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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Health Code Number (HCN) Development Procedure

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September 2013

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Summary

This report provides the detailed description of health code numbers (HCNs) and the procedure of how each HCN is assigned as originally developed by Rocky Petrochhi and Doug Craig. It contains many guidelines and rationales of HCNs. HCNs are used in the chemical mixture methodology (CMM), a method recommended by the department of energy (DOE) for assessing toxic health effects as a result of exposures to airborne aerosols in an emergency. The procedure is a useful tool for proficient HCN code developers. Intense training and quality assurance with qualified HCN developers are required before an individual comprehends the procedure to develop HCNs for the Department of Energy (DOE). The procedure was first published as a URS report (28008-2009.03-A). In order to make it more publicly available, it is presented as a Pacific Northwest National Laboratory project report. This document is searchable and downloadable in the public domain. Future revisions are expected to update the content of the procedure. When a revision is published, HCN developers are advised to use the newest version for instructions. This report will serve as an important historical document for CMM development and a valuable reference in the future.

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level (EPA)
AIHA	American Industrial Hygiene Association
BEI	Biological Exposure Index
C	Ceiling
Ca	Carcinogen designation by OSHA and NIOSH
CASRN	Chemical Abstracts Service Registry Number
CHRIS	Chemical Hazards Response Information System (U.S. Coast Guard)
CMM	Chemical Mixture Methodology
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guideline (AIHA)
HCN	Health Code Number
HI	Hazard Index (Exposure Concentration divided by Exposure Limit)
HSDB	Hazardous Substances Data Bank (U.S. National Library of Medicine)
IARC	International Agency for Research on Cancer
ID	Insufficient data
LC50	Lethal Concentration to 50% of the experimental population
LClo	Lethal Concentration, low (lethal threshold)
LD50	Lethal Dose to 50% of the experimental population
LDlo	Lethal Dose, low (lethal threshold)
MAK	Federal Republic of Germany Maximum Concentration Values in the Workplace
NAS	National Academy of Sciences
NIC	Notice of Intended Changes (ACGIH TLV Booklet)
NIOSH	U.S. National Institute for Occupational Safety and Health
NTP	U.S. National Toxicology Program
OEV Guide	ACGIH Guide to Occupational Exposure Values
OSHA	U.S. Occupational Safety and Health Administration
OHMTADS	Oil and Hazardous Materials—Technical Assistance Data System (EPA)
PAC	Protective Action Criterion (a generic term for any of the several emergency exposure limit values)

RTECS	Registry of Toxic Effects of Chemical Substances (NIOSH)
SAX	Sax's Dangerous Properties of Industrial Materials (John Wiley & Sons)
SCAPA	U.S. DOE Subcommittee on Consequence Assessment and Protective Actions
STEL	Short-Term Exposure Limit
TClo	Toxic Concentration, low (inhalation toxicity threshold)
TDlo	Toxic Dose, low (toxicity threshold by any route except inhalation)
TLV	Threshold Limit Value

Acknowledgments

This procedure was first developed by Rocky Petrochhi and Doug Craig. Major revisions were made in collaboration with the Chemical Mixture Methodology (CMM) team in 2008. We thank Department of Energy Emergency Management Program (NA-41) for their support of the CMM. Xiao-Ying Yu would like to thank Ms. Juan Yao for proof-reading and reformatting this document. The CMM team would like to acknowledge programmatic support from Mr. Clifford Glantz and Ms. Eva Hickey.

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Tables

1.0 Introduction

1.1 SCAPA Chemical Mixture Method

A chemical mixture methodology (CMM) for assessing exposures to chemical mixtures in an emergency release setting has been developed and published by the Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Actions (SCAPA) to allow emergency planning personnel to evaluate the potential impact on human health from the simultaneous airborne exposure to a released mixture of several chemicals [Craig et al., 1999]. For each chemical in a mixture, the CMM uses the following information to analyze the exposure:

- Protective action criteria (PACs) emergency exposure limits
- Health Code Numbers (HCNs) representing target-organ adverse health effects
- Measured or estimated exposure concentrations at the receptor point of interest.

1.2 Traditional Methods for Chemical Mixture Analysis

Traditionally, some planners and analysts treat each chemical in a released airborne mixture independently of one another. This is often a non-conservative approach since some of those chemicals likely target the same organs, which would make those effects additive to those target organs.

At the other end of the chemical mixture exposure analysis spectrum, a traditional and relatively simple first approximation of the health impacts from exposure to a chemical mixture is to sum all of the projected health effect impacts associated with each chemical in a mixture regardless of each chemical's target-organ effects. This approach does not consider that the individual chemicals may be targeting different organs and that their impact may not be completely additive. This type of analysis is usually always used by emergency planners and safety analysts as part of an initial bounding analysis. If the results are below thresholds of concern, then the planner or analyst usually needs to go no farther. However, this bounding analysis may prove to be too confining yielding unnecessarily conservative results that may result in misdirected or less than optimally utilized emergency preparedness and response assets. In this situation, the CMM approach may be used to conduct a more sophisticated target-organ analysis.

1.3 Chemical Mixture Method with Target-Organ Analysis

The CMM makes use of HCNs in a more realistic target-organ analysis that separates chemical exposure into various target-organ groups or “bins”. One assumption made in the CMM is that the different target-organ groups do not interact with one another to any significant degree. This allows exposures to be separated and added within these target-organ bins. This approach yields more realistic results than the bounding method of adding all exposures together

regardless of target-organ effects but more conservative than treating all chemicals in the mixture independently of one another.

It is recognized that in real life, different organs or organ systems interact with one another to one degree or another to modulate the toxicity of a chemical or a mixture of chemicals so that some cross-organ interactions may be occurring. However, to make the CMM workable, some simplifying assumptions were made so that the current CMM version does not take into consideration the complexities of cross-organ interactions. For a full explanation of the CMM, the reader is referred to the journal article describing this method [Craig et al., 1999].

1.4 New Acute Health Code Numbers Introduced

This revision of the HCN Development Procedure introduces several new acute HCNs (italicized and highlighted in Tables 1 and 2) that mirror many of the chronic HCNs that have been part of the CMM since its inception. This increases the number of HCNs from 47 to 60. Since acute health effects are the effects that are of immediate concern in an emergency event, the new acute HCNs will lend a degree of capability to the CMM that has not been available in the past.

1.5 Brief Description of SCAPA Chemical Mixture Method Operation

In addition to the chemical mixture data and receptor point concentrations required to be entered by the user in the CMM Excel file *Input* worksheet, other essential data that are required before the CMM can be used are PAC exposure limits that must be defined for each chemical and HCNs for target-organ health effects that must also be determined for each chemical in the mixture.

HCNs and PACs are entered in the look-up table, which is the last worksheet called "*HCN-PAC*" of the CMM workbook Excel file. The CMM workbook automates implementation of the many calculations involved in the CMM. As mentioned, the *HCN-PAC* worksheet acts as a look-up and fetching table for the CMM software macros. The macros fetch HCNs and PACs from the *HCN-PAC* worksheet for the chemicals in the mixture and use them together with other user-entered data in the *Input* worksheet to perform all of the CMM calculations. Intermediate results are displayed as Hazard Indices (HIs) in the *Import*, *HIs by Mode*, and *HIs by Target Organ* worksheets. Final HI exposure results for the mixture are displayed in the *Output* worksheet for both the bounding method and the target-organ "binning" method.

1.6 CMM Workbook Availability

The CMM workbook is available on the DOE SCAPA website at http://orise.orau.gov/emi/scapa/hcn.htm. This website also offers access to the *CMM User's Guide* which provides detailed instructions on how to use the workbook.

2.0 HCN Development Procedure

The following procedure describes a method that is followed by the CMM development team for deriving target-organ HCNs for individual chemicals. This procedure provides consistency in the way HCNs are derived and has been used during the past several years for developing HCNs for more than 2400 chemicals of concern within the DOE community.

2.1 HCN Status of a Chemical

- Determine if HCNs already exist for the chemical being considered.
- Check the Chemical Abstracts Service Registry Number (CASRN, preferred since it is unique), SAX Number, or chemical name against the current HCN database in the *HCN-PAC* worksheet.
- If HCNs already exist for this chemical, make a note of this and skip to the next chemical.
- If HCNs do not exist for the chemical being considered, continue with the procedure.

2.2 Reference Priority and Codes

Select target-organ-effect HCNs from the references listed in priority order in this section. Use the most recent copy of each reference except for the last three references (2.2.9 to 2.2.11) where a recent copy is acceptable (within about the last 5 years if possible). Normally all references are consulted for each chemical with the possible exception of the last three references and other exceptions as mentioned below in the "NOTEs" for this section. If conflicts arise between references, choose the data from the highest priority reference unless there is a compelling reason to do otherwise. An example of a conflict would be differences in the degree of irritation, e.g., severe, moderate, mild, or none. As in all cases, credible human data are generally preferred to animal data regardless of the reference priority. In the absence of human data, the higher priority reference governs unless there is good reason to do otherwise. Absence of the mention of an effect in a reference does not constitute a conflict with respect to the mention of that effect in another reference.

Use the reference codes in Appendix A to insert in the "Reference" column of the HCN-PAC look-up table (see also Section 2.3.2). All references and their codes that have been used in the past for HCN development are listed in Appendix A to facilitate future updates when needed.

Some chemicals have many synonyms. To avoid confusing one chemical with another using chemical names, use the CASRN when possible to find the chemical in the references since these numbers are unique. Verify that the chemical found in the references is the correct chemical by comparing CASRNs.

The following are recommended references to be used in the priority order indicated:

2.2.1 Acute Exposure Guideline Levels (AEGLs), National Academy of Sciences (NAS) Documentation [NAS, 2000-2007]. These are the six volumes of documentation supporting development of the current Final AEGL values for 38 chemicals as of December 2007. In addition, some Interim AEGLs have Technical Support Documents that are available only online at the AEGL website [AEGL Website].

2.2.2 Emergency Response Planning Guidelines (ERPGs) Documentation, American Industrial Hygiene Association (AIHA) [AIHA, 2001-2007]

2.2.3 CHEM-BANK Silver Platter CD ROM Toxicology Databases [Croner/Ovid, 2001-2008]

- Registry of Toxic Effects of Chemical Substances (RTECS), National Institute for Occupational Safety and Health (NIOSH)
- Hazardous Substances Data Bank (HSDB), National Library of Medicine

  NOTE: Many chemicals in this database use data from different but similar chemicals used as surrogates or data from a broad class of chemicals. When possible, use data for the specific chemical being considered rather than data from surrogate chemicals or data from a broad class of chemicals.
- Chemical Hazards Response Information System (CHRIS), U.S. Coast Guard
- Pocket Guide to Chemical Hazards, NIOSH
- Oil and Hazardous Materials—Technical Assistance Data System (OHMTADS), Environmental Protection Agency, 1991

  NOTE: Since development of this database was stopped in 1991, some of its data may be obsolete.

2.2.4 Sax's Dangerous Properties of Industrial Materials (SAX) CD ROM [SAX, 1998-2004]

2.2.5 Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) (TLV Booklet), American Conference of Governmental Industrial Hygienists (ACGIH) [ACGIH TLV, 1998-2007]

NOTE: Although the TLV Booklet exposure values would rarely if ever be used as the basis for any HCN selections, do not use the values in the "Notice of Intended Changes" (NIC) section of the TLV Booklet since these can either change or may not be adopted. However, the "TLV Basis—Critical Effect(s)" (target organ effects) in the NIC section could be used since these are unlikely to change.

2.2.6 Documentation of TLVs, ACGIH [ACGIH Doc, 1991-2007]

NOTE: Consult the ACGIH "Documentation of the TLVs and BEIs" only to clarify health effect notations in the TLV Booklet. Otherwise, this reference duplicates what is in the TLV Booklet and does not need to be consulted on a regular basis.

2.2.7 Guide to Occupational Exposure Values (OEV Guide), ACGIH [ACGIH OEV, 1998-2007]

2.2.8 Patty's Industrial Hygiene and Toxicology [Patty, 1985]

NOTE: The following references may be eliminated from the search if, in the developer's judgment, a representative number of target-organ effects have been found using the above higher priority references, particularly if target-organ effects begin to repeat many times.

2.2.9 Hawley's Condensed Chemical Dictionary [Hawley, 1993, 2001]

2.2.10 Handbook of Chemistry and Physics [CRC Handbook, 1981, 2001, 2005]

2.2.11 Material Safety Data Sheets (MSDSs) and Other References.

- For some chemicals having very little data in the normal references, MSDSs may have some very useful information. However, due to the inherent conservative nature of MSDSs in protecting a company's liability, "may" statements should not be used for HCN development. More positive statements, such as "causes", "produces", etc., are examples of statements that can by used for HCN development. The Sigma-Aldrich Company provides well prepared MSDSs at http://www.sigmaaldrich.com/Area_of_Interest/The_Americas/United_States.html for a large number of chemicals. After selecting "CAS No." and entering the CASRN in the search window, click on a product (preferably one that is fairly pure). Then click on the "MSDS" hyperlink under "Related Information" and an MSDS will pop up in a separate window as an Adobe pdf document that can be saved. Note that "popup blocker" must be turned off for the MSDS popup window to function. The MSDS should be saved to facilitate discussion between the developer and QA reviewer. MSDSs from other companies may be used as well at the discretion of the HCN developer.
- Other references may be used at the developer's discretion, particularly if data do not exist in the references normally used. These may include the United States NIOSH modified version of the International Chemical Safety Cards (ICSCs) at http://www.cdc.gov/niosh/ipcs/nicstart.html and any other references that the developer thinks are appropriate. However, primary journal article references should rarely if ever be used since doing so takes much time and is cost prohibitive.

2.3 HCN Development Guidelines

The following are general HCN development guidelines:

- Human data should be preferred to animal data regardless of the reference priority. In cases where there is an abundance of human data, human data only may be used.
- Only whole animal (mammalian) toxicity data should be used. Due to the difficulty of correlating in-vitro mutagenicity data to human exposure, in-vitro mutagenicity data should not be used.
- Use more specific HCNs rather than more general HCNs when the data in the references state that specific effects occur to a specific target organ. When the effects in the references are non-specific, use more general HCNs. For example, use 7.00 (General nervous system—acute effects) for unspecified acute nervous system effects. If the data show that there is a more specific result, like an acute effect that affects the CNS for example, then use 7.01 (Central nervous system—acute effects). However, see cautions on the use of the generalized HCNs 4.00 and 3.00 in Section 2.3.8.

2.3.1 File Preparation

Use a copy of the most recent version of the CMM workbook for entering all HCNs and other data in the *HCN-PAC* worksheet, which is the last worksheet in the CMM workbook. When this procedure was prepared, the most recent version of the CMM workbook was the 11/20/2007 version and could be found at http://orise.orau.gov/emi/scapa/hcn.htm. The *HCN-PAC* worksheet is used by the CMM workbook software as a look-up table for accessing the HCNs and PACs for each chemical. Before starting data entry, either insert the following 12 additional columns after "Category" (Column O) in the *HCN-PAC* worksheet or assure that they have already been inserted. Label them according to the following:

- "HCN Basis References" (Column P)
- "Comments" (Column Q)
- "QA Status, TBD = To be done, IP = In process, D = Done" (Column R)
- "HCN Dates" (Columns S-AA). These columns track initial development, review, and revision of HCNs and Category for chemicals.
  - "First derived" (Columns S-U). These columns are used when HCNs/Category are first developed for a chemical.
    - "Date" (Column S, all cells in column must be date formatted, mm/dd/yyyy). Insert the date that HCNs/Category were originally first developed.
    - "Author" (Column T). Insert the developer's initials.
    - "QA" (Column U). Insert the QA reviewer's initials. No date is needed.
  - "Last reviewed" (Columns V-X). These columns are used when HCNs/Category that are already developed for a chemical are reviewed, usually several years after initial development.

        - "Date" (Column V, all cells in column must be date formatted, mm/dd/yyyy). Insert the date that the HCNs/Category were reviewed.
        - "Author" (Column W). Insert the reviewer's initials.
        - "QA" (Column X). Insert the QA reviewer's initials. No date is needed.
    - "Last revised" (Columns Y-AA). These columns are used when a chemical's HCNs/Category are not only reviewed but also revised (changed)
        - "Date" (Column Y, all cells in column must be date formatted, mm/dd/yyyy). Insert the date that the HCNs/Category were revised.
        - "Author" (Column Z). Insert the reviser's initials.
        - "QA" (Column AA). Insert the QA reviewer's initials. No date is needed.

2.3.2 Data Entry

The following are general data entry guidelines:

- Before entering data into the electronic file, it may be helpful to enter the data on a hardcopy version first since some of the data may change as different references are consulted. This will also serve as a hardcopy backup in case the electronic file is somehow lost or corrupted.
- As data are entered, check them off on the hardcopy version so that it is certain that the data were entered. This will tend to minimize non-entry of data.
- When hand entering data, double check all entries after entering the data (self-QA check). This will tend to minimize manual data entry errors.

Using target-organ information found in the references listed in Section 2.2, the HCNs listed in Table 1 "HCNs—Listed in HCN Order" below that was adapted from the CMM journal paper [Craig et al., 1999], and the HCN development guidelines in the rest of Section 2.3, enter the following:

- Select up to 10 HCNs for each chemical. Place the HCNs in the HCN columns of the HCN-PAC worksheet. The HCNs can be placed in the HCN columns in any order. They do not need to be in any numerical or priority order. There are columns for up to 10 HCNs per chemical.
- In the "Chemical Category" column, insert the category number (see Section 2.4).
- In the "References" column, insert the reference codes corresponding to the references where the HCN target-organ information was found. Use Appendix A as a guide for these codes.
- If there are issues to resolve for a particular chemical, insert a "Q" (Question) in front of the reference codes to tag that chemical for follow-up resolution.
- Insert any needed comments and/or excess HCNs (see Section 2.3.3) in the "Comments" column.

- If there is more than one person developing HCNs, an author designation such as the developer's initials or some other appropriate unique code should be entered in the "Author" column to designate the HCN developer. In previous HCN development work, the codes "C" (Craig) and "P" (Petrocchi) were used to designate the HCN developers.
- As a practical matter when developing HCNs for chemicals already listed in the HCN-PAC worksheet but without HCNs, insert the HCNs in the blank HCN cells and then highlight that row so it can be identified easily for quality assurance checking purposes.
- If new chemicals need to be entered that are not in the HCN-PAC worksheet, begin entering their chemical names and other data after the last chemical in the worksheet.

2.3.3 More Than 10 HCNs

There are columns for up to 10 HCNs in the *HCN-PAC* worksheet. However, experience has shown that of the chemicals chosen for HCN development using the references cited above, about 10-15% of them had more than 10 HCNs selected. In the event where there are more than 10 HCNs for a chemical, select the 10 HCNs with the most significant health effects (i.e., highest rank) using Table 2 "HCNs—Listed by Effect-Based Rank". This table was developed in part using national vital statistics data for the year 2000 for death from various causes published by the National Center for Health Statistics [NCHS, 2001]. It ranks HCN health effects in the order of their seriousness from serious bodily injury or death in a fraction of a second to generally low-risk health effects. As before, the 10 priority-selected HCNs do not need to be placed in the 10 HCN columns in any particular order. The remaining HCNs can be entered in the Comments column so they are not lost to the development process although they will not appear in the final *HCN-PAC* worksheet of the CMM workbook on the DOE SCAPA website.

2.3.4 Carcinogens, OSHA

If the Occupational Safety and Health Administration (OSHA) regulates the chemical as a carcinogen (Ca), then use HCN 1.00 or its subsets (i.e., 1.01 Bladder Carcinogen or 1.02 Liver Carcinogen).

2.3.5 Carcinogens, Other Than OSHA

If OSHA does not regulate the chemical as a carcinogen, but ACGIH, the Environmental Protection Agency (EPA), the International Agency for Research on Cancer (IARC), the Federal Republic of Germany Maximum Concentration Values in the Workplace (MAK), the National Institute for Occupational Safety and Health (NIOSH), or the National Toxicology Program (NTP) Annual Report on Carcinogens have designated the chemical as a confirmed or suspected human or animal carcinogen in the following categories:

- ACGIH TLV categories A1, A2, A3
- EPA categories A, B1, B2, C (1986); K, L (1996); CaH, L, S (1999, 2005)
- IARC categories 1, 2A, 2B
- MAK categories 1, 2

- NIOSH category Ca
- NTP categories K, R

then use HCN 2.00 or its subsets (i.e., 2.01 Kidney Carcinogen or 2.02 Liver Carcinogen).

2.3.6 Target Organ Not Listed

If the toxicity references do not list a target organ for a chemical but only mention chronic or acute effects in general, toxicity should be assumed to be systemic (i.e., HCN 3.00 for chronic or 4.00 for acute). See Section 2.3.8 for more guidance on the use of HCN 4.00.

Table 1: HCNs—Listed in HCN Order

Rank	HCN	Target-Organ Effect
29	1.00	OSHA carcinogen (29 CFR 1910.1000) —*chronic effect*
30	1.01	Bladder carcinogen—*chronic effect*
31	1.02	Liver carcinogen—*chronic effect*
32	2.00	Suspect carcinogen or mutagen—*chronic effect*
33	2.01	Kidney carcinogen—*chronic effect*
34	2.02	Liver carcinogen—*chronic effect*
55	3.00	Systemic toxin—chronic effects
45	3.01	Bladder—chronic effects
41	3.02	Hematological effects—chronic, unspecified
46	3.03	Bone—chronic effects
42	3.04	Bone marrow—chronic blood-forming system and other chronic effects
35	3.05	Brain—chronic effects
47	3.06	Eye—chronic ocular effects
44	3.07	Gastrointestinal tract—chronic effects
28	3.08	Heart, Cardiovascular system—chronic effects
40	3.09	Kidney—chronic effects
43	3.10	Liver—chronic effects
52	3.11	Skin—chronic effects including dermatitis and sensitization
54	3.12	Skin perforation—nasal septum perforation and other chronic effects other than skin absorption
13	4.00	Systemic toxin—acute short-term high hazard effects
9	4.01	Eye—acute, other than irritation
20	*4.02*	*Nose—acute effects other than irritation*
26	*4.03*	*Bladder—acute effects*
23	*4.04*	*Bone marrow—acute blood-forming system and other acute effects*
15	*4.05*	*Brain—acute effects*
22	*4.06*	*Hematological effects—acute, unspecified*
25	*4.07*	*Gastrointestinal tract—acute effects*
14	*4.08*	*Heart, Cardiovascular system—acute effects*
21	*4.09*	*Kidney—acute effects*
24	*4.10*	*Liver—acute effects*
51	*4.11*	*Skin—acute effects other than irritation*
53	*4.12*	*Skin perforation—acute effects other than skin absorption*
27	*4.13*	*Bone—acute effects*
49	5.00	Reproductive toxin—acute effects
50	*5.10*	*Reproductive toxin—chronic effects*
4	6.00	Cholinesterase toxin—*acute effect*
18	7.00	Nervous system toxin—acute effects
16	7.01	Central nervous system—acute effects
37	*7.10*	*Nervous system toxin—chronic effects*
36	*7.11*	*Central nervous system—chronic effects*
17	8.00	Narcotic—*acute effect*

39	9.00	Respiratory sensitizer—*chronic effect*
38	10.00	Respiratory toxin—chronic effects
19	11.00	Respiratory toxin—acute effects other than irritation
10	*11.01*	*Respiratory irritant—acute severe or moderate but not mild irritant effects*
48	12.00	Blood toxin, anemia—*chronic effect*
3	13.00	Blood toxin, methemoglobinemia—*acute effect*
6	14.00	Severe irritant
5	14.01	Eye irritant—severe
11	14.02	Skin irritant—severe
8	15.00	Moderate irritant
7	15.01	Eye irritant—moderate
12	15.02	Skin irritant—moderate
57	16.00	Mild irritant
56	16.01	Eye irritant—mild
58	16.02	Skin irritant—mild
1	17.00	Asphyxiants, anoxiants—*acute effect*
2	18.00	Explosive, flammable safety (no adverse effects with good housekeeping)
59	19.00	Generally low risk health effects—nuisance particles, vapors or gases
60	20.00	Generally low risk health effects—odor

Adapted from: [Craig et al., 1999] *NOTE: New HCNs and new acute/chronic designations are italicized and highlighted*

Table 2: HCNs—Listed by Effect-Based Rank

Rank	HCN	Target-Organ Effect
1	17.00	Asphyxiants, anoxiants—*acute effect*
2	18.00	Explosive, flammable safety (no adverse effects with good housekeeping)
3	13.00	Blood toxin, methemoglobinemia—*acute effect*
4	6.00	Cholinesterase toxin—*acute effect*
5	14.01	Eye irritant—severe
6	14.00	Severe irritant
7	15.01	Eye irritant—moderate
8	15.00	Moderate irritant
9	4.01	Eye—acute, other than irritation
10	*11.01*	*Respiratory irritant—acute severe or moderate but not mild irritant effects*
11	14.02	Skin irritant—severe
12	15.02	Skin irritant—moderate
13	4.00	Systemic toxin—acute short-term high hazard effects
14	*4.08*	*Heart, Cardiovascular system—acute effects*
15	*4.05*	*Brain—acute effects*
16	7.01	Central nervous system—acute effects
17	8.00	Narcotic—*acute effect*
18	7.00	Nervous system toxin—acute effects
19	11.00	Respiratory toxin—acute effects other than irritation
20	*4.02*	*Nose—acute effects other than irritation*
21	*4.09*	*Kidney—acute effects*
22	*4.06*	*Hematological effects—acute, unspecified*
23	*4.04*	*Bone marrow—acute blood-forming system and other acute effects*
24	*4.10*	*Liver—acute effects*
25	*4.07*	*Gastrointestinal tract—acute effects*
26	*4.03*	*Bladder—acute effects*
27	*4.13*	*Bone—acute effects*
28	3.08	Heart, Cardiovascular system—*chronic effects*
29	1.00	OSHA carcinogen (29 CFR 1910.1000) —*chronic effect*
30	1.01	Bladder carcinogen—*chronic effect*
31	1.02	Liver carcinogen—chronic effect
32	2.00	Suspect carcinogen or mutagen—*chronic effect*
33	2.01	Kidney carcinogen—*chronic effect*
34	2.02	Liver carcinogen—*chronic effect*

35	3.05	Brain—chronic effects
36	*7.11*	*Central nervous system—chronic effects*
37	*7.10*	*Nervous system toxin—chronic effects*
38	10.00	Respiratory toxin—chronic effects
39	9.00	Respiratory sensitizer—*chronic effect*
40	3.09	Kidney—chronic effects
41	3.02	Hematological effects—chronic, unspecified
42	3.04	Bone marrow—chronic blood-forming system and other chronic effects
43	3.10	Liver—chronic effects
44	3.07	Gastrointestinal tract—chronic effects
45	3.01	Bladder—chronic effects
46	3.03	Bone—chronic effects
47	3.06	Eye—chronic ocular effects
48	12.00	Blood toxin, anemia—*chronic effect*
49	5.00	Reproductive toxin—acute effects
50	*5.10*	*Reproductive toxin—chronic effects*
51	*4.11*	*Skin—acute effects other than irritation*
52	3.11	Skin—chronic effects including dermatitis and sensitization
53	*4.12*	*Skin perforation—acute effects other than skin absorption*
54	3.12	Skin perforation—nasal septum perforation and other chronic effects other than skin absorption
55	3.00	Systemic toxin—chronic effects
56	16.01	Eye irritant—mild
57	16.00	Mild irritant
58	16.02	Skin irritant—mild
59	19.00	Generally low risk health effects—nuisance particles, vapors or gases
60	20.00	Generally low risk health effects—odor

Adapted from: [Craig et al., 1999] *NOTE: New HCNs and new acute/chronic designations are italicized and highlighted.*

2.3.7 Acute vs. Chronic

References vary in their definitions for the acute time period. Some define acute as less than one week. Others define it as one week. Still others define it as more than one week up to about two weeks. Since we are addressing short-term emergency exposures and for consistency, the decision was made to set the cutoff for acute effects at one week. Any time period longer than one week should be considered chronic. Although one week to about 90 days is usually considered subchronic, there is currently no HCN designation for this time period. Therefore, subchronic effects should be considered chronic for HCN purposes. If the acute or chronic nature of the target-organ effect is not mentioned in the literature and the nature of the effect itself does not offer any clues as to whether it is acute or chronic, then assume an acute effect for emergency planning and response purposes.

2.3.8 Limitations on the Use of HCNs 4.00 and 3.00

Routinely assigning the broad categories HCN 4.00 (Acute short-term high hazard effects) and/or HCN 3.00 (Chronic effects) to chemicals for any acute or chronic effect will essentially result in most chemicals with these kinds of effects being placed in nearly all acute and chronic categories. When used in the CMM, it forces the exposures for all HCN 4.00 and HCN 3.00 chemicals in the mixture to be added together, thereby defeating the CMM purpose of separating exposures by target-organ effects. Following the guidelines below will minimize this undesirable overly conservative effect while at the same time assuring that HCN 4.00 and HCN 3.00 are assigned when appropriate, but only when high-hazard acute effects or general chronic effects exist in the absence of any more specific acute or chronic effects.

In addition, the need to use HCN 4.00 in the past has been alleviated to a large extent by the introduction of new acute HCNs that mirror the chronic HCN effects.

Do not assign HCNs 4.00 or 3.00 if there are other more specific acute organ effects that have any of the following HCNs assigned:

- For HCN 4.00
  - 4.01 through 4.13
  - 5.00, 6.00, 7.00, 7.01, 8.00, 11.00, 11.01, 13.00, 17.00, 18.00, 19.00, 20.00
  - 14.00, 14.01, 14.02, 15.00, 15.01, 15.02, 16.00, 16.01, 16.02
- For HCN 3.00
  - 1.00 through 2.02
  - 3.01 through 3.12
  - 5.10, 7.10, 7.11, 9.00, 10.00, 12.00

Do not assign HCNs 4.00 or 3.00 if "Slightly toxic," "mildly toxic," or "low toxicity" are noted for the chemical. These degrees of toxicity do not rise above the level of significant concern for emergency management purposes and do not meet the definition of "Acute short-term *high hazard* effects" in the case of HCN 4.00.

If none of the above limitations on the use of HCNs 4.00 or 3.00 apply and if the SAX Safety Profile or other references note "poisonous," "highly toxic," "toxic," or "moderately toxic" for the chemical and there is no further specificity for the acute or chronic effect, then consider assigning HCNs 4.00 or 3.00.

As a further limitation on the use of HCNs 4.00 or 3.00, do not assign these HCNs for acute or chronic effects arising from routes of entry other than inhalation, skin absorption, and ingestion. Inhalation, skin absorption, and ingestion are the routes of entry normally encountered during emergency events involving chemical releases. Routes of entry that should not be used for HCNs 4.00 or 3.00 include those such as intravenous, intraperitoneal, subcutaneous, etc. However, ingestion is used due to the fact that chemical vapors and particulates dissolved in or deposited on the mucous layer of the lung are transported by the lung's clearance mechanism (mucociliary escalator) to the back of the throat where they are swallowed, thereby entering the gastrointestinal tract. This limitation on the use of routes of entry currently applies to HCNs 4.00 and 3.00 only but not to other HCNs in an effort to leave other HCNs open to a broader and more conservative interpretation of the available toxicology literature.

2.3.9 Irritation to the Respiratory System

When a notation of "irritating to mucous membranes" occurs with no other indication of acute lung involvement, assume that the chemical is at least moderately irritating to the respiratory system and use HCN 11.01. However, use 11.01 only when the irritation is severe or moderate. Mild respiratory system irritation does not rise to the level of high concern for emergency management since mild irritation usually does not interfere with the protective action ability. HCN 11.00 is to be used for any other acute respiratory effects other than irritation.

HCN 11.01 is reserved exclusively for severe or moderate respiratory irritation only. If conflicts arise in the references, see the example in Section 2.2.

2.3.10 Anoxia

When a notation of "anoxia" is encountered in the references, note whether any information is available with respect to differentiating between "anoxia" (HCN 17.00, simple asphyxiant) and "methemoglobinemia" (HCN 13.00, a more complex form of chemically induced anoxia that binds the oxygen-carrying hemoglobin in the blood so it cannot deliver oxygen to body tissues).

2.3.11 Irritation to Eyes and Skin

For irritation (HCNs 14.00, 15.00, 16.00, and their subsets), use SAX, HSDB, RTECS, CHRIS, Patty, and the TLV Booklet. Terms such as “vesicant”, “corrosive”, “causes burns”, “causes severe burns” would indicate severe irritation (HCN 14.00 and its subsets). If the severity of irritation is not given, assume the severity to be moderate (HCN 15.00 and its subsets). If conflicts arise in the references, see the example in Section 2.2.

2.3.12 Generic Compounds Used as Surrogates

When using toxicity data for generic compound classes (for example “Nickel and compounds”) due to limited specific toxicity data for a chemical, distinguish between soluble and insoluble compounds since the toxicity to a particular target organ can increase or decrease depending on the chemical’s solubility in water. If the compound is water soluble, then exposure is to both the cation and the anion separately. If the compound is not water soluble, then exposure is only to the compound itself. In an effort to promote consistency in the way generic compound classes are used to develop HCNs for chemicals with limited toxicity data, see examples of HCNs for several generic compound classes in Appendix B.

2.3.13 Explosives and Pyrophorics

When a chemical is a contact explosive or spontaneously ignites or explodes in contact with air at ambient temperature and pressure (pyrophoric), use HCN 18.00. This HCN is intended to highlight the uncommon, insidious, and potentially immediately lethal nature of this kind of hazard. Otherwise, do not use this code unless it appears in Patty. Terms that do not apply to HCN 18.00 are terms such as “highly combustible”, “ignites in contact with chemical x”, or “reacts with chemical y”, etc. The focus of HCN 18.00 is a chemical that will spontaneously ignite or explode in the handler's hands when exposed to air or when shocked (picking up the container or opening it or setting it back down) at normal temperature and pressure with no external ignition source needed.

2.3.14 Insufficient Data

For chemicals with very little or insufficient data, make the following assumptions:

- Assume the chemical is soluble in water if there are no solubility data. Then base the HCNs on the toxicity of the cation and anion or the dissociated species separately. For example, Lithium Nitrite (CASRN 13568-33-7) currently has no toxicity data in the references cited in Section 2.2. However, the Handbook of Chemistry & Physics notes that it is water soluble. Therefore, the HCNs would be based on the toxicity of the Lithium cation and Nitrite anion that would be circulating in the body if a person were exposed to it by the inhalation route because it would dissolve in the lung fluids into the Lithium cation and Nitrite anion and then be circulated within body systems.
- If no other data except non-specific (no target-organ effect mentioned) animal toxicity data are available, assign HCN 4.00 and/or HCN 3.00 if the data meet any of the following criteria (based in part on SAX Hazard Rating criteria):
  - For HCN 4.00:
    - LD50 < 4000 mg/kg
    - LDlo < 400 mg/kg
    - LC50 < 500 ppm
    - LClo < 100 ppm
  - For HCN 3.00:
    - TDlo < 4000 mg/kg
    - TClo < 400 ppm
- If there are absolutely no data on which to base HCNs, then the chemical should be assumed to have acute and chronic toxicity until data exist to prove otherwise. Assign the default HCNs of 4.00 and 3.00 (acute and chronic health effects respectively). Insert "ID" in the Reference column.

2.4 Chemical Category

Using Table 3 below and the HCNs in the ten HCN columns (excluding any HCNs that may have been placed in the Comments column), select the appropriate Chemical Category in the following priority order.

- If OSHA or ACGIH have a Ceiling (C) and/or Short-Term Exposure Limit (STEL) value for the chemical, then category 1A takes precedence over any other category.
- If the chemical is an irritant and OSHA or ACGIH do not have a Ceiling and/or STEL value for it, then category 1B takes precedence over the remaining categories.
- If categories 1A or 1B do not apply, then use category 1C when it occurs in Patty (see Table 3, Note C below), which takes precedence over the remaining categories.
- If categories 1A, 1B, or 1C do not apply, then assign category 2, 3, or 4 based on whether the effects are acute, chronic, or combined acute and chronic, respectively.

Table 3: Chemical Categories

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

Source: [Craig et al., 1999]

NOTES: Although these notes may not be directly related to HCN development (except for Note C), they may be of interest to HCN developers and are taken from the same source [Craig et al., 1999].

A These categories are taken directly from Table 6.7, *Patty's Industrial Hygiene and Toxicology* [Patty, 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 technologic 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 (Table 6.9) for a listing of category 1C chemicals.

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.

2.5 Summary of Data Entry in the CMM Workbook HCN-PAC Worksheet

- Insert up to 10 HCNs for each chemical in the "HCN" columns of the HCN-PAC worksheet of the CMM workbook following the above procedure.
- Insert the Chemical Category code in the "Chemical Category" column.

- Insert the reference codes in the "References" column.
- If there are issues to resolve with a particular chemical, insert “Q” (Question) in front of the reference codes in the “Reference” column to tag this chemical for follow-up resolution.
- Enter any comments and/or excess HCNs in the “Comments” column.
- If more than one person is developing HCNs, insert an Author code in the “Author” column.

3.0 References

[ACGIH Doc, 1991-2007] American Conference of Governmental Industrial Hygienists (ACGIH), *Documentation of the Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)*, 6th Edition (1991) and 7th Edition (2001), ACGIH, Cincinnati, OH (6th Edition, 1991 with supplemental updates through 2000) and (7th Edition, 2001 with supplemental updates through 2007).

[ACGIH OEV, 1998-2007] American Conference of Governmental Industrial Hygienists (ACGIH), *Guide to Occupational Exposure Values,* ACGIH, Cincinnati, OH, (1998-2007).

[ACGIH TLV, 1998-2007] American Conference of Governmental Industrial Hygienists (ACGIH), *TLVs and BEIs [TLV Booklet]*, ACGIH, Cincinnati, OH, (1998-2007).

[AEGL Website] Environmental Protection Agency, Acute Exposure Guideline Levels Website at http://www.epa.gov/oppt/aegl, last accessed 8/14/2008.

[AIHA, 2001-2007] American Industrial Hygiene Association (AIHA), *Emergency Response Planning Guidelines (ERPGs) Complete [Documentation] Set,* AIHA Press, Fairfax, VA, (2001-2007).

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

[CRC Handbook, 1981, 2001, 2005] *CRC Handbook of Chemistry and Physics*, 62nd Edition (1981), Robert C. Weast and Melvin J. Astle, Editors; 82nd Edition (2001-2002), David R. Lide, Editor-in-Chief; and 86th Edition (2005-2006), David R. Lide, Editor-in-Chief, CRC Press, LLC, Boca Raton, FL, (1981, 2001, 2005).

[Croner/Ovid, 2001-2008] SilverPlatter International, N.V., *CHEM-BANK* CD ROM: *Hazardous Substances Data Bank (HSDB)* from National Library of Medicine, *Registry of Toxic Effects of Chemical Substances (RTECS)* from NIOSH, *Chemical Hazards Response Information System (CHRIS)* from United States Coast Guard, *NIOSH Pocket Guide to Chemical Hazards* from NIOSH, *Oil and Hazardous Materials—Technical Assistance Data System (OHMTADS)* from Environmental Protection Agency (development of this database was stopped in 1991), Croner, division of Wolters Kluwer (UK) Limited, England [formerly distributed by Ovid Technologies, Inc., Norwood, MA], (2001-2008).

[Hawley, 1993, 2001] Richard J. Lewis, Sr., Editor, *Hawley's Condensed Chemical Dictionary*, 12th Edition: Van Nostrand Reinhold Company [out of business], New York, NY, (1993) and 14th Edition: John Wiley & Sons, Inc., New York, NY, (2001).

[NAS, 2000-2007] National Academy of Sciences, *Acute Exposure Guideline Levels for Selected Airborne Chemicals*, Volumes 1 through 6, National Academy Press, Washington, D.C., (2000-2007). [At the time of this writing, all six volumes could be found on the NAS website at http://search.nap.edu/nap-cgi/de2007.cgi?term=Acute+Exposure+Guideline+Levels+for+Selected+Airborne+Chemicals&GO.x=32&GO.y=10. Free pdf downloads were also available after signing in with the NAS website. Website accessed 11/28/2007.]

[NCHS, 2001] Minino, A.M. and B.L. Smith, *Deaths: Preliminary Data for 2000*, National Vital Statistics Reports, Vol. 49, No. 12, National Vital Statistics System from the National Center for Health Statistics, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, Hyattsville, Maryland, DHHS Publication No. (PHS) 2001-1120, PRS 01-0599 (10/2001), 9 October 2001. This report was found on the Internet at http://www.cdc.gov/nchs/data/nvsr/nvsr49/nvsr49_12.pdf and last accessed on 2/29/2008.

[Patty, 1985] *Patty's Industrial Hygiene and Toxicology*, 2nd edition, Lewis J. Cralley and Lester V. Cralley, Editors, Vol. 3, Part A, Chapter 8 "Models for Adjusting Occupational Exposure Limits", Subchapter 8.2 "OSHA Model," Dennis J. Paustenbach, pp. 150-185, John Wiley & Sons, New York, NY, (1985).

[SAX, 1998-2004] *Sax's Dangerous Properties Of Industrial Materials*, 9th Edition (1998), 10th Edition (2000), and 11th Edition (2004), Richard J. Lewis, Sr., Editor, Electronic Database on CD ROM, John Wiley & Sons, Inc., New York, NY, (1998-2004).

Appendix A: Reference Codes Listed in Priority Order

Reference codes **((bolded in double parentheses below for easy visibility))** are to be inserted in the "References" column (without parentheses) of the *HCN-PAC* look-up table. These codes or updates of them should be used for consistency and to promote easy recognition and discussion between various HCN developers. All references and their codes that have been used in the past for HCN development are listed to facilitate future updates when needed.

The following reference codes are listed in priority order identical to the priority order in Section 2.2 of this procedure:

1. Acute Exposure Guideline Levels (AEGLs) National Academy of Sciences (NAS) Documentation [NAS, 2000-2007]
    - **((Av))** where A = AEGL NAS Documentation for FINAL AEGLs, v = volume, e.g. A6 = AEGL NAS Documentation, Volume 6.
    - **((A-TSDmmyy))** where A-TSD = AEGL Technical Support Document for INTERIM AEGLs, mm = month number, yy = year, e.g. A-TSD0707 = AEGL Technical Support Document, 7-2007.

2. Emergency Response Planning Guidelines (ERPGs) Documentation, American Industrial Hygiene Association (AIHA) [AIHA, 2001-2007]
    - **((Eyy))** where E = ERPG Documentation, yy = year, e.g. E07 = ERPG Documentation 2007.

3. CHEM-BANK SilverPlatter CD ROM Toxicology Databases [Croner/Ovid, 2001-2007]
    - **((RTECSmm-yy))** where RTECS = Registry of Toxic Effects of Chemical Substances, mm = month number, yy = year, e.g. RTECS09-07 = RTECS September 2007.
    - **((HSDBmm-yy))** where HSDB = Hazardous Substances Data Bank, mm = month number, yy = year, e.g. HSDB09-07 = HSDB September 2007.
    - **((CHRIS-yy))** where CHRIS = Chemical Hazards Response Information System, yy = year, e.g. CHRIS-00 = CHRIS 2000.
    - **((Nmm-yy))** where N = National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards, mm = month number, yy = year, e.g. N09-06 = NIOSH Pocket Guide September 2006.
    - **((OHMTADS-1991))** Oil and Hazardous Materials—Technical Assistance Data System, Environmental Protection Agency, 1991 (Since development of this database was stopped in 1991, some of its data may be obsolete.)

4. Sax's Dangerous Properties of Industrial Materials (SAX) CD ROM [SAX, 1998-2004]
    - After 1998: **((Se))** where S = SAX CD-ROM, e = edition number, e.g. S11 = SAX CD ROM 11th edition (2004).
    - For 1998: **((S8r))** where S = SAX CD-ROM, 8 = 1998 (9th edition), r = release number, e.g. S84 = SAX CD-ROM 1998 (9th edition), release 4.

5. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) (TLV Booklet), American Conference of Governmental Industrial Hygienists (ACGIH) [ACGIH TLV, 1998-2007]
    - **((Tyy))** where T = ACGIH TLV Booklet, yy = year, e.g. T07 = ACGIH TLV Booklet 2007.
    - **((TyyN))** where T = ACGIH TLV Booklet, yy = year, N="Notice of Intended Changes," e.g. T07N = ACGIH TLV Booklet 2007 Notice of Intended Changes.
    - For 1998 (when the TLV Booklet was first used for HCN development), simply **((T))** was used where T = ACGIH TLV Booklet, 1998.

6. Documentation of TLVs, ACGIH [ACGIH Doc, 1991-2007]
    - **((Tdyy))** where Td = ACGIH Documentation of TLVs and BEIs, yy = year of supplemental update used, e.g. Td07 = ACGIH TLVs and BEIs Documentation 2007.

7. Guide to Occupational Exposure Values (OEV Guide), ACGIH [ACGIH OEV, 1998-2007]
    - **((Gyy))** where G = ACGIH OEV Guide, yy = year, e.g. G07 = ACGIH OEV Guide, 2007.
    - For 1998 (when the OEV Guide was first used for HCN development), simply **((G))** was used where G = ACGIH OEV Guide, 1998.

8. Patty's Industrial Hygiene and Toxicology [Patty, 1985]
    - **((P))** = Patty, 2nd edition, Volume 3, Part A, pp. 153-185, 1985. This is a table of chemicals and their target-organ HCNs.

9. Hawley's Condensed Chemical Dictionary [Hawley, 1993, 2001]
    - **((He))** = Hawley's Condensed Chemical Dictionary, e = edition, e.g. H14 = Hawley's Condensed Chemical Dictionary, 14th edition, 2001.
    - For the 12th edition (when the Dictionary was first used for HCN development), simply **((H))** was used where H = Hawley's Condensed Chemical Dictionary, 12th edition, 1993.

10. Handbook of Chemistry and Physics [CRC Handbook, 1981, 2001, 2005]

- **((Ce))** where C = Handbook of Chemistry and Physics, e = edition, e.g. C86 = Handbook of Chemistry and Physics, 86th Edition, 2005-2006.
- For the 62nd edition, when the Handbook was first used for HCN development, simply **((C))** was used where C = Handbook of Chemistry and Physics, 62nd edition, 1981-1982.

11. Material Safety Data Sheets (MSDSs) and Other References

- **MSDS: ((Company Name "MSDS" MSDS Number)),** for example "Sigma-Aldrich MSDS 123456"
- **Other References:** Describe the reference in enough detail so that someone else can find it.

12. Insufficient Data

- **((ID))** = Insufficient data. See Section 2.3.14 for an explanation of this notation.

Appendix B: Examples of HCNs for Several Generic Compound Classes

Notes: 1. Alphanumeric numbers in parentheses are SAX reference numbers.

2. After the chemical name, "Reviewed" alone indicates that the health effects (HCNs) and comments were reviewed but no changes were made. "Reviewed & Revised" indicates that the health effects were reviewed and revised (changes made) from the previous version.

Alkalies (Reviewed 8-13-2008)

- **S11 (AFM500)—Loosely applied to hydroxides and carbonates of alkali metals and alkaline earth metals, as well as the bicarbonate and hydroxide of ammonium.**
  - 3.11
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Antimony & Antimony Compounds (Reviewed & Revised 8-14-2008)

- **HSDB06-08 (HSDB Accession Number 6903)—Antimony Compounds**
  - 11.00, 4.07, 4.06, 4.08, 4.09, 4.10, 4.11, 10.00, 3.08, 3.09, 3.10, 3.11, 3.02, 3.06, 3.12
- **S11 (AQD500)—Antimony Compounds**
  - 15.02, 11.01
- **T08—Antimony and compounds, as Sb**
  - 11.01, 15.02
- **G08—Antimony & compounds, as Sb**
  - 2.00 (MAK-2)
- **P—Antimony & compounds (as Sb)**
  - 3.08

Arsenic & Arsenic Compounds (Inorganic) (Reviewed & Revised 8-27-2008)

- **HSDB06-08 (HSDB Accession Number 6994)—Arsenic Compounds (Human data only)**
  - Irritation: 14.02 (Trivalent), 15.01, 15.02, 11.01
  - Acute poisoning: 4.07, 4.09, 4.10, 4.08, 7.01, 7.00, 4.11, 11.00, 12.00, 4.06

- Chronic poisoning: 3.02, 3.10, 3.07, 3.09, 3.01, 3.11, 3.08, 7.10, 3.04, 3.06, 10.00, 3.12, 3.03
- The toxicity of arsenical compounds decreases as follows: arsine (-III) > organo-arsine derivatives > arsenites (+III) > arsenoxides > (+III) > arsenates (+V) > pentavalent organic compounds (+V) > arsonium metals (+I) > metallic arsenic (0).

➢ **S11 (ARF750)—Arsenic Compounds**

- 1.01, 1.02, 3.07, 3.10, 3.02, 3.09, 7.10, 3.11, 10.00, 4.07
- Inorganic arsenicals are more toxic than organics.
- Trivalent is more toxic than pentavalent.

➢ **T08—Arsenic and inorganic compounds, as As**

- 2.00 (A1), 10.00

➢ **G08—Arsenic & inorganic compounds (except arsine), as As**

- 1.00 (OSHA-Ca), 2.00 (EPA-A, IARC-1, MAK-1, NIOSH-Ca, NTP-K, ACGIH-A1)

➢ **P—Arsenic & compounds (as As)**

- 2.00

Barium & Barium Compounds (Soluble) (Reviewed & Revised 7-24-2008)

➢ **HSDB06-08—Barium Compounds (soluble data only) (Accession Number 6934)**

- 7.00, 7.01, 4.07, 4.08, 3.09, 4.01, 8.00, 11.01, 10.00, 15.01, 15.02

➢ **S11 (BAK500)—Barium Compounds (soluble)**

- Barium Chromate (Cr VI) is human carcinogen: 2.00
- Barium oxide: 4.07, 4.08, 7.00, 15.01, 15.02, 11.01, 3.11
- Barium sulfide, carbonate: 15.01, 15.02, 11.01, 3.11

➢ **T08—Barium and soluble compounds, as Ba**

- 15.01, 15.02, 4.07, 7.00

➢ **G08—Barium and soluble compounds, as Ba**

- Cancer determination below HCN guidelines.

➢ **P—Barium (soluble compounds)**

- 3.08, 10.00, 3.05

Cadmium & Cadmium Compounds (Reviewed & Revised 8-27-2008)

➢ **RTECS06-08—Cadmium compounds (Accession Number EV0260000)**

- 2.00, 10.00

- **HSDB06-08—Cadmium compounds (Accession Number 6922) (Human data only)**
  - Acute: 4.07, 12.00, 4.09, 4.10, 11.00, 7.01
  - Chronic: 10.00, 3.09, 3.10, 3.02, 7.10, 3.03, 5.10 (prostate cancer)
- **S11 (CAE750)—Cadmium Compounds**
  - 2.00, 10.00, 4.07, 11.00, 3.09
  - Metal Fume Fever: See entry
- **T08—Cadmium and compounds, as Cd**
  - 3.09
- **G08—Cadmium and compounds, as Cd**
  - 1.00 (OSHA-Ca), 2.00 (EPA-B1, IARC-1, NIOSH-Ca, NTP-K, ACGIH-A2)
- **P—Cadmium dust (as Cd)**
  - 3.09, 10.00

Cerium Compounds (Reviewed & Revised 8-13-2008)

- **S11 (CDA250)**
  - Generally of low toxicity.
  - 3.11, 7.00, 11.00, 8.00, 4.08,
  - Chloride, bromide, nitrate, bromate, and perchlorate salts are water soluble—more likely to cause systemic effects when ingested.
  - Sulfates, iodides, and iodates—less water soluble.
  - Oxides, oxalates, sulfides, carbonates, fluorides, and phosphates—water insoluble.
  - Salts of Cerium increase blood coagulation rate: 4.06
  - Cerium tartrate: 4.08
  - Cerium oxalate—used to suppress motion sickness and vomiting during pregnancy: 7.00, 3.07
  - For soluble Cerium compounds, the toxicity may be assumed to be that of the Cerium cation in addition to the toxicity of the anion if it has a toxicity of its own.
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Chromium & Chromium Compounds (Reviewed & Revised 8-28-2008)

- **S11 (CMJ500)—Chromium Compounds**

- Chromate salts (VI): 2.00, 10.00, 3.12
- Chromic acid (VI) and its salts: 14.01, 14,02, 11.01, 3.12
- Hexavalent (VI) more toxic than trivalent (III)
- Trivalent (III): 3.11

➢ **T08—Chromium and inorganic compounds, as Cr**

- **Metal and Cr III compounds**
  - 11.01, 15.02
- **Water-soluble Cr VI compounds**
  - 2.00 (A1), 11.01
- **Insoluble Cr VI compounds**
  - 2.00 (A1)

➢ **G08—Chromium and Chromium Compounds**

- **Chromium Metal**
  - Cancer determination below HCN guidelines.
- **Chromic acid and chromates**
  - 2.00 (MAK-2, NIOSH-Ca, ACGIH-A1)
- **Chromium (II) inorganic compounds, as Cr**
  - No data
- **Chromium (III) inorganic compounds, as Cr**
  - Cancer determination below HCN guidelines.
- **Chromium (VI) inorganic compounds, water soluble**
  - 2.00 (EPA-K, IARC-1, NIOSH-Ca, NTP-K, ACGIH-A1, MAK-2)
- **Chromium (VI) inorganic compounds, certain water insoluble**
  - 2.00 (EPA-K, IARC-1, NIOSH-Ca, NTP-K, ACGIH-A1, MAK-2)

➢ **P**

- **Chromates (VI), certain insoluble forms (as Cr)**
  - 2.00, 10.00, 3.11
- **Chromic acid (VI) & chromates (VI) (as Cr)**
  - 2.00, 10.00, 3.12
- **Chromium, soluble chromic (III), chromous (II) salts (as Cr)**
  - 10.00, 3.11

Cobalt Metal (Reviewed & Revised 8-21-2008)

- **HSDB06-08 (Accession Number 519)—Cobalt, elemental (Human data only, hard metal (e.g., Tungsten Carbide) potentiation and/or synergism excluded.)**
  - 3.07, 7.10 (sense of smell), 3.02, 3.10, 3.06, 16.01, 16.02, 11.01, 9.00, 10.00, 3.08, 3.11, 2.00 (ACGIH-A3)
- **S11 (CNA250)—Cobalt**
  - 18.00 (powder), 10.00, 3.11
- **T08—Cobalt and inorganic compounds, as Co**
  - 2.00 (ACGIH-A3), 9.00, 11.00, 4.08
- **G08—Cobalt and compounds; Cobalt and inorganic compounds, as Co**
  - 2.00 (ACGIH-A3, IARC-2B, MAK-2)
- **P—Cobalt, metal, fume & dust (as Co)**
  - 3.11, 9.00, 10.00

Cobalt Compounds—Soluble Salts (Reviewed & Revised 8-21-2008)

- **HSDB06-08 (Accession Number 7141)—Cobalt Compounds (Human data only, hard metal (e.g., Tungsten Carbide) potentiation and/or synergism excluded.)**
  - 4.07, 4.06, 4.08, 3.11, 7.00
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Cobalt Compounds—Salts, Not Otherwise Specified (Reviewed & Revised 8-21-2008)

- **HSDB06-08 (Accession Number 7141)—Cobalt Compounds (Human data only, hard metal (e.g., Tungsten Carbide) potentiation and/or synergism excluded.)**
  - 3.11, 3.02, 3.08, 3.10, 10.00, 11.01, 9.00, 3.09
- **S11 (CNB850)—Cobalt Compounds**
  - 4.07, (single human poisoning case: 4.09, 4.10), 3.11, 4.06, 11.00
- **T08—Cobalt and inorganic compounds, as Co**
  - 2.00 (ACGIH-A3), 9.00, 11.00, 4.08
- **G08—Cobalt and compounds; Cobalt and inorganic compounds, as Co**
  - 2.00 (ACGIH-A3, IARC-2B, MAK-2)
- **P—No entry**

Copper Compounds (Reviewed & Revised 8-13-2008)

- **S11 (CNK750)—Copper Compounds**
  - 4.06, 10.00
  - Sublimed oxide may cause Metal Fume Fever (see entry)
  - Copper chloride & sulfate: 15.02, 15.01, 3.11
  - Copper sulfate: 4.07, 7.01, 7.00, 12.00, 4.09, 4.10
  - Cuprous oxide: 15.01, 11.01
  - Many copper-containing compounds are used as fungicides.
  - Many copper salts form highly unstable acetylides.
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Fluorides (Reviewed & Revised 8-28-2008)

- **S11 (FEY000)—Fluorides**
  - Inorganic fluorides—generally highly irritating and toxic due to HF formation.
  - Organic fluorides—generally less toxic than other halogenated hydrocarbons.
  - Inorganic fluorides: 14.01, 14.02, 110.1, 3.03, 4.07, 9.00, 10.00, 12.00, 3.02, 7.00, 3.11
- **T08—Fluorides, as F**
  - 3.03
- **G08—Fluorides, as F**
  - Cancer determination below HCN guidelines.
- **P—Fluoride (as F)**
  - 14.01, 11.01, 3.03

Germanium Compounds (Reviewed & Revised 8-21-2008)

- **S11 (GEA000)—Germanium Compounds**
  - Considered to be generally low in toxicity.
  - 4.06 (hypothermia), 4.07, 11.00, 4.08
  - GeCl4 inhalation: 11.00

- Germanium tetrachloride & tetrafluoride: 15.01, 15.02, 11.01
- Dimethyl germanium: 5.00
- Germanium hydride—hemolytic gas: 4.06
- Ge organics probably have higher toxicity than inorganics like other organometals.

➢ **T08—No entry**

➢ **G08—No entry**

➢ **P—No entry**

Lead & Lead Compounds (Reviewed & Revised 9-9-2008)

➢ **HSDB06-08 (HSDB Accession Number 6923)—Lead Compounds (Human data only)**

- Acute: 4.07, 7.01, 12.00, 4.09
- Chronic: 3.07, 7.11, 7.10, 3.02, 3.09, 3.06, 3.05, 5.10, 10.00, 3.08, 3.03

➢ **S11 (LCF000)—Lead**

- 2.00, 12.00, 7.10, 7.11, 3.07, 3.09, 3.10, 3.05, 3.08, 3.02, 5.10

➢ **S11 (LCT000)—Lead Compounds**

- 10.00, 3.09
- Lead carbonate, monoxide, and sulfate—more toxic than metallic lead or other lead compounds.
- Lead arsenate—very toxic due to presence of arsenic radical.
- Organolead compounds—rapidly absorbed by the respiratory and gastrointestinal systems and through the skin.
- Tetraethyl lead—converted in the body to triethyl lead, which is a more severe neurotoxin than inorganic lead.

➢ **T08—Lead and inorganic compounds, as Pb**

- 7.10, 7.11, 3.02

➢ **G08**

- **Lead and inorganic compounds**
  - 2.00 (EPA-B2, NTP-R, ACGIH-A3, IARC-2A [inorganic compounds], IARC-2B, MAK-2)
- **Lead, Organic compounds**
  - Cancer determination below HCN guidelines.
- **P—Lead, Inorganic fumes & dusts (as Pb)**

- 3.02, 7.10, 5.10

Lithium Compounds (Reviewed & Revised 9-9-2008)

- **HSDB06-08 (HSDB Accession Number 6900)—Lithium Compounds (Human data only)**
  - 4.07, 7.00, 7.01, 4.08, 4.11, 3.02, 3.08, 3.09, 3.06, 10.00, 5.10
- **S11 (LHE000)—Lithium Compounds**
  - Lithium oxide, hydroxide, carbonate, etc.—strong bases. Solutions in water are very caustic.
  - Otherwise, toxicity is function of solubility.
  - Halide salts (except fluoride)—highly soluble in water.
  - Carbonate, phosphate, oxalate, fluoride—relatively insoluble in water.
  - Lithium carbonate—used in psychiatry
  - Lithium hydride—most hazardous of lithium compounds in industry, produces large amounts of hydrogen gas when exposed to water. This reaction causes severe tissue damage: 14.00, 11.01
  - Lithium ion (water soluble): 7.01, 7.00, 4.07, 4.09, 3.08, 3.02, 3.04, 12.00, 3.09, 7.10, 7.11

Manganese & Manganese Compounds (Reviewed & Revised 8-6-2008)

- **S11 (MAR500)—Manganese Compounds**
  - 7.11, 10.00, 7.00
- **T08—Manganese and inorganic compounds, as Mn**
  - 7.11
- **G08—Manganese and inorganic compounds, as Mn**
  - Cancer determination below HCN guidelines.
- **P—Manganese & compounds (as Mn)**
  - 7.11, 10.00

Mercury & Mercury Compounds, inorganic (Reviewed & Revised 9-11-2008)

- **RTECS06-08—Mercury, inorganic compounds (Accession Number OW5072000)**
  - 4.06
- **HSDB06-08—Mercury Compounds (Accession Number 6943) (Human data only)**

- **Mercury vapor**
  - 11.00, 3.07, 7.11
- **Inorganic**
  - 4.07, 4.09, 4.01, 7.01, 7.00
- **Soluble Salts**
  - 14.01, 14.02, 11.01
- **Inorganic salts (Not Otherwise Specified)**
  - 4.07, 4.08, 11.00, 4.09, 3.02
- **Iodides**
  - 3.11, 10.00, 7.11, 15.02, 11.01
- **Organic Alkyls**
  - 14.01, 14.02, 11.01, 7.01, 7.00, 7.11, 7.10, 4.01, 4.11, 3.07, 3.10, 5.10, 3.02, 3.08, 3.06
- **Organic Aryls & Alkoxyalkyls**
  - 14.02, 4.11, 11.00, 4.07, 4.08, 3.09, 7.11, 7.10
- **Mercury compounds (Not Otherwise Specified)**
  - 14.01, 15.02, 7.01, 4.01, 4.11

➢ **N06-08—Mercury compounds [except (organo) alkyls] (as Hg)**

- 15.01, 15.02, 11.01, 11.00, 7.01, 4.07, 4.09

➢ **S11 (MCZ000)—Mercury Compounds, inorganic**

- 7.10, 7.11, 3.07
- Mercury fulminate: 4.11, 11.01
- Soluble salts: 14.00, 4.07, 4.09, 11.01
- Many explosively unstable: 18.00

➢ **T08—Mercury, as Hg**

- **Alkyl compounds:** 7.10, 7.11, 4.09
- **Aryl compounds:** 7.11, 4.09
- **Elemental and inorganic forms:** 7.11, 4.09

➢ **G08—Mercury, as Hg**

- **Alkyl compounds:** Cancer determination below HCN guidelines.
- **Aryl compounds:** Cancer determination below HCN guidelines.
- **Elemental:** Cancer determination below HCN guidelines.

- **Inorganic compounds:** Cancer determination below HCN guidelines.

➢ **P**

- **Mercury, (organo) alkyl compounds, (as Hg):** 7.01, 7.11, 14.02
- **Mercury, inorganic (as Hg):** 7.01, 7.11, 4.07

Metal Fume Fever (Reviewed & Revised 8-13-2008)

➢ **S11 (see WBJ000—Welding Fumes)**

- Symptoms: chills, fever, oppression in chest like influenza, cough, pneumonitis, weakness, lassitude, leukocytosis (increase in number of white blood cells)
- 11.00, 7.00, 4.06

➢ **T08—No entry**

➢ **G08—No entry**

➢ **P—No entry**

Molybdenum & Molybdenum Compounds (Reviewed & Revised 7-18-2008)

➢ **S11 (MRC750)—Molybdenum Compounds (Soluble and Insoluble forms determined from effects given, e.g., lung deposition reaching kidney, liver, and spleen would have to be water soluble.)**

- **Soluble**
  - 4.07, 4.08, 10.00, 3.02, 3.08, 3.10, 3.09
  - MoO_3 and Na_2MoO_4 are soluble.
  - Hexavalent molybdenum compounds are readily absorbed through the gastrointestinal tract.
- **Insoluble**
  - 10.00
  - $CaMoO_4$, MoO, and MoS_2 are insoluble.

➢ **T08**

- **Molybdenum, Soluble compounds, as Mo**
  - 11.01
- **Molybdenum, Metal and insoluble compounds, as Mo**
  - No health effects data

➢ **G08**

- **Molybdenum, Soluble compounds, as Mo**
  - 2.00 (ACGIH-A3)

- **Molybdenum and insoluble compounds, as Mo**
  - No carcinogenicity data

➢ **P**

- **Molybdenum (as Mo) (solubles)**
  - 3.10, 3.09, 3.02, 16.01, 11.01
- **Molybdenum (as Mo) (insolubles)**
  - 3.10, 3.09, 3.02, 16.01, 11.01

Nickel & Nickel Compounds (Reviewed & Revised 8-21-2008)

➢ **S11 (NDB000)—Nickel Compounds**

- All airborne dusts: 2.00
- Inhalation: 10.00, 9.00
- Contact: 3.11, 3.06
- Ingestion: 4.07, 7.01, 13.00
- Nickel carbonyl: 2.00, 11.01, 13.00
- Nickel dust, NiCl2, NiO: 10.00
- Ni (II) divalent: 3.02, 3.09, 3.10, 3.08

➢ **T08**

- **Nickel, soluble inorganic compounds (NOS), as Ni**
  - 10.00
- **Nickel, insoluble inorganic compounds (NOS), as Ni**
  - 2.00 (ACGIH-A1), 10.00

➢ **G08**

- **Nickel, soluble compounds, as Ni**
  - 2.00 (NIOSH-Ca, NTP-K)
- **Nickel, insoluble compounds, as Ni**
  - 2.00 (ACGIH-A1, NIOSH-Ca, NTP-K)

➢ **P—Nickel, metal & insoluble compounds**

- 2.00, 10.00, 3.11

Nitrates (Reviewed & Revised 8-13-2008)

➢ **S11 (NED000)—Nitrates**

- 4.07, 7.01
- Practically all nitrates are powerful oxidizing agents that may cause a violent reaction or detonate with reducing materials. Some may explode when shocked or self-detonate under certain conditions, e.g. ammonium nitrate: 18.00

➢ **T08—No entry**

➢ **G08—No entry**

➢ **P—No entry**

Nitrides (Reviewed 8-13-2008)

➢ **S11 (NEH000)—Nitrides**

- The details of the toxicity of nitrides as a group are unknown.
- Many nitrides react with moisture to evolve ammonia. This gas is an irritant to mucous membranes: 11.01, 15.01

➢ **T08—No entry**

➢ **G08—No entry**

➢ **P—No entry**

Nitrites (Reviewed & Revised 8-13-2008)

➢ **S11 (NEJ000)—Nitrites**

- 4.07, 13.00, 3.08, 3.06
- Organic nitrites may explode when shocked: 18.00

➢ **T08—No entry**

➢ **G08—No entry**

➢ **P—No entry**

Organophosphate Pesticides [Parathion as surrogate for this class]

(Reviewed & Revised 8-22-2008)

➢ **HSDB06-08 (HSDB Accession Number 197)—Parathion (Human data only)**

- 6.00, 4.07, 4.06, 7.00, 4.01, 4.08, 7.01, 11.00, 4.05, 8.00, 10.00

➢ **S11 (PAK000)—Parathion**

- 8.00, 11.00, 4.09, 4.03, 6.00, 5.10

➢ **T08—Parathion**

- 6.00

- **G08—Parathion**
  - 2.00 (EPA-C)
- **P—Parathion**
  - 6.00, 5.10

Oxalates (Reviewed & Revised 8-13-2008)

- **S11 (OKY000)—Oxalates**
  - 14.00, 11.01, 4.07
  - Soluble Oxalates can cause severe kidney damage: 4.09
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Phosphates (Reviewed 8-13-2008)

- **S11 (PGX500)—Phosphates**
  - Alkali metal phosphates are powerful irritants: 14.00
  - Organophosphates—often highly toxic pesticides, e.g. Parathion (see Organophosphate Pesticides)
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Phosphides (Reviewed & Revised 8-13-2008)

- **S11 (PGX750)—Phosphides**
  - Phosphides are particularly dangerous because they tend to decompose to very toxic and flammable phosphine gas upon contact with moisture, water, steam, acid, or acid fumes.
  - Phosphine—S10 (PGY000): 7.01, 11.01, 4.08, 4.06, 7.00, 12.00, 10.00, 3.07, 3.06, 18.00
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Selenium & Selenium Compounds (Reviewed & Revised 8-22-2008)

- **HSDB06-08 (HSDB Accession Number 6909)—Selenium Compounds (Human data only)**
  - 7.01, 3.08, 11.00, 3.07, 3.03, 3.11, 5.10, 14.01, 14.02, 11.01, 4.11, 3.02, 4.01
- **S11 (SBP500)—Selenium Compounds**
  - 7.00, 11.01, 3.11, 7.01, 3.07
  - Selenium oxychloride: 14.00
- **T08—Selenium and compounds, as Se**
  - 15.01, 11.01
- **G08—Selenium Compounds, as Se**
  - Cancer determination below HCN guidelines.
- **P—Selenium compounds (as Se)**
  - 15.01

Silicates, soluble alkaline (Reviewed 8-13-2008)

- **S11 (SCM500)—Silcates**
  - 3.11
- **T08—No entry**
- **G08—No entry**
- **P—No entry**

Strontium Compounds (Reviewed & Revised 8-22-2008)

- **HSDB06-08 (Accession Number 6924)—Strontium Compounds (Human data only)**
  - 4.07, 3.03, 7.00
- **S11 (SMH500)—Strontium Compounds**
  - Chemically and biologically similar to calcium
  - Highly dangerous if compound contains radioactive isotope ^{90}Sr
  - Strontium salicylate—most toxic compound
  - Oxides and hydroxides—moderately caustic
  - 4.07, 6.00, 3.03
- **T08—No entry**
- **G08—No entry**

- **P—No entry**

Tellurium & Tellurium Compounds (Reviewed & Revised 8-22-2008)

- **HSDB06-08 (Accession Number 7057)—Tellurium Compounds (Human data only)**
  - 8.00, 3.07, 3.11, 11.01, 3.10, 14.02
- **S11 (TAJ500)—Tellurium Compounds**
  - 7.01, 8.00, 4.07, 3.11
- **T08—Tellurium and compounds (NOS), as Te (excluding hydrogen telluride)**
  - No useful data
- **G08—Tellurium & compounds, as Te**
  - No data
- **P—Tellurium**
  - 7.01

Tin & Tin Compounds (Reviewed & Revised 8-22-2008)

- **HSDB06-08 (Accession Number 7001)—Tin Compounds (Human data only)**
  - Alkyl tins are more toxic than aryl tins.
  - Short-chain alkyl tins are more toxic than longer-chain alkyl tins.
  - Organic tin compounds: high toxicity
  - Organotin salts are irritants: 15.01, 15.02, 11.01
  - Organic tin compounds: 7.01, 14.02, 4.10
  - Dibutyl and tributyl tin: 3.11, 14.01, 14.02, 11.01, 3.07, 4.11
  - Dimethyl and trimethyl tin: 7.01, 4.10, 4.06
  - Methyl, ethyl, triethyl, tetraethyl tin: 7.00, 4.01
  - Inorganic tin salts: low toxicity
  - Inorganic tin compounds (except the oxides) are irritants: 15.01, 15.02, 11.01, 4.07
  - Inorganic tin salts when gain access to blood system (soluble): 7.00, 7.01
  - Tin metal dust and tin salts: 10.00
- **S11 (TGC500)—Tin Compounds**
  - Elemental tin and inorganic tin compounds: low toxicity
  - Some inorganic tin salts are irritants: 15.00
  - Tin hydride: highly toxic, similar to arsenic hydride

- Generally alkyl tin compounds are more toxic than aryl compounds
- Short chain compounds are more toxic than long-chain compounds
- Toxicity increases with number of alkyl groups
- Tetramethyl tin chloride and triethyl tin chloride are very toxic: 7.00, 7.01
- Tin dusts: 10.00

➢ **T08**

- **Tin, Organic compounds, as Sn**
  - No data
- **Tin Oxide & inorganic compounds, except tin hydride, as Sn**
  - 11.00, 15.01, 11.01

➢ **G08**

- **Tin, Organic compounds, as Sn**
  - Cancer determination below HCN guidelines.
- **Tin metal, oxide, and inorganic compounds, except tin hydride, as Sn**
  - No data

➢ **P**

- **Tin (Organic compounds) (as Sn)**
  - 14.02
- **Tin (Inorganic compounds, except oxide) (as Sn)**
  - No usable data

Uranium & Uranium Compounds—(Reviewed & Revised 8-25-2008)

➢ **HSDB06-08 (HSDB Accession Number 6925)—Uranium Compounds (Human data only)**

- Soluble: 4.09, 3.09, 11.01, 11.00, 15.01, 14.02, 4.07, 2.00 (lymphatic), 4.08, 3.02, 3.03 (bone sarcoma much more prevalent than leukemia), 7.00, 7.01
- The uranyl compounds (+6) are of most importance biologically because the uranic compounds (+4) are usually oxidized to +6 during absorption into the body.
- Insoluble salts are least toxic chemically, although they may be highly toxic radiologically when lodged in lung tissues: 10.00
- [From Absorption, Distribution, and Excretion section] Once absorbed, uranium rapidly leaves blood and is deposited in tissues. Hexavalent uranium has a predilection for kidney and bone tissue whereas the tetravalent form shows a

preference for liver, kidney (cortex), and bone (epiphyseal tissue). The critical organs are kidney, bones, and in case of inhalation, the lung: 4.09, 3.09, 3.03, 3.10, 10.00

- **S11 (UNS000)—Uranium**
  - Soluble (chemical toxicity dominant): 4.09, 4.08, 18.00
    - Most soluble examples: Uranium hexafluoride (UF_6), Uranyl nitrate ($UO_2(NO_3)_2$), Uranyl chloride (UO_2Cl_2), Uranyl fluoride (UO_2F_2), and uranyl acetates, sulfates, and carbonates
    - Moderately soluble examples: Uranium tetrafluoride (UF_4), Uranium dioxide (UO_2), Uranium peroxide (UO_4), Ammonium uranate ($(NH_4)_2U_2O_7$, UO_3), and uranyl nitrates
  - Insoluble (radiotoxicity dominant): 10.00
    - Least soluble examples: high-fired Uranium dioxide (UO_2), Triuranium octaoxide (U_3O_8), and uranium hydrides and carbides
- **T08—Uranium (natural), Soluble and insoluble compounds, as U**
  - 4.09, 2.00 (A1)
- **G08—Uranium (natural), Soluble & insoluble compounds, as U**
  - 2.00 (NIOSH-Ca, ACGIH-A1)
- **P—Uranium**
  - Soluble: 3.09
  - Insoluble: 3.09, 10.00

Zirconium & Zirconium Compounds (Reviewed & Revised 8-26-2008)

- **HSDB06-08 (HSDB Accession Number 7347—Zirconium Compounds (Human data only)**
  - 4.07, 4.06, 4.09, 4.10, 4.08, 7.01, 10.00, 9.00, 3.11
- **N06-08 (Guide Number 677)—Zirconium Compounds**
  - 10.00, 3.11, 15.02, 15.01, 11.01, 18.00 (powder form only)
- **S11 (ZQA000)—Zirconium Compounds**
  - Zirconium tetrachloride ($ZrCl_4$) inhalation: 3.02
  - Most compounds are insoluble and relatively inert.
  - Inhalation: 10.00
  - Sodium zirconium lactate: 3.11
- **T08—Zirconium and compounds, as Zr**
  - No data

- **G08—Zirconium, Elemental; Zirconium Compounds, as Zr; Zirconium Inorganic compounds, as Zr; Zirconium Soluble compounds**
  - Either no data or cancer determination below HCN guidelines.
- **P—Zirconium Compounds (as Zr)**
  - 10.00, 3.11

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