Chemical Substances and Biological Agents

Studies and Research Projects

TECHNICAL GUIDE **T-22**

Guide for the adjustment of permissible exposure values (PEVs) for unusual work schedules

4th edition revised and updated

Daniel Drolet

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Laboratory Services and Expertise, IRSST

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Ce document est également disponible en français à l'adresse suivante : http://www.irsst.qc.ca/files/documents/PubIRSST/T-21.pdf.

The adjustment code of each of the 705 substances of ROHS can be found in their individual record on the IRSST Web site. A search tool allows a search …

- by substance : http://www.irsst.qc.ca/en/-rsstlist.html
- by C.A.S.number : http://www.irsst.qc.ca/en/-rsstclist.html

New information in this version

This fourth version of the *Guide for the adjustment of permissible exposure values (PEVs) for unusual work schedules* contains some changes from the previous version. This version is necessary to be consistent with the changes to Schedule I of the ROHS published since January 2007. The new substances in Schedule I have been evaluated to assign them an adjustment category. As well, substances whose PEVs or notation(s) have been modified have also been reevaluated for the same purpose. Appendix IV of this guide contains the updated adjustment category list for each of the 705 substances in the ROHS.

Furthermore, the computer-based tool available on the IRSST's Web site integrates these modifications and allows users to apply the PEV adjustment principle to any of the substances in the ROHS.

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Preamble

The standards for chemical contaminants found in various national regulations and reference values such as the TLVs® (Threshold Limit Values) of the American Conference of Governmental Industrial Hygienists (ACGIH®)[2] have contributed greatly to the prevention of occupational diseases caused by worker exposure to hazardous substances. However, it is important to clearly understand the scope and limitations of the standards and TLVs® in order to discuss their adjustments. Standards such as TLVs® assume applicability to workers with a regular work schedule of 8 hours per day, five days per week. The ACGIH® emphasizes that the adjustment of TLVs® in the case of extended work schedules requires a *particular judgment* and has recommended, for several years, the use of the *Brief and Scala* correction model. Since 2004, the ACGIH® has also referred to the model jointly developed by the Université de Montréal (DSEST) and the Institut de recherche Robert-Sauvé en Santé et en Sécurité du Travail of Québec described in this guide, while emphasizing that it generates results even closer to the physiologically-based toxicokinetic models (PBPK) than the *Brief & Scala* model

This guide is the result of scientific expertise, consultations and the bipartite consensus of Technical Committee (3.33.1) on Schedule I of the ROHS. It proposes a structured process that remains complex despite the efforts that have been made to simplify it without increasing worker health risks. However, this complexity reflects the significance and method of application of PEVs (Permissible Exposure Values) that serve as reference conditions.

PEV adjustment is based on the toxicological knowledge available in the scientific and technical literature. However, the limits of our knowledge have to be recognized regarding dose-response relationships applicable to humans, dose-absorption kinetics relating to saturation of defense mechanisms, animal-human extrapolation of toxicological data, the distribution of contaminants and their metabolites at the point of action of target organs, etc.

Introduction

Current knowledge on the adjustment of PEVs to unusual work schedules, meaning schedules other than eight hours per day, five days per week, was recently summarized in several publications particularly relevant to the Québec context[3,4,5,6,7,8,9]. These publications describe the main methods for calculating PEV adjustment factors in the case of substances that require an adjustment

> **Guiding principle**
>
> … ensuring an equivalent degree of protection to workers with a conventional schedule of 8 hours a day, 5 days a week, and to workers with unusual work schedules.

The PEV adjustment process in this guide is based on a guiding principle that was agreed on in Technical Committee 3.33.1 for Schedule I of the ROHS[7]. In toxicological terms, for many chemical contaminants, an equilibrium is established between the accumulation of a contaminant in the body during the time at work and the elimination of the contaminant during the time away from work (this period is assumed to be exposure-free) until the maximum body burden or accumulation plateau in the body is reached. The time-weighted average exposure value (TWAEV) applicable to workers exposed to these contaminants during unusual work schedules must therefore be modified to ensure that the maximum body burden does not exceed the maximum body burden reached by a worker with a conventional work schedule. As a corollary, *no adjustment of the standard is necessary for any means of exposure or any toxic action of a contaminant that is unrelated in any way to the body burden*.

With this guiding principle as a basis and using the logic of the Occupational Safety and Health Administration[3] (OSHA), as inspiration, a group of toxicologists met at the IRSST to propose adjustment categories[9] (I, II, III and IV) for each of the substances found in Schedule I of the ROHS as well as a method for calculating adjustment factors supported by toxicokinetic modeling[11,12]. This group of experts also defined the conditions and limitations of application of the adjustment procedure.

Using these recommendations, the members of Technical Committee 3.33.1 for Schedule I of the ROHS of the Commission de la Santé et de la Sécurité du Travail (CSST , Québec workers' compensation board) ont established a consensus on the conditions of application of PEV adjustment (see Appendix I). The present guide is the tool for facilitating the application of PEV adjustment for unusual work schedules using toxicological considerations as a basis as reviewed by consensus by the members of the Schedule I committee. It provides several definitions and conditions of application, explains the PEV adjustment process and the interpretation of the ***adjusted average exposure value*** (AAEV), and presents some application examples in the Appendix II.

Adjustment recommendations

Definitions

Repetitive work cycle: calendar period during which the work schedule (work shift) is exactly repeated on a daily and weekly basis.

> For example, a conventional schedule of 8h/d (Monday to Friday) and 5d/wk is a *repetitive calendar-week work cycle*; a schedule of 10 h/d (Tuesday to Friday) is also a *repetitive calendar-week work cycle*. However, a schedule of 12 h/d for 7 consecutive days, followed by 7 days off, would be a 14-day *repetitive cycle*. If this same schedule consists of alternating weeks of day and night shifts, it would *then be a 28-day repetitive cycle*.

Average exposure duration in hours per week based on a repetitive work cycle: the arithmetic mean in hours (H_w of the weekly total (7 days) of the work shifts during the repetitive work cycle.

> For example, a schedule of 8 h/d (Monday to Friday), 5 d/wk, gives an average exposure duration in hours per week based on a repetitive work cycle of 40 h/wk; a schedule of 10 h/d, 4 d/wk (Tuesday to Friday) also represents an average exposure duration in hours per week based on a repetitive work cycle of 40 h/wk. However, a schedule of 12 h/d for 7 consecutive days, followed by 7 days off, corresponds to an average exposure duration in hours per week based on a repetitive work cycle of 42 h/wk.

Multiple exposure: daily exposure to several substances

Nominal schedule: normal work schedule based on the agreement between the employer and worker without including overtime and occasional replacement work. As a general rule, this schedule should represent at least 80% of the hours actually worked.

Conditions of application

- The *short-term exposure values (STEV) and ceiling values (CV) are not subject* to the adjustment principle; only the TWAEVs are subject to the adjustment principle.
- The TWAEV adjustment process applies only to nominal schedules with shifts of no less than 4 hours and no more than 16 hours.
- In no case can the AAEV be greater than the TWAEV.
- In the case of daily exposures to several substances, the equation in part 3 of Schedule I of the ROHS applies by replacing T (TWAEV) by T_a (AAEV).
- The excursion limits for substances that have no STEV apply directly to the AAEV. Similarly, exposures between the STEV and the TWAEV must be taken into consideration as described in the ROHS by replacing the TWAEV by the AAEV.

PEV adjustment procedure

The adjustment procedure is based on the assignment of adjustment categories (Table 1) as proposed by OSHA[3]. Appendix IV gives the adjustment category for each of the substances in the RROHS, namely *no* adjustment (category I), *daily* adjustment (category II), *weekly* adjustment (category III), and *the most conservative* of the daily or weekly adjustments (category IV). The adjustment category for each of the substances in Schedule I of the ROHS is also available on the IRSST's Web site**.** A computer-based tool (an Excel bilingual file) for applying the adjustment procedure is also available on the Internet (Appendix III)

Table 1 : List of adjustment categories

Ad	Adjustment classification	Type of adjustment
I-a	Substances regulated by a ceiling value	**No** adjustment
I-b	Irritating or malodorous substances	
I-c	Simple asphyxiants, substances presenting a safety risk or a very low health risk, whose half-life is less than 4 hours. Technological limitations	
II	Substances that produce effects following *short-term* exposure	**Daily** adjustment
III	Substances that produce effects following *long-term* exposure	**Weekly** adjustment
IV	Substances that produce effects following a *short-* or *long-term* exposure	Daily or weekly adjustment **the most conservative of the two**

Calculating the AAEV

In the case of **Category I** substances, the TWAEV does not have to be adjusted, regardless of the type of work schedule. For substances belonging to the other categories, the TWAEV is adjusted by applying one of the following equations::

$$F_a = 8 / H_d$$ **Category II** substances, requiring a *daily* adjustment

$$F_a = 40 / H_{wk}$$ **Category III** substances, requiring a *weekly* adjustment

F_a = adjustment factor

H_d = exposure duration in hours per shift

H_{wk} = average duration of work shifts per week *based on a repetitive work cycle*.

In the case of **Category IV** substances, the F_a must be calculated for each of the two equations for Categories II and III, and the lowest F_a must be applied.

To obtain F_a rapidly, Appendix IV of this document supplies the adjustment categories for all of the substances in the ROHS, and Table 2 presents the F_a for most of the possible unusual schedules. The only exception to the application of Table 2 involves Category II and IV substances in the case of work schedules in which the work shifts vary in duration from day to day.

To use Table 2, the length of the repetitive work cycle must be determined and the average exposure durations be established based on the adjustment category of the substance considered.

Interpreting the AAEV

TWAEV

The ROHS defines the TWAEV in the following way:

> *"The time-weighted average concentration for an 8-hour workday and a 40-hour workweek of a chemical substance (in the form of gases, dusts, fumes, vapours or mists) present in the air in a worker's respiratory zone.."*

To verify compliance with the TWAEV, the occupational health and safety professional will evaluate the concentration of a substance present in the worker's breathing zone by weighting the result or results of the measured concentrations on the basis of a workshift of eight consecutive hours. In this case, *the repetitive work cycle* is one week and the duration of the work shifts is constant from day to day and corresponds to the duration of the hours worked, or eight hours. Regardless of the nature of the pathologies that can be caused by the presence of this substance in the workplace, *verification of compliance with the TWAEV or AAEV is always done a daily basis*.[13]

Tableau 2: Adjustment factor for unusual work schedules based on the duration of work shifts (h/d) and the average duration of work weeks (h/wk)

Category I : No adjustment

Category II*

h/day	F_A
8,0	1,00
8,5	0,94
9,0	0,89
9,5	0,84
10,0	0,80
10,5	0,76
11,0	0,73
11,5	0,70
12,0	0,67
12,5	0,64
13,0	0,62
13,5	0,59
14,0	0,57
14,5	0,55
15,0	0,53
15,5	0,52
16,0	0,50

* : the duration of work shifts must be equal from one day to the next.

Category III

h/wk	F_A
40	1,00
41	0,98
42	0,95
43	0,93
44	0,91
45	0,89
46	0,87
47	0,85
48	0,83
49	0,82
50	0,80
51	0,78
52	0,77
53	0,75
54	0,74
55	0,73
56	0,71
57	0,70
58	0,69
59	0,68
60	0,67

Category IV

h/wk, *base on the repetitive cycle*	h/day																
F_A	8,0	8,5	9,0	9,5	10,0	10,5	11,0	11,5	12,0	12,5	13,0	13,5	14,0	14,5	15,0	15,5	16,0
40,0	1,00	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
40,5	0,99	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
41,0	0,98	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
41,5	0,96	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
42,0	0,95	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
42,5	0,94	0,94	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
43,0	0,93	0,93	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
43,5	0,92	0,92	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
44,0	0,91	0,91	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
44,5	0,90	0,90	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
45,0	0,89	0,89	0,89	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
45,5	0,88	0,88	0,88	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
46,0	0,87	0,87	0,87	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
46,5	0,86	0,86	0,86	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
47,0	0,85	0,85	0,85	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
47,5	0,84	0,84	0,84	0,84	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
48,0	0,83	0,83	0,83	0,83	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
48,5	0,82	0,82	0,82	0,82	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
49,0	0,82	0,82	0,82	0,82	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
49,5	0,81	0,81	0,81	0,81	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50
50,0	0,80	0,80	0,80	0,80	0,80	0,76	0,73	0,70	0,67	0,64	0,62	0,59	0,57	0,55	0,53	0,52	0,50

Blue: The most conservative **daily** adjustment

Red: The most conservative **weekly** adjustment

Calculating the AAEV

In the case of AAEVs, three situations may arise based on the adjustment category, namely:

Daily adjustment

For a substance whose adjustment must be done on a daily basis (**Category II**), if the work shifts are all of the same length, e.g., 12 hours, the AAEV will be 0.67 * TWAEV, and the results of the concentrations will be weighted over 12 hours. The condition requiring work shifts of constant duration would represent the great majority of real situations

However, if the work shifts are not all of the same length, the simple approach resulting from the consensus of the Schedule I committee (use of the average duration of work shifts) cannot be applied due to toxicological reasoning because it could lead to situations in which the guiding principle would no longer be respected. It then becomes necessary to adjust the TWAEV for *each work shift duration* and to weight the results according to the duration of the corresponding work shift

Weekly adjustment

Category III substances, which require a weekly adjustment, consist of all the substances whose effects appear following a long-term exposure. Adjustment on the basis of the *average exposure duration in hours per week based on a repetitive work cycle* is logical toxicologically. Therefore, a work schedule of 12 h/d for 7 consecutive days followed by 7 days off gives an average of 42 h/wk and an adjustment factor of 40/42 or 0.95.

The adjustment factor is used only to calculate the AAEV. Weighting of the concentration measurement(s) to verify compliance with the standard must be calculated over the duration of the work shift. In the example, weighting will be over 12 hours. If work shifts are of unequal length from one shift to the next, the weighting must be done over the duration of each of the work shifts.

Daily or weekly adjustment *(the most conservative of the two)*

For **Category IV** substances, the most conservative of the daily or weekly adjustments must be calculated. The same calculation criteria for the AAEV and the weighting of the results apply to this category.

Using the AAEV

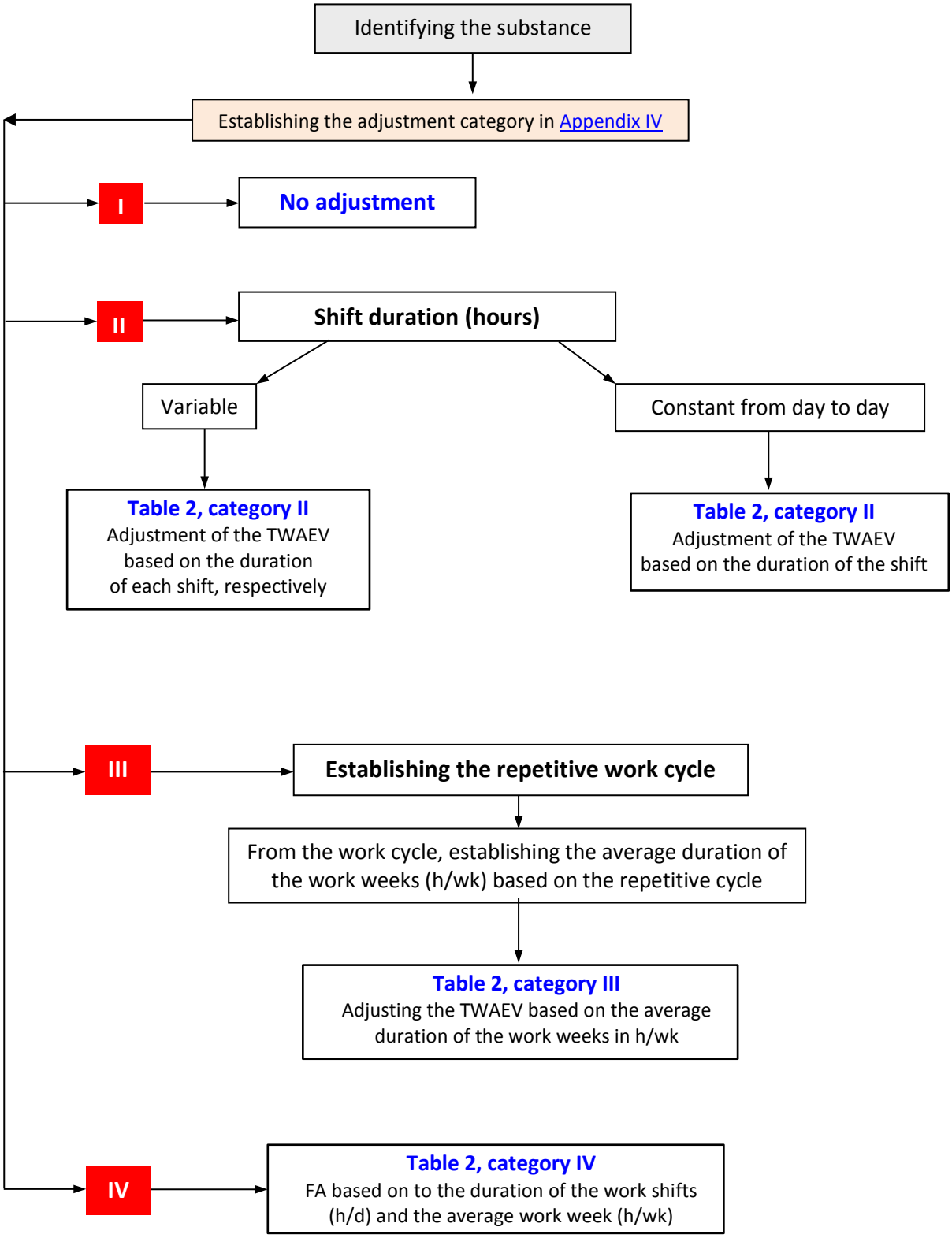
In the case of a daily exposure to a given substance for a worker working at several work locations and who has an unusual work schedule, calculation of the *average daily exposure* is done over the entire work shift and is then compared to the AAEV, as described in Part 2 of Schedule I of the ROHS[1].

In the case of a situation in which there is daily exposure to several substances and an unusual work schedule, the *mixed exposure index* (R_m) is calculated by using the AAEV instead of the TWAEV in the denominator, as described in Part 3 of Schedule I of the ROHS. The MIXIE computer-based tool developed jointly by the Département de santé environnementale et de santé au travail of the Université de Montréal (DSEST) Montréal and the IRSST can be an invaluable aid in identifying substances in the ROHS with similar effects on the same organs of the human body[14,15].

Conclusion

The process of adjusting TWAEVs into AAEVs is summarized in Figure 1. An AAEV cannot be greater than the TWAEV. STEVs and CVs are never adjusted. All the other definitions and provisions of the ROHS apply to the AAEV by replacing the TWAEV with the AAEV in the text.

Figure 1 : TWAEV adjustment process



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Appendix I : Consensus of the Schedule I Committee

Conditions of application

- The adjustment must not allow exposure above the time-weighted average exposure value (TWAEV).
- Short-term exposure values (STEV) are not subject to adjustment.

Assigning adjustment categories

- Add to Category I, without adjustment, "Substances whose half-life is less than 4 hours"
- Include acetone, aniline, chlorine, hexane (other isomers) and hydrogen sulfide in Category **I**, without adjustment.

Appendix II : Examples of PEV adjustment

The PEV adjustment process is presented in the form of scenarios taken from real workplace situations. Appendix IV indicates the adjustment categories for all the substances in Schedule I of the ROHS.

Scenario 1 : Hydrogen cyanide

Scenario 1 raises the question about exposure to ***hydrogen cyanide*** or HCN (hydrocyanic acid) by workers with different schedules of 8h/d, 5 d/wk.

The adjustment category for this substance as found in Appendix IV of this document or in the IRSST Web site (http://www.irsst.qc.ca/en/-RSST74-90-8.html) is **I-a** . Figure 1 informs us that for all Category **I** substances, there is no adjustment regardless of the work schedule.

Scenario 2 : Acetonitrile

A laboratory technician uses ***acetonitrile*** regularly as a solvent. He works 12 h/d, 4 d/wk, with alternating weeks from Monday to Thursday and from Tuesday to Friday. What is the AAEV that applies in his case?

Appendix IV or in the IRSST Web site (http://www.irsst.qc.ca/en/-RSST75-05-8.html) document indicates category **II** for acetonitrile, or a daily adjustment. Figure 1 indicates that for all category II substances, one first has to specify whether the work shifts in his nominal schedule are always the same length from day to day. In this case, the duration of the work shifts is constant at 12 hours, so we consult Table 2. Under the "Category II" heading, at 12.0 h/day, the adjustment factor is 0.67. The AAEV is therefore **45 mg/m³** (67 mg/m³ * 0.67).

The sampling strategy[16] must anticipate a 12-hour weighting of the representative results for the entire shift.

Scénario 3 : Lead

In a plant recovering ***lead*** from automobile batteries and other sources, workers have schedules with 12-hour shifts for two consecutive weeks of 3 days and 4 days. What would be the AAEV for lead that would apply to these workers?

Appendix IV or in the IRSST Web site (http://www.irsst.qc.ca/en/-RSST7439-92-1.html) indicates category **III** for "Lead and its inorganic compounds, dusts and fumes (expressed as Pb)", or a weekly adjustment. Figure 1 indicates that for all category **III** substances, the **repetitive work cycle** must first be specified, or two weeks (14 days), and *the average exposure duration in hours per week based on a repetitive work cycle*, or 42 hours (36+48)/2. This allows us to consult Table 2; under the "Category III" heading, at 42.0 h/week, the adjustment factor is 0.95. Therefore the AAEV becomes **0.14 mg/m³** (0.15 mg/m³ * 0.95).

The sampling strategy must anticipate a 12-hour weighting of the representative résults[16] for the entire shift.

Scenario 4 : Styrene

A fiberglass pleasure boat manufacturing plant has a work schedule consisting of three working days followed by three days off. All the work shifts are 12 h/d. For workers using ***styrene*** to manufacture the polymeric coating, what would the AAEV be?

Appendix IV or in the IRSST Web site (http://www.irsst.qc.ca/-RSST100-42-5.html) indicates category **IV** for styrene, or that the most conservative daily or weekly value must be used. Figure 1 indicates that for all category **IV** substances, categories II and III must be calculated and the most conservative result of the two must be applied.

Therefore, for category II, since all the work shifts are of the same length, or 12 hours, Table 2, under the "Category II" heading at 12 h/day, gives the adjustment factor as 0.67. The AAEV would therefore be **142 mg/m³** (213 mg/m³ * 0.67).

For category III, the **repetitive work cycle** must first be specified, which is 42 days, as summarized in the following table:

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	W	W	W	A	A	A	W
2	W	W	A	A	A	W	W
3	W	A	A	A	W	W	W
4	A	A	A	W	W	W	A
5	A	A	W	W	W	A	A
6	A	W	W	W	A	A	A

W : Work A : Absence

This cycle includes three weeks of 3 shifts (36 hours) and three weeks of 4 shifts (48 hours). The *average exposure duration in hours per week based on a repetitive work cycle* is 42 hours ((36*3)+(48*3))/6. We then consult Table 2; under the "Category III" heading, at 42.0 h/week, the adjustment factor is 0.95. Therefore the AAEV would be **203 mg/m³** (213 mg/m³ * 0.95)..

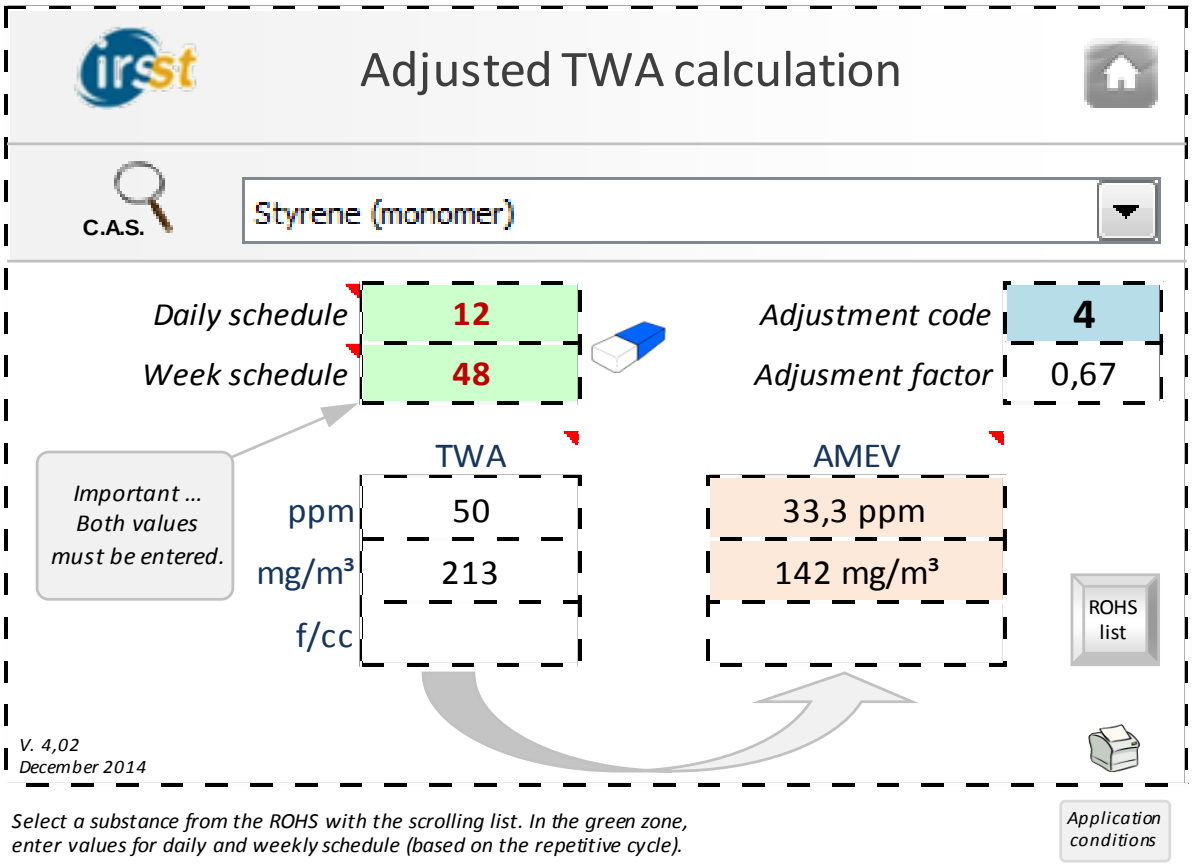
The AAEV of **142 mg/m³**, being the most conservative, is therefore applicable to these workers' exposure. Table 2 under the "Category IV" heading arrives at the same conclusion. In fact, the intersection point of the 42-hour row and the 12-hour column gives an adjustment factor (F_a) of 0.67.

The sampling strategy must anticipate a 12-hour weighting of the representative results[16] for the entire shift.

Appendix III : Excel-based tool for TWAEV adjustment

The following figure shows the EXCEL bilingual computer-based tool available on the IRSST's Web site. It works with Microsoft EXCEL version 2007 (or a later version) and can be downloaded from the following address:

The data for scenario 4 have been used as an example.



Appendix IV : Adjustment category for ROHS substances

Acetaldehyde	1A
Acetic acid	1B
Acetic anhydride	1B
Acetone	1C
Acetone cyanohydrin	1A
Acetonitrile	2
Acetophenone	1B
Acetylene	1C
Acetylsalicylic acid (Aspirin)	2
Acrolein	1B
Acrylamide	3
Acrylic acid	1B
Acrylonitrile	3
Adipic acid	3
Adiponitrile	4
Aldrin	4
Allyl alcohol	1B
Allyl glycidyl ether (AGE)	1B
Allyl propyl disulfide	1B
Aluminum [7429-90-5], (as Al), Alkyls (NOC)	1B
Aluminum (as Al), Metal	1C
Aluminum [7429-90-5], (as Al), Pyro-technical powders	1C
Aluminum [7429-90-5], (as Al), Soluble salts	1B
Aluminum [7429-90-5], (as Al), Welding fumes	1C
Aluminum oxide (as Al), Td	1C
4-Aminodiphenyl	3
2-Aminoethanol	3
2-Aminopyridine	2
Amitrole	3
Ammonia	1B
Ammonium chloride fume	1B
Ammonium perfluorooctanoate	3
Ammonium sulfamate	1B
Aniline	1C
o-Anisidine	2
p-Anisidine	2
Antimony [7440-36-0], metal and compounds (as Sb)	3
Antimony trioxide (as Sb)	3
Antimony trioxide, production (as Sb)	3
ANTU (alpha-Naphthylthiourea)	2
Argon	1C
Arsenic, elemental [7440-38-2], and inorganic compounds (except Arsine) (as As)	3
Arsenic trioxide, production	3
Arsine	4
Asbestos, Actinolite	3
Asbestos, Amosite	3
Asbestos, Anthophyllite	3
Asbestos, Chrysotile	3
Asbestos, Crocidolite	3
Asbestos, Tremolite	3
Asphalt (petroleum) fumes	3
Atrazine	2
Azinphos-methyl	4
Barium, soluble compounds (as Ba)	2
Barium sulfate, Td	3
Barium sulfate, Rd	3
Benomyl	1C
Benz(a)anthracene	3
Benzene	3
Benzidine (production)	3
Benzo(a)pyrene	3
Benzo(b)fluoranthene	3
p-Benzoquinone	1B
Benzoyl peroxide	1B
Benzyl chloride	4
Beryllium [7440-41-7], metal and compounds (as Be)	3
Biphenyl	1B
Bismuth telluride (as Bi2Te3), Se-doped	3
Bismuth telluride (as Bi2Te3), Undoped	1C
Boron oxide	1B
Boron tribromide	1A
Boron trifluoride	1A
Bromacil	3
Bromine	1B
Bromine pentafluoride	1B
Bromoform	4
Bromotrifluoromethane	1C
1,3-Butadiene	3
Butane	1C
2-Butoxyethanol	3
n-Butyl acetate	1B
sec-Butyl acetate	1B
tert-Butyl acetate	1B
n-Butyl acrylate	1B
n-Butyl alcohol	1A
sec-Butyl alcohol	2
tert-Butyl alcohol	2
tert-Butyl chromate (as CrO3)	1A
n-Butyl glycidyl ether (BGE)	3
n-Butyl lactate	1B
Butyl mercaptan	1B
n-Butylamine	1A
o-sec-Butylphenol	1B
p-tert-Butyltoluene	3
Cadmium elemental and compouds (as Cd)	3
Calcium carbonate, Td	1C
Calcium chromate (as Cr)	3
Calcium cyanamide	1B
Calcium hydroxide	1B
Calcium oxide	1B
Calcium silicate (synthetic), Td	1C
Calcium sulfate, Td	1C
Calcium sulfate, Rd	1C
Camphor (synthetic)	1B
Caprolactam, Dust	1B
Caprolactam, Vapour	1B
Captafol	3
Captan	3
Carbaryl	4
Carbofuran	4
Carbon black	3
Carbon dioxide	1C
Carbon disulfide	4
Carbon monoxide	4
Carbon tetrabromide	4
Carbon tetrachloride	4
Carbonyl fluoride	4
Δ-3 Carene	1B
Catechol	4
Cellulose (paper fibres), Td	1C
Cesium hydroxide	1B
Chlordane	4
Chlorinated camphene	4
Chlorinated diphenyl oxide	3
Chlorine	1C
Chlorine dioxide	2
Chlorine trifluoride	1A
Chloroacetaldehyde	1A
Chloroacetone	1A
alpha-Chloroacetophenone	1B
Chloroacetyl chloride	1B
Chlorobenzene	4
o-Chlorobenzylidene malononitrile	1A
Chlorobromomethane	3

Chlorodifluoromethane	1C
Chlorodiphenyl (42% chlorine)	3
Chlorodiphenyl (54% chlorine)	3
Chloroform	4
Chloromethyl methyl ether	3
bis (Chloromethyl) ether	3
1-Chloro-1-nitropropane	2
Chloropentafluoroethane	1C
Chloropicrin	2
β-Chloroprene	4
3-Chloropropene	3
2-chloropropionic acid	3
o-Chlorostyrene	4
o-Chlorotoluene	1B
Chlorpyrifos	4
Chromite ore processing (chromate) (as Cr)	3
Chromium (metal)	3
Chromium (III) compounds (as Cr)	3
Chromium VI, water insoluble inorganic compounds (as Cr)	3
Chromium VI, water soluble inorganic compounds (as Cr)	3
Chromyl chloride	3
Chrysene	3
Clopidol	1C
Coal dust (less than 5% crystalline silica), Rd	3
Coal dust (more than 5% crystalline silica), Rd	3
Coal tar pitch volatiles, as benzene solubles	3
Cobalt, elemental and inorganic compounds (as Co)	3
Cobalt hydrocarbonyl (as Co)	2
Cobalt tetracarbonyl (as Co)	2
Copper [7440-50-8], Fume (as Cu)	2
Copper [7440-50-8], Dust and mists (as Cu)	1B
Corundum, Td	1C
Cotton dust, cotton waste processing operation of waste recycling and garnetting	3
Cotton dust, in yarn manufacturing and cotton washing operations	3
Cotton dust, in textile mill waste house operations or in yarn manufacturing to dust from "lower-grade washed cotton"	3
Cotton dust, in textile slashing and weaving operations	3
Cresol (all isomers)	1B
Crotonaldehyde	1B
Crufomate	4
Cumene	2
Cyanamide	1B
Cyanides (as Cn)	1A
Cyanogen	1B
Cyanogen chloride	1A
Cyclohexane	1B
Cyclohexanol	4
Cyclohexanone	3
Cyclohexene	1B
Cyclohexylamine	1B
Cyclonite	3
Cyclopentadiene	1B
Cyclopentane	4
Cyhexatin	1C
2,4-D	3
DDT (Dichlorodiphenyltrichloroethane)	4
Decaborane	4
Demeton®	4
Di-sec-octyl phthalate	3
2,6-Di-tert-butyl-p-cresol	1C
Diacetone alcohol	1B
1,6-Diaminohexane	1B
Diazinon®	4
Diazomethane	4
Diborane	4
1,2-Dibromoethane	3
Dibutyl phenyl phosphate	4
Dibutyl phosphate	1B
Dibutyl phthalate	1B
2-N-Dibutylaminoethanol	3
1,3-Dichloro -5,5-dimethyl hydantoin	1B
Dichloroacetylene	1A
o-Dichlorobenzene	1A
p-Dichlorobenzene	3
3,3'-Dichlorobenzidine	3
1,4-Dichloro-2-butene	3
Dichlorodifluoromethane	1C
1,1-Dichloroethane	4
1,2-Dichloroethane	3
Dichloroethyl ether	2
1,1-Dichloroethylene	3
1,2-Dichloroethylene	4
Dichlorofluoromethane	4
1,1-Dichloro-1-nitroethane	2
1,2-Dichloropropane	4
Dichloropropene (cis and trans)	4
2,2-Dichloropropionic acid	1B
1,2 Dichloro-1,1,2,2-tetrafluoroethane	1C
Dichlorvos	4
Dicrotophos	4
Dicyclopentadiene	3
Dicyclopentadienyl iron	1C
Dieldrin	4
Diethanolamine	1B
Diethyl ether	1B
Diethyl ketone	2
Diethyl phthalate	3
Diethylamine	1B
2-Diethylaminoethanol	1B
Diethylene triamine	3
Difluorodibromomethane	4
Diglycidyl ether (DGE)	3
Diisobutyl ketone	1B
Diisopropyl ether	1B
Diisopropylamine	1B
Dimethyl carbamoyl chloride	3
Dimethyl sulfate	3
N,N-Dimethylacetamide	4
Dimethylamine	1B
N,N-Dimethylaniline	4
N,N-Dimethylformamide	3
1,1-Dimethylhydrazine	3
Dimethylphthalate	1B
Dinitolmide	3
Dinitro-ortho-cresol	3
Dinitrobenzene (all isomers)	4
Dinitrotoluene	4
Dioxane	3
Dioxathion	3
Diphenylamine	4
Dipropylene glycol monomethyl ether	2
Diquat, Td	3
Diquat, Rd	3
Disulfiram	2
Disulfoton	4
Diuron	1C
Divinyl benzene	1B
Emery, Td	1C
Endosulfan	4
Endrin	2
Enflurane	2
Epichlorohydrin	4
EPN	4
Ethane	1C
Ethion	4
2-Ethoxyethanol (EGEE)	4
2-Ethoxyethyl acetate (EGEEA)	4

Ethyl acetate	1B
Ethyl acrylate	3
Ethyl alcohol	1B
Ethyl amyl ketone	1B
Ethyl benzene	3
Ethyl bromide	4
Ethyl butyl ketone	2
Ethyl chloride	4
Ethyl formate	1B
Ethyl mercaptan	1B
Ethyl silicate	3
Ethylamine	1B
Ethylene	1C
Ethylene chlorohydrin	1A
Ethylene glycol (vapour and mist)	1A
Ethylene glycol dinitrate	1A
Ethylene imine	4
Ethylene oxide	3
Ethylenediamine	3
Ethylidene norbornene	1A
N-Ethylmorpholine	2
Fenamiphos	4
Fensulfothion	4
Fenthion	4
Ferbam	1B
Ferrovanadium (dust)	1B
Fibres, Artificial Vitreous Mineral Fibres, Fibrous glass, continuous filament, Td	1C
Fibres, Artificial Vitreous Mineral Fibres, Fibrous glass, microfibres	3
Fibres, Artificial Vitreous Mineral Fibres, Insulation wool fibres, Glass wool	1B
Fibres, Artificial Vitreous Mineral Fibres, Insulation wool fibres, Rock wool	1B
Fibres, Artificial Vitreous Mineral Fibres, Insulation wool fibres, Slag wool	1B
Fibres, Artificial Vitreous Mineral Fibres, Refractory fibres (ceramic or others)	3
Fibres, Natural Mineral Fibres, Attapulgite	3
Fibres, Natural Mineral Fibres, Erionite	1A
Fibres-Natural Mineral Fibres, Wollastonite, Td	1B
Fibres-Natural Mineral Fibres, Wollastonite, Rd	1B
Fibres, Organic Synthetic Fibres, Carbon and graphite fibres, Td	3
Fibres, Organic Synthetic Fibres, Carbon and graphite fibres, Rd	3
Fibres, Organic Synthetic Fibres, Para-aramide fibres (Kevlar®, Twaron®)	3
Fibres, Organic Synthetic Fibres, Polyolefin fibres, Td	1C
Fluorides (as F)	3
Fluorine	1B
Fonofos	4
Formaldehyde	1A
Formamide	3
Formic acid	1B
Furfural	1B
Furfuryl alcohol	1B
Gasoline	2
Germanium tetrahydride	2
Glutaraldehyde	1A
Glycerin (mist)	1C
Glycidol	1B
Grain dust (oat, wheat, barley), Td	4
Graphite (all forms except fibers), Rd	3
Gypsum, Td	1C
Gypsum, Rd	1C
Hafnium	3
Halothane	4
Helium	1C
Heptachlor	4
Heptachlore epoxide	3
n-Heptane	2
Hexachlorobenzene	3
Hexachlorobutadiene	3
Hexachlorocyclopentadiene	4
Hexachloroethane	3
Hexachloronaphthalene	3
Hexafluoroacetone	4
Hexamethyl phosphoramide	3
Hexamethylene diisocyanate	3
n-Hexane	4
Hexane (other isomers)	1C
sec-Hexyl acetate	1B
Hexylene glycol	1A
Hydrazine	3
Hydrogen	1C
Hydrogen bromide	1A
Hydrogen chloride	1A
Hydrogen cyanide	1A
Hydrogen fluoride (as F)	1A
Hydrogen peroxide	1B
Hydrogen selenide (as Se)	4
Hydrogen sulfide	1C
Hydrogenated terphenyls	3
Hydroquinone	4
2-Hydroxypropyl acrylate	1B
Indene	1B
Indium [7440-74-6] and compounds (as In)	4
Iodine	1A
Iodoform	2
Iron pentacarbonyl (as Fe)	2
Iron salts, soluble (as Fe)	1B
Iron trioxide, dust and fume (as Fe)	3
Isoamyl alcohol	2
Isobutyl acetate	1B
Isobutyl alcohol	1B
Isocyanate oligomers	3
Isooctyl alcohol	2
Isophorone	1A
Isophorone diisocyanate	3
Isopropoxyethanol	3
Isopropyl acetate	1B
Isopropyl alcohol	2
Isopropyl glycidyl ether (IGE)	3
Isopropylamine	1B
N-Isopropylaniline	2
Kaolin, Rd	3
Ketene	2
L.P.G. (Liquified petroleum gas)	1C
Lead and inorganic compounds	3
Lead arsenate (as Pb3(AsO4)2)	4
Lead chromate (as Cr)	3
Lead tetraethyl (as Pb)	3
Lead tetramethyl (as Pb)	3
Limestone, Td	1C
Lindane	4
Lithium hydride	1B
Magnesite, Td	1C
Magnesium oxide fume (as Mg)	2
Malathion	4
Maleic anhydride	4
Manganese, Fume, dust and compounds (as Mn), Td	4
Manganese cyclopentadienyl tricarbonyl (as Mn)	4
Manganese methyl cyclopentadienyl tricarbonyl (as Mn)	4
Manganese tetroxide	3
Mercury [7439-97-6], Alkyl compounds (as Hg)	4
Mercury [7439-97-6], aryl compounds	3
Mercury [7439-97-6], inorganic compounds (as Hg)	3
Mercury [7439-97-6], mecury vapor (as Hg)	3
Mesityl oxide	1B
Methacrylic acid	1B
Methane	1C
Methomyl	4
Methoxychlor	4
2-Methoxyethanol (EGME)	4

2-Methoxyethyl acetate (EGMEA)	4
4-Methoxyphenol	1B
Methyl acetate	2
Methyl acetylene	1C
Methyl acetylene-propadiene mixture (MAPP)	1C
Methyl acrylate	3
Methyl alcohol	4
Methyl amyl alcohol	1B
Methyl n-amyl ketone	1B
Methyl bromide	4
Methyl tert-butyl ether	4
Methyl n-butyl ketone	3
Methyl chloride	4
Methyl chloroform	2
Methyl 2-cyanoacrylate	3
Methyl demeton	4
Methyl ethyl ketone (MEK)	1B
Methyl ethyl ketone peroxide	1A
Methyl formate	1B
Methyl hydrazine	1A
Methyl iodide	4
Methyl isoamyl ketone	1B
Methyl isobutyl ketone	1B
Methyl isocyanate	3
Methyl isopropyl ketone	1B
Methyl mercaptan	1B
Methyl methacrylate (monomer)	1B
Methyl parathion	4
Methyl propyl ketone	2
Methyl silicate	2
alpha-Methyl styrene	2
Methylacrylonitrile	4
Methylal	1B
Methylamine	1B
N-Methylaniline	4
Methylcyclohexane	1B
Methylcyclohexanol	3
o-Methylcyclohexanone	1B
Methylene chloride	4
4,4'-Methylene bis (2-chloroaniline) (MOCA)	4
Methylene bis (4-cyclohexylisocyanate)	3
4,4'-Methylene dianiline	3
Methylene bis (4-phenyl isocyanate) (MDI)	3
Metribuzin	2
Mica, Rd	3
Mineral oil (mist)	3
Molybdenum [7439-98-7] (as Mo), Insoluble compounds	1C
Molybdenum [7439-98-7] (as Mo), Soluble compounds	1C
Monocrotophos	4
Morpholine	1B
Naled	4
Naphthalene	1B
β-Naphthylamine	3
Neon	1C
Nickel, Metal	3
Nickel [7440-02-0], Insoluble compounds (as Ni)	3
Nickel [7440-02-0], Soluble compounds (as Ni)	3
Nickel carbonyl (as Ni)	2
Nickel sulfide roasting, fume and dust (as Ni)	3
Nicotine	2
Nitrapyrin	1C
Nitric acid	2
p-Nitroaniline	4
Nitrobenzene	4
p-Nitrochlorobenzene	4
4-Nitrodiphenyl	3
Nitroethane	1B
Nitrogen	1C
Nitrogen dioxide	4
Nitrogen monoxide	2
Nitrogen trifluoride	2
Nitroglycerin (NG)	1A
Nitromethane	4
1-Nitropropane	3
2-Nitropropane	3
N-Nitrosodimethylamine	3
Nitrotoluene (all isomers)	2
Nitrous oxide	3
Nonane	2
Octachloronaphthalene	3
Octane	2
Osmium tetroxide (as Os)	1B
Oxalic acid	1B
Oxygen difluoride	1A
Ozone	1A
Paraffin wax, fume	1B
Paraquat, respirable particulates, Rd	3
Parathion	4
Particulates Not Otherwise Classified (PNOC), Td	1C
Pentaborane	2
Pentachloronaphthalene	3
Pentachloronitrobenzene	3
Pentachlorophenol	3
Pentaerythritol	1C
n-Pentane	2
n-Amyl acetate	1B
sec-Amyl acetate	1B
tert-Amyl acetate	1B
Isoamyl acetate	1B
2-Methyl-1-butyl acetate	1B
3-Pentyl actetate	1B
Perchloroethylene	4
Perchloromethyl mercaptan	2
Perchloryl fluoride	4
Perfluoroisobutylene	1A
Perlite, Td	1C
Perlite, Rd	1C
Phenol	4
Phenothiazine	3
Phenyl ether, vapour	1B
Phenyl glycidyl ether (PGE)	3
Phenyl mercaptan	1B
meta-Phenylenediamine	3
ortho-Phenylenediamine	3
p-Phenylenediamine	3
Phenylhydrazine	3
n-Phenyl-ß-naphthylamine	3
Phenylphosphine	1A
Phorate	4
Phosdrin	4
Phosgene	2
Phosphine	2
Phosphoric acid	1B
Phosphorus (yellow)	1B
Phosphorus oxychloride	1B
Phosphorus pentachloride	1B
Phosphorus pentasulfide	1B
Phosphorus trichloride	1B
Phthalic anhydride	3
m-Phthalodinitrile	1C
Picloram	1C
Picric acid	3
Pindone	3
α-Pinene	1B
β-Pinene	1B
Piperazine dihydrochloride	3
Plaster of Paris, Td	1C
Plaster of Paris, Rd	1C
Platinum, Metal	3
Platinum [7440-06-4], Soluble salts (as Pt)	3

Polytetrafluoroethylene decomposition products	2
Portland cement, Td	1B
Portland cement, Rd	1B
Potassium hydroxide	1A
Propane	1C
Propane sultone	3
Propargyl alcohol	1B
β-Propiolactone	3
Propionic acid	1B
Propoxur (baygon)	4
n-Propyl acetate	1B
n-Propyl alcohol	1B
n-Propyl nitrate	2
Propylene	1C
Propylene glycol dinitrate	4
Propylene glycol monomethyl ether	4
Propylene imine	3
Propylene oxide	3
Pyrethrum	3
Pyridine	3
Resorcinol	2
Rhodium [7440-16-6], Metal and insoluble compounds (as Rh)	3
Rhodium [7440-16-6], Soluble compounds (as Rh)	3
Ronnel	4
Rosin core solder pyrolysis products (as Formaldehyde)	3
Rotenone	4
Rouge, Td	1C
Rubber solvent (Naphtha)	2
Selenium and compounds (as Se)	4
Selenium hexafluoride (as Se)	4
Sesone	3
Silica, Amorphous, Diatomaceous earth (uncalcined), Td	1C
Silica - Amorphous, fumes, Rd	3
Silica, Amorphous, fused, Rd	3
Silica, Amorphous, gel, Rd	1C
Silica, Amorphous, precipitated, Td	1C
Silica, Crystalline, Cristobalite, Rd	3
Silica, Crystalline, Quartz, Rd	3
Silica, Crystalline, Tridymite, Rd	3
Silica, Crystalline, Tripoli, Rd	3
Silicon, Td	1C
Silicon carbide (non fibrous), Td	1C
Silicon tetrahydride	2
Silver, Metal	3
Silver [7440-22-4], Soluble compounds (as Ag)	3
Soapstone, Td	3
Soapstone, Rd	3
Sodium azide	1A
Sodium bisulfite	1B
Sodium fluoroacetate	2
Sodium hydroxide	1A
Sodium metabisulfite	1B
Borates, tetra, sodium salt , Anhydrous	1B
Borates, tetra, sodium salt , Decahydrate	1B
Borates, tetra, sodium salt , Pentahydrate	1B
Starch, Td	3
Stibine (as Sb)	4
Stoddard solvent	4
Strontium chromate (as Cr)	3
Strychnine	2
Styrene (monomer)	4
Subtilisins (Proteolytic enzymes as 100 % pure crystalline enzyme)	1C
Succinaldehyde	1B
Sucrose	1C
Sulfometuron methyl	3
Sulfotep	4
Sulfur dioxide	1B
Sulfur hexafluoride	1C
Sulfur monochloride	1A
Sulfur pentafluoride	1A
Sulfur tetrafluoride	1A
Sulfuric acid	1B
Sulfuryl fluoride	3
Sulprofos	4
2,4,5-T	1C
Talc, fibrous	3
Talc, non fibrous, Rd	3
Tantalum [7440-25-7], metal and oxide dusts (as Ta)	1C
Tellurium and compounds (as Te)	4
Tellurium hexafluoride (as Te)	2
Temephos	4
TEPP	4
Terephthalic acid	1C
Terphenyls	1A
1,1,2,2-Tetrabromoethane	4
1,1,1,2-Tetrachloro-2,2-difluoroethane	4
1,1,2,2-Tetrachloro-1, 2-difluoroethane	4
1,1,2,2-Tetrachloroethane	4
Tetrachloronaphthalene	3
Tetrahydrofuran	1B
Tetramethyl succinonitrile	2
Tetranitromethane	4
Tetrasodium pyrophosphate	1B
Tetryl	3
Thallium, elemental [7440-28-0], and soluble compounds (as Tl)	3
4,4'-Thiobis (6-tert-butyl-m-cresol)	1C
Thioglycolic acid	1B
Thionyl chloride	1A
Thiram®	3
Tin, Metal	3
Tin [7440-31-5], Organic compounds (as Sn)	3
Tin [7440-31-5], Oxide and inorganic compounds, except SnH4 (as Sn)	3
Titanium dioxide, Td	1C
o-Tolidine	3
Toluene	4
Toluene diisocyanate (TDI) (isomers mixture)	3
o-Toluidine	4
m-Toluidine	2
p-Toluidine	4
Tributyl phosphate	1B
Trichloroacetic acid	1B
1,2,4-Trichlorobenzene	1B
1,1,2-Trichloroethane	4
Trichloroethylene	2
Trichlorofluoromethane	1A
Trichloronaphthalene	3
1,2,3-Trichloropropane	3
1,1,2-Trichloro-1,2,2-trifluoroethane	2
Tri-o-cresyl phosphate	3
Triethanolamine	3
Triethylamine	4
Triglycidyl isocyanurate (TGIC) (alpha-)	3
Triglycidyl isocyanurate (TGIC) (beta)	3
Triglycidyl isocyanurate (TGIC) (mixed isomers)	3
Trimellitic anhydride	3
Trimethyl benzene	3
Trimethyl phosphite	1B
Trimethylamine	1B
2,4,6-Trinitrotoluene (TNT)	3
Triphenyl amine	1C
Triphenyl phosphate	4
Tungsten [7440-33-7] (as W) , Insoluble compounds	1C
Tungsten [7440-33-7] (as W) , Soluble compounds	2
Turpentine	1B
Uranium [7440-61-1] (natural) , Insoluble compounds (as U)	3
Uranium (natural) [7440-61-1], Soluble compounds (as U)	3
n-Valeraldehyde	1B
Vanadium pentoxide, fume and res-	1B

pirable dust (as V2O5)	
Vegetable oil mists (except castor, cashew and other similar irritant oils)	1C
Vinyl acetate	1B
Vinyl bromide	3
Vinyl chloride (monomer)	3
Vinyl cyclohexene dioxide	3
Vinyl toluene	1B
VM&P Naphtha	1B
Warfarin	4
Welding fumes (not otherwise classified)	2
Wood dust (western red cedar), Td	3
Wood dust hard and soft, except red cedar, Td	3
Xylene (o-,m-,p- isomers)	2
m-Xylene-alpha, alpha'-diamine	1A
Xylidine (mixed isomers)	3
Yttrium [7440-65-5], metal and compounds (as Y)	3
Zinc chloride, fume	2
Zinc chromates [13530-65-9;11103-86-9; 37300-23-5] (as Cr)	3
Zinc stearate	1C
Zinc, oxide, Dust, Td	1C
Zinc, oxide, Fume	2
Zirconium [7440-67-7] and compounds (as Zr)	1C