

**Default Methodology for Analysis of Airborne Exposure to Mixtures
of Chemicals in Emergencies:**
The User's Guide for the Chemical Mixture Methodology

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1. INTRODUCTION

This paper provides a brief users guide for the Chemical Mixture Methodology (CMM) workbook. The CMM workbook is set up to automatically apply the DOE Subcommittee on Consequence Assessment and Protective Actions (SCAPA) recommended default methodology for a user-supplied mixture of chemicals. This methodology is published in the *Annals of Occupational and Environmental Hygiene* (Volume 14[9], 609-617, 1999) and is available at <http://orise.orau.gov/emi/scapa/files/DOE-SCAPA-Mixture-Methodology-Paper.pdf>).

The CMM provides recommended default emergency exposure guidelines for mixtures of chemicals. The CMM is a more realistic predictor of potential human health impacts than can be obtained using the non-conservative method of separately analyzing the consequences of each chemical component or the overly-conservative method of adding the exposures from each chemical together regardless of the organ targeted by the chemical. The CMM is recommended by SCAPA for potential use in Emergency Planning Hazards Assessments (see [DOE O 151.1C](#)), Documented Safety Analyses (see [10 CFR 830](#)), and for consequence assessments supporting emergency response exercises or actual accident situations.

When using the CMM, a hazard index (HI) is calculated for each component of a chemical mixture at the chosen receptor point. The "HI_i" is the concentration of chemical "i" (Conc_i) divided by the concentration limit for chemical "i" (Limit_i). The appropriate concentration limit for a chemical is determined based on its Protective Action Criteria (PAC). The PACs have been developed to assist in emergency planning of chemical release events and are based on the chemical concentration limits provided in the Acute Exposure Guideline Level (AEGLE), Emergency Response Planning Guideline

(ERPG), and Temporary Emergency Exposure Limit (TEEL) data sets¹. The PACs are presented in a searchable database (see <http://www.atlintl.com/DOE/teels/teel.html>) and as lists of tables and spreadsheets (see http://www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel.html).

For a given chemical, an $HI_i \leq 1$ means that the PAC concentration limit for that single chemical "i" has not been exceeded. However, if the hazard indices for all chemicals in a mixture are summed, and the cumulative hazard index is greater than one, then an unacceptable condition may exist for human health and safety and mitigating strategies may need to be considered. Unless the health effects of the components are known to be independent in their mode of toxicity, the toxic consequences of all components should, as an initial step in an assessment, be considered to be additive. This represents the most conservative upper-bound approach for assessing exposures to mixtures².

If this upper-bound approach produces unacceptable results, the next step is to classify the chemicals in the mixture according to their toxic consequences. The toxicologic classification of specific chemicals can be done using the health code numbers (HCNs) established for each chemical.

HCNs are used in the CMM to identify the target-organ effects of each chemical in the mixture. Any chemicals that target the same or similar organs or operate by the same acute (i.e., short-term) or chronic (i.e., long-term) mode of toxicity should be considered additive to that target organ or

¹ The AEGLs are developed by the U.S. Environmental Protection Agency (EPA) National Advisory Committee and the National Research Council AEGL Subcommittee, ERPGs are produced by the American Industrial Hygiene Association (AIHA) Emergency Response Planning Committee, and TEELs are developed by SCAPA. The committee-based process for developing AEGLs and ERPGs is thorough and time-consuming. In contrast, TEELs can be quickly produced using a semi-automated approach that quickly examines a variety of data sources. The TEEL development methodology has always called for preferentially using AEGL or ERPG data, when available, in the TEEL data set. Recently, the generic term "PAC" was introduced to emphasize that the "PAC data set" (formerly the "TEEL data set") incorporates AEGL and ERPG values as well as TEEL values.

² The CMM does not consider reactions between the chemicals in the mixture that in some cases could generate new chemicals, alter the chemical mixture, or change the mixture's dispersion properties. This level of complexity is beyond the current scope of the CMM.

by that same mode of toxicity. For simplicity in this discussion, target-organ effects and modes of toxicity are considered simply as target-organ effects.

Summation of the HIs for all chemicals in a mixture having the same toxic consequences (i.e., the same or similar HCNs) enables determination of the acceptability or unacceptability of exposure to any specific mixture of chemicals using this more discerning and realistic approach.

HCNs offer a convenient way of performing this exposure addition by numerically "binning" identical or similar target-organ effects. All of the individual exposure HIs that are binned into the same or similar HCN bin are added together to yield an "HI sum" for that target-organ bin.

Any of the individual HI sums that exceed a value of 1.0 indicate that the exposure limit has been exceeded and that some kind of mitigating action should be taken to reduce the exposure to that target organ below the applicable limit. Some organizations have established an "action level," typically 50% of the limit, which triggers initiation of mitigating strategies in an effort to assure that the limit itself is never exceeded.

2. THE CMM WORKBOOK

The Excel-based CMM workbook employs six worksheets:

1. "Input"
2. "Import"
3. "HIs by mode"
4. "HIs by target organ"
5. "Output"
6. "HCN-PAC"

To use the CMM workbook, the user enters information on a mixture of chemicals into the *Input* worksheet. This information includes the name of each chemical in the mixture, an identification number for each chemical, the specific PAC of concern, and the concentration of each chemical at a common (to all chemicals in the mixture) user-selected receptor location.

The *Input* worksheet has room for the entry of up to thirty (30) chemicals in a given mixture. If the user has a mixture involving more than 30 chemicals, it will be necessary to contact the SCAPA Chemical Mixtures Working Group points of contact (see <http://orise.orau.gov/emi/scapa/contacts.htm>). As of November, 2007 these working group contacts are Doug Craig (803-599-4018; craigdk@earthlink.net) and Rocky Petrocchi (303-843-3236; rocky.petrocchi@wgint.com).

To provide the user with ready access to the chemical-specific information required to complete the *Input* worksheet, reference information for each chemical is provided in the *HCN-PAC* worksheet. This information consists of the name of each chemical, its Chemical Abstracts Service Registry Number (CASRN), HCN values, and PACs.

In this version of the CMM workbook, HCN data (presented in Columns E through N of the *HCN-PAC* worksheet) are available for all the chemicals that are contained in the Rev. 19 of the TEEL data set³. PAC data are provided for all the chemicals in PAC data set Rev. 23 (presented in Columns P through S of the *HCN-PAC* worksheet). As a result of the lag in creating HCNs for all chemicals in the PAC data set, chemicals that were introduced since Rev. 19 are listed in this worksheet with their PAC data but without HCN data. As a result, the impact of these chemicals in a mixture cannot be assessed using their specific target organ effects. In 2008, plans call for closing this gap and providing HCN values for many of those chemicals in the PAC data set that don't yet have HCN values.

Information on the chemical concentrations at the user-specified receptor location, as required in the *Input* worksheet, must be provided by the user. This is typically obtained from hand-calculations or atmospheric dispersion modeling results (e.g., EPICode, ALOHA).

The CMM workbook is designed to execute calculations automatically once data are entered or removed from the *Input* worksheet. However, in some cases it may be necessary to manually start the calculations. To execute the CMM worksheet calculations on a PC, simultaneously press "Ctrl" and "=" on the keyboard, or simply press the "F9" key. (*On an Apple computer, simultaneously press "Apple" or "Command" and "=" on your keyboard.*) After executing the calculations, HI information for each chemical in the input mixture and the sum of all HIs for the entire mixture will be provided in the *Output* worksheet. Intermediate and supplementary information is also provided in three other worksheets: *Import*, *HIs by mode*, and *HIs by target organ*.

³ The change in name from the "TEEL data set" to the "PAC data set" was made after the release of TEEL Rev 21.

Figure 1 provides an overview on how to use the CMM workbook.

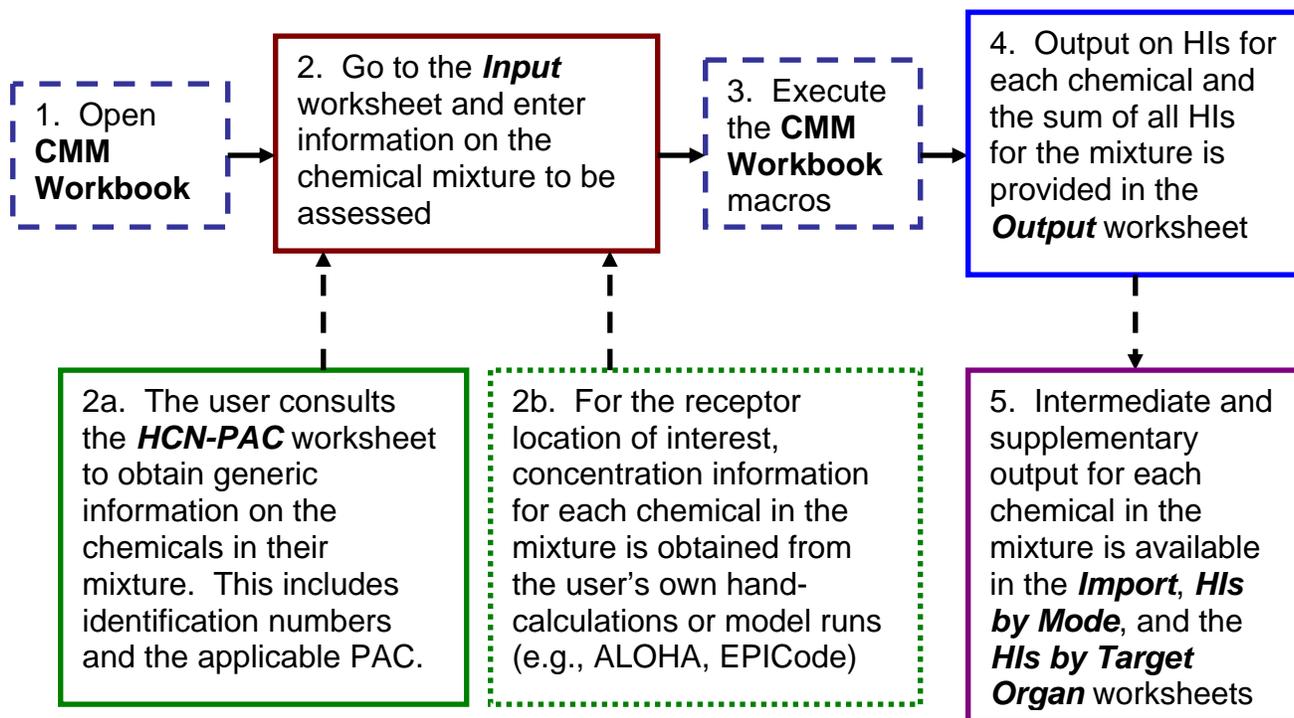


Figure 1. Simple Overview on How to Use the CMM Workbook. Steps 1-4 are the key steps, Steps 2a and 2b provide information in support of Step 2, and Step 5 provides optional intermediate and supplementary information.

Note that only the *Input* worksheet is used by the user to input information. While the *HCN-PAC* worksheet can also be modified by the user (e.g., to add new chemicals or updated PAC data), the other four worksheets are “password protected” to maintain the integrity of the CMM software. The four protected worksheets can be unprotected, by selecting *Protection* from the *Tools* menu and entering the password. However, the password can only be obtained from one of the CMM workbook developers (see <http://orise.orau.gov/emi/scapa/contacts.htm#teels> for contact information).

3. USING THE CMM WORKBOOK

The following are the steps to be completed when using the CMM workbook:

1. Open the CMM worksheet and if a security warning is displayed click the "**Enable Macros**" button.

Note: The CMM Excel workbook uses macros to perform all of its data lookups and calculations. Excel offers its users four levels of security (i.e., very high, high, medium, and low) for workbooks that use macros (to guard against macros that may have a malicious function). If your version of Excel has its macro security level set to "Very High" or "High", your computer will likely block execution of the CMM workbook's macros. To be able to execute the macros in the CMM workbook, the Excel security level should be set no higher than "Medium". To check the Excel security level, open the CMM workbook, and go to Tools → Macro → Security → Security Level (see Figure 2).

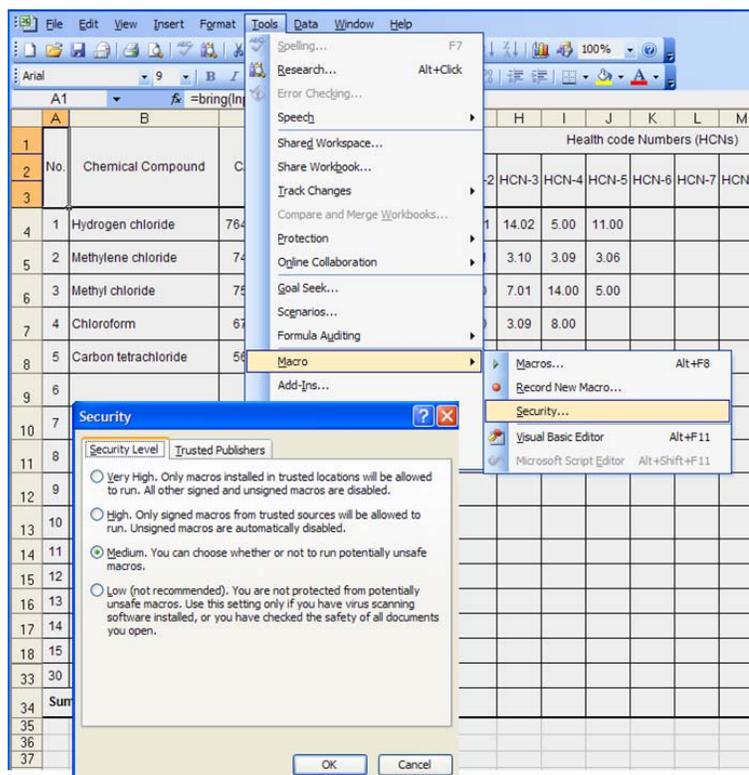


Figure 2. Setting the Security Level for Macros

Once the security level in any Excel workbook is set, it will stay at that level for all Excel applications until changed. At the "Medium" security level, a security warning (Figure 3) will be displayed when the user opens the CMM workbook and the user can choose to either enable or disable the workbook's macros. Clicking the "Enable Macros" button will allow the workbook to execute its macros.

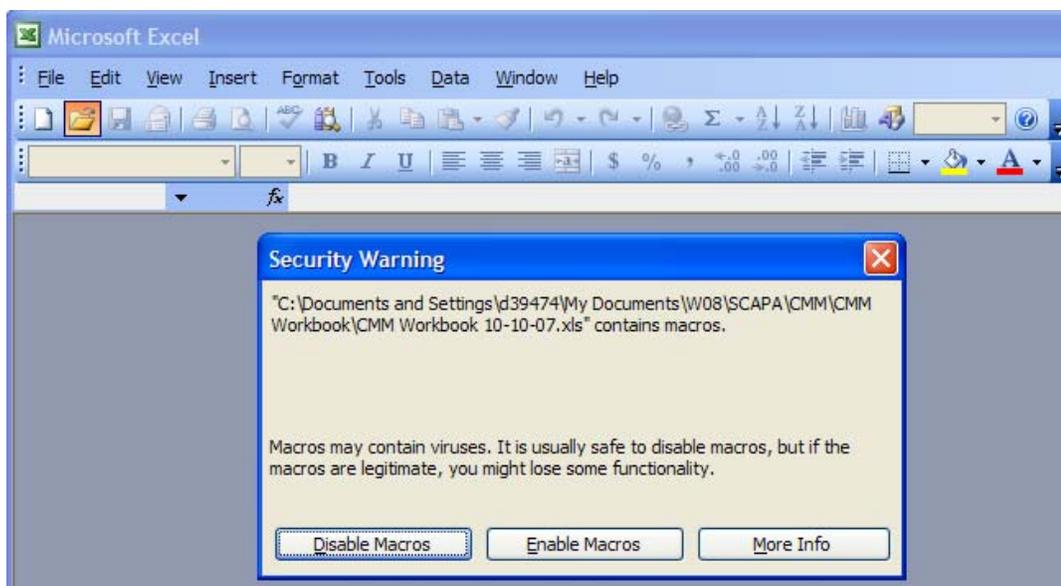


Figure 3. The Excel Security Warning about Macros

2. Go to the *Input* worksheet. Upon accessing the *Input* worksheet, input information for a sample mixture of chemicals is likely to be displayed. This mixture may be the example scenario that came pre-loaded with the workbook or it may be input data from the last time the workbook was saved. These "old" entries are provided for illustrative purposes only and the data containing information for chemicals not in the mixture being considered should be "cleared" from the worksheet (i.e., as shown in Figure 4, highlight the data entered in Columns B-F for the rows to be removed, right click this selection, and click "Clear Contents"). Do not "delete" or "cut" cell contents using the *Edit* menu, or by using the right mouse button's "delete" function. Only the "Clear Contents" selection (accessed from the Edit menu or by clicking the right mouse button) or the delete key on the keyboard should be used.

No.	Chemical Compound	CASRN	Receptor Point (RP)	Concentration Limit (LI) at RP (Enter "TEEL-0", "PAC-1", "PAC-2", or "PAC-3")	Conc. (C) at Receptor Point (mg/m ³)
1	Hydrogen chloride	7647-01-0	300 m	PAC-2	10
2	Methylene chloride	75-09-2	300 m	PAC-2	200
3	Methyl chloride	74-87-3	300 m	PAC-2	400
4	Chloroform	67-66-3	300 m	PAC-2	100
5	Carbon tetrachloride	56-23-5	300 m	PAC-2	50

The *Input* worksheet may display "factory-installed" demo input data or data from the last time the CMM workbook was used. Before entering information for a new mixture, clear the old entries from this worksheet (i.e., highlight the data entered in Columns B-F for the rows to be removed, right click this selection, and click "Clear Contents").

Note that the Concentration Limit (LI) values entered in Column E must be either "TEEL-0", "PAC-1", "PAC-2", or "PAC-3" (minus the quotes). PAC values are based on the applicable AEGLE, ERPG, or TEEL value (see <http://orise.orau.gov/emf/scapa/teels.htm> for definitions).

In the remote event that there are more than 15 chemicals in the mixture, rows 19-32 (chemicals numbered 16-29 in Column A) need to be unhidden.

To do this for this Input worksheet:
1. Highlight rows 18 and 33.
2. Go to the "Format" menu, then to "Rows", and click on "Unhide".

When finished entering the chemical data in a mixture, execute the macros if they have not executed on their own:

Using a PC:
Click "Ctrl" and "-" (at the same time) -- or -- Click "F9"

Using a Mac:
Click "Command" and "-" (at the same time)
-- or --
Click "Apple" and "-" (at the same time)

The *Output* worksheet shows final results for the chemical mixture as well as the contributions made by each chemical.

Intermediate results are presented in the *Import*, *His by Mode*, and *His by Target Organ* worksheets. If there are more than 15 chemicals and intermediate results need to be seen, contact the PAC & CMM development team (an email address and other contact information is provided at <http://orise.orau.gov/emf/scapa/contacts.html#teels>) for instructions on how to unhide rows 19-32 in those worksheets. The maximum number of chemicals in a given mixture that can be analyzed using this workbook is 30.

Figure 4. Clearing Old Data from the Input Worksheet

- In the *Input* worksheet enter the names of all the chemicals in the mixture in Column B. Enter one chemical name per row. This information is used to label output products. The chemical names, CASRN, HCNs, and PAC values for all chemicals supported in the workbook are provided in the *HCN-PAC* worksheet.

Users should check the *HCN-PAC* worksheet lookup table to ensure that each chemical in their mixture is listed in this worksheet before entering that chemical in the *Input* worksheet. The workbook will not make any calculations for chemicals not listed in the *HCN-PAC* worksheet.

Note: As chemical names and other information are entered into the *Input* worksheet, this input is shared and displayed in the other worksheets.

4. In the *Input* worksheet, enter the CASRN in Column C for each chemical listed in Column B. CASRN numbers should be obtained from Column C of the *HCN-PAC* worksheet. In cases where a listed chemical does not have a CASRN, a "substitute" CASRN number has been provided that the workbook will treat as a CASRN. If a CASRN is not entered in the *Input* worksheet for a given chemical; the workbook cannot calculate HIs for that chemical.
5. In the *Input* worksheet, enter location information for the receptor point of interest (e.g., "offsite at 600 m", "onsite at 300 m", "local at 400 m") in Column D. This information is not used in workbook calculations but is useful to the user in selecting input values for other *Input* worksheet parameters and for documentation purposes.
6. In the *Input* worksheet, determine the governing "concentration limit" at the receptor point and enter this information in Column E. The governing concentration limit is the applicable PAC (i.e., TEEL-0, PAC-1, PAC-2, or PAC-3)⁴. Input must be in this format (e.g., "PAC-2"). The PAC data in the *HCN-PAC* worksheet incorporate applicable AEGL, ERPG, and TEEL data.

If the chemical entered in the *Input* worksheet is listed in the *HCN-PAC* worksheet, the workbook uses the "TEEL-0" or "PAC-n" (where n = 1, 2, or 3) entry in Column E to obtain the actual concentration limit value from the appropriate PAC column in the *HCN-PAC* worksheet. The value obtained is automatically inserted as the concentration limit (in units of mg/m³) in Column D of the *Import* worksheet.

7. Calculate or otherwise obtain the airborne concentration (C_i) of each chemical "i" at the receptor point (from column D of the *Input* worksheet) and enter this value in Column F of the *Input* worksheet. This concentration must be in units of **mg/m³**. Concentrations may be obtained using values from existing data tables, manual calculations of atmospheric dispersion, or output from atmospheric dispersion models (e.g., ALOHA, EPICode).

⁴ The definitions for TEEL-0, -1, -2, and -3; AEGL-1,-2, and -3; and ERPG-1, -2, and -3 are provided at <http://www.atlintl.com/DOE/teels/teel/teeldef.html>.

8. If the calculations have not executed on their own, then manually execute the workbook calculations. On a PC, this is done by simultaneously pressing "Ctrl" and "=" on your keyboard, or by pressing the "F9" key. On an Apple computer, simultaneously press "Apple" or "Command" and "=" on your keyboard.

From this point forward, the workbook performs the calculations and the rows and columns in all subsequent worksheets are automatically completed.

9. The Hazard Index (HI_i) for each chemical (see Eqn. 1) at the receptor point of interest is reported in the *Import* worksheet in Column E and also in the *Output* worksheet in Column D.

$$HI_i = C_i / PAC_i \quad \text{Eqn. 1}$$

An HI_i that is 1.0 or greater indicates that a concentration limit (i.e., PAC limit value) has been exceeded.

10. Initially, the workbook sums all the HI_i values (see Eqn. 2) to determine acceptability of the scenario being evaluated, and whether protective actions or administrative controls should to be applied.

$$\sum_{i=1}^n HI_i = HI_1 + HI_2 + \dots + HI_n \quad \text{Eqn. 2}$$

The sum of the HI_i values is provided in the *Import* worksheet in the last row of Column E and also in the *Output* worksheet in Column E. If the sum of the HI_i values is less than or equal to 1.0 (as shown in Eqn. 3) there is no need to proceed with a further assessment.

$$\sum_{i=1}^n HI_i \leq 1 \quad \text{Eqn. 3}$$

If the sum of the HI_i values is greater than 1.00, then HCNs need to be employed to provide a more realistic, though still somewhat conservative, assessment of the hazard. To do this, the workbook continues with the following steps.

11. The workbook determines the toxicological classification of each chemical (i.e., their HCNs) from the values provided in the *HCN/PAC* worksheet (columns E through N). Up to 10 HCN values may be entered for each chemical. These values are derived by the CMM workbook development team. The workbook copies the HCN data for each chemical entered in the *Input* worksheet into the *Import* worksheet (columns F through O).

The category of each chemical is provided in *HCN/PAC* worksheet in Column O and is copied into Column P of the *Import* worksheet. The category gives the concentration-limit classification used to determine whether the toxicological consequences of exposure to a chemical are concentration-dependent, dose-dependent, or both (see Table 1). While the category is used in HCN and TEEL determination, it is not used explicitly in the mixture methodology. However, it may aid the user in determining whether a longer or shorter time period than the recommended 15-minute duration may logically be used in measuring or modeling the user-supplied concentration at the receptor point of interest (Column F in the *Input* worksheet).

12. The workbook sums the HIs of all chemicals having the same HCNs. For example, the HIs for those chemicals that are carcinogens (HCNs 1 and 2) are summed; chronic, systemic toxins (HCN = 3.00, 3.01-3.12) are separately summed; and acute systemic toxins (HCN = 4.00, 4.01-4.12) are also separately summed. These summations are done automatically by the workbook. Results for each major HCN grouping are presented in Columns D through S in the *HI by Mode* worksheet. The sum of the HIs for each HCN must be less than or equal to 1.00 for the exposure to be within prescribed limits. For the user's convenience, all summed HIs greater than or equal to the 0.5 action level are bolded **red**.

Table 1: Chemical Categories Used in the *Import Worksheet*: Column P. This table is from Craig et al., (1999)⁵.

Category ^A	Concentration-limit Classification ^A	Exposure duration treatment ^B
1A	Ceiling standard	Concentration-dependent ^D
1B	Irritants	Concentration-dependent ^D
1C	Technologic feasibility ^C	Concentration-dependent ^D
2	Acute toxicants	Dose-dependent ^E (exposure limits for 8 hours/day)
3	Cumulative toxicants	Dose-dependent ^E (exposure limits for 40 hours/wk)
4	Both acute and cumulative	Dose-dependent ^E (exposure limits for 8 hours/day and/or 40 hours/week)

Notes:

- A These categories are taken directly from Table 6.7, *Patty's Industrial Hygiene and Toxicology*, 2nd edition, volume 3A, page 156, John Wiley & Sons, New York (1985).
- B For release durations less than 15 minutes, concentrations may be calculated over a shorter time period, but not less than 1 minute if the chemical is known to exert immediate toxic effects.
- C Permissible exposure limits (PELs) for substances in this category have been set (by the U.S. Department of Labor Occupational Safety and Health Administration) either by technological feasibility or good hygiene practices, and no adjustments should be made based on the length of exposure, that is, these PELs are treated as ceiling limits. (See *Patty* reference in Note A)
- D For concentration-dependent chemicals, the concentration at the receptor point of interest is calculated as the peak 15-minute time-weighted average (TWA) concentration.
- E For dose-dependent chemicals, the concentration at the receptor point of interest may be calculated as the peak 60-minute TWA concentration.

⁵ D. K. Craig, R. L. Baskett, J. S. Davis, L. Dukes, D. J. Hansen, A. J. Petrocchi, T. J. Powell, P. J. Sutherland, and T. E. Tuccinardi, Jr. (1999). *Recommended Default Methodology for Analysis of Airborne Exposures to Mixtures of Chemicals in Emergencies*. Applied Occupational and Environmental Hygiene. Volume 14(9): 609-617, 1999

In performing summations, irritants are a special case. Irritants may be denoted as severe (HCN = 14.00), moderate (HCN = 15.00), or mild (HCN = 16.00) (as described in Craig et al., 1999). These are added together and weighted by severity (i.e., multiplied by 1.00 for severe, 0.5 for moderate, 0.25 for mild). Irritants that affect only one target organ can also be separately considered. For example, irritants affecting only the eyes are indicated by HCN = 14.01, 15.01, and 16.01 and irritants affecting only the skin are indicated by HCN = 14.02, 15.02, and 16.02.

The CMM workbook carries out computations for all chemicals that have HCN values listed in the *HCN-PAC* worksheet. If a chemical is not listed in the *HCN-PAC* worksheet, it may be added in the row after the last chemical on the list. The user will have to supply applicable HCNs and PACs for such chemicals. If there are no HCNs for a chemical in the mixture, but the chemical does have PACs, the user may use default HCNs by inserting 3.00 and 4.00 in Columns E and F, respectively.

The display of the CMM Workbook has been optimized for PCs at a zoom setting of 100%. Typical of the Excel workbook software, if a column is too narrow to display a cell's contents, the symbol "#####" will appear in that cell. To remedy this problem on worksheets that have not been password-protected, the column width can be manually expanded to display the worksheet's contents. On password-protected worksheets the column width cannot be adjusted; however, increasing the zoom percentage (e.g., from 75% to 100%) should allow the worksheets contents to be displayed. If the problem persists or if the printout also shows "#####" for some or all of the data, please email or call one of the SCAPA CMM contacts (see <http://orise.orau.gov/emi/scapa/contacts.htm#teels>).

4. SUMMARY DESCRIPTIONS OF THE CMM WORKSHEETS

In this section, summary descriptions are provided of each of the CMM workbook's worksheets and each worksheet column.

Worksheet 1 – Input (required user input)

Chemical Compounds, Receptor Point, Concentration Limit and Concentrations of Chemicals in the Mixture

Col. Information in the Column

- A** Sequential numbering of the chemicals in the mixture
- B** Names of the chemicals in the mixture
- C** CASRNs of the chemicals in the mixture. Includes alternate "Z" number IDs for chemicals that do not have CASRNs.
- D** Receptor Point
- E** Concentration Limit at Receptor Point. This is the applicable PAC, provided in the form of a "TEEL-0" or "PAC-n" (minus the quotation marks), where n is 1, 2, or 3.
- F** Concentration at Receptor Point (in units of mg/m³)

Note: Rows 19 through 32 are hidden, but may be viewed if needed, (e.g., there are more than 15 chemicals in the mixture), by highlighting rows 18 and 33, then clicking on *Format* in the menu bar, and then selecting *Row* and then *Unhide*. The *Input* worksheet is not protected. The chemicals on this worksheet at the moment are there for illustrative purposes, and should be replaced with the user's chemicals.

Worksheet 2 – Import (calculations performed automatically)**HI Calculation and HCNs for Chemicals in Mixture****Col. Information in the Column**

- A** Sequential numbering of the chemicals in the mixture
- B** Names of the chemicals in the mixture
- C** CASRNs of the chemicals in the mixture. Includes alternate "Z" number IDs for chemicals that do not have CASRNs.
- D** Concentration Limit – a PAC (mg/m³).
This is the actual concentration limit value for the "TEEL-0" or "PAC-n" specified in the *Input* worksheet, Column E. The concentration limit value, in units of mg/m³, is obtained from the *HCN-PAC* worksheet, Column P, Q, R or S for TEEL-0, PAC-1, PAC-2, or PAC-3, respectively.
- E** Hazard Index (HI), *Input* Column F divided by *Import* Column D

F-O Health Code Numbers (HCNs)

- F** HCN-1, Column E from *HCN-PAC* worksheet
- G** HCN-2, Column F from *HCN-PAC* worksheet
- H** HCN-3, Column G from *HCN-PAC* worksheet
- I** HCN-4, Column H from *HCN-PAC* worksheet
- J** HCN-5, Column I from *HCN-PAC* worksheet
- K** HCN-6, Column J from *HCN-PAC* worksheet
- L** HCN-7, Column K from *HCN-PAC* worksheet
- M** HCN-8, Column L from *HCN-PAC* worksheet
- N** HCN-9, Column M from *HCN-PAC* worksheet
- O** HCN-10, Column N from *HCN-PAC* worksheet
- P** Category Column O from *HCN-PAC* worksheet

Check to see if all of the HIs values in Column E are less than or equal to 1.00. If the sum is \leq 1.00, then the exposure is within established limits and there is no need to consult the next worksheet. Row 34 presents the Sum of the HIs for all chemicals in mixture.

Rows 19 through 32 are hidden, but may be viewed, if needed, by first "unprotecting" this worksheet. This may be done by selecting *Protection* from the *Tools* menu and entering the password. However, the password can only be obtained from one of the CMM workbook developers (see <http://orise.orau.gov/emi/scapa/contacts.htm#teels> for contact information).

Worksheet 3 - HIs by Mode (calculation performed automatically)**Summation of HIs by Mode of Toxic Action for Chemicals in Mixture****Col.** **Information in the Column**

- A** Sequential numbering of the chemicals in the mixture
- B** Names of the chemicals in the mixture
- C** CASRNs of the chemicals in the mixture. Includes alternate "Z" numbers for chemicals without CASRNs.

D-K **Hazard Indices for Chemicals with same HCNs**

- D** HCN = 1 or 2 Carcinogens
- E** HCN = 14, 15, or 16 Irritants,(weighted sums at foot of column)
- F** HCN = 3 Chronic Systemic Toxins
- G** HCN = 4 Acute Systemic Toxins
- H** HCN = 5 Reproductive Toxins
- I** HCN = 6 Cholinesterase Toxin
- J** HCN = 7 Nervous System Toxin
- K** HCN = 8 Narcotics

L-S **Hazard Indices for Chemicals with same HCNs**

- L** HCN = 9 Respiratory Sensitizer
- M** HCN = 10 Chronic Respiratory Toxin
- N** HCN = 11 Acute Respiratory Toxin
- O** HCN = 12 Blood Toxin Anemia
- P** HCN = 13 Blood Toxin Methemoglobinemia
- Q** HCN = 17 Asphyxiants
- R** HCN = 18 Explosive, flammable safety
- S** HCN = 19, 20 Other & nuisance

All "Sums of Toxic Mode or Endpoint-specific HIs" (Row 34: Columns D - S) must be ≤ 1.00 to be within established limits. If not, individual HIs need to be examined to pinpoint the chemicals in the mixture that are contributing most to the sum(s).

Rows 19 through 32 are hidden, but may be viewed, if needed, by first unprotecting this worksheet. This may be done by selecting *Protection* from the *Tools* menu and entering the password. However, the password can only be obtained from one of the CMM workbook developers (see <http://orise.orau.gov/emi/scapa/contacts.htm#teels> for contact information).

Worksheet 4 – HIs by Target Organ (calculation performed automatically)**Summation of Hazard Indices by Target Organ for Chemicals in Mixture**

Note: (C) = Chronic, (A) = Acute

Col. Information in the Column

- A** Sequential numbering of the chemicals in the mixture
- B** Names of the chemicals in the mixture
- C** CASRNs of the chemicals in the mixture. Includes alternate "Z" numbers for chemicals without CASRNs.

D-I Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)

- D** HCN = 1.00, or 2.00 Carcinogens unspecified target organ (C)
- E** HCN = 1.01, 1.00 or 2.00 Bladder cancer (C)
- F** HCN = 2.01, 1.00, or 2.00 Kidney cancer (C)
- G** HCN = 1.02, 2.02, 1.00, or 2.00 Liver cancer (C)
- H** HCN = 3.01 or 3.00 Bladder toxin (C)
- I** HCN = 4.03 or 4.00 Bladder toxin (A)

J-O Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)

- J** HCN = 3.02 or 3.00 Hematological system unspecified effects (C)
- K** HCN = 4.06 or 4.00 Hematological system unspecified effects (A)
- L** HCN = 3.03 or 3.00 Bone toxin (C)
- M** HCN = 4.13 or 4.00 Bone toxin (A)
- N** HCN = 3.04 or 3.00 Bone marrow toxin (C)
- O** HCN = 4.04 or 4.00 Bone marrow toxin (A)

(continued)

Col. Information in the Column**P-U Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)**

- P** HCN = 3.05 or 3.00 Brain toxin (C)
Q HCN = 4.05 or 4.00 Brain toxin (A)
R HCN = 3.06 or 3.00 Eye toxin (chronic ocular effects) (C)
S HCN = 4.01 or 4.00 Eye toxin (acute, other than irritation) (A)
T HCN = 3.07 or 3.00 Gastrointestinal tract toxin (C)
U HCN = 4.07 or 4.00 Gastrointestinal tract toxin (A)

V-AA Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)

- V** HCN = 3.08 or 3.00 Heart, Cardiovascular system toxin (C)
W HCN = 4.08 or 4.00 Heart, Cardiovascular system toxin (A)
X HCN = 3.09 or 3.00 Kidney toxin (C)
Y HCN = 4.09 or 4.00 Kidney toxin (A)
Z HCN = 3.10 or 3.00 Liver toxin (C)
AA HCN = 4.10 or 4.00 Liver toxin (A)

AB-AG Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)

- AB** HCN = 3.11 or 3.00 Skin toxin, incl. dermatitis & sensitization (C)
AC HCN = 4.11 or 4.00 Skin toxin, other than irritation (A)
AD HCN = 3.12 or 3.00 Skin perforation (C)
AE HCN = 4.12 or 4.00 Skin perforation (A)
AF HCN = 4.02 or 4.00 Nose toxin, other than irritation (A)
AG HCN = 5.10 or 3.00 Reproductive system toxin (C)

(continued)

Col. Information in the Column

AH-AN Hazard Indices for Chemicals with same HCNs: (HI sums in row 34)

AH HCN = 5.00, 4.00 Reproductive system toxin (A)

AI HCN = 7.00, 7.01, 8.00, 6.00 or 4.00 Nervous system, including CNS, narcosis, cholinesterase toxin (A)

AJ HCN = 7.10, 7.11, or 3.00 Nervous system, including CNS (C)

AK HCN = 9.00, 10.00 or 3.00 Respiratory system toxin, including sensitizers (C)

AL HCN = 11.00, 11.01, or 4.00 Respiratory system toxin, including severe & moderate irritation (A)

AM HCN = 12.00, 3.02, or 3.00 Blood toxin, anemia (C)

AN HCN = 13.00, 17.00, 4.06 or 4.00 Blood toxin, Methemoglobinemia and asphyxiants (A)

All "Sums of Organ-specific HIs" (Row 34 Columns D through AN) must be ≤ 1.00 to be within established limits.

Rows 19 through 32 are hidden, but may be viewed, if needed, by first unprotecting this worksheet. This may be done by selecting *Protection* from the *Tools* menu and entering the password. However, the password can only be obtained from one of the CMM workbook developers (see <http://orise.orau.gov/emi/scapa/contacts.htm#teels> for contact information)

Worksheet 5 – Output (calculations performed automatically)**Mixture Methodology Output Summary****Col. Information in the Column**

- A** Sequential numbering of the chemicals in the mixture
- B** Names of the chemicals in the mixture
- C** CASRNs of the chemicals in the mixture. Includes alternate "Z" numbers for chemicals without CASRNs.
- D** Individual Hazard Index (HI)
- E** Sum of all HIs
- F** Blank
- G-H Toxic Mode or Endpoint-specific HIs*
- G** Mode or Endpoint
- H** HI sums that are ≥ 0.25 (values ≥ 0.5 are displayed using a **bolded, red** font)
- I-J Sum of Organ-specific HIs:*
- I** Organ
- J** HI sums that are ≥ 0.25 (values ≥ 0.5 are displayed using a **bolded, red** font)

This worksheet summarizes information in worksheets 2, 3, and 4. If the sum of all HIs ≤ 1 , there is no need to consult the information contained further to the right in this worksheet. If all endpoint-specific or organ-specific HIs ≤ 1 , exposure is within established limits.

Columns H and J present HI sums ≥ 0.25 . This value was chosen because it captures HI sums that are potentially significant. Values ≥ 0.5 are further highlighted because these HI sums are within a factor of two of exceeding the exposure limit.

Worksheet 6 – HCN-PAC⁶ (used by the Workbook as a look-up table only):

HCNs and PACs (mg/m³)

Col. Information in the Column

- A** Sequential numbering of the chemicals in the mixture (Column A)
- B** Names of the chemicals in the mixture (Column B). For a given chemical, if any of the "PAC" values are AEGLs, then the name is in **12 point font and bolded**. Similarly, if any of the "PAC" values are ERPGs, then the name is in **10 point font and bolded**.
- C** CASRNs of the chemicals in the mixture (Column C). Includes alternate "Z" numbers for chemicals without CASRNs. For a given chemical if any of the "PAC" values are AEGLs, then the CASRN is in 12 point font and bolded. Similarly, if any of the "PAC" values are ERPGs, then the CASRN is in 10 point font and bolded.
- D** SAX number⁷ (Column D)

E-N Applicable HCNs from Rev. 19 of the PAC/TEEL Data Set

- E** Health Code Number - HCN 1
 - F** Health Code Number - HCN 2
 - G** Health Code Number - HCN 3
 - H** Health Code Number - HCN 4
 - I** Health Code Number - HCN 5
 - J** Health Code Number - HCN 6
 - K** Health Code Number - HCN 7
 - L** Health Code Number - HCN 8
 - M** Health Code Number - HCN 9
 - N** Health Code Number - HCN 10
- O** Category - this gives the concentration-limit classification used to determine whether the toxicological consequences of exposure to a chemical are concentration-dependent, dose-dependent, or both

⁶ The HCN-PAC worksheet was called the "HCN-TEEL" worksheet in all versions of the workbook released prior to October, 2007.

⁷ See Lewis RJ, Sr. *Sax's Dangerous Properties of Industrial Materials* (CD ROM), 11th ed. New York, NY: John Wiley & Sons, 2004.

P-S PACs (in mg/m³) which incorporate available AEGLs, ERPGs, and TEELs. Values are based on the Rev 23 of the PAC data set. If a PAC value is an AEGL, then it is in 12 point font and bolded. If a PAC value is an ERPG then it is in 10 point font and bolded. TEELs are in 10 point font, regular.

P TEEL-0
Q PAC-1
R PAC-2
S PAC-3

All PAC/TEEL values are given in units of mg/m³. Some of these values were converted from different "original units" (e.g., ppm).

Data in this worksheet are copied from other sources of information. This worksheet is not intended to be printed as part of the mixture methodology file.

This worksheet will be updated periodically as PACs and HCNs are developed for new chemicals or PACs are otherwise changed (see <http://orise.orau.gov/emi/scapa/teels.htm> for more information).