanol + 1-propanol	0.847	129.63	0.92	1.21	60.00	total miscibility
6	2 4	ethanol + 2-propanol	0.057	87.14	1.15	2.00	75.69	total miscibility
7	2 5	ethanol + allyl alcohol	0	95.17	0.98	1.65	62.20	total miscibility
9	3 5	1-propanol + allyl alcohol	0	95.17	0.98	1.65	62.20	total miscibility
10	4 5	2-propanol + allyl alcohol	0.864	86.83	1.14	2.00	74.80	total miscibility

Note that mixture 7 and 9 show a composition of the first compound in the mixture equal to 0: this means that the second compound in the mixture (allyl alcohol) satisfies all the a priori defined criteria. This shows that the MixD routine is also able to identify the pure compounds matching the a priori defined constraints, if any compound with such characteristics is present in the database.

The pure compound properties (M_w , Cost, ρ , LC_{50} , η , V_m) for the 5 alcohols employed for the mixture design are reported in Appendix B, Table B2.

1.d) Choose AI and check its solubility

1.d.1 Target

The objective here is to choose an Active Ingredient which provide the function of repelling the mosquitoes (AI for an insect repellent, for instance Picaridin) and to verify its solubility in the mixtures designed in §1.c.

1.d.2 Solution

The virtual PPD-lab hosts Active Ingredients databases, therefore the user can first check the virtual lab databases and the relative information collected there. The solubility of the AI in the mixtures designed in §1.c can be checked in two different ways: the virtual PPD-lab can be employed, or the ICAS software can be accessed and calculations can be performed using the thermodynamic tools hosted.

The virtual PPD-lab performs the solubility calculations using a criteria based on the solubility parameters: Hildebrand or Hansen solubility parameters. According to this criteria, two compounds are miscible/soluble within each other if their solubility parameter values are similar. In this tutorial, the Hildebrand parameters are used. An additional constraint needs to be added to Eqs. (1)-(3):

$$\delta_{AI} - 1 \leq \delta \leq \delta_{AI} + 1 \quad \text{MPa}^{1/2} \quad (4)$$

That is, all the solvent mixtures with a Hildebrand solubility parameter value which is far from the AI solubility parameter will be rejected.

1.d.3 Solution with the virtual PPD-lab

Step 1. At first, the user needs to consult the AIs databases through the AI/AIs selection box (Figure 9), and choose the mosquito repellents database.

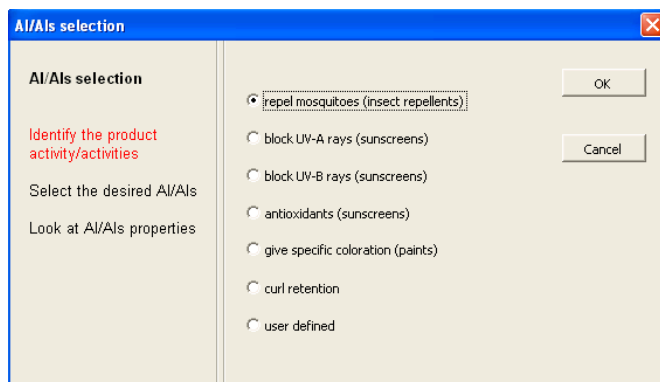


Figure 9. Dialog box in which the user can choose the desired product activities.

Step 2. The database for insect repellents AIs is displayed as shown in Figure 10. The user can select, for instance, Picaridin.

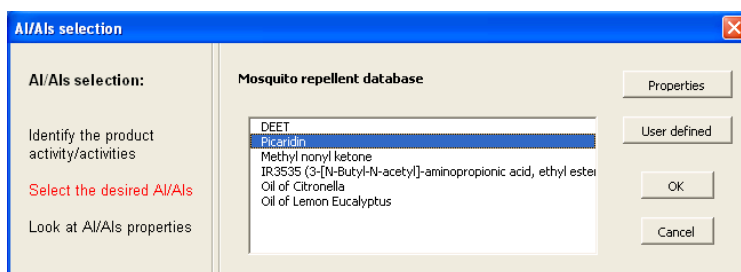


Figure 10. Database for insect repellent Ais, from the AI/AIs selection task.

Step 3. The user has now to check the properties of Picaridin as shown in Figure 11. The user can also update the data or introduce new data and then save them in the database.

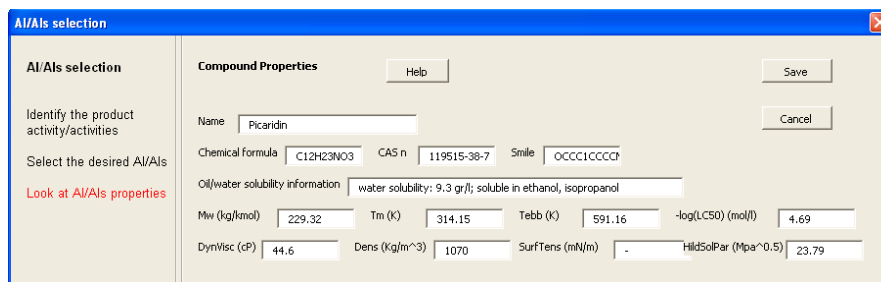


Figure 11. The chemical and physical properties for Picaridin, the selected AI.

The Hildebrand solubility parameter for Picaridin is $23.79 \text{ MPa}^{1/2}$.

Step 4. The user has now to go back to the ‘Problem definition’ task, and to introduce a new constraint in the performance criteria dialog box of Figure 6: the AI solubility. This is shown in Figure 12.

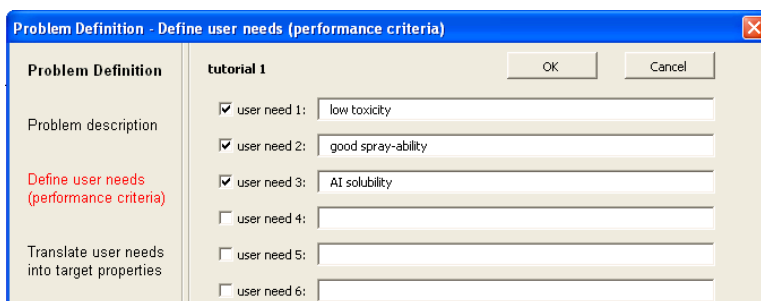


Figure 12. The introduction of the new performance criteria concerning the AI solubility.

Step 5. In the following dialog box, the user has to select the target properties related to the user need ‘AI solubility’, which is the Hildebrand solubility parameter (HildSolPar), as shown in Figure 13.

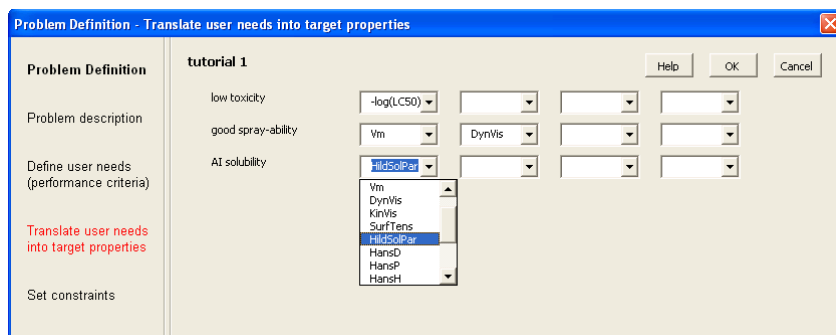


Figure 13. The translation process for the AI solubility criteria.

Step 6. The user needs to set the constraint on the Hildebrand solubility parameter (Eq. (4)), as shown in Figure 14.

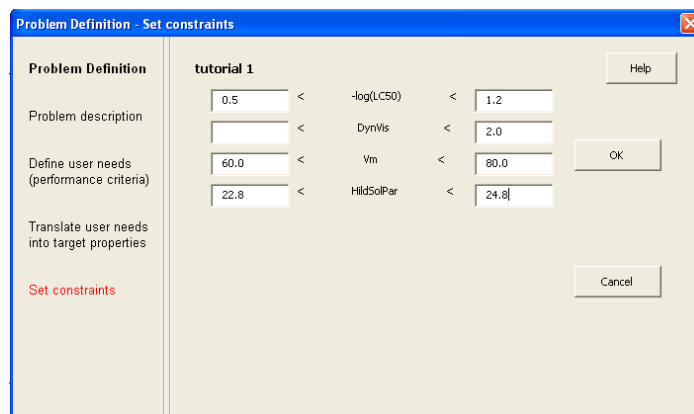


Figure 14. The addition of the solubility constraint to the previously set constraints.

Step 7. The user has now to access the ‘Solvent mixture design’ task and runs the MixD routine as done in §1.b, the results of Table 4 are displayed.

Table 4. Solvent mixtures matching the a priori defined constraints, when the solubility constraint has also been introduced. The mixtures numbers refer to the mixtures previously listed in Table 3.

Mix n°	Comp. n° (1) (2)	Names	x_1	Cost (\$/kmol)	$-\log(LC_{50})$ (mol/l)	η (cP)	V_m (l/kmol)	δ_{Hild} (MPa ^{1/2})	stability
3	1 4	methanol + 2-propanol	0.209	74.07	1.01	1.74	69.25	24.80	tot. mix
6	2 4	ethanol + 2-propanol	0.057	87.14	1.15	2.00	75.69	23.70	tot. mix
10	4 5	2-propanol + allyl alcohol	0.864	86.83	1.15	2.00	74.80	24.06	tot. mix

It can be noted that:

- All the possible binary combinations between the selected solvents (water soluble alcohols) were 10 (Table 2);
- Applying 3 constraints, the number was reduced to 8 feasible mixtures (Table 3);
- Applying the solubility constraints, only 3 mixtures result feasible (Table 4).

If the cost is chosen as performance index, the mixture methanol + 2-propanol is the cheapest, therefore it is selected as the best performing solvent mixture.

1.e) Choose additive and check its solubility

1.e.1 Target

The objective is to choose an additive for the above define blend of Picaridin in methanol + 2-propanol, and to verify its solubility in the solvent mixture. The additive could be, for instance, an aroma compound, since the Active Ingredients for insect repellents usually have a strong and unpleasant scent.

1.e.2 Solution

The virtual PPD-lab hosts also additives databases. The solubility of the additive in the mixtures designed in §1.d can be checked in two different ways (as for the AI): the virtual PPD-lab can be employed, or the ICAS software can be accessed and calculations can be performed using the thermodynamic tools hosted. Here, the first option (solution through the virtual PPD-lab) is highlighted.

1.e.3 Solution with the virtual PPD-lab

Step 1. The user has to access the ‘Additives selection’ task. Here is possible to perform a search in the aroma database picking ‘scent’ as the desired quality to enhance (Figure 15).

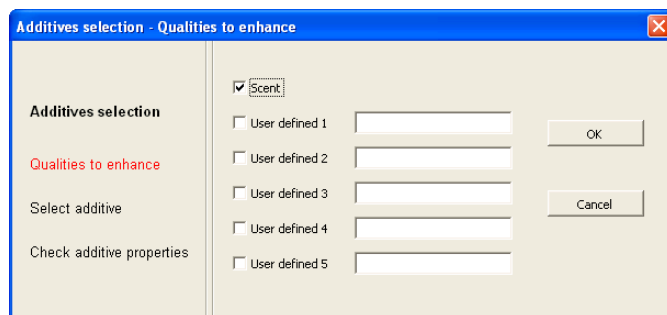


Figure 15. The additives selection box, where the user can choose the scent as quality to improve.

Step 2. The search in the database can be performed by name of the compound, CAS number, smile, smell or solubility information (Figure 16).

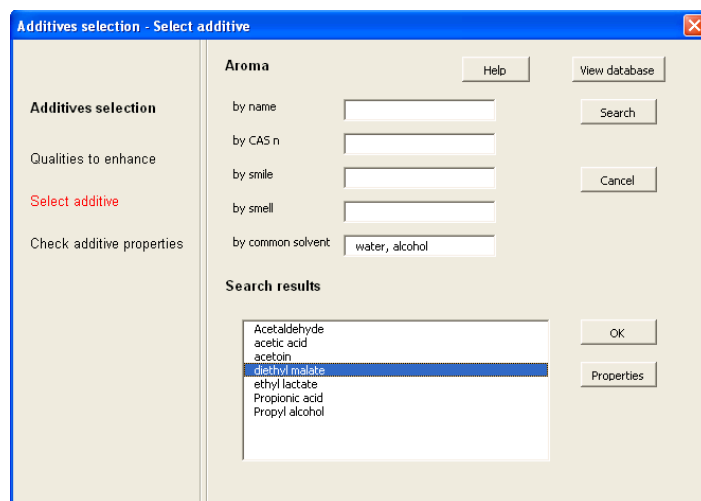


Figure 16. The aroma database search. In this tutorial the search is performed by common solvent.

A combined search is also allowed (search by common solvent and smell, for instance). In the case study under consideration, the search is performed ‘by common solvent’ since the objective is to identify an aroma compound which is soluble in the solvent mixture (constituted by alcohols). In addition, since all the alcohols in the solvent mixture are water soluble, the additive should be water soluble too.

Step 3. When the search is performed, results are displayed as in Figure 16.

Step 4. The user can select one compound and look at its properties with the ‘Properties’ command button, as shown in Figure 17.

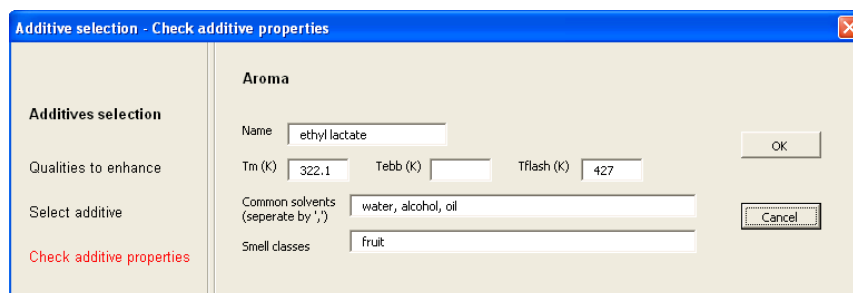


Figure 17. Property and information about one of the aroma compound resulting from the search.

Table 5 collects the properties/information about the solvent matching the search criteria. The user can select one of the compound, for instance ethyl lactate with a fruity scent.

Table 5. Aroma compounds resulting from the aroma database search. The search criteria is by common solvents: water and alcohol.

Name	Common solvent	CAS n°	Smile	Scent	...
acetaldehyde	alcohol, water, oil	75-07-0	CC=O	pungent	
acetic acid	alcohol, water, oil	64-19-7	CC(=O)O	sour	
acetoin	alcohol, water, oil	513-86-0	CC(C(=O)C)O	cream	
diethyl malate	alcohol, water, oil	7554-12-3	CCOC(=O)CC(C(=O)OCC)O	sweet	
ethyl lactate	alcohol, water, oil	97-64-3	CCOC(=O)C(C)O	fruit	
propionic acid	alcohol, water, oil	79-09-4	CCC(=O)O	pungent	
propyl alcohol	alcohol, water, oil	71-23-8	CCCO	pungent	

Step 5. When the user selects the desired aroma compound, he/she is redirected to the summary worksheet (Figure 18) which summarizes all the choices made by the user and the results of the calculations. Therefore, when designing a product, the summary worksheet contains the final product recipe.

	A	B	C	D	E	F
1						
2	Product to be designed: tutorial 1					
3						
4	User needs and their physical/chemical properties:					
5						
6		low toxicity				
7		good spray-ability				
8		All solubility				
9						
10						
11	Constraints:					
12						
13		-log(LC50): from .5 to 1.2				
14		Vm: from 60 to 80				
15		DynVis: from -1000 to 2				
16		HildSolPar: from 22.8 to 24.8				
17						
18						
19	Selected AI/AIs: Picaridin					
20						
21	Solvent database: Alcohols-water soluble					
22						
23	Additives:					
24		Scent				
25		ethyl lactate				
26						
27	User defined qualities:					
28						
29						
30						

Figure 18. The summary worksheet with the product recipe.

2. Tutorial 2

2.1 Target

The objective is to design an insect repellent formulation for the European market (non-tropical areas). A market survey reports that:

- Consumer want an effective product,
- The product should not be toxic,
- Consumer prefer a spray formula,

- Good drying time,
- Good stability,
- Pleasant scent,
- Low price.

2.2 Solution

At first, the above targets should be translated into physicochemical properties (target properties). The following translation is performed:

- Effective product: function of the AI selected;
- Toxicity: LC_{50} ;
- Spray formula: ν (KinVisc), V_m ;
- Drying time: T_{90} ;
- Stability: δ (HildSolPar) ;
- Scent: aroma compound needed as additive;
- Price: the cost should be minimized.

The constraints on the physicochemical properties defined above (LC_{50} , ν , V_m , T_{90} , δ) are:

$$1.4 \leq -\log(LC_{50}) \leq 1.6 \quad \text{mol/l} \quad (5)$$

$$2.9 \leq \nu \leq 3.1 \quad \text{cS} \quad (6)$$

$$86.0 \leq V_m \leq 88.0 \quad \text{l/kmol} \quad (7)$$

$$600.0 \leq T_{90} \leq 1000.0 \quad \text{l/kmol} \quad (8)$$

$$22.8 \leq \delta \leq 24.8 \quad \text{MPa}^{1/2} \quad (9)$$

The problem is now defined. The AI needs to be selected keeping in mind the market requirements. Then, a solvent mixture matching the target (Eq. (5)-(9)) needs to be designed. Solvents usually employed in insect repellent formulations are alcohols, and water can be also included. An aroma compound has also to be selected.

2.3 Solution with the virtual PPD-lab

Step 1. At first, the user needs to define the problem in the ‘Problem definition’ task, as explained in §1.c.3 (Figures 5-8). But in this case, the insect repellent is one of the products for which knowledge base is available, and the user can directly pick the insect repellent from the list of formulated products in the product description dialog box (Figure 19).

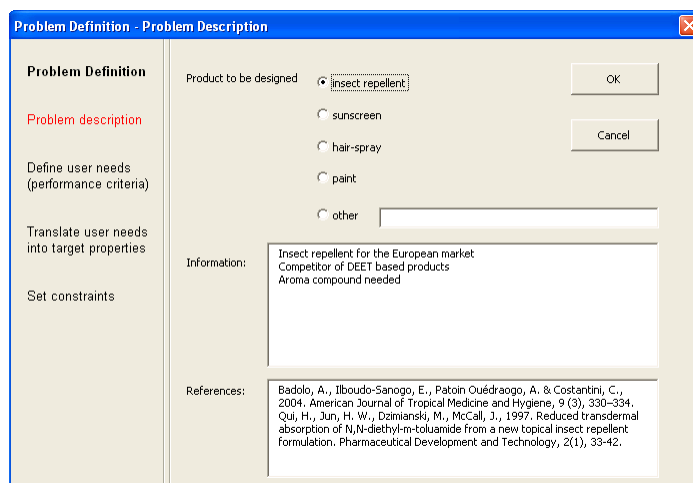


Figure 19. The choice of the insect repellent in the problem description dialog box.

Step 2. When the user confirm the selection of the desired product, a list of performance criteria is proposed and the user has to select the user needs listed in §2.1, as in Figure 20.

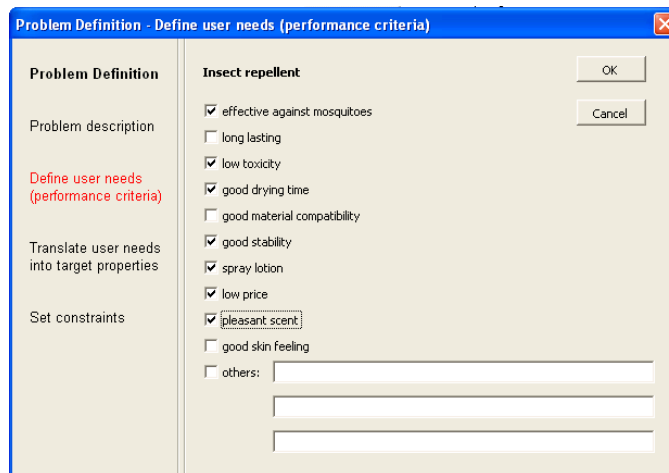


Figure 20. The choice of the performance criteria for the insect repellent.

Step 3. In the following dialog box, the user needs does not need to perform the translation from user needs to target properties, since the selection has already been done based on the

knowledge base, as shown in Figure 21. If the user wants to change the assigned/default target properties, he/she can always perform this change, as was shown in Figure 7.

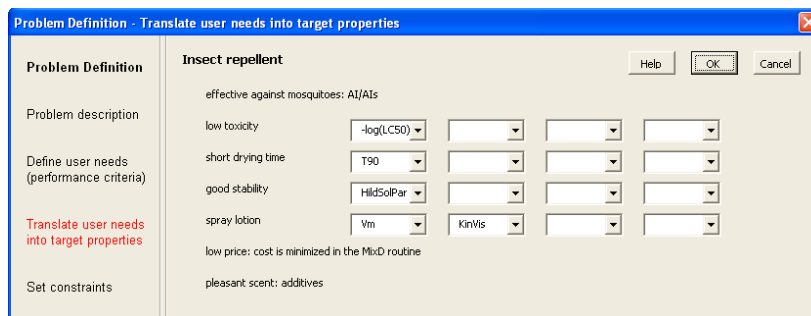


Figure 21. The translation of performance criteria into target properties.

Step 4. The user has to set the constraints in the next dialog box (as was shown in Figure 8).

Step 5. The AI selection is performed in the 'AI/AIs selection' box. The insect repellent database contains Picaridin, DEET and other biorepellents. Picaridin can be chosen as the AI (as was shown in Figure 10).

Step 6. The solvent mixture can now be designed. Alcohols and water can be potential solvent candidates, therefore both the alcohol databases (water soluble, water insoluble) are selected, plus water, as shown in Figure 22.

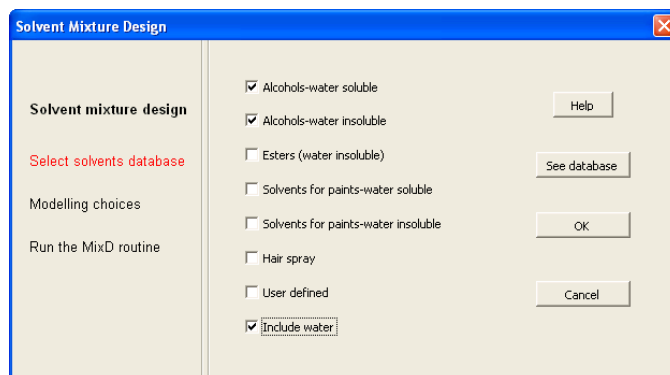


Figure 22. The selection of several solvent databases for the mixture design.

Step 7. The MixD routine is then launched as was shown in §1.b (Figures 2-4). Results are summarized in Table 6 and 7.

Note that mixture 7 shows partial miscibility, but the composition of interest (0.918) is in the single liquid phase region.

If the preferred performance index is the toxicity, the least toxic mixture is 2-propanol + 1-butanol.

Table 6. Solvent mixtures matching the a priori defined targets for the insect repellent.

Mix n°	Comp. n° (1) (2)	Names	x_1	Cost (\$/kmol)	$-\log(LC_{50})$ (mol/l)	ν (cS)	V_m (l/kmol)	δ_{Hild} (MPa ^{1/2})	T_{90} (s)
1	1 6	methanol + 1-butanol	0.118	128.11	1.58	2.97	86.0	23.37	870.6
2	2 6	ethanol + 1-butanol	0.174	136.45	1.59	2.94	86.0	23.23	834.1
3	2 20	ethanol + 2,2-dimethyl-1-butanol	0.524	161.93	1.56	3.06	86.0	24.49	793.7
4	3 6	1-propanol + 1-butanol	0.318	164.51	1.60	3.01	86.6	23.18	779.0
5	4 6	2-propanol + 1-butanol	0.397	119.07	1.51	3.02	86.0	22.93	676.3
6	5 6	allyl alcohol + 1-butanol	0.203	131.81	1.59	2.97	86	23.54	816.5
7	6 75	1-butanol + water	0.918	130.17	1.60	3.08	86	24.61	901.8

Table 7. Liquid-liquid information about the solvent mixtures reported in Table 6.

Mix n°	Comp. n° (1) (2)	Names	x_1	Stability information
1	1 6	methanol + 1-butanol	0.118	total miscibility
2	2 6	ethanol + 1-butanol	0.174	total miscibility
3	2 20	ethanol + 2,2-Dimethyl-1-butanol	0.524	total miscibility
4	3 6	1-propanol + 1-butanol	0.318	total miscibility
5	4 6	2-propanol + 1-butanol	0.397	total miscibility
6	5 6	allyl alcohol + 1-butanol	0.203	total miscibility
7	6 75	1-butanol + water	0.918	partial miscibility $x_1^\alpha=0.019$ $x_1^\beta=0.468$

Step 8. Once the solvent mixture has been designed, the aroma compound for the insect repellent formulation can be selected from the ‘Additive selection’ task. The desired solvent should be alcohol soluble. The preferred scent for the formula could be, for example, lemon. The aroma compounds matching these criteria are shown in Table 8.

Table 8. Aroma compounds which are soluble in alcohol and have a lemon scent.

Aroma	Smile	CAS n°	Solvents	Smell class	T_{melt} (K)	T_{flash} (K)
citral	<chem>CC(=CCCC(=CC=O)C)C</chem>	5392-40-5	alcohol, oil	fruit, aromatic leaf and seed	365.4	501
d-limonene	<chem>CC1=CC[C@@H](CC1)C(=C)C</chem>	5989-27-5	alcohol, oil	fruit, aromatic leaf and seed	321.5	450
octanal	<chem>CCOC(=O)CC(C(=O)OCC)O</chem>	7554-12-3	water, alcohol, oil	fruit, green, soap	325	443

The information shown in Table 8 are displayed as in Figure 17.

Step 9. Citral is selected since it is the safest ingredient (highest flash point). When the user select citral, he/she is redirected to the summary worksheet, where the product recipe is shown.

Appendix A

Installation notes

The virtual PPD-lab consists of a folder named 'Product-Process Design Lab'. This folder has to be placed in the CAPEC folder which is present in the C drive. The path is:

C:\CAPEC\Product-Process Design Lab.

To access the user interface, the user has to open the 'Framework' directory contained in the 'Product-Process Design Lab' directory. Here, the user has to open the file: 'Pre-framework.xls'.

Notes:

- The user should not change the names of the files contained in each folder;
- The user can access each Excel file contained in any of the folders, and the user can make modifications, add data, but the user can not change the order of the columns in the file.

Appendix B

Tutorial 1: pure compound properties

Table B1 shows some information and the UNIFAC group decomposition for the water soluble alcohols of tutorial 1, while Table B2 shows the pure compound properties.

Table B1. Information and UNIFAC (VLE and LLE) decomposition for the water soluble alcohols of tutorial 1.

Name	Formula	CAS n	Smile	UNIFAC VLE (occurrence, sub-group n°)	UNIFAC LLE (occurrence, sub-group n°)
methanol	CH4O	67-56-1	OC	1 16	1 1 1 14
ethanol	C2H6O	64-17-5	OCC	1 1 1 2 1 15	1 1 1 2 1 14
1-propanol	C3H8O	71-23-8	OCCC	1 1 2 2 1 15	1 15
2-propanol	C3H8O	67-63-0	OC(C)C	2 1 1 3 1 15	1 16
allyl alcohol	C3H6O	107-18-6	C=CCO	1 2 1 5 1 15	1 2 1 5 1 14

Table B2. Pure compound properties for the water soluble alcohols of tutorial 1.

Name	M_w (kg/kmo)	ρ (kg/l)	C (\$/kmol)	$-\log(LC_{50})$ (mol/l)	μ (cP)	V_m (l/kmol)	δ (MPa ^{0.5})
methanol	32.04	0.79	30.86	0.4	0.55	40.76	29.61
ethanol	46.07	0.80	114.30	0.85	1.08	57.30	26.52
1-propanol	60.09	0.80	214.64	1.3	1.97	74.96	24.54
2-propanol	60.09	0.78	85.51	1.17	2.06	76.79	23.53
allyl alcohol	58.08	0.93	95.17	0.98	1.65	62.20	27.46

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