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Derivation of Temporary Emergency Exposure Limits (TEELs)

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Short-term chemical concentration limits are used in a variety of applications, including emergency planning and response, hazard assessment and safety analysis. Development of emergency response planning guidelines (ERPGs) and acute exposure guidance levels (AEGLs) are predicated on this need. Unfortunately, the development of peer-reviewed community exposure limits for emergency planning cannot be done rapidly (relatively few ERPGs or AEGLs are published each year). To be protective of Department of Energy (DOE) workers, on-site personnel and the adjacent general public, the DOE Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has developed a methodology for deriving temporary emergency exposure limits (TEELs) to serve as *temporary guidance* until ERPGs or AEGLs can be developed. These TEELs are approximations to ERPGs to be used until peer-reviewed toxicology-based ERPGs, AEGL or equivalents can be developed. Originally, the TEEL method used only hierarchies of published concentration limits (e.g. PEL- or TLV-TWAs, -STELs or -Cs, and IDLHs) to provide estimated values approximating ERPGs. Published toxicity data (e.g. LC_{50}, LC_{LO}, LD_{50} and LD_{LO} for TEEL-3, and TC_{LO} and TD_{LO} for TEEL-2) are included in the expanded method for deriving TEELs presented in this paper. The addition here of published toxicity data (in addition to the exposure limit hierarchy) enables TEELs to be developed for a much wider range of chemicals than before. Hierarchy-based values take precedence over toxicity-based values, and human toxicity data are used in preference to animal toxicity data. Subsequently, default assumptions based on statistical correlations of ERPGs at different levels (e.g. ratios of ERPG-3s to ERPG-2s) are used to calculate TEELs where there are gaps in the data. Most required input data are available in the literature and on CD ROMs, so the required TEELs for a new chemical can be developed quickly. The new TEEL hierarchy/toxicity methodology has been used to develop community exposure limits for over 1200 chemicals to date. The new TEEL methodology enables emergency planners to develop useful approximations to peer-reviewed community exposure limits (such as the ERPGs) with a high degree of confidence. For definitions and acronyms, see Appendix. Copyright © 2000 Westinghouse Safety Management Solutions LLC obtained pursuant to US government contract.

INTRODUCTION

The Department of Energy (DOE) and its contractor facilities perform emergency planning, including hazard evaluation and consequence analysis. To be protective of DOE facilities, employees, guests and adjacent communities, community exposure limits must be used in the emergency planning process. The DOE uses emergency response planning guidelines (ERPGs) as the community exposure limits of choice.

These ERPGs are developed using original data sources and are published annually in a peer review process conducted by the Emergency Response Planning Committee of the American Industrial Hygiene Association (AIHA).[1] The ERPGs, ERPG Document Sets and 'ERPG/WEEL Handbooks' are available from the AIHA. The ERPGs are developed by the AIHA as guidelines for use in evaluating health effects of accidental chemical releases on the general public. For specific chemicals, ERPGs are estimates of concentration ranges above which acute exposure would be expected to lead to adverse health effects (of increasing severity for concentrations at ERPG-1, ERPG-2 and ERPG-3). The ERPG Document development process results in high-quality community exposure limits that are recognized and used internationally.

The number of approved ERPGs is now ca. 90. The rate of generation of ERPGs is not fast enough to keep up with the immediate need for community exposure limits for emergency planning at DOE facilities. Furthermore, many chemicals may exist at one or two DOE sites in sufficient quantities to require com-

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munity exposure limits for emergency planning; however, these chemicals may be too obscure to ever make it onto a priority list for community exposure limit development. The DOE currently has over 1200 chemicals at its facilities for which community exposure limits have been requested for emergency planning.

Necessary adjuncts to ERPGs

Because many chemicals of interest lack ERPGs, the temporary emergency exposure limit (TEEL) methodology was developed[2] to produce temporary exposure guidance for chemicals of interest until ERPGs are available. The TEEL methodology was originally based on hierarchies of commonly available published and documented concentration-limit parameters (Table 1).

The original TEEL hierarchy methodology was approved by the DOE and has been incorporated into their Emergency Management Guidelines.[3] The TEELs are approximations to ERPGs to be used until peer-reviewed, toxicology-based ERPGs, AEGL or equivalents can be developed. The original TEEL hierarchy method has been expanded to include other published concentration limits, including National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits[4,5] (RELs), AIHA workplace environmental exposure limits[1] (WEELs), German maximum allowable concentrations[5] (MAKs), and others.[6] Because there are no published concentration limits for many chemicals, this methodology was expanded further to include the use of published toxicity parameters (LC_{50}, etc.).

Table 1. Original hierarchy of alternative concentration-limit parameters[a]

Primary guideline	Hierarchy of alternative guidelines	Source of concentration parameter
ERPG-3		AIHA 1999[1]
	EEGL (30-min)	NAS 1985[17]
	IDLH	NIOSH 1997[4]
ERPG-2		AIHA 1999[1]
	EEGL (60-min)	NAS 1985[17]
	LOC	EPA 1987[18]
	PEL-C	CFR 29:1910.1000[19]
	TLV-C	ACGIH 1999[20]
	REL-C[a]	NIOSH 1997[4,5]
	WEEL-C[a]	AIHA 1999[1]
	TLV-TWA × 5	ACGIH 1999[20]
ERPG-1		AIHA 1999[1]
	PEL-STEL	CFR 29:1910.1000[19]
	TLV-STEL	ACGIH 1999[20]
	REL-STEL[a]	NIOSH 1997[4,5]
	WEEL-STEL[a]	AIHA 1999[1]
	OTHER-STEL[a]	e.g. German, Russian[6]
	TLV-TWA × 3	ACGIH 1999[20]
PEL-TWA		CFR 29: 1910.1000[19]
	TLV-TWA	ACGIH 1999[20]
	REL-TWA[a]	NIOSH 1997[4,5]
	WEEL-TWA[a]	AIHA 1999[1]
	MAK-TWA[a]	Germany 1999[5]
	OTHER-TWA[a]	e.g. Russian[6]
	CEGL	NAS 1985[17]

[a]Parameters added since initial publication of the hierarchy methodology.[2]

Expanding the TEEL database

Emergency planners and others required community exposure limits for many chemicals without alternative published exposure limits. Because there are no published concentration limits for many chemicals (i.e. TLVs, PELs, MAKs), the original TEEL methodology was expanded further to include the use of published toxicity parameters.[7–9] The TC_{LO} and TD_{LO} values can be used to estimate TEEL-2, and LC_{50}, LC_{LO}, LD_{50} and LD_{LO} can be used (in order of availability) to estimate TEEL-3.

In using toxicity data to determine TEELs, human data are given primary consideration over animal data, and rat data are preferred over those for other species. Inhalation data are preferred over data from other routes of uptake. This hierarchy is similar to that developed by the US Department of Transportation (DOT) and other agencies in establishing protective action distances for 'the Orange Book' (properly named the 1996 North American Guide Book).[10–12]

Previous authors have developed hierarchies of exposure limits and toxicity data to be used as less precise alternatives when ERPGs do not exist.[11] The use of human equivalent concentrations has been hinted at for emergency planning by some sources.[10,11] In the absence of peer-reviewed ERPG values, the DOE SCAPA Committee on TEELs decided that the human equivalent concentration method was a useful methodology to pursue for developing TEELs.

Relationship between ERPGs and toxicity parameters

To identify a relationship between ERPGs and toxicity parameters, data were extracted for all chemicals for which ERPGs were available (77 on 31 December 1997).[13] Regressions were carried out for two sets of data:

(i) lethality data (LD_{50}, LC_{50}, LD_{LO} and LC_{LO}) and ERPG-3s;
(ii) toxicity data (TD_{LO} and TC_{LO}) and ERPG-2s.

These analyses were done for all values ($N = 77$) and then for restricted ranges of ratios ($n < 77$, to eliminate ratios considered to be outliers in the sense that they distorted the means and standard deviations of most of the data). The resulting mean ratios were rounded and applied to lethality and toxicity data for new chemicals. Ultimately, the relationship between ERPG-2 and -3 and the toxicity data allowed TEEL-3s and TEEL-2s to be calculated from the available lethality and toxicity data for chemicals lacking official ERPG values.

METHODS

Data input

For new chemicals requiring TEELs, the following data input sequence is used:

(i) The name of the chemical compound is entered on the first worksheet of the Excel workbook,[14] along with its CAS number, SAX number,[7] molecular weight (MW) and the primary units (ppm or mg m^{-3}) of available concentration limits (e.g. PELs, TLVs, ERPGs, etc.).

(ii) For each chemical, LD_{50}, LD_{LO}, TD_{LO}, LC_{50}, LC_{LO} and TC_{LO} data from SAX, RTECS or HSDB[7–9] are entered. These data include dose (mg kg^{-1}), animal species and route of administration (Rte). The lowest reported dose or concentration reported for a given parameter (e.g. TC_{LO}) is used. For TD_{LO}, gender and nature of test and the number of exposure days are entered as well.

(iii) For inhalation exposures, exposure time and whether toxic effects of the chemical are concentration dependent are also entered. When data for more than one species are available, the priority for use is human data, followed by rat, mouse and other species in that order.

(iv) The lowest reported dose or concentration reported for a given parameter (e.g. TD_{LO}) is used.

(v) Default values for mean body weight (BW in kg) and breathing rate (ABR in m^3 day^{-1}) in species tested and an adjustment factor for route of administration (RAF) are included in two separate worksheets as look-up tables (Tables 2 and 3). These RAFs are somewhat arbitrary, and are under investigation.

Table 2. Default mean body weight and breathing rate values for different species[a]

Species	Abbreviation for species (Sp)	Mean BW (kg)	Mean ABR (m^3 day^{-1})
Bird	brd	0.5	0.525
Bird—tns	brd-t	1	1.05
Bird—wild	brd-w	0.04	0.42
Child	chd	20	8.64
Chicken	ckn	0.8	0.85
Cat	ct	2	1.25
Dog	dg	10	3.66
Duck	dck	2.5	2.625
Frog	frg	0.033	1.51
Guinea pig	gp	0.5	0.283
Hamster	ham	0.125	0.1
Human/man	hmn	70	20
Infant	inf	5	2.5
Monkey	mo	5	3.94
Mouse	mu	0.025	0.035
Pig	pg	60	20
Quail	quail	1	1.05
Rat	r	0.2	0.153
Rabbit	rb	2	1.3
Women	wmn	50	16

[a]The default body weight (BW) data are from SAX.[7] The daily inhalation rates (ABR) are commonly used values for human males, females, children and infants, and laboratory animals. Similar sets of default values, for a more limited list of species, are presented by Calabrese[21] and Hayes.[22]

Table 3. Adjustment factors used for different routes of administration[a]

Route of administration	Abbreviation (Rte)	RAF
Eye	eye	0.20
Implant	imp	0.25
Inhalation	ih	0.50
Inhalation—gas/vapor	ih-g	0.50
Inhalation—particles	ih-p	0.25
Intracerebral	ice	0.50
Intradermal	idr	0.10
Intramuscular	im	0.25
Intraperitoneal	ip	0.75
Intrapleural	ipl	0.50
Intratesticular	itt	0.25
Intratracheal	it	0.25
Intravaginal	ivg	0.25
Intravenous	iv	1.00
Oral	os	0.25
Skin	sk	0.10
Skin—insoluble	sk-i	0.10
Skin—soluble	sk-s	0.20
Subcutaneous	sc	0.10
Unknown	uk	0.25

[a]The route of administration adjustment factors (RAF) presented are rough estimates used to account partially for the differences between administered dose and absorbed dose. In practice, these values would be expected to vary from chemical to chemical, depending upon solubility in body fluids, metabolic changes and other factors. The RAFs for inhaled material are used only when data are given in dose units (mg kg^{-1}).

Calculations

All subsequent Excel worksheets to calculate TEELs based on toxicity data are linked to the data entered (above) on the first worksheet. The TEELs are established as follows:

(i) If possible, hierarchy-based TEELs are first calculated by direct application of the hierarchy methodology[2] to the chemicals for which concentration limits are required (when the hierarchy method can be applied, i.e. alternative exposure limits exist).

(ii) Minimum values (i.e. hierarchy-based values below which subsequently calculated toxicity-based TEEL-2s or TEEL-3s must not fall) are calculated because it would be inappropriate for TEEL-2, for example, to be less than TEEL-1. Factors used to convert ppm units to mg m^{-3} at 25°C and 760 mmHg for use in subsequent worksheets are computed next, followed by toxicity-based TEELs.

(iii) Dose data (in mg kg^{-1}) are first converted to concentrations (in mg m^{-3}) by applying simple mean body weight and breathing rate (Table 2) and route of intake adjustment factors (Table 3) to account for differences in uptake from different routes of exposure.

(iv) For repeated TD_{LO} dose data, the published mg kg^{-1} dose is divided by the number of exposure days before conversion to a human-equivalent concentration.

(v) Concentration data from these calculations, or from inhalation exposure data, LC_{50}, LC_{LO} or TC_{LO} if available, are converted to human-equivalent LC_{50}, LC_{LO} and TC_{LO} values[14] in mg m^{-3}.
(vi) No route of administration adjustment is used when input data are in concentration units (i.e. ppm or mg m^{-3}).
(vii) A judgement must be made as to whether toxic consequences of exposure to a particular chemical are concentration dependent (Y) or exclusively dose dependent (N). Any chemicals for which there are short-term concentration limits similar to PEL-STEL, TLV-STEL, PEL-C or TLV-C are assumed to have concentration-dependent toxic consequences. When repeated TC_{LO} inhalation exposure data are used, the daily exposure concentration is used. All toxic concentration data are reduced to a 15-min exposure time. If the exposure time is not given, 15 min is assumed for concentration-dependent chemicals and 60 min is assumed for dose-dependent chemicals.[14] The concentration adjustment is made as follows:

$$C_{adj} = C \times (t_{exp}/t)^n$$

where C = reported or calculated concentration for the specific endpoint (e.g. LC_{50}, LC_{LO}, TC_{LO}, etc.), t_{exp} = reported exposure time, t = 15 min and n = 0.5 for concentration-dependent chemicals (Y) and 1.0 for exclusively dose-dependent chemicals (N).
(viii) Toxicity-based TEEL-2s are calculated using mean ratios of the human-equivalent concentrations for TC_{LO} and TD_{LO} data (in order of availability) to ERPG-2s.
(ix) Toxicity-based TEEL-3s are calculated using mean ratios of the human-equivalent concentrations for LC_{50}, LC_{LO}, LD_{50} and LD_{LO} data (in order of availability) to ERPG-3s (Table 4).

The mean ratios were calculated between matched pairs of toxicity and ERPG data, resulting in correlations for all chemicals having official ERPGs. These correlations were calculated for matched pairs of ERPG values and the following toxicity parameters:

(i) All LC_{50}, LD_{50} and TD_{LO} data and corresponding rat-only data.
(ii) All LC_{LO}, LD_{LO} and TC_{LO} data and corresponding human-only data.

Correlations were conducted on all matched pairs and then repeated for pairs within arbitrarily selected ratio ranges to eliminate outliers. A trial-and-error procedure was used to maximize the number of data pairs and to minimize the coefficient of variation of the mean ratios in restricting the ratio ranges.

For some chemicals, data are not available to develop a full set of TEEL values. For these cases, default ratios are used to estimate the 'missing' TEEL value from the existing TEELs above or below it. The default ratios were derived as follows. Ratios of all existing ERPG-2 to ERPG-1 values, and ERPG-3 to ERPG-2 values, were calculated. The means, standard deviations and coefficients of variation of these ratios were calculated. This analysis was conducted for all available ratios (N), and then repeated after eliminating some extreme outlier ratios (n, where $n < N$). The mean ratio of ERPG-2 to ERPG-1 was used to estimate TEEL-1s from TEEL-2s if no hierarchy-based TEEL-1 was available. The mean ratio of ERPG-3 to ERPG-2 was used to estimate TEEL-2s from TEEL-3s, or vice versa, if there were neither hierarchy-based nor toxicity-based TEEL-2 or TEEL-3 values.

Procedure-based TEELs result from selection of hierarchy-based values first, followed by toxicity-based TEEL-2 and TEEL-3 values, followed by default values in the absence of either hierarchy-or toxicity-based TEELs. Procedure-derived TEELs at all levels (i.e. TEEL-0, TEEL-1, TEEL-2 and TEEL-3) are calculated next. The raw numbers are rounded down to factors of ten of 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0 and 7.5, unless the value is within 5% of the next highest value, in which case it is rounded up (e.g. 290 would become 300, not 250). Procedure-based TEELs are adjusted to recommended TEELs to ensure that there are no blanks, and that all TEELs are at least equal to the previously calculated minimum hierarchy-based values, i.e.

$$\text{TEEL-3} \geqslant \text{TEEL-2} \geqslant \text{TEEL-1} \geqslant \text{TEEL-0}$$

It also reduces all TEEL values for materials in aerosol form (mg m^{-3} units) to a maximum of 500 mg m^{-3}.

RESULTS

The mean ratio of ERPG-2 to ERPG-1 was determined to be ca. 7. This ratio is used to estimate TEEL-1s from TEEL-2s when no hierarchy-based TEEL-1 is available. The mean ratio of ERPG-3 to ERPG-2 was determined to be ca. 5; this ratio is similarly used to estimate TEEL-2s from TEEL-3s, or vice versa, if there are neither hierarchy-based nor toxicity-based TEEL-2 or TEEL-3 values.

The TEEL rounding protocol is similar to that used by others (OSHA, ACGIH and AIHA). The maximum TEEL value of 500 mg m^{-3} is the upper limit of stability for an aerosol.

Results of statistical analysis of the available toxicity and ERPGs are presented in Table 4. All available LC_{50} data are plotted against ERPG-3s for these chemicals in Fig. 1. Using only the restricted-range data, mean ratios of TC_{LO} to ERPG-2s were ca. 15 for all the data and 10 for the human data only. Mean ratios of TD_{LO} to ERPG-2s were ca. 1.5 for all the data and ca. 1 for rat data only. The results were rounded and used to estimate TEEL-2 values.

Mean ratios of LC_{50} to ERPG-3s were ca. 100 for all the data and for rat data. Mean ratios of LC_{LO} to ERPG-3s were ca. 100 for all the data and 50 for the human data. Mean ratios of LD_{50} to ERPG-3 for all the data and for rat data were both <2, whereas mean ratios of LD_{LO} to ERPG-3s for all data and for human data were both close to unity. The results were rounded and used to estimate TEEL-3 values.

The rounded mean ratios of human-equivalent toxicity parameters to ERPG-2s (toxicity) and to ERPG-3s (lethality) are summarized in Table 5. A sample of

Table 4. Results of statistical correlations between human-equivalent toxicity parameters and ERPGs[a]

Regression parameters		*n* = *N* (data from all matched pairs)				*n* < *N* (restricted ratio range data)			
Limit	Toxicity	Data	*N*	Mean	*r*	Range	*n*	Mean	*r*
ERPG-3	LD_{50}	All	55	19.4	0.41	10–0.01	43	1.32	0.74
	LD_{50}	Rat	48	21.7	0.41	10–0.01	37	1.30	0.74
	Log LD_{50}	All	55		0.53	10–0.01	43		0.77
	Log LD_{50}	Rat	48		0.51	10–0.01	37		0.74
ERPG-3	LD_{LO}	All	40	29.7	0.05	5–0.005	35	0.771	0.69
	LD_{LO}	Human	18	1.82	0.84	5–0.005	16	0.570	0.89
	Log LD_{LO}	All	40		0.36	5–0.005	35		0.59
	Log LD_{LO}	Human	18		0.53	5–0.005	16		0.68
ERPG-3	LC_{50}	All	67	666	0.72	500–5	55	109	0.84
	LC_{50}	Rat	55	747	0.72	500–5	46	107	0.84
	Log LC_{50}	All	67		0.79	500–5	55		0.93
	Log LC_{50}	Rat	55		0.81	500–5	46		0.94
ERPG-3	LC_{LO}	All	39	302	0.35	250–2.5	28	68.0	0.71
	LC_{LO}	Human	18	79.0	−0.02	250–2.5	13	43.6	0.75
	Log LC_{LO}	All	39		0.70	250–2.5	28		0.90
	Log LC_{LO}	Human	18		0.72	250–2.5	13		0.84
ERPG-2	TD_{LO}	All	31	17.9	0.37	15–0.15	20	1.49	0.46
	TD_{LO}	Rat	16	30.4	−0.05	15–0.15	8	0.700	0.35
	Log TD_{LO}	All	31		0.56	15–0.15	20		0.86
	Log TD_{LO}	Rat	16		0.24	15–0.15	8		0.83
ERPG-2	TC_{LO}	All	36	1431	0.02	150–0.15	26	16.0	0.12
	TC_{LO}	Human	30	1696	0.01	150–0.15	22	6.05	0.25
	Log TC_{LO}	All	36		0.38	150–0.15	26		0.80
	Log TC_{LO}	Human	30		0.36	150–0.15	22		0.88

[a] *N* = total number of data points for the parameter of interest; *n* = number of data points within the stated range (this was obtained by eliminating a few ratios judged to be outliers, in the sense that these data points grossly distorted the mean of the majority of the data); *r* = correlation coefficient for $Y = mX + b$, where *X* = ERPG-2, ERPG-3, log ERPG-2, or log ERPG-3, *Y* = stated toxicity parameter or log of toxicity parameter and $b = 0$.

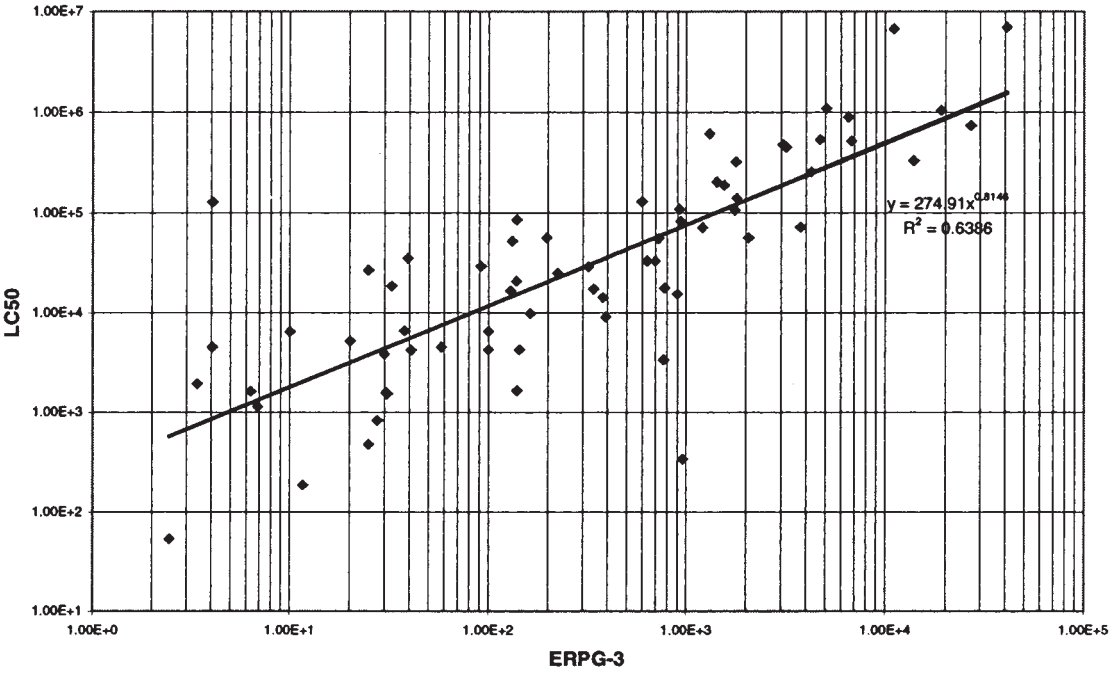

Figure 1. The LC_{50} data versus ERPG-3.

Table 5. Adjustment factors to derive toxicity-based TEELs from human-equivalent toxicity concentration values

Species	ERPG-3				ERPG-2	
	LC_{50}	LC_{LO}	LD_{50}	LD_{LO}	TC_{LO}	TD_{LO}
Human only	—	50	—	1	10	—
Rat only	100	—	2	—	—	1
All data	100	100	2	1	15	1.5

the input and output for five chemicals for which differing input data are available is included in Tables 6 and 7, respectively.

The TEELs for 1251 chemicals, including 77 for which 'official' ERPGs had been published,[1] are included in the document WSMS-SAE-99-0001, dated 4 January 1999. This document is available on the DOE (Department of Environment, Safety and Health) Chemical Safety home page: *http://tis-hq.eh.gov/web/chem_safety/*, under 'Documents'. The methodology described above was applied to develop TEELs for all these chemicals.

DISCUSSION

The published[2] hierarchy methodology for deriving TEELs is in use and is included in the United States Department of Energy Emergency Management Guidelines.[3] The toxicity-based procedure described was developed because of the lack of existing concentration limits for many of the chemicals for which acute exposure limits are required. Further default procedures, such as the determination of ratios of ERPG and TEEL levels, were developed to fill in the remaining gaps in the recommended TEELs.

Regarding data selection, if there are data for the same parameter (e.g. LC_{LO}) for more than one species, human data are used first, followed by rat data, mouse data and data for other species in order. The reason for this choice is that there is far more rat and mouse toxicity data than are available for other animal species.

The selection of route adjustment factors (RAFs) is based on professional judgement. For example, intravenous (i.v.) administration has been assumed to have an RAF of 1.00, because the material is injected directly into the bloodstream, whereas oral administration (o.s.) has been assigned an arbitrary RAF value of 0.25 (Table 3).

It is recognized that the conversion of animal toxicity data to human-equivalent concentrations is controversial. Mean ratios of animal-equivalent concentrations for LD_{50}, LD_{LO} and TD_{LO} data (or animal concentration data for LC_{50}, LC_{LO} and TC_{LO}) could have been computed instead. This would actually simplify the computation slightly, but should not affect significantly the toxicity-based TEELs. Because the TEEL procedure is based on the computed mean ratios of human-equivalent concentrations to existing ERPGs, it does not really matter.

The treatment of exposure time in the development of TEELs bears further explanation. Consideration must be given to whether the toxic consequences of exposure to a chemical may be concentration dependent (e.g. hydrogen sulfide), dose dependent (e.g. quartz) or both (e.g. benzene). In effect, the procedure described in this paper uses Haber's Law[15] ($C \times t = K$, where C is concentration, t is exposure time and K is a constant) for all chemicals for which toxic consequences are *exclusively* dose dependent.

For all other chemicals, rather than use the ten Berge[16] equation ($C^n \times t = K$, where n is a chemical-dependent exponent that lies in the approximate range 0.8–4), a decision was made to reduce the influence of exposure time t for concentration-dependent chemicals. Besides the fact that the exponent n would not be known for virtually all the chemicals to which the TEEL methodology would be applied, it is felt that for those chemicals for which toxic effects are concentration dependent it is the influence of time, not concentration, that needs to be adjusted.

CONCLUSIONS

The TEEL determination process (for TEEL-2 and TEEL-3) selects hierarchy-based values first, if available (e.g. TLV, PEL, etc.), followed by toxicity-based values (e.g. TC_{LO} and TD_{LO} for TEEL-2, or LC_{50}, LC_{LO}, LD_{50} and LD_{LO} for TEEL-3). However, human toxicity data take precedence over animal data, overriding the order of toxicity-parameter selection. The inhalation data cover a range of exposure times. Although acute exposure data (i.e. exposure times up to 4 h) are preferred, longer term exposure data are used if there are no acute exposure data. The TEEL hierarchy and toxicity methodology is listed in Table 8.

The software program described above calculates TEELs from these data and the default ERPG ratios. This methodology has been applied successfully to nearly 1200 chemicals lacking ERPGs. Most of the required input data parameters are already available on CD-ROMs. Application of the methodology to develop temporary emergency exposure limits requires only that data be entered on the first worksheet of the Excel workbook. These data are used to produce procedure-derived TEELs.

The work described greatly expands the number of chemicals for which TEELs can be derived, and its application will ensure consistency of TEEL values from one DOE site to another. It should be emphasized that TEELs are default, temporary, emergency exposure limits. They are derived using the methodology summarized in this paper, and are intended for use only until official acute exposure guidance levels are provided by the EPA, or ERPGs are published by the AIHA. Although TEEL-1, TEEL-2 and TEEL-3 have the same definitions as ERPG-1, ERPG-2 and ERPG-3, TEELs are not equivalent to ERPGs but are approximations. The latest revision of the recommended TEEL list is available on the DOE (Department of Environment, Safety and Health) Chemical Safety home page: *http://tis-hq.eh.gov/web/chem_safety/*, under 'Documents'.

Table 6. Input data for the calculation of TEELs[a]

No.	Chemical compound	CAS no.	SAX no.	MW	Units of limits
1	Chemical with ERPGs	00107-13-1	ADX500	53.07	ppm
2	Chemical with toxicity data only	00105-60-2	CBF700	115.18	mg m^{-3}
3	Chemical with HT-3, toxicity data, no HT-2	00140-88-5	EFT000	100.13	ppm
4	Chemical with no HTs and only LC_{50} data	28182-81-2	HEG300		mg m^{-3}
5	Chemical with HT-2 and some toxicity data	01310-65-2	LHI100	23.95	mg m^{-3}

		TEEL-0						TEEL-1						
		Time-weighted average concentration (TWA)							Short-term exposure limit (STEL)					3 × TLV
		PEL	TLV	REL	WEEL	Other	Note	ERPG-1	PEL	TLV	REL	WEEL	Other	TWA
1	ERPGs	2	2	1				10						
2	Tox data only		1	1		5	MAK			3	3			
3	HT-1, -3, tox data	25	5			5	MAK			15				
4	No HTs, LC_{50}													
5	HT-2, some tox													

		TEEL-2								TEEL-3		
		ERPG–2	EEGL	EPA	15-min celing concentration				5 × TLV	ERPG-3	EEGL	
			60 min	LOC	PEL	TVL	REL	WEEL	TWA		30 min	IDLH
1	ERPGs	35		50	10					75		85
2	Tox data only											
3	HT-1, -3, tox data											300
4	No HTs, LC_{50}											
5	HT-2, some tox							1				

		LD_{50}			LD_{LO}			TD_{LO}				
		Dose (mg kg^{-1})	Spec	Rte	Dose (mg kg^{-1})	Spec	Rte	Dose	Spec	Rte	Gender, exp. type	Days
1	ERPGs	78	r	os	2015	chd	sk	650	r	os	f, post	10
2	Tox data only	930	r	os	800	r	lp					
3	HT-1, -3, tox data	800	r	os	1800	r	sk	51500	r	os	2yr-I	260
4	No Hts, LC_{50}											
5	HT-2, some tox				200	mu	os					

		LC_{50}				LC_{LO}			
		Dose (ppm)	Dose (mg m^{-3})	Spec	Exp. *T* (min)	Dose (ppm)	Dose (mg m^{-3})	Spec	Exp. *T* (min)
1	ERPGs	425		r	240		1000	hmn	60
2	Tox data only		300	r	120				
3	HT-1, -3, tox data	2180		r	240	1204		rb	420
4	No Hts, LC_{50}		18500	r	60				
5	HT-2, some tox		960	r	240				

		TC_{LO}								Toxicity is concentration-dependent
		Dose (ppm)	Dose (mg m^{-3})	Spec	Exposure regimen				Exp. *T* (min)	
					Year	Week	Day	min		
1	ERPGs	16		hmn				20	20	Y
2	Tox data only		21.2	hmn					15	Y
3	HT-1, -3, tox data	50		hmn					15	Y
4	No Hts, LC_{50}									Y
5	HT-2, some tox									Y

[a]HT = hierarchy-based TEEL.
2yr-I, I = intermittent.

Table 7. The TEELs calculated from the input data in Table 6[a]

No.	Chemical	CAS no.	Recommended TEELs				Units of original limits
			TEEL-0	TEEL-1	TEEL-2	TEEL-3	
1	ERPGs	00107-13-1	2	10	35	75	ppm
2	Tox data only	00105-60-2	1	3	3	20	mg m^{-3}
3	HT-1, -3, tox data	00140-88-5	15	15	15	300	ppm
4	No Hts, LC_{50}	28182-81-2	7.5	25	200	500	mg m^{-3}
5	HT-2, some tox	01310-65-2	0.05	0.15	1	100	mg m^{-3}

[a]HT = hierarchy-based TEEL.

Table 8. The TEEL hierarchy and toxicity methodology[a]

Primary guideline	Hierarchy of alternative guidelines	Source of concentration parameter
ERPG-3		AIHA 1999[1]
	EEGL (30-min)	NAS 1985[17]
	IDLH	NIOSH 1997[4]
	LC_{50}	a
	LC_{LO}	a
	LD_{50}	a
	LD_{LO}	a
ERPG-2		AIHA 1999[1]
	EEGL (60-min)	NAS 1985[17]
	LOC	EPA 1987[18]
	PEL-C	CFR 29:1910.1000[19]
	TLV-C	ACGIH 1999[20]
	REL-C[b]	NIOSH 1997[4,5]
	WEEL-C[b]	AIHA 1999[1]
	TLV-TWA × 5	ACGIH 1999[20]
	TC_{LO}	a
	TD_{LO}	a
ERPG-1		AIHA 1999[1]
	PEL-STEL	CFR 29:1910.1000[19]
	TLV-STEL	ACGIH 1999[20]
	REL-STEL[b]	NIOSH 1997[4,5]
	WEEL-STEL[b]	AIHA 1999[1]
	OTHER-STEL[b]	e.g. German, Russian[6]
	TLV-TWA × 3	ACGIH 1999[20]
PEL-TWA		CFR 29:1910.1000[19]
	TLV-TWA	ACGIH 1999[20]
	REL-TWA[b]	NIOSH 1997[4,5]
	WEEL-TWA[b]	AIHA 1999[1]
	MAK-TWA[b]	Germany[5]
	OTHER-TWA[b]	e.g. Russian[6]
	CEGL	NAS 1985[17]

[a]See complete discussion in text regarding the use of toxicity parameters for deriving TEELs.
[b]Hierarchy parameters added since publication of the original hierarchy methodology.[2]

Further technical reports and applications literature describing this methodology[8] are available on the DOE SCAPA Home Page: *http://www.scapa.bnl.gov.*

APPENDIX

Definitions

Definitions for the different temporary emergency exposure limits (TEELs) are based on those for emergency response planning guidelines (ERPGs).

ERPG-1. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3. The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing life-threatening health effects.

TEEL-0. The threshold concentration below which most people will experience no appreciable risk of health effects.

TEEL-1. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

TEEL-2. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3. The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

Exposure time. It is recommended that, for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-min time-weighted average concentration. It should be emphasized that TEELs are default values, following the published methodology explicitly. The only judgement involved is that exercised in the extraction of data used to calculate the recommended TEELs.

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
BW	body weight of exposed species (kg)
BR	breathing rate of exposed species (m^3 day^{-1})
C	ceiling limit
CAS	Chemical Abstract Services registry number
CEGL	NAS continuous exposure guidance level
CFR	US Code of Federal Regulations
DOE	US Department of Energy
EEGL	NAS emergency exposure guidance level
EPA	US Environmental Protection Agency
ERPG	AIHA emergency response planning guideline
HT	hierarchy-based TEEL
HT-2	hierarchy-based TEEL-2
HT-3	hierarchy-based TEEL-3
IDLH	NIOSH immediately dangerous to life or health
LOC	EPA level of concern
LD_{50}	lethal dose to 50% of the exposed population (in mg kg^{-1} body weight)
LD_{LO}	lowest dose at which mortality is observed in exposed population (mg kg^{-1})
TD_{LO}	lowest dose at which toxicity is observed in exposed population (mg kg^{-1})
LC_{50}	lethal concentration to 50% of the exposed population (in mg m^{-3} or ppm)
TC_{LO}	lowest concentration at which mortality is observed in exposed population (mg m^{-3} or ppm)
LC_{LO}	lowest concentration at which toxicity is observed in exposed population (mg m^{-3} or ppm)
MAK	Germany maximum allowable concentration
NAS	US National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
OSHA	US Occupational Safety and Health Administration
PEL	OSHA permissible exposure limit
RAF	route adjustment factor
REL	NIOSH recommended exposure limit
SAX	Name of reference book 'SAX's Dangerous Properties of Industrial Materials'[7]
SCAPA	US. DOE Subcommittee on Consequence Assessment and Protective Actions
STEL	short-term exposure limit
TEEL	SCAPA temporary emergency exposure limit
TLV	ACGIH threshold limit value
TWA	time-weighted average
WEEL	AIHA workplace environmental exposure limit

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