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Valeurs d'exposition admissibles des contaminants de l'air en milieu de travail

Analyse critique des modifications du règlement
« Qualité du milieu de travail »

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Note de l'éditeur,

Une première édition de ce document a déjà paru en janvier 1994 sous le titre **Analyse critique des valeurs d'exposition admissibles des contaminants de l'air en milieu de travail du point de vue de la santé publique** « Qualité du milieu de travail - Modifications » *Gazette officielle du Québec, 125e année, no 50, pages 8205-8251.* Les auteurs faisaient à l'époque partie de l'Équipe de santé publique de l'Hôpital du Sacré-Coeur de Montréal. Cette seconde impression est une réédition du même texte.

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1. Préambule

Ce document présente les commentaires de l'Équipe de santé publique de Montréal sur les valeurs d'exposition admissibles (VEA) des contaminants de l'air publiées dans la Gazette Officielle du Québec le 1er décembre 1993 (pages 8205-8251).

Nous critiquons essentiellement: 1) le fondement "scientifique" des valeurs d'exposition admissibles publiées par la Commission de la Santé et de la Sécurité du Travail du Québec (CSST), et 2) le processus par lequel la CSST établie de telles valeurs d'exposition admissibles.

On met en évidence tant quantitativement que qualitativement les limites des valeurs d'exposition admissibles et des classifications cancérogènes avancées dans la Gazette Officielle du Québec le 1er décembre 1993.

On présente également d'autres méthodologies d'élaboration de telles limites d'exposition, dont en particulier celle adoptée par un comité de l'*American Public Health Association* ("*Health Based Exposure Limits Subcommittee*", président Dr. Grace Ziem), et ayant conduit à estimer des valeurs limites d'exposition dites "*Health Based Exposure Limits*" (HBEL). De telles méthodes, basées sur les principes d'analyse du risque, sont en effet des alternatives possibles par rapport à des méthodes telles que celles de l'*American Conference of Governmental Industrial Hygienists* (ACGIH). Car force est de constater que les valeurs d'exposition admissibles promulguées par la CSST sont pour le moins très similaires aux valeurs d'exposition publiées par l'ACGIH.

2. Analyse des nouvelles valeurs d'exposition admissibles proposées

Nous avons fait une comparaison des valeurs d'exposition admissibles pour les substances répertoriées par ces deux organismes (CSST et ACGIH). Au total 674 substances sont présentes dans la liste de la CSST, et 667 dans la documentation relative aux TLV ("*Threshold Limit Values*") de ACGIH (1992-1993). Sur les 674 normes de la CSST, 378 sont exprimées en ppm et 645 en mg/m^3. Ce qui signifie que certaines substances disposent de deux valeurs (l'une en ppm et l'autre en mg/m^3, en fait 376), tandis que d'autres disposeront le plus souvent que d'une seule norme exprimée en mg/m^3. Notons qu'une dose en mg/m^3 peut très facilement être convertie en ppm (et réciproquement). Elles sont donc "équivalentes". C'est seulement l'unité qui diffère.

2.1. *Comparaison des valeurs d'exposition admissibles de la CSST avec celles de l'ACGIH*

Nous avons étudié comment se comportaient les valeurs d'exposition admissibles promulguées par la CSST (VEA) par rapport aux *threshold limit values* publiées par l'ACGIH (TLV). Sont-elles inférieures, égales ou supérieures ?. La distribution des valeurs

d'exposition moyenne pondérée est présentée sur la **figure 1** (uniquement pour les valeurs d'exposition exprimées en mg/m^3).

On peut constater sur cette figure, que **90.4%** de ces valeurs d'exposition (soit 538 sur un total de 595 valeurs, exprimées en mg/m^3, comparées) sont **strictement égales** à celles de l'ACGIH, tandis que **4.2%** de ces valeurs d'exposition (soit 25) sont **supérieures** à celles de l'ACGIH, et que **5.4%** (soit 32) sont **inférieures** à celles de l'ACGIH.

En considérant non plus les valeurs d'exposition admissibles exprimées en mg/m^3 mais celles exprimées en ppm, les résultats sont très comparables, avec **91.7%** (n=330/360) des valeurs d'exposition ainsi exprimées **strictement égales** à celles de l'ACGIH.

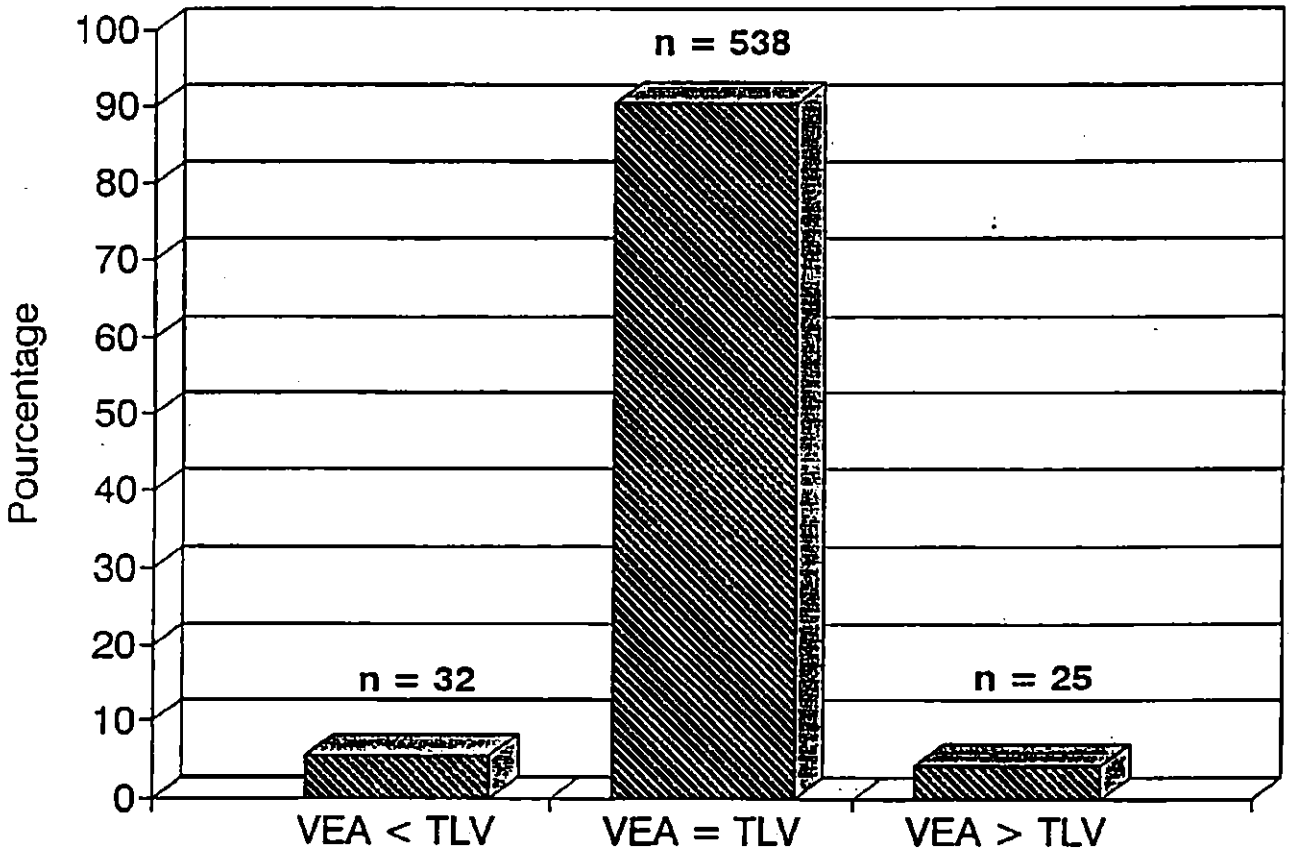
Nous nous sommes également intéressés au comportement du ratio entre la valeur d'exposition admissible proposée par la CSST et celle publiée par l'ACGIH. On s'intéresse donc ici à la valeur du rapport (ou ratio) obtenu lorsque l'on divise la valeur d'exposition proposée par la CSST par celle publiée par l'ACGIH. Rappelons qu'un tel ratio lorsqu'il est inférieur à 1 met en évidence que la valeur d'exposition proposée par la CSST est **plus** "sévère", d'un facteur égal à la valeur du ratio, à celle publiée par l'ACGIH, tandis qu'un ratio supérieur à 1 met en évidence que la valeur d'exposition admissible proposée par la CSST est **moins** "sévère", d'un facteur égal à la valeur du ratio, à celle publiée par l'ACGIH. En considérant pour cette analyse les résultats des ratios issus des valeurs d'exposition admissibles exprimées en mg/m^3, nous avons donc observé un total de 25 ratios supérieurs à 1 et un total de 32 ratios inférieurs à 1.

Donc dans 25 situations le rapport (valeur CSST/valeur ACGIH) est supérieur à 1, ce qui traduit donc que 25 niveaux d'exposition promulgués par la CSST sont "moins sévères" (car plus élevés) que ceux de l'ACGIH. Or qui dit niveaux d'exposition plus élevés dit plus grand risque de survenu d'effets toxiques ou autres chez les travailleurs. Notons que sur l'ensemble des 25 ratios déterminés (valeur CSST/valeur ACGIH), le ratio minimum obtenu est de 1.002 tandis que le ratio maximum est de 40.5 (cf. **figure 2**). Ce qui signifie, dans ce dernier cas, un niveau d'exposition admissible pour la CSST 40 fois supérieur à celui publié par l'ACGIH. Enfin signalons que la moyenne arithmétique des 25 ratios est de 5.1. Ce qui signifie que lorsque une valeur d'exposition admissible CSST est supérieure à une valeur d'exposition ACGIH, elle l'est en moyenne (sur 25 comparaisons) d'un facteur 5.

Mais il y a aussi quelques ratios inférieurs à 1. En fait 32 ratios (ou rapports entre la valeur CSST et la valeur ACGIH) sont inférieurs à 1. Pour ces 32 ratios inférieurs à 1 signalons une valeur moyenne du rapport des deux niveaux d'exposition admissibles de 0.47 (soit un niveau d'exposition admissible CSST en moyenne 2 fois plus faible que celui de l'ACGIH), avec un minimum de 0.001 (niveau d'exposition CSST 1000 fois plus faible que celui de l'ACGIH) et un maximum de 0.99 (soit un niveau d'exposition CSST quasi identique à celui de l'ACGIH).

Figure 1

Pourcentage des VEA de la CSST inférieures, égales ou supérieures aux TLV de l'ACGIH

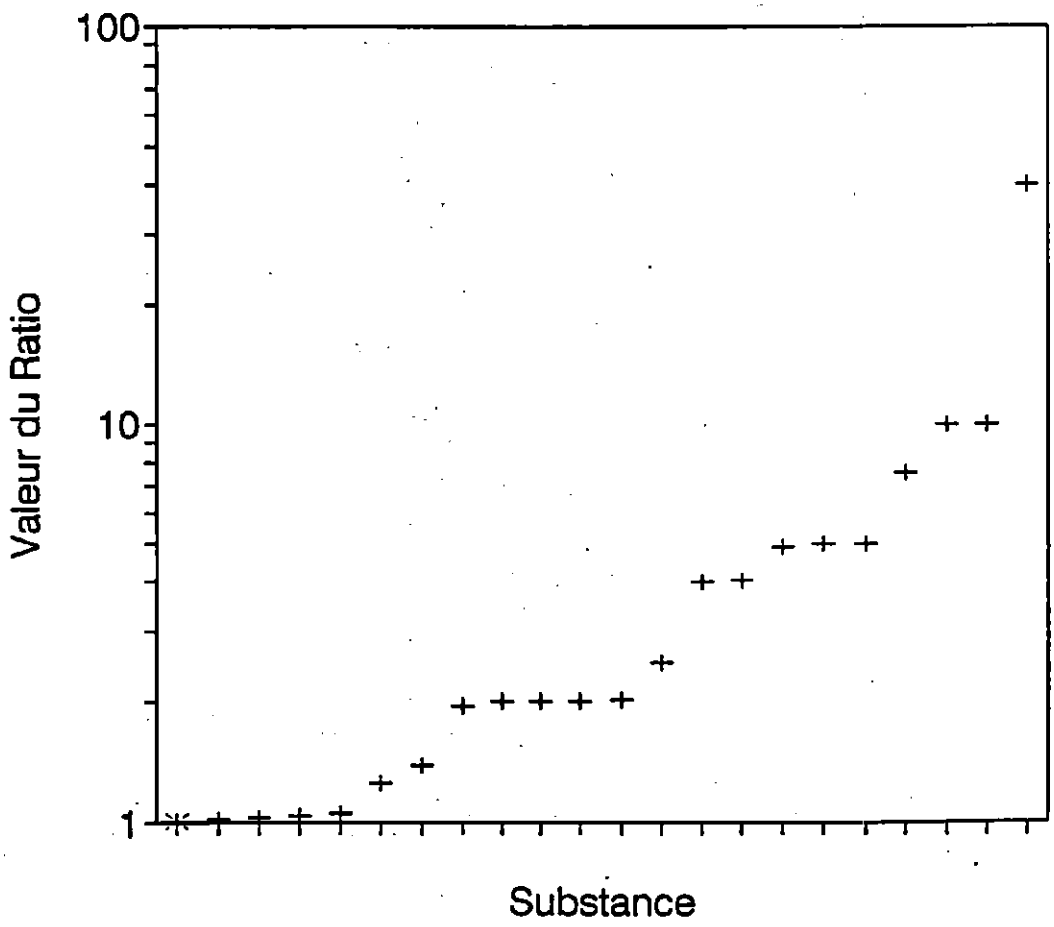


VEA : Valeur d'Exposition Admissible (proposée par la CSST)
TLV : Valeur proposée par l'ACGIH

Figure 2

Distribution du ratio CSST versus ACGIH

lorsque VEA > TLV



RATIO = Valeur d'Exposition Admissible proposée par la CSST (VEA) / Valeur proposée par l'ACGIH (TLV)

Cependant, alors que la majorité des valeurs limites d'exposition promulguées par la CSST s'avèrent être similaires à celles de l'ACGIH (pour environ 91% de l'ensemble des valeurs d'exposition admissibles proposées), on aimerait connaitre les raisons ayant amené la CSST à définir un niveau d'exposition plus sévère que celui de l'ACGIH (dans au moins 32 cas), mais aussi est surtout les raisons l'ayant conduit à réévaluer à la hausse (par rapport aux TLV de l'ACGIH) 25 niveaux d'exposition.

La liste des substances dont les niveaux d'exposition CSST sont **moins sévères** que ceux de l'ACGIH (n=25) est fournie dans le **tableau 1**, tandis que la liste des substances dont les niveaux d'exposition CSST sont **plus sévères** que ceux de l'ACGIH (n=32) est fournie dans le **tableau 2**. Il serait donc nécessaire que la CSST explicite en détail les raisons l'ayant conduit à réévaluer à la baisse (n=32), voire même à la hausse (n=25), 57 niveaux d'exposition.

Tableau 1. Liste des 25 substances dont les niveaux d'exposition proposés par la CSST (VEA) sont supérieurs à ceux de l'ACGIH (TLV), et ratio correspondant.

Substance	CAS	VEA (mg/m³)	TLV (mg/m³)	VEA/TLV
Alcool Isopropylique	67-63-0	985	983	1.002
Dichloro-1,2 propane	78-87-5	350	347	1.009
Chlorure de thionyle	7719-09-7	5	4.9	1.02
Azoture de sodium	26628-22-8	0.3	0.29	1.034
Amino-2 pyridine	504-29-0	2	1.9	1.053
Graphite naturel (poussière)	7782-42-5	2.5	2	1.25
Monoxyde de carbone	630-08-0	40	29	1.379
Talc (non fibreux)	14807-96-6	3	2	1.5
Diméthylamine	124-40-3	18	9.2	1.957
Triméthylamine	75-50-3	24	12	2
Chlore	7782-50-5	3	1.5	2
Toluène	108-88-3	377	188	2.005
o-Dichlorobenzène	95-50-1	301	150	2.007
Méthylamine	74-89-5	13	6.4	2.031
Coton brut (poussière)	xxxxx-xx-x	0.5	0.2	2.5
Formaldéhyde	50-00-0	1.2	0.37	3.243
Dinitrate d'éthylène glycole	628-96-6	1.24	0.31	4
Nitroglycérine	55-63-0	1.86	0.46	4.043
Acide acrylique	79-10-7	29	5.9	4.915
Kaolin	1332-58-7	10	2	5
Thiram	137-26-8	5	1	5
Chlorobenzène	108-90-7	345	46	7.5
TEPP	107-49-3	0.47	0.047	10
Dinitrotoluène	25321-14-6	1.5	0.15	10
Bromoéthane	74-96-4	891	22	40.5

CAS : *Chemical Abstract Service*
VEA : Valeur d'Exposition Admissible
TLV : *Threshold Limit Value*
xxxxx-xx-x : substance sans numéro de CAS

Tableau 2. Liste des 32 substances dont les niveaux d'exposition proposés par la CSST (VEA) sont inférieurs à ceux de l'ACGIH (TLV), et ratio correspondant.

Substance	CAS	VEA (mg/m³)	TLV (mg/m³)	VEA/TLV
Rhodium (composés solubles)	7440-16-6	0.001	1	0.001
Nickel carbonyle	13463-39-3	0.007	0.12	0.058
Benzène	71-43-2	3	32	0.094
Phosphate de tributyle normal	126-73-8	0.22	2.2	0.1
Dichloro-1,2 éthane	107-06-2	4	40	0.1
Fluor	7782-41-4	0.2	1.6	0.125
Chlorure de vinyle (monomère)	75-01-4	2.5	13	0.192
Pentane normal	109-66-0	350	1770	0.198
Dichloro-1,1 éthylène	75-35-4	4	20	0.2
Fibre de laine isolante (laine de verre)	xxxxx-xx-x	2	10	0.2
Méthyl éthyl cétone	78-93-3	150	590	0.254
Tétraméthyle de plomb	75-74-1	0.05	0.15	0.333
Disulfure de carbone	75-15-0	12	31	0.387
Amosite (amiante)	12172-73-5	0.2	0.5	0.4
Chloroforme	67-66-3	24.4	49	0.498
Chrysotile (amiante)	12001-29-5	1	2	0.5
Tétraéthyle de plomb	78-00-2	0.05	0.1	0.5
Tétrahydrofurane	109-99-9	300	590	0.508
Silice amorphe (précipité)	1343-98-2	6	10	0.6
Silice amorphe (terre diatomée)	61790-53-2	6	10	0.6
Silice amorphe (gel)	63231-67-4	6	10	0.6
Oxyde de mésityle	141-79-7	40	60	0.667
Méthyl propyl cétone	107-87-9	530	705	0.752
Caprolactame (vapeur)	105-60-2	20	23	0.87
p-Dichlorobenzène	106-46-7	405	451	0.898
Tétrafluorure de soufre	7783-60-0	0.4	0.44	0.909
Terphényles	26140-60-3	4.7	5	0.940
Cyclohexalamine	108-91-8	40	41	0.976
Phosdrin	7786-34-7	0.09	0.092	0.978
Solvant de caoutchouc	8030-30-6	1570	1590	0.987
Dichloro-1,1 éthane	75-34-3	400	405	0.988
Chlorobromométhane	74-97-5	1058	1060	0.998

CAS : *Chemical Abstract Service*
VEA : Valeur d'Exposition Admissible
TLV : *Threshold Limit Value*
xxxxx-xx-x : substance sans numéro de CAS

2.2. *Le cas particulier des substances cancérogènes*

Chacun des deux organismes dispose d'une classification qualitative du potentiel cancérogène d'une substance chimique. La classification CSST comporte trois niveaux (C1, C2 et C3), tandis que la classification ACGIH en comporte deux (A1 et A2). Les niveaux strictement comparables sont: C1-A1, et C2-A2.

Sur les 674 substances répertoriées par la CSST, 90 ont fait l'objet d'une classification C1-C2-C3, tandis que sur les 667 substances répertoriées par l'ACGIH, 72 ont fait l'objet d'une classification A1-A2. La répartition de ces nombres de substances classifiées en fonction des catégories correspondantes est fournie dans le **tableau 3.**

Tableau 3. Répartition des substances classifiées pour leur potentiel cancérogène

Classification qualitative du potentiel cancérogène	CSST	ACGIH
Cancérogène confirmé chez l'homme (C1-A1)	21	21
Cancérogène suspecté chez l'homme (C2-A2)	53	51
Cancérogène confirmé chez l'animal (C3)	16	sans objet
Total	90	72

Ce tableau semblerait donc indiquer une relative similarité de classification entre ces deux organismes. Mais analysons ces mêmes résultats dans le **tableau 4** qui permet une comparaison plus précise.

Sur ce tableau on peut observer que sur un total de 716 substances (pour l'ensemble des deux organismes): i) la CSST répertorie 49 substances que l'ACGIH ne considère pas (cf. **annexe 1**), ii) l'ACGIH répertorie 42 substances que la CSST ne considère pas (cf. **annexe 2**)), et iii) 539 n'ont pas fait l'objet d'une telle classification, ni par l'un ni par l'autre de ces deux organismes.

Tableau 4. Analyse comparative des classifications cancérogènes CSST et ACGIH

ACGIH	CSST					Total
	C1	C2	C3	Sans classification	Non considérée	
A1	16	.	.	.	5	21
A2	2	38	1	3	7	51
Sans classification	.	13	13	539	30	595
Non considérée	3	2	2	42	.	49
Total	21	53	16	584	42	716

. : valeur manquante

Parmi ces 716 substances, 16 ont été classées C1 par la CSST et A1 par l'ACGIH (classification qualitative similaire qui signifie: substance cancérogène confirmé chez l'homme). Mais que l'ACGIH a dans sa liste 5 substances classées A1 qui ne sont pas présentes dans la liste proposée par la CSST.

Par contre on peut remarquer que 2 substances classées C1 par la CSST ne sont

classées que A2 (cancérogène suspecté chez l'homme) par l'ACGIH, tandis que 38 ont une classification qualitative similaire pour ces deux organismes (C2-A2). Mais on peut également observer sur ce tableau qu'**une** substance classée A2 par l'ACGIH (cancérogène humain suspecté) n'a été classée que C3 par la CSST (cancérogène animal confirmé), que **trois** autres substances classées A2 par l'ACGIH n'ont pas fait l'objet d'une classification par la CSST, et que 7 substances classées A2 par l'ACGIH ne sont pas présentes dans la liste promulguées par la CSST.

Les quatre substances non classifiées pour leur potentiel cancérogène par la CSST (mais classées A2 par l'ACGIH) sont: le **dinitrotoluène**, l'**hexachloroéthane**, le **bromoéthane**, et l'**acrylate d'éthyle**. Notons d'ailleurs pour cette dernière substance que le Centre International de Recherche sur le Cancer (CIRC, 1987) la classe dans le groupe 2B soit une substance ***possiblement*** **cancérogène** chez l'homme.

De plus deux de ces quatres substances ont une valeur d'exposition admissible CSST supérieure à celle de l'ACGIH (cf. bas du tableau 1):

- le dinitrotoluène a une valeur limite d'exposition admissible CSST de 1.5 mg/m^3, soit **10 fois plus élevée** que celle de l 'ACGIH (avec 0.15 mg/m^3),
- le bromoéthane a une valeur d'exposition admissible CSST de 891 mg/m^3, soit **40.5 fois plus élevée** que celle publiée par l'ACGIH (avec 22 mg/^{3}).

On recommande donc d'évaluer tant la possibilité de reconnaitre ces substances comme cancérogènes (ou suspectées de l'être), en envisageant une classification de type C2 voire au minimum C3 (d'après les définitions données à ces catégories par la CSST), que les niveaux d'exposition admissibles promulgués par la CSST.

Cependant l'algorithme décisionnel de la classification qualitative du potentiel cancérogène de la CSST n'est pas explicité. On sait juste qu'il comporte trois niveaux (C1-C2-C3) et à quoi ces niveaux correspondent (cancérogène humain confirmé (C1), cancérogène humain suspecté (C2) et cancérogène animal confirmé (C3)). La classification ACGIH présente d'ailleurs le même problème (cet organisme refusant même de considérer une substance comme le benzène "cancérogène humain confirmé" malgré les nombreuses études épidémiologiques existantes, ayant démontré une association entre survenue de cancer et exposition au benzène).

Nous avons donc envisagé, une comparaison de la classification qualitative CSST avec celle du CIRC (Centre International de Recherche sur le Cancer) qui dispose d'une méthodologie très bien explicitée.

La classification du CIRC, qui comporte 5 niveaux, peut être résumée comme suit:
Groupe 1 = substance cancérogène chez l'homme, Groupe 2A = substance probablement cancérogène chez l'homme, Groupe 2B = substance possiblement cancérogène chez l'homme, Groupe 3 = substance inclassable en regard de son potentiel cancérogène chez

l'homme, et Groupe 4 = substance probablement non cancérogène pour l'homme. Et les méthodologies de détermination et d'établissement de cette classification sont très clairement explicitées dans les documents publiés par le CIRC (CIRC, 1987).

Le **tableau 5** présente la répartition croisée des deux systèmes de classification qualitative du CIRC (1987) et de la CSST (01/12/1993).

Dans cette analyse on peut donc voir qu'au moins 7 à 8 substances (ou procédés) présentent une classification qualitative CSST qui sous estime celle du CIRC, qui a de plus été établie en 1987, alors que les données CSST datent de décembre 1993.

Il est donc fortement probable que cette analyse croisée ne reflète que partiellement les divergences existantes (actualisation des études du CIRC depuis 1987), et il serait nécessaire de l'approfondir.

Tableau 5. Analyse comparative des classifications cancérogènes CSST (01/12/1993) et CIRC (1987)

Classification du CIRC (1987)	Classification de la CSST (01/12/1993)				Total
	C1	C2	C3	Sans classification	
Groupe 1	15	**1**	.	**1**	17
Groupe 2A	.	19	.	**3**	22
Groupe 2B	.	17	11	**2**	30
Groupe 3	1	5	.	49	55
Groupe 4	.	.	.	2	2
*	.	.	.	**6**	6
Sans classification	5	11	5	521	542
Total	21	53	16	584	674

. : valeur manquante
1 : substance cancérogène chez l'homme
2A : substance *probablement* cancérogène chez l'homme
2B : substance *possiblement* cancérogène chez l'homme
3 : substance *non classifiable*
4 : substance *probablement* non cancérogène chez l'homme
* : le CIRC considère la production d'aluminium cancérogène chez l'homme, or 6 composés d'aluminium sont présentés par la CSST sans aucune mention sur la production d'aluminium.
C1 : cancérogène confirmé chez l'homme
C2 : cancérogène suspecté chez l'homme
C3 : cancérogène confirmé chez l'animal

Néanmoins parmi les substances (ou procédés) dont la classification CSST sous estime celle du CIRC, notons: l'**arsenic** et le **trioxide d'arsenic** (reconnus cancérogènes chez l'homme par le CIRC sur la base de données épidémiologiques adéquates), trois formes

de **silice cristalline** sans classification CSST - **tripoli, cristobalite** et **tridymite** - et pourtant considérées comme *probablement* cancérogènes chez l'homme par le CIRC (1987) sur la base de données épidémiologiques limitées et de données animales suffisantes, le **plomb et ses composés inorganiques** sans classification CSST alors que le CIRC (1987) le considèrait *possiblement* cancérogène chez l'homme sur la base de données épidémiologiques inadéquates et de données animales suffisantes, ainsi que le **noir de carbone** lui aussi sans classification CSST alors que le CIRC (1987) le considérait, tout comme le plomb et ses composés inorganiques, *possiblement* cancérogène chez l'homme sur la base de données épidémiologiques inadéquates et de données animales suffisantes. Mais dans ce dernier cas la CSST considère-t-elle dans sa classification les extraits de noir de carbone, ou le noir de carbone en générale ?.

Cette analyse, même si elle n'est que très préliminaire et très certainement incomplète, met en évidence qu'il semble y avoir quelques problèmes sur la classification du potentiel cancérogène adoptée par la CSST, dont certains majeurs si on pense à **l'arsenic** et à **l'aluminium**. De plus, la problématique propre à ces deux dernières substances met en évidence que la non-inclusion, dans une telle proposition, de "catégories" du type *production* ou *procédé* propre à une substance donnée, est une lacune grave.

3. "Fondement scientifique" des normes proposées et alternatives possibles

Nous avons donc mis en évidence dans nos analyses que les niveaux d'exposition admissibles promulgués par la CSST sont pour environ 95% d'entre-eux supérieures ou égaux à ceux publiés par l'ACGIH.

Or ces normes (ou niveaux) d'exposition sont:

1) très critiquées: de nombreux auteurs se sont intéressés à ces niveaux d'exposition ces dernières années. Certains ont discuté de l'influence de l'industrie dans le processus de détermination des normes de l'ACGIH - en particulier lorsque l'industriel est producteur d'une substance et suggère un niveau d'exposition à celle-ci, ainsi que leur déficience par rapport à des critères de santé (Castleman et Ziem, 1988; Ziem et Castleman, 1989 - cf. **annexes 3 et 4** respectivement). D'autres ont critiqué les niveaux d'exposition publiés par l'ACGIH, qui se veulent être des niveaux d'exposition protégeant la quasi-totalité des travailleurs exposés, en mettant en évidence que les sources d'information de l'ACGIH étaient incorrectes et ne traduisaient aucunement le fait qu'une grande proportion de travailleurs puissent être malades aux niveaux d'exposition retenus. Sur 158 substances analysées par ces auteurs, seules les données de 11 d'entre elles se sont avérées supporter la TLV publié (absence d'effet adverse à ou au dessous de la TLV), pour les autres, soit 147, il apparaissait qu'au niveau d'exposition correspondant à la TLV, jusqu'à 100% des individus exposés pouvaient être affectés (Roach et Rappaport, 1990 - cf. **annexe 5**).

2) très critiquables: elles ne sont aucunement explicitées clairement, elles supposent en particulier le recours à des facteurs de sécurité dont les valeurs sont très difficilement retrouvables dans la documentation pourtant exhaustive publiée par cet organisme, et dans le cas des substances cancérogènes le recours à des facteurs de sécurité qui suppose l'existence d'un seuil dans la relation exposition-réponse est parfois injustifiable biologiquement parlant.

Ce sont les faits et constats essentiels qui ont conduit certains à "repenser" les méthodologies d'établissement de valeurs "limites" ou "acceptables" d'exposition en milieu professionnel.

La méthodologie alternative que nous présentons ici est celle des limites d'exposition basées sur la santé (*Health-Based Exposure Limits* ou HBEL) développée par le comité *Health Based Exposure Limits Subcommittee* de l'*American Public Health Association*. Ce comité a publié (cf. **annexe 6**) des valeurs limites d'exposition alternatives à celles de l'ACGIH, niveaux d'exposition dont nous avons montré qu'ils inspiraient fortement ceux proposés par la CSST.

Nous tenons à souligner ici qu'il s'agit d'une méthodologie, parmi d'autres méthodologies scientifiques et valides, qui seraient susceptibles d'être envisagées, voire adaptées ou développées pour ce contexte précis de niveaux d'exposition admissibles en milieu professionnel. Nous la présentons en effet essentiellement à des fins démonstratives.

Les calculs nécessaires à la détermination des HBEL ont été faits par le Dr. Kathleen Cunningham, une toxicologue qui travaille pour Abt Associates Inc, Cambridge, MA, E-U. La méthode utilisée est le suivante (Dr.K.Cunningham, communication personnelle; cf. **annexe 7**):

Les données: elles proviennent pour l'essentiel de la banque de données *Integrated Risk Information System* (IRIS) de l'*Environmental Protection Agency* (EPA) des États-Unis. Cette banque de données contient des informations toxicologiques actualisées et revues par des pairs. IRIS fournie principalement deux types d'information: des doses de référence (issues de l'étude d'effets toxicologiques aigus, chroniques non-cancérogènes, etc., et qui correspondent aux niveaux d'exposition journaliers maximums pour lesquels aucun effet systémique n'est supposé survenir) et des doses dites "virtuellement sûres" (issues de l'étude des effets cancérogènes). Pour certaines de ces doses les données pourront être de nature épidémiologique (humaine) ou de nature expérimentale (animale).

La détermination des niveaux d'exposition: Pour les **substances non-cancérogènes** aucun effet sur la santé ne doit être observé si l'exposition est au sous-dessous de la *health based limit*. Pour les **substances cancérogènes**, les coefficients de risque (ou plus exactement excès de risque) ont été utilisés (Q_1^* en $(mg/kg.jour)^{-1}$) dans la détermination des *health based limit*. Ces Q_1^* sont issus de la procédure de linéarisation du modèle multistage de l'US.EPA et ont été déterminés par l'US.EPA pour un excès de

risque de cancer vie-entière de 10^{-6} (1 excès de cas de cancer pour 1 million d'individus exposés).

Pour toutes les substances chimiques (cancérogènes ou non) étudiées par ce comité de l'APHA, les paramètres décrivant l'exposition ont été modifiés afin de refléter ceux observées en milieu professionnel (les valeurs fournies dans IRIS étant développées dans un contexte d'exposition environnementale vie entière - au sens sol, air, eau - il est donc nécessaire de les ajuster ne serait-ce que sur des paramètres tels que la durée d'exposition).

Seuls les résultats de notre analyse comparative des valeurs d'exposition admissibles de la CSST par rapport aux HBEL (décrites au paragraphe précédent) et uniquement pour les substances cancérogènes ou suspectées de l'être sont rapportés ici.

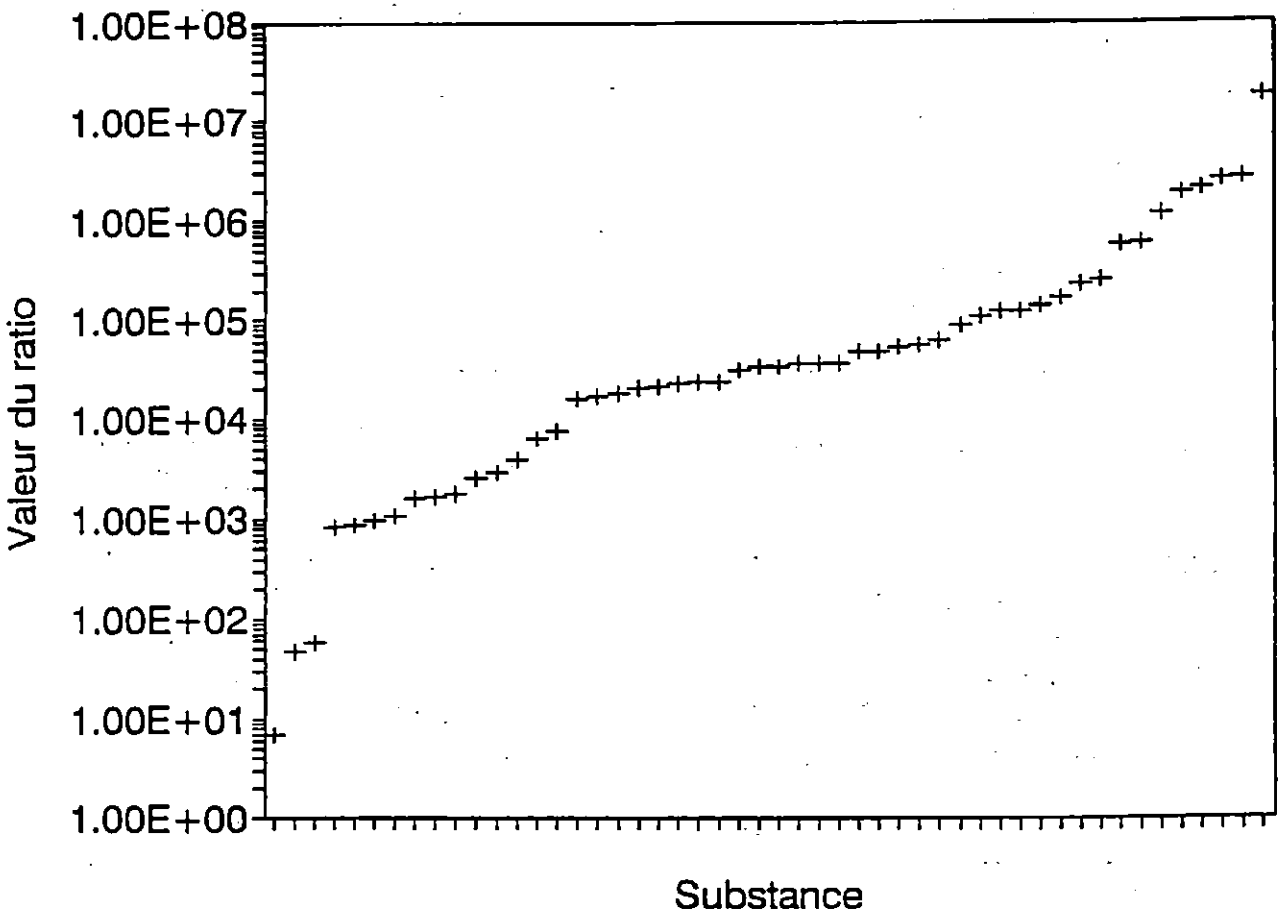
Nous avons là aussi (comme lors de la comparaison des valeurs d'exposition admissibles de la CSST avec les TLV de l'ACGIH) analysé le comportement du ratio (ou rapport) de la VEA-CSST et de la HBEL proposée par ce comité de l'*American Public Health Association*.

Seules 50 substances cancérogènes (ou suspectées de l'être) ont pu faire l'objet de cette comparaison entre leur VEA-CSST et leur HBEL. Ces 50 substances sélectionnées correspondent en fait aux 50 substances que nous avons facilement pu identifier avec leur numéro de CAS (*Chemical Abstract Service*). **L'ensemble des 50 ratios** (VEA-CSST divisée par la HBEL correspondante) se sont avérés être supérieur à 1 et ceci très nettement dans la majorité des cas. Ce qui signifie donc que toutes les valeurs d'exposition admissibles de ces 50 substances cancérogènes (ou suspectées de l'être) promulguées par la CSST sont nettement supérieures à celles susceptibles d'être obtenues par la méthodologie HBEL qui repose sur des critères de santé. En fait les **valeurs d'exposition admissibles promulguées par la CSST** apparaissent être, pour ces 50 substances, de **7 à 18.000.000 fois moins sévères** (18 millions de fois) que celles obtenues par la méthodologie **HBEL**.

La **figure 3** de ce document présente la distribution du ratio (soit: la VEA-CSST divisée par la HBEL correspondante) de l'ensemble des 50 substances cancérogènes sélectionnées.

Figure 3

Distribution du ratio CSST versus HBEL
pour les carcinogènes sélectionnés



RATIO = Valeur d'Exposition Admissible proposée par la CSST (VEA) / Valeur basée sur la santé (HBEL)

4. Résumé

Nous avons démontré que 538 valeurs d'exposition admissibles CSST (90.4%) sont similaires à celles de l'ACGIH (1992-1993). Il nous semble donc raisonable d'assumer que la CSST recopie quasi directement les niveaux d'exposition de l'ACGIH. Or de nombreux articles, critiquant ces niveaux d'exposition tant qualitativement que quantitativement (en particulier d'un point de vue santé), ont mis en évidence leur peu de valeur. Ces niveaux d'exposition sont en effet loin de protéger la santé de la majorité des travailleurs (contrairement à ce qu'en dit l'ACGIH) (cf. **annexe 5**, article de Roach et Rappaport, 1990).

Pour l'ensemble de ces substances et tout particulièrement pour les cancérogènes, il est nécessaire de réviser à la baisse les valeurs publiées dans la Gazette Officielle du Québec, et ce en utilisant toutes les données scientifiques disponibles. Nous croyons, préférable le recours à des méthodes d'évaluation de risque "*risk assessment*" pour définir de nouvelles valeurs d'exposition admissibles.

5. Recommandations

Compte tenu de tout ce que nous avons dit précédemment, nous recommandons donc:

1) **dès maintenant** des ajustements de la classification en terme de potentiel cancérogène des substances suivantes: **dinitrotoluène, hexachloroéthane, bromoéthane, acrylate d'éthyle, arsenic** et **trioxide d'arsenic, silice cristalline (tripoli, cristobalite** et **tridymite), plomb et ses composés inorganiques**, ainsi que le **noir de carbone**, et l'introduction de catégorie "particulière" permettant d'intégrer des procédés industriels dans leur ensemble. Sur ce point notons l'absence notable d'une classification propre à la **production d'aluminium**. Cette absence est d'autant plus grave que le CIRC considère l'*Aluminium production* comme cancérogène chez l'homme (soit une classification identique à celle du benzène ou de l'arsenic).

2) **dans une perspective de moyen terme**, une réévaluation de l'ensemble de ces valeurs d'exposition admissibles dans un but de protection de la santé des travailleurs.

Processus suggéré:

Tant dans une perspective de réévaluation des valeurs d'exposition admissibles actuelles que dans la perspective d'élaboration de valeurs d'exposition admissibles pour de nouvelles substances, il nous semble qu'il y aurait lieu de développer un processus permettant réévaluations et élaborations dans lequel les principaux intéressés pourraient intervenir.

Un tel processus permettrait à la CSST de se mettre, d'une certaine manière, à l'avant-garde de ce qui pourrait être fait en matière de normalisation des expositions en milieu professionnel.

Les suggestions suivantes s'inscrivent dans une telle perspective, et l'élaboration d'une telle démarche nécessiterait que les éléments indiqués ici soient pris en compte:

A. La CSST devrait créer un comité scientifique et technique en charge de la réalisation des tâches suivantes:

a) **Définir les méthodes scientifiques d'évaluation de risque acceptables dans une perspective d'élaboration de normes d'exposition en milieu professionnel.**
Le comité scientifique et technique devrait, en particulier et dans un premier temps, analyser les méthodes utilisées par le sous comité de l'*American Public Health Association* (expliquées dans ce document) pour déterminer si de telles méthodes seraient susceptibles d'être adoptées au Québec. Mais il devra également évaluer d'autres méthodologies, également fondées sur les principes de l'évaluation des risques, et aussi valables scientifiquement que la méthode proposée par le comité de l'APHA.

b) **Revoir toutes les normes.**
. De par l'ampleur d'un tel travail et les réponses nécessaires à plus ou moins court terme sur les niveaux d'exposition actuels, le comité scientifique et technique devrait examiner les normes développées dans d'autres juridictions ou pays et dont les méthodologies de détermination apparaitraient acceptables par ce comité.
. Toutes les normes issues de méthodes n'intégrant pas de méthodologie scientifique basée sur les principes de l'évaluation des risques (telles que celles de l'ACGIH) seront exclues.

c) **Évaluer les autres substances ou procédés industriels susceptibles d'être inclus, ainsi que réévaluer et définir une méthodologie appropriée en ce qui concerne le potentiel cancérogène des substances.**
Nous avons en effet montré au tableau 3 de ce document que la classification CSST pose problème. La CSST devrait donc adopter des classifications qualitatives en terme de potentiel cancérogène telles que celles utilisées par le CIRC et l'EPA. Le comité scientifique et technique devrait également être en charge de l'analyse des nouvelles monographies du CIRC, rapports techniques et banque de données de l'EPA, afin de déterminer si de nouvelles substances ou procédés industriels doivent être classifiées en regard de leur potentiel.

Notons qu'un tel comité scientifique et technique devrait être composé d'experts en toxicologie, épidémiologie, biostatistiques, évaluation de risque, hygiène industrielle et santé publique.

B. La CSST devrait créer un second comité chargé de passer en revue les recommandations du comité scientifique et technique et de la mise en place des normes après consultation des personnes et organismes intéressés, soit un comité de gestion des risques. Ce second comité devrait en particulier être en charge de: **Vérifier que les niveaux d'exposition définis à partir de critères de santé soient applicables selon des critères relevant de la gestion des risques, soit, par exemple, la faisabilité technique et économique.**
En effet, même si des valeurs d'exposition admissibles réduisant les risques sur la santé des travailleurs peuvent être déterminées pour de nombreuses substances en utilisant des principes scientifiques reconnus, il se peut qu'en pratique il soit nécessaire de modifier ces valeurs afin qu'elles tiennent compte de ce qui est raisonnablement faisable ou atteignable dans l'industrie selon les technologies disponibles.Cette notion rejoint en quelque sorte la détermination et la définition de ce qu'est un risque "acceptable". Nous pensons qu'un processus public ouvert pourrait, en vue de répondre à ces questions (définition et détermination d'un risque "acceptable"), être mis en place afin qu'un certain consensus soit atteint sur cette question. Une fois cette question "résolue" ne serait-ce que consensuellement par ce comité, il serait alors possible d'analyser les niveaux d'exposition admissibles établis sur des critères de santé en intégrant les dimensions de faisabilité technique, de critères économiques (par exemple étude du type coûts-bénéfices) et de risque "acceptable".

La composition de ce second comité (comité de gestion des risques) devrait inclure les experts des universités québécoises, la santé publique, l'IRSST, le CSST, les syndicats, des représentants du patronnat, ainsi que des représentants du comité scientifique et technique, des ingénieurs, des économistes de la santé, et des spécialistes sur les questions d'éthique.

C. Les recommandations suivantes devraient également être prises en considération par la CSST lors de la mise en place d'un tel processus scientifique et technique:
Le processus d'élaboration des normes d'exposition se doit d'être transparent au public (communité scientifique et des personnes) et aux parties concernées (i.e. les travailleurs et les employeurs). Lors de chaque révision des normes les deux comités devraient avoir des audiences publiques et devraient publier un rapport décrivant tout changement éventuel, en explicitant les méthodologies scientifiques et techniques utilisés, les données, hypothèses, et critères (santé, technique, économique, ...) à la base du processus de détermination du niveau d'exposition retenu.

6. Références

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ANNEXES

ANNEXE N°1

Liste des 49 substances non considérées par l'ACGIH mais présentes dans la liste de la CSST

Substances considérées par la CSST, non considérées par l'ACGIH	CAS	Classe
GYPSE poussières totales	10101-41-4	
GYPSE poussières respirables	10101-41-4	
p-ANISIDINE	104-94-9	
SODIUM, TETRABORATE DE (pentahydrate)	12045-88-4	
AMIANTE actinolite	12172-67-7	C1
FIBRES MINERALES NATURELLES attapulgite	12174-11-7	C1
EMERI	12415-34-8	
MANGANESE, TETROXYDE DE	1317-35-7	
SODIUM, TETRABORATE DE (anhydre)	1330-43-4	
FIBRES MINERALES NATURELLES wollastonite	13983-17-0	
AMIANTE anthophyllite	17068-78-9	C1
DIISOCYANATE DE TOLUENE mélange d'isomères {TDI}	26471-62-5	
PLATRE DE PARIS poussière totale	26499-65-0	
PLATRE DE PARIS poussière respirable	26499-65-0	
PLOMB, ARSENIATE DE	3687-31-8	
POUSSIERES CHARBONNEUSES (<5% de silice cristalline)	53570-85-7	
POUSSIERES CHARBONNEUSES (>5% de silice cristalline)	53570-85-7	
ZINC, STEREATE DE	557-05-1	
CIMENT PORTLAND poussière totale	65997-15-1	
CIMENT PORTLAND poussière respirable	65997-15-1	
FIBRES MINERALES NATURELLES érionite	66733-21-9	
PLATINE métal	7440-06-4	
PLATINE sels solubles	7440-06-4	
RHODIUM métal et composés insolubles	7440-16-6	
URANIUM NATUREL composés insolubles	7440-61-1	
URANIUM NATUREL composés solubles	7440-61-1	
ZIRCONIUM ET COMPOSES	7440-67-7	
BARYUM, SULFATE DE poussière totale	7727-43-7	
BARYUM, SULFATE DE poussière respirable	7727-43-7	
CALCIUM, SULFATE DE poussière totale	7778-18-9	
CALCIUM, SULFATE DE poussière respirable	7778-18-9	
PERLITE (poussière totale)	83969-76-0	
PERLITE (poussière respirable)	83969-76-0	
NITROTOLUENE	88-72-9	
o-ANISIDINE	90-04-0	C3
POLYTETRAFLUOROETHYLENE	9002-84-0	
BOIS DE CEDRE ROUGE WESTERN, poussière de	xxxxx-xx-x	
BOIS DUR ET MOU A L'EXCEPTION DU CEDRE ROUGE, poussière de	xxxxx-xx-x	
FIBRE DE LAINE ISOLANTE laine de laitier	xxxxx-xx-x	C2
FIBRE DE LAINE ISOLANTE laine de roche	xxxxx-xx-x	C2
FIBRE DE VERRE EN FILAMENT CONTINU	xxxxx-xx-x	
FIBRES REFRACTAIRES (céramique ou autres)	xxxxx-xx-x	C3
MICROFIBRES DE VERRE	xxxxx-xx-x	
FIBRES SYNTHETIQUES ORGANIQUES carbone & graphite (tot)	xxxxx-xx-x	
FIBRES SYNTHETIQUES ORGANIQUES carbone & graphite (resp)	xxxxx-xx-x	
FIBRES SYNTHETIQUES ORGANIQUES para-aramides (kevlar,taron)	xxxxx-xx-x	
FIBRES SYNTHETIQUES ORGANIQUES polyoléfines	xxxxx-xx-x	
GRAPHITE (synthetique sauf fibres) poussière totale	xxxxx-xx-x	
TREMOLITE		

xxxxx-xx-x: substance sans numéro de CAS

ANNEXE N°2

Liste des 42 substances non considérées par la CSST mais présentes dans la liste de l'ACGIH

Substances considérées par l'ACGIH, non considérées par la CSST	CAS	Classe
4-VINYL CYCLOHEXENE	100-40-3	A2
m-PHENYLENEDIAMINE	108-45-2	
DIPROPYL KETONE	123-19-3	
1,6-HEXANEDIAMINE	124-09-4	
BORATES, TETRA, SODIUM SALTS anhydrous	1303-96-4	
BORATES, TETRA, SODIUM SALTS decahydrate	1303-96-4	
BORATES, TETRA, SODIUM SALTS pentahydrate	1303-96-4	
TANTALUM oxide dusts	1314-61-0	
CALCIUM CHROMATE	13765-19-0	A2
BENZO(B)FLUORANTHENE	205-99-2	A2
DIBUTYL PHENYL PHOSPHATE	2528-36-1	
ANISIDINE (o-,p- isomers)	29191-52-4	
DIPROPYLENE GLYCOL METHYL ETHER	34590-94-8	
PERFLUOROISOBUTYLENE	382-21-8	
PARAQUAT total dust	4685-14-7	
PARAQUAT respirable fraction	4685-14-7	
TOLUENE-2,4-DIISOCYANATE {TDI}	584-84-9	
2-CHLOROPROPIONIC ACID	598-78-7	
SILICA AMORPHOUS silica, fume	69012-64-2	
PLATINUM metal	7440-06-4	
PLATINUM soluble salts	7440-06-4	
RHODIUM metal	7440-16-6	
RHODIUM soluble compounds	7440-16-6	
LEAD CHROMATE as Pb	7758-97-6	A2
LEAD CHROMATE as Cr	7758-97-6	A2
LEAD ARSENATE	7784-40-9	
STRONTIUM CHROMATE	7789-06-2	A2
PENTACHLORONITROBENZENE	82-68-8	
NITROTOLUENE	88-72-2	
PERLITE	93763-70-3	
o-PHENYLENEDIAMINE	95-54-5	A2
TALC containing AMOSITE fiber	P25	A1
TALC containing CHRYSOTILE fiber	P25	A1
TALC containing CROCIDOLITE fiber	P25	A1
TALC containing OTHER FORMS of ASBESTOS fiber	P25	A1
COAL DUST	P27	
MINERAL WOOL FIBER	P28	
POLYTETRAFLUOROETHYLENE DECOMPOSITION PRODUCTS	P29	
STEARATES	P30	
WOOD DUST certain hard woods as beech & oak	P31	
WOOD DUST soft wood	P32	
ASBESTOS other forms	P33	A1

ANNEXE N°3

Article de:

Castleman B.I. and Ziem G.E., 1988,
Corporate influence on threshold limit values.
American Journal of Industrial Medicine, **13**, 531-559.

American Journal of Industrial Medicine 13:531-559 (1988)

Corporate Influence on Threshold Limit Values

Barry I. Castleman, ScD, and Grace E. Ziem, MD, DrPH

Investigations into the historical development of specific Threshold Limit Values (TLVs) for many substances have revealed serious shortcomings in the process followed by the American Conference of Governmental Industrial Hygienists. Unpublished corporate communications were important in developing TLVs for 104 substances; for 15 of these, the TLV documentation was based solely on such information. Efforts to obtain written copies of this unpublished material were mostly unsuccessful. Case studies on the TLV Committee's handling of lead and seven carcinogens illustrate various aspects of corporate influence and interaction with the committee. Corporate representatives listed officially as "consultants" since 1970 were given primary responsibility for developing TLVs on proprietary chemicals of the companies that employed them (Dow, DuPont). It is concluded that an ongoing international effort is needed to develop scientifically based guidelines to replace the TLVs in a climate of openness and without manipulation by vested interests.

Key words: unpublished corporate communications, TLV committee, carcinogen, conflict of interest, industrial experience, OSHA standards

INTRODUCTION

The Threshold Limit Values (TLVs) published by the American Conference of Government Industrial Hygienists (ACGIH) have been widely adopted as workplace exposure standards. The ACGIH values have been very influential over the past 40 years in Belgium, West Germany, Austria, Italy, The Netherlands, Portugal, Denmark, Sweden, Finland, Norway, Spain, Switzerland, the United Kingdom, and Japan [Toyama, 1985; Vigliani et al., 1977]. In the developing countries as well, the TLVs have been relied upon by governmental occupational health authorities [Noweir, 1986].

However, it has nonetheless been widely recognized that the TLVs for chemical substances are in most cases poorly supported by scientific evidence. This is clear from even a casual review of the *Documentation of the Threshold Limit Values and Biological Exposure Limits* (5th Edition, 1986). West Germany adopted the ACGIH values in 1955 and has been influenced by the ACGIH in setting exposure limits ever since. But the German authorities, upon review of the documentary adequacy of their MAKs, concluded that less than 10 percent of the limits were based on "sufficient

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animal tests and/or field experience" [Henschler, 1984]. This finding, based initially on a review of 150 substances, has been more recently corroborated by review of 300 more substances on the German MAK list [Henschler, 1985]. ACGIH's TLVs have been directly criticized by both industry and labor representatives for scientific inadequacy [Henderson, 1975; Samuels, 1981].

This report examines the historic role of industry in the development of the TLVs.

Role of Industry in TLV Process

The American Conference of Governmental Industrial Hygienists established a Committee on Threshold Limits which issued annual reports starting in 1946. ACGIH was and continues to be a voluntary organization with no formal ties to the U.S. government despite its name. Its members were initially federal, state, and local officials, and within a few years, academics and well-known industry consultants were also included.

From the beginning, the TLVs were acknowledged to involve a balancing of health considerations and cost to industry [Report, 1948]. Industry data were invited. In order to understand this interaction, it is necessary to appreciate the dependence of the TLV committee on information from industry, especially prior to the 1970s.

In the United States, government toxicologists and industrial hygienists of this era had very limited access to knowledge of dose-effect relationships in industry. There was no federal regulation of general industry workplace hazards until 1971; and state and local agencies were thinly staffed and minimally funded. These agencies had little if any regulatory power and lacked laboratory and other technical resources so vital to the surveillance of hazards in industry.

At U.S. universities, faculty occupational health professionals depended upon industry goodwill for research funding, consulting, and field experience and jobs for their students. Government funding for occupational health research was virtually nonexistent.

Dr. John Knox, medical officer for Turner and Newall, an asbestos-based multinational corporation headquartered in Britain, recorded his impressions in notes of a 1960 visit to his company's U.S. subsidiary [Knox, 1960]:

> "The legislative framework under which industries operate in the U.S.A. makes it difficult for me here to follow the lines of thought which prompt action over there in the matter of standards of industrial practice. In many industries, the employers seem so far in front of legislation as to have created a special code of practice for themselves."

It was well recognized that, to the extent that data existed on exposures to toxic agents and ill health in industry, they had been mostly developed by industry. Industrial concerns in the U.S. were in no way compelled to share what they knew.

Under the chairmanship of toxicologist Herbert Stokinger, the TLV committee first tried the approach of prodding industry by issuing a "Notice of Intent" to change some TLVs in 1964. A number of companies responded, supplying data, leading to 9 of 23 new additions that year [Notice of Intent, 1965]. Stokinger wrote to the Manufacturing Chemists' Association (now Chemical Manufacturers Association) [Stokinger, 1964]:

> "This was particularly encouraging in view of the fact that the committee has never had a significant amount of voluntary contributions from (industrial sources) as long as I can recall (13 years), despite annual exhortations welcoming such information."

By 1966, a committee of the Industrial Medical Association (now American Occupational Medical Association) expressed concern over the growing impact of the TLVs on industry. At the same time, it was acknowledged that industry had data on file and the means to develop more data that could "contribute constructively to the establishment of realistic TLVs" [Golz et al., 1966].

Over the years, Stokinger had had a number of meetings with industry groups at the Mellon Institute/Industrial Hygiene Foundation to discuss proposed changes in TLVs. The TLV committee's 1968 "Notice of Intent" even invited industry data via the Industrial Hygiene Foundation "Repository of Anonymous Occupational Health Data" [Committee, 1968]. However, little if anything of value was ever obtained in this way [Stokinger, 1986–87]. From the time the idea was first suggested, the Industrial Medical Association had apprehensively observed that documents in a data repository might be subject to subpoena in damage suits [Minutes, 1967].

In 1969, Stokinger described the lack of appropriate industrial hygiene data as the greatest problem facing the TLV Committee. Describing the American chemical industry's contribution of data on new substances to the TLV committee as "pathetic", Stokinger, who was employed at the U.S. Public Health Service, addressed industry's responsibility directly [Stokinger, 1969]:

> "The TLVs are industry's values. . . industry has the sole responsibility to develop data on its own products; government is not in a position to develop the facilities to handle the problem *in total*, nor should it, when reliable toxicologic consultants are now available." (Original emphasis)

Regarding chronic animal exposure data, Stokinger commented [Stokinger, 1969]:

> "The data are in short supply because industries either do not develop long-term studies, or if they do, more often than not, do not see fit to release the data in the open literature. Various reasons are given for this: legal protection of their products, lack of staff time to put data in publishable form. Whatever the reason, the data are not forthcoming."

The following year, (1970), the Occupational Safety and Health Act was passed by the U.S. Congress, and virtually the entire 1968 list of TLVs became enforceable federal standards. In future OSHA standards development, the TLV committee could well have been expected to have a considerable influence.

In the chemical industry, the Dow Chemical Company had developed some rapport with the TLV committee in the 1960s. Dow had provided unpublished data on at least 5–10 products, commented on the committee's documentation for specific TLVs, and discussed work published by Dow toxicologists and others around the world. In 1970, this relationship deepened, with the enlistment of Dow toxicologist V.K. Rowe as a "liaison member" of the TLV committee and his co-worker Theodore

TABLE I. TLV Documentation Assignments

Substance (trade name)	Person assigned	Year first assigned
2,4,5 -T	Rowe	1970
ethylene glycol	Torkelson	
vinyl chloride	Torkelson	1971
methyl bromide		
propylene glycol methyl ether ("Dowanol PM")		
methyl chloride	Torkelson	1972
1,2 dibromoethane (ethylene dibromide)		
1,2 dichloroethane		
o-chlorostyrene		
methylene chloride		
1,2,4 trichlorobenzene		
vinylidine chloride		
dicyclopentadiene		
clopidol ("Coyden")		
tricyclohexyltin hydroxide ("Plictran")		
chlorpyrifos ("Dursban")		
picloram ("Tordon")		
dimetholate		
3,5 dinitro-o-tolamide ("Zoalene")		
dimethyl sulfate	Morgan	1972
tris(2,3-dibromopropyl phosphate)	Morgan and Torkelson	1973
styrene	Torkelson	
bis-chloroethyl ether		
1,2,3 trichlorobenzene		
chloroform		
dipropylene glycol methyl ether ("Dowanol DPM")		
ethanolamine		
2-chloro-6-trichloromethyl pyridine ("N-Serve")		
crufomate ("Ruelene")		
chlorodifluoromethane	Morgan	1973
chromates		
methomyl ("Lannate")		
perfluoroalkanes		
cyclopentane		
m-xylene, α,α' -diamine		
bromacil ("Hyvar X")		
diuron ("Karmex")		
dioxane	Torkelson	1974
calcium hydroxide		
cyclopentadiene		
dibromochloropropane		
cyanamide	Morgan	1974
azodrin	Zavon	1975
dicrotophos ("Bidrin")		
m-phthalodinitrile		
isophthalonitrile		
dioxin	Torkelson	1975

(continued)

TABLE I. TLV Documentation Assignments (Continued)

Substance (trade name)	Person assigned	Year first assigned
phosgene	Morgan	1975
m-toluene diamine		
hexamethyl phosphoramide		
formamide	Morgan	1976
dimethyl sulfoxide		
dichloromonofluoromethane		
4,4'-methylene bis (2-chloroaniline) ("MOCA")		
tetramethyl thiourea	Zavon	1976
hexachlorobutadiene	Torkelson	1976
3-amino, 1,2,4 triazole ("Amitrol")		
deodorized kerosene		
toluene concentrate		
acrylonitrile		

Torkelson as alternate industry liaison member. Dupont industrial hygienist James Morgan joined the committee in 1972, and together with Torkelson, he played an active role in the work of the committee for the rest of the 1970s and into the present decade. Torkelson and Morgan became two of the four members of the new subcommittee on carcinogenic substances established in 1972 [Minutes, 1972].

The minutes of the TLV committee in 1972–1976 show that primary responsibility for reviewing documentation in developing TLVs was borne by corporate representatives for major products of their own companies and new products about which little or nothing had been published.

Torkelson was well situated to know about the toxicity of Dow Chemical's halogenated hydrocarbons and pesticides ("Tordon", "Ruelene", "Dursban", and "Plictran"). By the same token, Morgan would appear to have been well placed to know about DuPont's carcinogenic products (dimethyl sulfate, lead chromate, "Moca", hexamethyl phosphoramide), chlorofluorocarbons ("Freon" products), and pesticides ("Lannate", "Hyvar X", and "Karmex"). Dow and DuPont also had substantial economic reasons for wanting to influence the TLV committee on these and other products. But these economic considerations were adverse to the free and full flow of information from the companies.

The 1970s would see government regulators charged with the protection of workers, the environment, and consumers very busy with some of the chemicals in Table I. The demonstration of vinyl chloride's carcinogenicity cast a shadow over a large number of halogenated hydrocarbons. A reference point for regulators in every case would be the currently accepted limit for maximum human exposure, namely workplace exposure. And since most of OSHA's limits were from the aging 1968 list of TLVs, regulators looked to the current TLV lists and designations of carcinogenicity by the TLV committee for guidance. The chemical companies and trade associations contesting standards at OSHA, the Environmental Protection Agency, and the Consumer Product Safety Commission included Dow and DuPont. High TLVs tended to reduce the costs of regulation to the chemical industry.

Moreover, there were liability considerations in addition to regulatory ones. Manufacturers of products involved in damage suits before juries readily resort to the claim that the use of the product was not expected to exceed the TLV and was thus

considered "safe." The "TLV defense" offers manufacturers the plausible deniability that any harm sustained was foreseeable. Where a manufacturer has evidence that the exposure involved was in fact below the TLV, this may even be used to support a denial that the product caused health impairment.

Duplicity of corporate representatives clearly angered longtime Massachusetts occupational health official and TLV committee member Hervey Elkins, who, writing a letter of retirement to Chairman Stokinger in 1975 [Elkins, 1975], stated:

> "In looking over the new documentation I was taken aback by that for ethylene glycol; the limit of 100 ppm was found intolerable by sedentary volunteers in a few minutes (or seconds). I believe that {industry representative} recommended this figure. In spite of his knowledge he seems to come up with some recommendations for TLVs that are way too high, in my judgment. The same can be said for most of the other industry representatives we have had. In many cases they recommend a TLV much above the action levels used in their own plants."

By the time of Elkins' complaint, Dow Chemical had long been assigning internal corporate exposure limits for toxic substances. Other firms, including Rohm and Haas, had also decided to adopt this practice. Corporate workplace exposure limits have served as a managerial tool both for substances with assigned TLVs and others for which TLVs had not been adopted [Paustenbach and Langner, 1986]. Regulatory and liability concerns appear to have deterred corporate management from publishing these lists and supporting rationales—despite their obvious practical value and potential importance in preventing occupational disease.

MATERIALS AND METHODS

The 1986 *Documentation of the Threshold Limit Values and Biological Exposure Indices* was reviewed for all chemical substances. Where reference appeared in the text to unpublished communications and internal corporate reports, etc., a determination was made as to whether such information had been important in setting the TLV or classifying the substance's carcinogenic status. This was a matter of judgement based on the full text for each chemical substance listed. Due to the wide variation in type and quantity of information used as a basis for the various TLVs, rigid criteria could not be used; it is presumed that different experts conducting such a review would come up with slightly different lists of TLVs for which unpublished corporate communications would be judged important.

The important communications can be generally described as animal data, data from tests on human volunteer subjects, and "industrial experience."

Communications coming from corporations and trade associations are in many cases so identified in the *Documentation*. However, in many other cases only the names of individuals are published in the *Documentation*. The institutional affiliations of these people at the times they sent information to the Committee on Threshold Limits have been investigated in various ways. The sources checked included: contemporary publications by the same people; past directories of professional associations (American Industrial Hygiene Association, American Occupational Medical

Association. ACGIH); and retired members of the TLV committee contacted by telephone for their recollections.

Attempts were made in several ways to obtain copies of unpublished material cited in the *Documentation*. The New Jersey Department of Health requested copies of specific references on 67 substances in 1985 from ACGIH and companies named in the *Documentation* for the purpose of developing chemical fact sheets (later, as a pattern of irretrievable unpublished corporate statements emerged, the information was reanalyzed for this paper). An examination was also made of the historic TLV Committee files at the National Institute for Occupational Safety and Health (NIOSH) in Cincinnati. The surviving files kept there by United States government employees who had served on the TLV Committee, covering years from the late 1950s through the 1970s, contained a small number of letters and reports cited in the *Documentation*.

Though ACGIH has copies of TLV committee minutes for the last 10 years, the Board of Directors would not grant access to them [Kelly, 1986–87].

RESULTS

For a total of 89 substances, the 1986 TLV *Documentation* placed important reliance on unpublished corporate communications (Table II). Another 15 substances were assigned TLVs *solely* on the basis of unpublished corporate studies and reports (Table III). This investigation was able to locate written copies of far less than half of the above unpublished corporate material from the NIOSH files, ACGIH, and the corporations.

Of the 89 substances in the first group above, corporate affiliation of the referenced source person was not published for 25. For the 15 TLVs based solely on unpublished corporate communications, the companies providing information were all identified in the *Documentation*.

There was thus a total of 104 substances for which important or total reliance was placed on unpublished corporate communications. This accounts for over one sixth of the number of (less than 600) chemical substances listed in the 1986 *Documentation*.

Of the 17 corporations asked for documentation they had provided to the TLV committee, nine sent old documentation or commented on their work to the New Jersey Department of Health. The unpublished documentation in most cases was unobtainable from the companies (Table IV) and the historic TLV committee records in NIOSH files. There were no files available from ACGIH itself; nor did former longtime committee members (Stokinger, Elkins) have personal files on the chemicals. Stokinger admits that some of the information was never conveyed in writing but came over the telephone [Stokinger, 1986–87]. In any event, most of these important unpublished corporate communications are now unobtainable in written form for independent scientific examination.

Industrial Experience

The TLV committee's reliance upon unpublished corporate communications included reports of "industrial experience" on dozens of chemical substances. The content of these reports rendered in the *Documentation* often appears in just the space of a sentence or two (Table V). The scientific community is left unable to determine whether there was more information originally conveyed; and where there was, no

TABLE II. TLVs for Which Unpublished Corporate Data was Important*

Substance	
acrylic acid	fonofos
acrylonitrile	hydroquinone
asphalt fumes[a]	isooctyl alcohol[a]
benomyl	isophorone
benzene[a]	2-isopropoxyethanol
n-butyl acrylate	lead chromate
sec-butyl alcohol[a]	manganese and compounds
n-butyl glycidyl ether	manganese tetroxide
caprolactam[a]	methacrylic acid
carbon disulfide[a]	methomyl
catechol	4-methoxyphenol
chlorinated camphene (60%)	methyl n-butyl ketone
chlorinated diphenyl oxide	methyl chloride
chloroacetaldehyde	methyl 2-cyanoacrylate
chloroacetyl chloride	methylene bis-4-cyclohexyl-isocyanate[a]
chlorodifluoromethane[a]	methylene bisphenyl isocyanate
o-chlorostyrene	methylene chloride
o-chlorotoluene	4,4' methylene dianiline
chlorpyrifos	methyl isocyanate
copper[a]	metribuzin[a]
cyclopentadiene	monocrotophos
cyhexatin	paraquat[a]
dibutyl phthalate	piperazine dihydrochloride
dichlorodifluoromethane	propionic acid
dichloroethylene	quinone[a]
dichlorofluoromethane	resorcinol
2,2 dichloropropionic acid	rosin core solder pyrolysis products[a]
dichlorotetrafluoroethane	silicon tetrahydride
dicrotophos	silver and compounds[a]
dicylopentadienyl iron	sulfuryl fluoride
diethyl phthalate	sulprofos[a]
diglycidyl ether	tetraethyl lead[a]
dimethyl acetamide	tetramethyl lead[a]
dimethylamine	tetrahydrofuran[a]
dimethylformamide	thioglycolic acid
dimethyl sulfate	1,2,4 trichlorobenzene[a]
diphenylamine[a]	trichlorofluoromethane
di-sec-octyl phthalate	1,1,2 trichloro 1,2,2 trifluoroethane
endrin[a]	trimethyl phosphite
ethion	tungsten compounds[a]
ethylene dichloride[a]	vinylcyclohexene dioxide
ethylenimine	xylidine[a]
n-ethyl morpholine	zinc stearate
fenamiphos[a]	

*Includes substances' assigned carcinogenicity status. Does not include papers presented at scientific conferences.

[a]Corporate affiliation of correspondent not published in Documentation of TLVs.

TABLE III. Documentation of TLVs Solely by Unpublished Corporate Communications

Substance	Animal data, acute	Animal data, subacute or chronic	Human data	Source, year
n-butyl lactate			x	Philips Endoven 1969 British Petroleum 1972
o-sec-butylphenol	x		x	Dow/1977
clopidol		x (2 yrs:teratol)		Dow/1973
dinitolmide		x (2 yrs:teratol)		Dow/1973
divinylbenzene	x		x	Dow/1977
ethyl amyl ketone*	x		x	Shell/1958, 1965
2-hydroxypropyl acrylate	x	x (30 da.)		Dow/1977
isophorone diisocyanate	x	x (4 wks)		Veba-Chemie
n-isopropyl aniline	x			Dow/1977
methyl acetylene-propadiene mixture		x (4 mos.)		Dow/1964
nitrapyrin		x (93 days)		Dow
phenylphosphine	x	x (90 day)		DuPont/ 1970
tetrasodium pyrophosphate			x	Dow/1977
triphenyl amine	x		x	Kodak/ 1973
m-xylene α,α' diamine	x			Dupont/ 1973 Sherwin-Williams 1978

*Includes an industrial hygiene bulletin by Shell Chemical Corporation claiming no systemic effects in workers exposed to concentrations above the TLV recommended by the company.

way exists to look up the original source and resolve questions about the basis of statements published in the *Documentation*, including methodology utilized and whether the statement was based on any study or merely an impression.

Because of the weight given to these reports and the great value of studies industry could perform on the workers exposed to these agents, special attention to these communications is warranted.

The information provided by companies and published by ACGIH in the *Documentation* raises obvious and fundamental questions. What exactly did Dow's "routine" medical examinations and any analysis performed on them show to establish that "no evidence of over-exposure" occurred at the reported concentrations of methyl chloride? What tests were conducted and what analysis was carried out by Dow? What was the scientific content and methodology of the unpublished negative mortality studies on acrylonitrile, benzene, dimethyl sulfate, and ethylenimine? What were

TABLE IV. Requests of Data from Corporations

Corporation	Number of Chemicals	Results
Dow	33	No information received.
Hooker	2	The company provided a report for one (chlorotoluene) of the two requested chemicals. Study methods and results were described (animal study).
Hercules	2	For one chemical (chlorinated camphene), Hercules stated they had sold the operation to Nor-Am and stated any toxicologic information "must now come from Nor-Am." (Hercules did not say they no longer had the information.) Nor-Am stated they no longer produced it, and that much of the correspondence and reports had been discarded. For the other chemical (Rosin core solder pyrolysis products), the study was provided with detailed methods and results. However, inflammation and hyperemia in multiple organs for both controls and exposed animals causes one to wonder about (inadvertent) exposure of "controls."
Crown Zellerbach	1	The Documentation states, "industrial experience has been good over the years." Crown Zellerbach's correspondence describes 3 yr experience manufacturing the chemical (catechol), with only "a few mild toxic reactions." CZ notes "no physical abnormalities . . . noted by observation" (not stated whether all workers had physical exams) or in "multichannel blood tests" (type, frequency, other methods unspecified). While catechol is an irritant, there is no mention of the use of symptom questionnaires or lung function tests in this 1975 communication.
FMC	1	No information received (carbofuran).
Rohm and Haas	2	Significant material sent describing study methods and results for animal studies on both chemicals. Study report noted "Squamous metaplasia" of nasal mucosa, thought secondary to irritation (ethyl acrylate). This effect not noted in Documentation.
American Cyanamid	2	The company provided information on one (phorate) of the two chemicals requested. This was an inhalation study (level unspecified) for 8 hr involving 12 animals observed for 7 days after exposure. The report merely says "there was no evidence that they were affected in any way." There is no mention of whether pathologic studies or biologic monitoring were conducted let alone reporting of such findings. The criteria for no effects were unspecified.
DuPont	7	Some information (not always complete) was sent for all 7 chemicals. The Documentation states that there were "no complaints of illness" and no abnormal liver function tests in employees exposed at roughly half the TLV for several years (dimethyl formamide). The information provided by the company to NJDOH does not appear to be a reference upon which such a statement could have been based; the original basis for the statement not be located. An epidemiological study of 143 workers exposed to dimethyl sulfate showed that few deaths from respiratory cancer occurred among them while employed by DuPont. The work force was not broken down in terms of either time elapsed from onset of exposure or duration of exposure to DMS. No follow-up of ex-employees and retirees was done.

(continued)

TABLE IV. Requests of Data from Corporations (Continued)

Corporation	Number of Chemicals	Results
		No data were provided to substantiate Zapp's communication (1970) to the ACGIH that methylene bis (4-cyclohexyliso-cyanate) was less toxic on inhalation than TDI.
		Dupont's subacute study on dogs, found to have no skin irritation or sensitization effects, unlike "results. . . previously reported" (tetrahydrofuran), was given greater credence than the published positive studies by the TLV committee "because of the greater number of animals involved". The DuPont study used 4 dogs.
		A 90-day study of phenylphosphine contained adequate discussion of methods and results. DuPont's study of m-xylene α,α' diamine found "generally mild" sensitization in all 10 guinea pigs tested. This is mentioned in the Documentation as "evidence of sensitization" without noting that all animals were affected.
		The Documentation refers to a subacute study by DuPont in 6 rats as one which "caused no fatalities" (dicyclopentadienyl iron). The Documentation omits data showing that in addition to irritability and weight loss, all 6 rats showed testicular atrophy. It is unclear whether these effects were ever communicated to the TLV committee (report was obtained from the company but not in the TLV files).
Western Electric	1	Western Electric did not provide the correspondence for isophorone, but it was obtained from the TLV committee files and consisted of five sentences noting two symptom complaints, urinanalysis and "kidney function checks." No methods discription was given, nor was the number of employees noted, nor whether questionnaires were used or if they waited for employees to complain. No medical surveillance data was provided even in summary form.
Sherwin Williams	1	No response to request for information (m-xylene α,α' diamine).
Mobil Oil	1	Epidemiologic study conducted on employees (for eye effects only) with exposure levels evaluated, study methods described. Unclear whether study was ever published (trimethyl phosphite).
Ethyl Corp	1	No response to request seeking information (tetraethyl lead).
Koppers	1	The Documentation states that "a survey of 180 men employed in work involving resorcinol revealed that none complained of irritation or discomfort at exposure levels of 10 ppm." The company provided no information about any study but merely sent a safety data sheet on the chemical. No discussion of methods was provided in Koppers' letter to the TLV committee, which was located in the committee's files.
Eastman Kodak	4	Letters on animal studies were located for 2 chemicals (o-chlorotoluene, triphenylamine). Observations on workers could not be located for the other 2 (dibutyl phthalate, di-sec-octyl phthalate).
Union Carbide	4	No response to request for information.
Shell Oil	3	Shell no longer makes the 3 chemicals and states that correspondence concerning them is no longer available.
B.F. Goodrich	1	The Documentation states "observations in the rubber industry have revealed no adverse effects from many years of inhalation of zinc stearate dust." The company had

TABLE V. Unpublished Industrial Experience Cited in TLV Documentation

acrylonitrile	Monsanto, 1981, epidemiology negative on carcinogenic effects.
asphalt fumes	Hammond (Humble Oil) 1968—opinion of industrial hygienists that conditions were satisfactory at 10 mg·m^3.
benzene	Ott et al. (Dow), 1975, epidemiology "revealed no excess mortality."
sec-butyl alcohol	Banks (Shell Chemical Company) 1966—hygienist reports that "many years of industrial experience (at 100 ppm) have resulted in no difficulties."
n-butyl lactate	Turner (British Petroleum), 1972, reported that 7 ppm was not found to be objectionable or injurious.
caprolactam	Ferguson (Allied Chemical), 1972, reports on 143 workers, "some of whom were exposed up to 17 years to vapor concentration as high as 5–10 ppm without any evidence of damage to health."
carbofuran	Tobin (FMC Corporation), undated, given as source: "Workers exposed to concentrations approaching 0.1 mg·m^3 per day have not shown any effects."
carbon disulfide	Calhoun (American Viscose), 1968, reports no cases of carbon disulfide poisoning since 1942, when exposures averaged below 2.5 ppm.
catechol	Crown Zellerbach, 1975, referenced as reporting industrial experience has been good under adequately controlled conditions.
chlorinated camphene (toxaphene)	Hercules, Inc., 1969, reports that review of records of 137 employees, "some" exposed up to eighteen years, "failed to reveal any adverse effects that could be associated with toxaphene."
chlorodifluoromethane	Reinhardt (DuPont), undated, reports that cardiac arrythmias are not considered a possibility "under currently recommended industrial hygiene practices."
o-chlorotoluene	Hopton (Hooker Chemical), 1962, reports that no cases or dermatitis or poisoning from this compound had been encountered.
dibutylphthalate diethylphthalate di-sec-octylphthalate	Raleigh (Kodak), undated, reports workers exposed to 1–6 ppm of mixed phthalates had no phthalates in their blood and had no peripheral polyneuritis.
diglycidyl ether	White (Shell Chemical Company), 1962, recommends a ceiling limit of 0.5 ppm "on the basis of a no-effect level in animal studies and industrial experience." (TLV-TWA: 0.1 ppm)
dimethylformamide	DuPont, undated, reports no complaints of illness and no abnormal liver function tests at about one half the TLV.
dimethylsulfate	DuPont, 1972, epidemiology "covering a period of 15 years" and an update in 1976 show no excess of lung cancer in exposed workers.
diphenylamine	Dernehl (Union Carbide), 1967, cites "industrial experience" in recommending a satisfactory operating level. On this basis, the same value was selected as the TLV (10 mg/m^3).
endrin	Jager (Shell): no medical effects seen with 233 workers, comparing them before and after 10 years' exposure to endrin and related pesticides (body weight, blood pressure, WBCs, and SREs).
ethylene dichloride	Fassett (Kodak), 1964, "Experience in one plant indicated that concentrations in the range of 25 to 50 ppm were safe for prolonged exposure."
ethylenimine	Dow report of BASF, 1973, epidemiological study "revealed no evidence" of carcinogenicity in 144 workers "some of whom had 40 years' experience."
hydroquinone	Fassett (Kodak), undated, reports that clinical and environmental studies of workers "confirm that no systemic effects arise at (the TLV)."

(continued)

TABLE V. Unpublished Industrial Experience Cited in TLV Documentation (Continued)

manganese and compounds	Whitman (Bethlehem Steel), 1976, reports no cases of manganism in workers exposed for years to 1 to 5 mg/m^3 of manganese dioxide dust.
methyl *n*-butyl ketone	Raleigh (Tennessee Eastman Co.), 1976, reports "no history of muscular weakness, parathesia, loss of coordination or clinical evidence of neuropathy in 37 employees engaged for 3 years in the manufacture of (methyl n-butyl ketone)."
methyl chloride	Dow, undated, reports that a "routine periodic medical program did not identify evidence of overexposure to methyl chloride" at concentrations averaging 30 ppm.
methylene bisphenyl isocyanate	Imperial Chemical Industries, 1962, reports no cases of skin irritation during early industrial experience handling this compound.
4,4' methylene dianiline	Dow, 1977, reports "no morbidity findings" for exposures ranging from 0.03 to 0.4 ppm over 26 years.
monocrotophos	Shell Chemical, undated, reports no decrease in field workers' cholinesterase concentrations following exposure.
paraquat	Gage (Imperial Chemical Industries), 1968, is cited as reporting that "no serious injury or illness resulted from eight years' agricultural use of paraquat."
propionic acid	Dow, 1977, reports that, at reported exposure levels, no irritation was noted. Medical reports include mild eye redness and one case of mild cough and asthmatic response.
resorcinol	Koppers Company, 1974, reports that none of 180 men exposed to 10 ppm complained of irritation or discomfort.
tetraethyl lead tetramethyl lead	Linch (DuPont), 1968, reports that exposures averaging about 20% over the TLVs produce average urinary lead concentrations "not significantly elevated above a high normal" (no values above 0.15 mg/l). Ethyl Corporation, undated, reports that 3/4 of the TLV for tetraethyl lead "is a rough guideline for an allowable (TLV)."
trimethyl phosphite	Mobil Chemical Co., 1980 reports no ocular changes among 179 workers with exposures reported. "Plant exposure data could be interpreted to indicate that concentrations of 1 ppm certainly, and very likely 2 to 4 ppm, are without significant adverse effect." TLV raised from 0.5 to 2 ppm in 1982.
tungsten compounds	Dernehl (Union Carbide), 1966, reports that "long industrial experience" has indicated workers exposed to solely tungsten and its insoluble compounds do not develop pneumoconiosis.
vinyl cyclohexene dioxide	Dernehl (Union Carbide), 1973, referenced as source: "In the U.S., industrial experience over the past 10 to 20 years has been good."
zinc stearate	B.F. Goodrich Rubber Co., undated, referenced as source: "Observations in the rubber industry have revealed no adverse effects from many years inhalation of zinc stearate dust." (no concentrations given)

the parameters and data underlying Hercules' unpublished communication to the effect that a review of employee medical records "failed to reveal any adverse affects that could be associated with toxaphene?"

Similar questions arise over the nature and quality of industrial experience relied upon by the TLV Committee for 32 other chemical substances (see Table V). An even larger number of TLV substances were assigned exposure limits after significant reliance on unpublished corporate communications about animal experiments.

In this survey, a TLV *Documentation* reference was counted as "published" even if it was from a manufacturer's safety data sheet or an unsupported statement published in a text by a corporate health professional. The brevity, age, and obscurity of such documentation raises serious questions of reliability despite the fact of such references being "published."

Manufactureres' safety data sheets, while briefly noting chemicals' health effects or lack of effects, are not generally useful as primary sources for detailing the scientific basis of health effects statements. Safety data sheets are not written to convey the important data underlying statements like, "no health problems have been attributed to the use of this agent in industry"; or "it is an irritant but not a sensitizer." Yet TLVs are still based on such statements by manufacturers on safety data sheets issued in the 1950s (e.g., ethyl ketone, methylamine, nitromethane). The use of corporate safety data sheets of even recent vintage is inappropriate for documenting TLVs.

Some reports of "no adverse industrial experience" in the 1986 *Documentation* originally appeared in classical texts but were unsubstantiated by data and are now very old. In the case of morpholine, the text refers to the 1963 edition of Patty's toxicology text as a basis for saying that "no chronic effects have been reported." The primary source cited was a 1948 review on morpholine issued by the American Petroleum Institute. Patty's text was in large part written by industry professionals; and some of the statements appearing in the text, though unexplained there, went on to be cited as the basis for TLVs. Patty himself reported on ethyl acetate concentrations he had measured during a period of "several months" during which time "no adverse symptoms or illnesses were observed." Patty, who was an industrial hygienist at General Motors, did not explain whether the observations made were those of physicians, himself, or other medically untrained management officials (supervisors, foremen, personnel managers).

TLVs for Carcinogens

The case studies of six carcinogenic materials will be considered next, in order to examine in some detail the work of the TLV committee in this important area. These summaries illustrate a number of ways in which the committee was informed and influenced by industrial parties.

Some of the materials on the first lists of MACs, as they were called in the early years, were known or suspected of being human carcinogens. These agents included asbestos (1946), arsenic (1947), and chromates (1950). Threshold limits for these materials appear not to have been based on their carcinogenic effects, however.

Arsenic

In the case of arsenic and its compounds, the 1947 value was 100 $\mu g/m^3$. The following year, Hill and Faning produced strong epidemiological evidence of a lung and skin cancer hazard in a factory making sodium arsenite sheep-dip [Hill and Faning, 1948]. Median room air concentrations of arsenic measured in the chemical plant were 71, 254, 373 and 696 μg As/m^3. Average urinary arsenic concentrations of the workers were in the range of 0.09 to 0.24 mg/liter [Perry et al., 1948].

For reasons not explained at the time, the threshold limit for arsenic was *raised* in 1948 from 100 to 500 $\mu g/m^3$. In the first published documentation of the TLVs in 1962, the "subsequent experience" of the American Smelting and Refining Company

was cited as supporting 500 $\mu g/m^3$. The source of this information was the company medical director [Pinto, 1961; Documentation, 1962]. In acknowledging Pinto's confidential report, Stokinger replied, "It was surprising to see what a clean bill of health you were able to produce, in view of the many implications of arsenic and lung cancer." [Stokinger, 1961].

Pinto's work was published in 1963, showing that both employees exposed to arsenic and employees with "non-arsenic exposure" had a greater incidence of lung cancer than males in the state of Washington. The "exposed" group had urinary arsenic levels of 0.82 mg/liter, and the "unexposed" smelter employees had urinary arsenic burdens averaging 0.13 mg/liter [Pinto and Bennett, 1963]. Pinto later conceded that the latter group in this controversial report was in fact exposed to "low arsenic levels," but denied a suggestion published by the Occupational Safety and Health Administration (OSHA) that there had been under-reporting of lung cancer cases in the 1963 study [Pinto and Nelson, 1976].

The National Institute for Occupational Safety and Health evaluated Pinto's 1963 report as showing an increase in lung cancer mortality, contrary to the conclusions of the authors [Inorganic, 1975]. A 1974 mortality study on the workers at the same Asarco copper smelter confirmed their lung cancer hazard [Milham and Strong, 1974]. In 1975, OSHA responded to mounting reports of lung cancer in arsenic-exposed workers by proposing a reduction in the workplace standard for arsenic, from 500 to 4 $\mu g/m^3$. (The original standards was 500 because the 1968 TLV values for most substances were adopted en masse as enforceable standards with the passage of the Occupational Safety and Health Act of 1970).

The Threshold Limits Committee of ACGIH followed by adopting two TLVs for arsenic trioxide in 1977: 50 $\mu g/m^3$ at smelters and 250 $\mu g/m^3$ in non-smelting environments. This aroused bitter resentment at NIOSH and OSHA, where the actions of the TLV Committee were seen as aiding the industry challenges to the government standard. The government researchers and regulators were especially piqued at Dr. Stokinger, who was then Chairman of the TLV Committee while drawing a government salary at NIOSH. Referring to the actions of the TLV Committee on arsenic, OSHA said: "The detailed basis for arriving at these levels is not clear on the record" [Occupational Exposure, 1978]. OSHA's final standard for inorganic arsenic, issued in 1978, was 10 $\mu g/m^3$ of air, averaged over an 8-hr period [Occupational Exposure, 1978].

The TLV Committee first listed "arsenic trioxide production" as a human carcinogen in Appendix A of the TLV booklet in 1975. In 1980, arsenic trioxide production was reclassified as a suspect human carcinogen; and numerical TLVs for this process and for insoluble arsenic compounds were completely eliminated.

Asbestos

The TLV adopted by ACGIH in 1946 to 1970 for asbestos was based upon the "tentative" recommendations of a Public Health Service study published in 1938 [Dreessen et al., 1938]. The P.H.S. survey showed that workers exposed to more than 5 million particles per cubic foot (MPPCF) of total dust in the air of asbestos plants clearly developed asbestosis. But the P.H.S. survey also found "early to moderate" asbestosis in workers with less than 50 MPPCF—years of cumulative exposure. The P.H.S. findings and those of an earlier medical survey by Pennsylvania

labor authorities strongly indicated that workers eventually would develop asbestosis from exposures under 5 MPPCF [Fulton et al., 1935].

Lung cancer among asbestos workers was first reported in the mid-1930s, and by 1939, German state insurance carriers were compensating lung cancer in combination with even slight asbestosis as an occupational disease [Baader, 1939]. Pathologists around the world continued to contribute data and comments on the coincidence of those two diseases through the 1940s. In 1949 the British government published powerful confirmatory statistical evidence: in 235 deaths in which asbestosis had played a role, fully 31 (13.2 percent) also involved cancer of the lung or pleura [Annual Report, 1949].

The old 5 MPPCF threshold was never regarded as safe by leading asbestos industry consultants (Drs. Leroy Gardner, Arthur Vorwald, and Anthony Lanza). A similar lack of faith in this TLV as an index of safety was expressed publicly and privately in the 1940s, 1950s, and 1960s by executives and health professionals of the leading asbestos companies in the United States and the United Kingdom, as well as health authorities in these and other countries [Castleman, 1986]. In 1964, the old TLV for asbestos was repeatedly criticized by government and industry speakers at a widely publicized conference on asbestos held by the New York Academy of Sciences [Ann. N.Y., 1965]. By this time, it was evident that nearly half of all asbestos insulation workers, whose average exposure was of the same order of magnitude as the TLV, were dying from occupational cancer and asbestosis.

The ACGIH Threshold Limits Committee had included asbestos industry consultants from its earliest years. Industrial hygienist Manfred Bowditch, who was on the Committee in 1946 and 1947, was then also trying to fulfill contracts the Saranac Laboratory had made with the asbestos industry [Castleman, 1986]. Bowditch's deceased predecessor at Saranac, Leroy Gardner, had performed studies in confidence for asbestos manufacturers, and the manufacturers wanted to publish some of the results (not the animal studies showing asbestos causing lung cancer, however.

Dr. Arthur Vorwald, the next director of the Saranac Laboratory, accommodated asbestos industry sponsors with his publication of Gardner's non-cancer related research in 1951 [Castleman, 1986; Vorwald et al., 1951 and Vorwald, 1948]. That year, he joined the Threshold Limits Committee, on which he served until 1956. During these years, Vorwald evaluated at least 30 cases of suspected and proven asbestosis and cancer, many of which were the subject of compensation claims, for companies in the United States and Canada. He also conducted a confidential animal inhalation study which appears to have re-confirmed asbestos' carcinogenicity in the early 1950s; however, this was never discussed in Vorwald's publications [Castleman, 1986; Vorwald, 1952].

Dr. Paul Gross, at the Industrial Hygiene Foundation (since 1971, Industrial Health Foundation), became a member of the Threshold Limits Committee from 1964–1983. Gross' consulting work on asbestos included case pathology reviews for Johns-Manville in the 1950s and confidential animal research on brake drum dust for Johns-Manville in the 1960s [Castleman, 1986]. As a member of a U.S. Public Health Service committee in 1969, Gross secretly provided draft copies of a report to three asbestos companies. Dr. Robert deTreville, President of the Industrial Hygiene Foundation, inviting comment, explained: "(W)e will attempt to see that needed corrections are introduced by Dr. Paul Gross, a member of the Committee" [deTreville, 1969]. In 1976, Gross resigned from a committee of the National Academy

of Sciences, amid charges of improperly sharing information with a company he consulted for — the issue was health effects of asbestos in drinking water [Wade, 1976]. Upon joining the Threshold Limits Committee, Gross became chairman of the subcommittee on insoluble respirable dusts [Minutes, 1965].

ACGIH's Threshold Limits Committee briefly considered having a separate, more stringent TLV for the crocidolite variety of asbestos. A 1968 Notice of Intent was circulated, "so that industry-connected individuals principally, but others also, may have an opportunity to help shape the deliberations of the Committee prior to its (published) recommendation of tentative changes in the 1967 Threshold Limits List." Commenters were asked to write either to Dr. Stokinger at the Public Health Service, or to the "Repository of Anonymous Occupational Health Data" in care of Dr. deTreville at the Industrial Hygiene Foundation (Committee, 1968). "Revisions under consideration. . . proposed for 1968 List (of TLVs)" included the following for asbestos:

> A limit of 5 MPPCF, based on impinger samples counted by light-field technics (sic), is satisfactory to control exposures to most forms of asbestos. Crocidolite, however, has been shown to produce, in addition to the asbestotic inflammation, also mesothelioma. Since no safe limit can be established for this form of asbestos at this time, until more definite data are obtained, it is recommended that workers exposed to crocidolite be equipped with air-supplied helmets.

This idea of stringently controlling exposure to crocidolite asbestos dust was dropped before the publication of the 1968 book of TLVs.

Over the next few years, the ACGIH published notices of intent to lower the TLV for all varieties of asbestos and change the method of analysis to phase contrast microscopy, but the formally adopted value remained 5 MPPCF through 1970. Finally, in 1974, ACGIH listed an adopted TLV of 5 f/cc for asbestos (using phase contrast microscopy), two yr after OSHA had established a standard at that level through formal rulemaking. In 1980, ACGIH lowered its TLV for chrysotile asbestos, the most abundant variety, to 2 f/cc, and set lower limits for crocidolite and amosite. By this time, government standards for chrysotile had been in effect at the 2 f/cc level for 4 yr in the United States and 11 yr in Britain. The TLV for crocidolite asbestos only (0.2 f/cc) is equal to the current (1986) OSHA asbestos standard for all types of asbestos. No notice of intended change for asbestos has been published by ACGIH since 1980.

It is noteworthy that, despite the comparatively slow process governments must follow in developing standards under their laws and despite the reluctance of conservative governments to regulate industry in the 1980s, ACGIH has lagged behind both OSHA and the British government in lowering limits for workplace exposure to the leading recognized cause of occupational cancer.

Vinyl Chloride

Upon the recommendation of Dr. Robert Scala at Esso, the TLV committee proposed lowering the limit for vinyl chloride gas to 50 ppm from 500 ppm [McFarland, 1965]. This was largely based on animal tests published by Torkelson in 1961, where effects were noted at 100 ppm and a TLV of 50 ppm was recommended

[Torkelson et al., 1961]. Following the circulation of the committee's 1966 Notice of Intent, Chairman Stokinger was invited to the Industrial Hygiene Foundation (IHF) in early 1966 to discuss the proposed changes in the TLV list. There, he met with 50 representatives of companies with membership in IHF in Pittsburgh. Stokinger was told that, "industrial experience suggests that (50 ppm) may be too low" [Report, 1966].

Consequently, the proposed change of vinyl chloride's TLV was "put off, on suggestion of Dr. Torkelson, that the Committee await further accumulating experience" [Stokinger, 1966]. The committee lowered the TLV to 200 ppm in 1971, based on unpublished Dow findings of liver dysfunction in workers exposed to 300 ppm (vinyl chloride combined with 5 ppm vinylidine chloride) [Documentation, 1971]. Dow representatives maintain that the company reduced its internal employee exposure limit to 50 ppm in 1961; but in practice this limit was knowingly exceeded, as Dow first reported the above data in 1968 [Documentation, 1971; Paustenbach and Langner, 1986].

The first U.S. workplace standard for vinyl chloride was 500 ppm, the 1968 TLV. It was revealed in 1974 that vinyl chloride workers had died from angiosarcoma of the liver and that similar tumors had been produced in experimental animals at 50 and 250 ppm. OSHA issued a proposed standard for vinyl chloride, specifying that exposures be below detectability using instrumentation sensitive to 1 ppm. But official U.S. government statements that the safety of the gas had not been demonstrated at any level were publicly denounced by Stokinger as "irrational" and "unfortunate" in a letter to the National Cancer Institute. In an interview with the *New York Times*, Stokinger went on to say that there was "ample and increasing evidence that there are threshold levels for carcinogens below which there is little risk" [Official, 1974].

OSHA issued a 1 ppm standard for vinyl chloride later in 1974, and the U.S. industry not only met that goal but promptly resumed its growth [PVC, 1976].

In the meantime, the TLV committee had taken on members from industry, including Torkelson of Dow Chemical, a major manufacturer of vinyl chloride. Torkelson had primary responsibility for TLVs for vinyl chloride and a number of other high-volume, halogenated hydrocarbons, starting in 1971 [Minutes and Agenda, 1970–1976]. It was not until 1977 that the committee issued a new TLV for vinyl chloride, 5 ppm, which still stands.

The TLV for vinyl chloride was thus set at one tenth the concentration carcinogenic to animals for a proven human carcinogen. This conflicts with the current TLV committee claim that safety factors of 100 to 1,000 have "traditionally" been used to determine TLVs for carcinogens [Identification, 1986].

Dimethyl Sulfate

The TLV for this vapor, used as a war gas in World War I, was originally set at 1 ppm in 1946. German reports in the late 1960s showed that DMS was carcinogenic in rats and probably also in workers; and the Germans lowered their MAK for this vapor to 0.01 ppm in 1971, as animal studies revealed serious lung damage at 0.5 ppm [Henschler, 1975].

The TLV committee had published its first listing of carcinogens as an appendix to the TLV booklet in 1971, consisting of only nine entries (mostly dye intermediates). In early 1972, the committee's annual Notice of Intended Changes informed readers that this list was being expanded, with separate groupings of human and "experimen-

tal" carcinogens. The listing of DMS in the former category prompted inquiries from five chemical companies. Stokinger replied to them, sending copies of underlined articles and saying: "a sufficient number of human cancers of the lung have been observed to make it highly probable that dimethyl sulfate is a carcinogen for man" [Stokinger, 1972].

A few months later, DuPont provided Stokinger with a copy of a letter from a doctor at BASF, a German manufacturer of dimethyl sulfate. The writer pointed out that the German MAK list denoted dimethyl sulfate as an experimental animal carcinogen but not a human carcinogen [Morgan, J.F., 1972]. The next month, DuPont sent Stokinger an epidemiological report "which formed the basis of our conclusion that dimethyl sulfate is not known to have produced human cancers among potentially exposed persons." Stokinger was asked to limit distribution of the study to persons having a need to see it [Morgan, J.F., 1972].

The DuPont study examined employee lung and larnyx cancer rates at three plants where DMS had been handled. However, "usable data" identifying the employees exposed to DMS before 1961 were available for only one plant. During 1932–1970, 97 wage roll workers and 46 salaried employees had worked at some time in the DMS area. There were two deaths each from lung and larynx cancer among the DMS workers between 1956–1970, with retirees and ex-employees clearly *not* followed up.

When OSHA issued an Emergency Temporary Standard for carcinogens in 1973, Stokinger argued for a distinction to be made between "*known* human carcinogens" and others on the OSHA list. Writing as Chairman of the TLV committee, Stokinger relied on the unpublished DuPont report to assert that no excess of respiratory cancers had occurred among DMS workers: "Manufacturing exposure control was completely effective, without the requirement for air-pressurized suits. . ." Stokinger cited other unpublished reports from DuPont and Dow to argue that two of these companies' products covered by the OSHA standard (MOCA, ethylenimine) also were not human carcinogens [Stokinger, 1973].

The TLV committee member with responsibility for DMS in the period 1972–1976 was James Morgan of DuPont (sole U.S. manufacturer of DMS) [Minutes and Agenda, 1970–1976]. The committee assigned a TLV of 0.1 ppm in 1977, ten times the limit previously accepted in Germany.

Benzene

The TLV for benzene was adjusted downward from 100 ppm in 1946, 50 ppm in 1947, 35 ppm in 1948, to 25 ppm in 1957. The TLV committee adopted 25 ppm as a ceiling exposure limit in 1963. An industry consensus "standard" of 10 ppm (with daily 10-min peaks of 50 ppm) was issued in 1969 by the American National Standards Institute. Consequently, 10 ppm was the first benzene limit adopted by OSHA (NIOSH, 1974).

British industry and government writers urged Stokinger to abandon the 25 ppm ceiling in favor of a 10 ppm average value as early as 1966 [King, 1970; Stokinger, 1966]. The TLV committee first proposed this change in 1968, but deferred its adoption until 1977.

Hueper had assessed benzene as almost certainly a proven cause of leukemia in 1942 [Hueper, 1942]. The German MAK commission had listed benzene in 1971 among nine human carcinogens, "for which zero concentration values are given

because the objectionable concentration is not yet known" [Morgan, L., 1972]. Benzene was classified by the TLV committee as a "suspected" human carcinogen in 1975.

The 1986 *Documentation* contains no references less old than 1977 and relies on one report whose findings were reversed in 1977. That year, OSHA issued an emergency temporary standard and proposed a permanent standard of 1 ppm for benzene. An adverse Supreme Court ruling in 1980 based on the record of the benzene standard issued in 1978 prompted OSHA to conduct quantitative cancer risk assessment and again propose a 1 ppm limit in 1985.

The 1986 *Documentation* refers to unpublished work by Ott in 1975 as showing no excess mortality among benzene-exposed workers. However, Ott concluded that this same cohort of Dow Chemical employees demonstrated a significant excess of myelogenous leukemia cases—prompting Dow to announce a new corporate ceiling limit of 10 ppm in 1977 [Benzene, 1977; Ott et al., 1978]. Dow epidemiologists have now seen 4 deaths from myelogenous leukemia in this work force, versus 0.9 expected; a fifth worker with leukemia was listed as dying with pneumonia [Bond et al., 1986]. Infante at OSHA notes that average benzene exposure of these workers was 5.5 ppm [Infante, 1987].

Similarly, the 1986 *Documentation* makes no mention of dose-related chromosomal abnormalities among Dow workers exposed to benzene concentrations below 10 ppm [Infante and White, 1983]. These findings were withheld by Dow during the OSHA benzene hearings in 1977, prompting the researcher involved to quit in 1978 in order to release his results. Because of the company's delay in releasing these findings, the researcher denounced Dow as "unethical" and "immoral" [Picciano, 1979; Scott, 1978].

The TLV committee, which adopted a companion short-term exposure limit of 25 ppm to go with the 10 ppm average for benzene in 1980, is discarding the short-term limit in 1987. Exposure at even 10 ppm for eight min is illegal under the OSHA benzene standard published September 11, 1987. The standard requires that exposures average no more than 1 ppm, with 15-min peaks no more than 5 ppm.

The committee's position in 1987 thus resembles that of the American Petroleum Institute in its 1978 court challenge to the overturned benzene standard. The past decade of benzene toxicology research has not been incorporated into the TLV *Documentation*. The research and policy at Dow Chemical (whose senior toxicologist was an active member of the TLV committee), if known to the committee, have been disregarded without mention.

Acrylonitrile

Following the reports of positive animal studies by inhalation and ingestion, as well as positive epidemiological findings, OSHA regulated acrylonitrile as a carcinogen in 1978. Acrylonitrile was also classed by ACGIH as a human carcinogen in 1978. Following the publication of an inconclusive epidemiological study in Britain and the receipt of epidemiological "communications to the TLV committee" from Monsanto Company in 1981, acrylonitrile was reclassified under "industrial substances suspect of carcinogenic potential for man." The Monsanto conclusions were quoted by the TLV committee; no published study is yet available for scrutiny by the scientific community.

Ethylenimine

When OSHA proposed to regulate this compound as a carcinogen in 1973, Dow's Dr. D.J. Kilian provided the basis for the TLV committee observation, that despite this chemical's toxic and carcinogenic effects in animal studies, "industrial experience has been good." The entire basis for this was the following second-hand report of a telephone conversation between two major manufacturers: [Kilian, 1973]

> "Today, I talked by telephone to Dr. Theiss, medical Director of Badische Anilin and Soda-Fabrik in Germany (the only other major manufacturing site of ethylenimine) and he stated that they had just finished an epidemiological study of 144 of their EI workmen. The exposure time on some was 40 years and they found no evidence that EI was a human carcinogen."

Dr. Kilian also wrote that he and Dr. Theiss planned to combine their companies' experience "in a medical publication in the near future." It does not appear that any study was subsequently published. Ethylenimine was removed from the TLV booklet's appendix list of "experimental carcinogens" after 1974, presumably upon the recommendation of the subcommittee on carcinogens, which included Torkelson of Dow Chemical (sole U.S. producer of the material).

Carcinogens in General

The TLV committee has now stated its intent to "formally" evaluate chemicals classified as carcinogens by other organizations but not ACGIH [Spirtas et al., 1986]. ACGIH has published a table listing the carcinogenic status of more than 300 substances, according to five national and international organizations [Identification, 1986]. The most appropriate comparison is with the list of the German Research Society maximum workplace concentrations (MAK) Commission.

The ACGIH classifies 11 materials in the aforementioned table as human carcinogens; the MAK Commission's total is 17. The ACGIH classifies 40 other entries as suspected human carcinogens; the corresponding MAK commission totals are 42 compounds proven carcinogenic in animal experimentation only, and 61 more "justifiably suspected of having carcinogenic potential" [Identification, 1986; Maximum, 1984].

The TLV committee avoided listing animal carcinogens of major industrial importance, including trichloroethylene and dioxane. These and other unnamed compounds were exempted by the "Committee Guidelines for Classification of Experimental Animal Carcinogens" published in 1976. The guidelines are unique in that they set maximum carcinogenic dosages, above which no "practical importance" is attributed for positive animal experiments.

Lead

Because of their enormous significance in occupational health and the manner in which their TLVs emerged, the story of inorganic and organic lead compounds could hardly be overlooked in this review.

Inorganic Lead

From 1946 through 1956, the TLV for lead and its inorganic compounds was 0.15 mg/m^3. This followed earlier recommendations of the U.S. Public Health

Service and an American Public Health Association committee on lead. Later editions of the Documentation observed that this limit proved "difficult to achieve in many industries."

Explaining the 1957 decision to raise the lead TLV to 0.20 mg/m^3, the first edition of the Documentation said: "Long industrial experience with the 0.15 mg/m^3 limit, however, showed that. . . lead absorption, as measured by urinalysis, were (sic) not indicative of harmful exposure." No reference for this was given. The 1966 Documentation went on to describe the blood lead concentration of 80 micrograms per 100 ml as "normal", and noted that repeated exposures above 0.20 mg/m^3 could cause higher blood lead burdens "indicative of incipient lead poisoning."

Pressure for lowering the TLV developed in November, 1968, when an international commission on occupational health recommended 0.15 mg/m^3. In preparation for discussions with industry, the TLV committee summarized recent developments on lead toxicity and reviewed the "Basis of Present TLV." Under this last heading were three items, all unpublished corporate communications, from: Bowditch (Lead Industries Association); Dooley (Texaco); and Nelson (Asarco) [Review, 1970]. Neither Stokinger nor Elkins can now recall what information was provided by these individuals over 30 years ago, and no primary written documentation has been found in Stokinger's old files at NIOSH.

On May 1, 1970, a meeting was held by TLV committee members Stokinger and Frederick with representatives of the automotive and lead industries, state health officials, and others. Industrial representatives said they used blood lead analyses for health control measures, and urged that air sampling be advised only as an engineering guide. General Motors hygienist Vincent Castrop acknowledged that his company used 0.15 mg/m^3 as its guideline [Stokinger, 1970].

The TLV committee then readopted the former value of 0.15 mg/m^3, which has remained unchanged since 1973. A short-term (15-min) exposure limit of 0.45 mg/m^3 was also adopted in 1976, later to be discarded in 1986. The current Documentation includes an attack on NIOSH for recommending a standard of 0.10 mg/m^3 and rejects the OSHA standard of 0.05 mg/m^3 promulgated in 1978.

Organic Lead Compounds

When tetraethyl lead was introduced as a gasoline additive in the 1920s, lead poisoning was a major by-product of the industry. About 80% of the workers at DuPont's New Jersey production facility were believed to have been lead poisoned; and the plant was known to workers as "the House of the Butterflies" because of the hallucinations afflicting employees there. DuPont was accused of suppressing information from the press even in cases where workmen were hospitalized and died from lead poisoning [Rosner and Markowitz, 1985].

Tetraethyl lead (TEL) and tetramethyl lead (TML) were given TLVs of 0.075 mg/m^3 in 1963 and 1967, respectively. The main basis for the tetraethyl lead TLV consisted of statements by industry representatives that this limit was observed by Ethyl Corporation without apparent ill effects on the workers [Documentation, 1966].

Publication of the second of these TLVs brought forth a "Confidential" letter of protest in 1967 from Dr. Robert Kehoe, the lead industry's foremost medical expert, its consultant and a defender of the tetraethyl lead industry since the 1920s [Rosner and Markowitz, 1985]. Kehoe urged that both TLVs be discarded, "with the least possible fanfare." His "Dear Herb" letter concluded: [Kehoe, 1967]

> "I would not take the risk of subjecting a group of men to working conditions represented by this atmospheric standard for any reason whatever, and yet this level is being adopted on a worldwide basis, and I have little doubt that it will be applied literally by someone, sometime, as being authoritative. It is not so applied in any part of the industry at present."

Kehoe invited Stokinger to be his lunch guest at the Queen City Club, a private club in Cincinnati catering primarily to businessmen [Kehoe, 1967]. Stokinger accepted, and recalls that Kehoe "pontificated" without supplying any data. Stokinger was aware that Kehoe had become a wealthy man over decades as the principal U.S. industry expert on lead poisoning. Though Kehoe presumably represented industrial interests in this matter, no firms were specifically named [Stokinger, 1986–87].

The most influential members of the TLV committee rejected the idea of dropping the limits for TEL and TML, and instead cautiously challenged the responsible industries to produce some dose-response data. In its January, 1968 "Notice of Intent", the committee wrote that a *downward* revision of the TLVs for both lead alkyls was being considered. No new proposed limits were given [Committee, 1968].

At least one manufacturer of these compounds found that operations involving each of these chemicals exceeded even the then-current TLV of 0.075 mg/m^3. But organic lead air concentrations averaging as high as 0.121 mg/m^3 for TEL and 0.179 mg/m^3 for TML reportedly corresponded to average urinary lead concentrations "not significantly above a high normal" — meaning, less than 0.15 mg/l. The source of this encouraging news was A.L. Linch, whose employer (never noted in the Documentation) was DuPont. The date of this communication to the TLV committee chairman is recorded as April 1, 1968.

The TLV committee held its semiannual meeting over the next two days, April 2–3, 1968, and decided to *raise* the TLVs to 0.10 mg/m^3 for TEL and 0.15 mg/m^3 for TML [Stokinger, 1968]. These limits were formally adopted in 1970, and remain the same to this day. No written communication from Linch to Stokinger has been found; and given the rapid sequence of events here, the cited report from Linch appears to have been a telephone call [Stokinger, 1986–87].

It has been proposed recently that OSHA try to adopt current TLVs to "update" the exposure limits for hundreds of substances. While this would yield stricter limits for many substances whose OSHA limits are still the 1968 TLVs, the opposite would result for the lead alkyls. This is especially worrisome in view of the fact that the OSHA standard for organic lead compounds is now more permissive than that for the inorganic lead compounds, which are less toxic; this anomaly will be worsened if OSHA adopts the current TLVs for the lead alkyls.

Bias of TLV Committee Membership

Dr. Hector Blejer, resigning from the committee in 1980 after 10 years as a member, protested what he called "an increasingly stronger pro-industry bias. . . particularly among almost all the Committee consultants and among the members who consult privately for private industry." Blejer went on to blame this pro-industry bias and repeated "unnecessary" disagreements with NIOSH and OSHA for having made the TLV committee and ACGIH appear "anti-NIOSH, anti-OSHA, and anti-labor" [Blejer, 1980].

To its discredit, the committee has long turned a blind eye to conflicts of interest, both overt and subtle. Health and safety professionals tend to view policy issues from a spectrum of opinions: from those who would resolve the benefit of doubt in assuring the fullest worker protection to those who are more sensitive to corporate financial priorities where health and safety is in practice regarded as an expenditure to be controlled as much as possible. It is no accident that professionals with the latter point of view are more likely to consult for or be employed by corporations, and those closer to the former viewpoint are more likely to be independent of corporate funding, perhaps working in government or for labor unions, public interest groups, etc.

The TLV committee never acknowledged this reality or attempted to achieve a balance between corporate- and union-affiliated health professionals. Only occasional token efforts were made to get a union industrial hygienist on the TLV committee. There, the union person could expect to be marginalized at least as badly as was Dr. Blejer (a NIOSH expert on lead, arsenic, cadmium, and asbestos), by the sheer force of numbers and adversaries with vastly superior technical resources. The TLV committee never offered unions and other strong advocates of worker protection a chance to participate on a fully equal basis. The occasional token offers for participation in effect only gave unions the "choice" of participating in an unequally balanced arena and depleting their resources with little chance of being heard — or of no participation at all.

CONCLUSIONS AND RECOMMENDATIONS

While earlier reviews of the TLVs themselves have been critical, the process of TLV development has not been critically examined in the past. The unavailiabity of unpublished corporate "documentation" precludes scientific scrutiny of the primary basis for nearly one sixth of the "documented" TLVs. At the same time, the TLV committee's uncritical acceptance of industry assertions based on scant, unpublished "data" raises yet greater concern.

The documentation of TLVs for their own companies' products by industry members of the TLV committee constitutes a major conflict of interest. This happened on a large scale in the 1970s, with the Dow Chemical representative primarily responsible for TLV development for major Dow products (vinyl chloride, vinylidine chloride, chloroform, methyl chloride, ethylene dichloride, ethylene dibromide, trichlorobenzene, dioxane, ethanolamine, dipropylene oxide methyl ether, styrene, ethylene glycol,dibromochloropropane, "Tordon", "Ruelene", "Dursban", and "Plictran"); and the DuPont representative doing the same for major DuPont products (dimethyl sulfate, "MOCA", lead chromate, formamide, dichloromonofluoromethane, "Lannate", "Karmex", and "Hyvar X") [Chemical Week, 1975; Minutes and Agenda 1970–1976].

The listing of dominant corporate TLV committee members as "consultants" and the issuance of statements to the effect that they did not officially vote on the TLVs were deceptive [Lee, 1987]. The concealment of industry influence on the TLVs is a serious matter, quite apart from the exercise of that influence itself.

Aside from the participation of industry-employed health professionals, the TLV committee has extended full membership to full-time industry consultants as early as 1951 (Dr. Arthur Vorwald of the Saranac Laboratory). To this day, TLV

committee members can and do earn a substantial fraction of their incomes as industrial consultants, while publishing only their university affiliations in the TLV booklet. ACGIH has no policy either restricting TLV committee membership in such cases or requiring public disclosure of consulting work for financially interested parties. Similarly, there is no policy restricting the chemicals assigned to TLV committee members because of conflicts of interest through employment, consulting, and research grants [Kelly, 1986–87].

The TLV committee's lack of adequate resources is evident from its finances. As part of the ACGIH, a volunteer organization, the committee now has an annual budget of $30,000, most of which goes for travel and lodging expenses to conduct meetings [Kelly, 1986–87]. The members of the committee must rely on whatever technical resources and support services are available to them as individuals (computer searches, libraries, research assistants, clerical assistants), and borne by them and/or their employers for their unpaid committee work (e.g., long-distance telephone calls). Over the years, this has meant that committee members have had to work on TLVs on their own time and their own expense, with their own resources, unassisted. As a result, documentation on many chemicals seems to have been prepared with minimal review of the literature.

The TLVs have nonetheless been widely represented and accepted as scientifically based limits that would protect virtually all workers from health impairment over a lifetime of exposure on the job [Lee, 1987]. The TLVs are assumed by many to be first world, "first class" guidelines for worker protection. The consequences of such misplaced confidence in the TLVs are profound and global. The credibility of the ACGIH limits as scientifically, independently, and verifiably determined persists as an obstacle to a better standard of worker protection.

Industrial hygienists need clear instruction regarding the limited nature of the TLVs. Hygienists too often assume or convey to workers that exposure below the TLV can be regarded as safe. They need training which would enable them to assess more adequately the scientific grounds upon which the TLVs are based. They also need increased training in eliciting and evaluating worker complaints of illness during field inspections. This approach should replace the technician approach of simply "cranking out numbers" with monitoring, comparing them to a table, and then assuming all is well if exposures measured are less than the TLVs.

OSHA is now considering adopting current TLVs to replace its exposure limits from the 1968 TLV list (Z table). While for some chemicals this may represent an improvement, it is clear that we cannot assume that the current TLVs are scientific or adequate. Since more rigorous and thorough documentation has been done for the chemicals for which NIOSH recommends specific maximum exposure levels, OSHA should adopt NIOSH levels where these are stricter than those of the ACGIH. Finally, since many chemicals have not been assessed by NIOSH and others need updating, OSHA should consider the adoption of TLVs or NIOSH values as a stopgap measure, not a substitute for ongoing rigorous assessment of chemical exposure values.

With the more recent emergence of better trained and equipped groups issuing workplace exposure limits and supporting documentation in North America, Europe, and elsewhere, it now seems appropriate for an international effort to be mounted to gradually replace the TLVs. This can be done under the auspices of an internationally respected organization, with the participation of leading experts from around the world, with sufficient financing. Corporations with their own internal lists of occu-

pational exposure limits can contribute to this process by publishing these lists and supporting data without further delay.

Openness of the process is essential, as is the exclusion of financially interested parties from having leverage in the deliberations. Policies regarding disclosure of income and conflicts of interest must be accepted by the participants so that the highest level of credibility maintained. Policies regarding making any use of and maintaining public repositories for unpublished documentation will also be needed. Public access to minutes of meetings should be assured and provided for.

Yet even a panel of the best technical experts would not overcome all obstacles inherent to the process of setting worker exposure limits.

There are implicit assumptions in any process of establishing some "acceptable" level of chemical insult to which humans may be exposed. Many scientists reject "safe" exposure levels for carcinogens and certain reproductive hazards. The concept of "safe" exposure limits for other chemicals is less often questioned however, even though scientists are unable in practice to determine "safe" exposures. They can only determine levels below which their limited measurement tools are unable to detect effects in a finite and often very limited number of workers. Thus the very concept of "safe" exposures to any chemical is inherently unscientific. Indeed, the term "threshold limit" embodies this unproven and probably unprovable concept that there is some known level of exposure which does not adversely affect the organism. Discarding the term "threshold limit" is a necessary first step in correcting this false ideology of the past.

Rather, the numerical values for exposure limits selected as "acceptable" by one social group (scientists) for another social group (workers) is very much a political as well as a scientific process. The Norwegian Administrative Norms, for example, explicitly acknowledge that the chemical exposure limits reflect economic as well as medical and technical considerations. The Norwegian authorities consider that while writing the documentation for chemicals is ideally a scientific process, the setting of numerical limits is a political process. It is time that we all openly acknowledge the political nature of decisions by unexposed scientists and regulators regarding maximum levels of chemicals to which other humans can knowingly be exposed. The decision process therefore must not only be freed from undue corporate influence; it must also include substantial participation by representatives of exposed persons.

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ANNEXE N°4

Article de:

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Threshold Limit Values: Historical Perspectives and Current Practice

Grace E. Ziem, MD, Dr PH; and Barry I. Castleman, ScD

A 1989 Occupational Safety and Health Administration standard mandates that workplace air concentrations be held below new permissible exposure limits for 376 substances. As more than 350 of these limits came from the 1987 list of "Threshold Limit Values" (TLVs), the medical basis of the TLVs is of direct importance to the health of millions of workers. However, the TLV development process has been gravely flawed by lack of scientific rigor, inadequate medical input, and lack of attention to financial conflicts of interest. The adoption by the Occupational Safety and Health Administration of many poorly supported values as permissible exposure limits reflects also the underutilization of industrial medicine in identifying health effects of exposures below the TLVs. It is thus the responsibility of the medical profession to act on the presumption that the TLV permissible exposure limits are unsafe limits until a sound underlying body of medical and scientific literature exists for the substances on the list. It is industry's responsibility to commit itself seriously to medical and exposure monitoring and to begin to remedy the knowledge deficit that exists about the less immediate health effects of most industrial materials.

Before reviewing the subject of occupational exposure limits, certain basic issues bear mention. First, the medical profession has a fundamental importance in the investigation and evaluation of the harmful effects of industrial materials. Second, the necessary medical resources need to be provided by industry to make possible the medical surveillance and care of workers exposed. Third, there is a need to develop and train the professional resources to meet the needs of the millions of places of employment. The adoption of standards with specified numerical exposure limits accomplishes nothing unless the necessary professional resources are provided to gather and evaluate information on exposures and health effects.

The Occupational Safety and Health Administration (OSHA) Standard for Air Contaminants

In the closing days of the Reagan Administration, OSHA adopted new permissible exposure limits for 376 substances.[1] Virtually all of these limits came from the 1987 list of Threshold Limit Values (TLVs) published by the American Conference of Governmental Industrial Hygienists. Industry is required to be in compliance by September, 1989.

In developing this standard, OSHA disregarded recommendations by the National Institute for Occupational Safety and Health (NIOSH) for stricter limits for 68 specific substances. The idea of adopting the TLVs had been suggested in 1983 by the Synthetic Organic Chemical Manufacturers' Association, and the chemical industry's response to this OSHA rulemaking was unusually favorable (C.B. Mackerron; *Chemical Week*, January 25, 1989; and comment from the Dow Chemical Company on OSHA's proposed air contaminants rule [July 1988]). The AFL-CIO and at least 16 industrial parties have gone to court over the standard.

OSHA has recently announced that it is considering additionally requiring medical monitoring and air monitoring in industries where regulated substances are used.

Physicians in industry have good cause, therefore, to wonder how protective the new limits are. In fact, the scientific quality of the process for developing the TLVs has been critically examined, and evidence of "corporate influence" in developing the TLVs has figured in the

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debate over the new OSHA rule. A paper on these issues, published in May 1988, has engendered a lively discussion, including more than 20 commentaries by the end of 1988 in the *American Journal of Industrial Medicine*.[2]

The purpose of this paper is to summarize the critique of the TLVs, referring to data already published as well as presenting information gathered since OSHA proposed its new rule in mid-1988. The material here will be addressed primarily to physicians in industry.

The story begins by recounting how the medical responsibility of relating working conditions and health was in large part assumed by a group of industrial hygienists, the American Conference of Government Industrial Hygienists (ACGIH).

Origins of the TLVs

ACGIH traces its history as a professional organization back to 1938. An ACGIH committee compiled a listing of state government exposure limits for various chemicals in 1942.[3] In 1946, ACGIH published its first annual list of recommended "Maximum Allowable Concentrations" (MACs) for 144 substances.[4] The primary sources for this were ACGIH's 1942 compilation and a 1945 paper by industrial hygienist Warren Cook.

It is interesting to recall what was said of the safety of these limits at the time, in view of later developments. ACGIH said in 1942, "The table is not to be construed as recommended safe concentrations." As if to underline that point, the text went on to say, "The material is presented without comment."[3] Cook,[5] whose paper supplied 118 of the exposure limits adopted, emphasized that his intent was "to provide a handy yardstick to be used as guidance for the routine control of these health hazards—not that compliance with the figures listed would guarantee protection against ill health." Cook went on to advise that maintenance of the limits he suggested should not be considered a substitute for medical monitoring.[5]

By 1946, most state governments had industrial health units, and so did some cities and counties. The MAC values reported by 27 of these agencies were quite variable for some chemicals. For *n*-butanol, the limits varied from 25 to 300 ppm in air, depending on where the workplace was located. For turpentine, the range was 100 to 700 ppm; for methanol, from 100 to 300 ppm; for nitrobenzene, 1 to 5 ppm. On the other hand, there was substantial agreement among the health agencies for many other chemicals.[6]

Up to this time, MACs in use had "on the whole [caused] no serious handicap to industry," according to J.J. Bloomfield, one of the leading industrial hygienists of the US Public Health Service.[6] However, there was a desire among the government people to harmonize their MACs and thus avoid the health and economic impacts of having divergent conditions for industry.

ACGIH acknowledged in 1946 that no uniform definition of MACs existed, citing three concepts then in use: no safety margin against known health effects, some safety margin against health effects, and protection from objectionable but not harmful concentrations. ACGIH initially declined to define what its MACs were or to state whether they were limits not to be exceeded for 30 minutes, 1 hour, 8 hours, or longer.[4] For example, the MAC for chlorine was 5 ppm, which compared unfavorably with 4 ppm recommended by Henderson and Haggard[7] for 30-minute to 1-hour exposure periods; the 100 ppm MAC for carbon monoxide had been recommended by Henderson and Haggard for "several hours."

The 1947 list included 155 MACs. The chairman of the Committee on Threshold Limits, chemist L.T. Fairhall, expressed great confidence that the industrial hygienist was well placed to set health standards: "He is in contact with the individuals exposed and therefore soon learns whether the concentrations measured are causing any injury or complaint."[8] Up to this point, the five-man TLV committee still did not include one physician member.

In 1948, the MACs were renamed Threshold Limit Values. Despite the very different emphasis of this new nomenclature, the term TLV was not defined at the time of its introduction. The TLV committee noted that, "People vary greatly in their response to drugs and toxic substances." To this irremovable obstacle was added the acknowledged difficulty of trying to protect the worker while not imposing an "impossible burden on the manufacturer."[9]

In 1953, a preface was added, wherein the TLVs were described as "maximum average concentrations of contaminants to which workers may be exposed for an 8-hour working day (day after day) without injury to health."[10] Both the term used and its definition now promoted the TLVs as health-hazard thresholds for exposure to chemical and mineral substances, many of which were known to have serious, irreversible effects. The TLV committee now sought to offer a guarantee where Cook had explicitly said no guarantee was warranted. Most of the exposure limits on the list were the same values recommended in 1945 by Cook.[5] Despite the accompanying preface assertion that the TLVs were based on the best available information, there is no evidence that any review was done or new rationale offered to justify this sweeping disregard for the uncertainties underlying the TLVs.

The TLV committee chairman, industrial hygienist Alan Coleman, used more qualified language at the ACGIH meeting of 1954. He described the TLV as the concentration of a substance that "should cause no significant injury to the health of the large majority of persons" exposed daily.[11] The committee itself tempered its description in 1958: "[TLVs] represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect."[12]

Precisely because the TLV committee had taken a very difficult technical, political, and economic problem off the shoulders of state and local agencies, the TLVs were uncritically welcomed as uniform limits across the country. State and local agencies reduced their proportional employment of medical personnel and all but stopped issuing MACs on their own in the early 1950s.[13]

As it became clear that the state and local officials on the TLV committee were not issuing terribly burdensome limits for their local plants to meet, industry adjusted to this state of affairs without protest.

Meanwhile, the commercialization of new chemicals by industry far outstripped the capabilities of a volunteer committee to keep up. As new chemicals were widely introduced by the hundreds, the TLV committee struggled to add to its list less than 10 per year. Revisions of the TLVs, once listed, were fewer still, and it is evident that, after the first few years, the primary focus of the TLV committee was on expanding the list. Until 1962, this responsibility was handled by a committee of only four to eight people.

Many pitfalls of reliance on the TLVs had been anticipated from the time they were launched. W.P. Yant, first President of the American Industrial Hygiene Association, told members of the Industrial Hygiene Foundation that monitored average concentrations of air contaminants would not take account of several factors: peak exposures that could be very harmful, synergistic effects of multiple exposures, and the great increases in respiration rates arising from high levels of physical activity and work in hot environments.[14]

Yant also observed that lists of limits gain "prestige and authority through mere copying and repetition." He warned that mandatory requirements, which the TLVs were clearly destined to become, were usually minimum requirements, "representative of the worst permissible conditions." Such requirements, he said, could "stifle progress and freeze endeavor at the established minimum."[14] Yant's apprehensions proved well founded, as the TLV committee fell further behind in its efforts to keep pace with innovation. As the list of TLVs grew longer, more of the limits would tend to be based on reviews and information not updated for years.

British authorities criticized American practice for its heavy emphasis on measurement and reliance on reference limits. Noting that TLVs were almost always amended in the downward direction, "reducing the concentration formerly accepted as safe," United Kingdom factory inspector Bryan Harvey[15] preferred to call them "theoretically allowable maximum concentrations." Medical Inspector of Factories A.I.G. McLaughlin[16] derided the very idea of threshold limits as reflecting an assumption that "man is a standardised machine." The indoctrination of American industry and professionals with a preoccupation with taking samples and designing controls to meet reference exposure limits was in turn seen as the basis of another serious shortcoming: a peculiarly American tendency to consider substitution of dangerous materials as the last line of approach to health hazard control instead of the first.[16]

Industrial physicians in the United States were also dismayed at the growing acceptance of the TLVs, issued by a committee dominated by industrial hygiene engineers, chemists, and toxicologists. Initially, not a single physician was on the TLV committee; at most, physicians comprised only a small minority of the committee members. Never had the chairman of the TLV committee been a physician (this would not happen until 1985). At a 1952 meeting of leaders of the Industrial Medical Association, clinician Frank Princi said: "[M]ost of the [TLVs] are picked out of a hat, 95 percent are on the basis of animal experiments only, incorporated into state codes, and we are faced with ridiculous standards. Is there a doctor among the group that puts out these standards?"[17]

After all, what industrial hygienist sees the workers' health status the way the plant doctor does? What toxicologist is intimate enough with his rats to learn whether they feel pain or are suffering from reduced mental acuity? What did these government engineers, chemists, and toxicologists read or know of the medical literature, even just what is imparted in *JAMA* or the *Lancet*? It would have been malpractice if a council of doctors had prescribed such a list of exposures as approved for consumption by all the workers in the country.

ACGIH nonetheless went on to make the essentially medical evaluations on which new TLVs were based. The industrial physicians' group did not undertake the task of either publicly criticizing the TLVs or proposing its own workplace exposure limits. Only occasionally did individual industrial physicians pass on information to the TLV committee through the 1950s and 1960s.

Led by toxicologist Herbert Stokinger of the Public Health Service, the TLV committee expanded its membership and output in the early 1960s. ACGIH also published for the first time a volume entitled *Documentation of Threshold Limit Values*,[18] where the basis for about 250 TLVs was stated, with references, in the space of 112 pages.

Stokinger approached the Manufacturing Chemists' Association (now Chemical Manufacturers Association) for increased input from member firms starting in 1964. This met with limited response. The companies had no statutory duty to disclose new knowledge about chemicals used in general industry before the passage of the Toxic Substances Control Act in 1976. In the years before the Occupational Safety and Health Act (1970), regulation of workplace health hazards by the states was minimal, and manufacturers were about the only parties capable of knowing what the exposures were in their plants and whether there were adverse medical consequences. ACGIH's annually republished claim that the TLVs were based on the "best available" information thus sidestepped the reality that the TLV committee was left begging for data. A committee of the Industrial Medical Association acknowledged that unpublished data was in the possession of companies that could contribute to the establishment of "realistic TLVs."[19]

Corporate Influence on the TLVs

The recommendations of corporate officials and consultants were given great weight by TLV Chairman Stokinger. Massachusetts health official and longtime TLV committee member Hervey Elkins complained in a letter to fellow committee member William Frederick in 1966: "It annoys me no end, that any action that could possibly adversely affect a certain chemical company is

immediately objected to by a consultant to said company, and the objection is always accepted by the Chairman." The companies themselves, individually and under the auspices of such groups as the Industrial Hygiene Foundation, also had periodic meetings with members of the TLV committee and communicated their concerns both orally and in writing.

Just as some corporate communications to the TLV committee delayed or prevented action, other unpublished information was accepted as the basis for setting TLVs. The growing reliance on unpublished corporate communications, some of which were phone calls and most of which do not survive in written form today, is reflected in the *Documentation*.[2,20]

By 1986, unpublished corporate communications were important in supporting TLVs for 104 substances out of less than 600 listed in the *Documentation* (5th ed). For twenty-five of these key communications from corporate employees (out of 104), the corporate affiliations of the correspondents were not stated in the *Documentation*. Of the 104, the 37 cases of unpublished "industrial experience" reflect a pattern of uncritical acceptance of assertions from financially interested parties, based on scant data of poor quality. These assertions, absent explanations of materials and methods used, would never be accepted for publication in medical or other scientific literature. Moreover, they include many evaluations of a medical nature that were reported by industrial hygienists and other nonphysicians.[2,20]

Some had expected that the story of the TLVs would have ended with the adoption by OSHA of most of the 1968 TLVs as its first set of exposure limits. Congress established and funded NIOSH for purposes of conducting research and making recommendations to OSHA for health standards. But the TLV committee not only remained as active as ever after 1970, it even permitted full-time employees of chemical companies to become centrally involved in the development of the TLVs.

The participation of industry representatives on the TLV committee began with the addition of Dow toxicologists V.K. Rowe and Theodore Torkelson as "liason members" in 1970. These men were assigned responsibility for developing "documentations" on which new or revised TLVs would be based. The chemicals assigned to them initially were *all* Dow products (2,4,5-T, vinyl chloride, ethylene glycol, methyl bromide, and propylene glycol methyl ether). No objection was evidently made over the fact that many of the chemicals assigned to these employees of Dow and industrial hygienist James Morgan of DuPont (starting in 1972) were products marketed by the firms that employed them. The chemical assignments of these individuals were regularly recorded in the minutes of the TLV committee, although publicly it was stated that these "consultants" did not actually vote on adoption of TLVs.[21]

Perhaps because the corporate representatives were paid for their work on the TLV committee and provided with the ample resources and support of their employers, they were among the most active contributors to the TLVs. TLV committee minutes and other records show that Torkelson, individually and as chairman of key subcommittees, was assigned at least 30 of Dow's halogenated solvents, pesticides, and other industrial chemical products between 1970 and 1988 (since 1977, including perchloroethylene, trichloroethylene, 1,3-dichloropropene, divinylbenzenes, carbon tetrachloride, chlorine, propylene dichloride, ethylene diamine, methylene chloride, and acrylamide). Similarly, Morgan and his successor Gerald Kennedy of DuPont obtained the task of documenting many DuPont pesticides, chlorofluorocarbons, and other products (since 1977, including hydrogen cyanide, acrylonitrile, hexafluoroacetone, *p*-nitrochlorobenzene, trichlorotrifluoroethane, and dimethyformamide).[2]

Dr Georg Kimmerle has been listed in TLV booklets since 1981 simply as "German MAK Commission liason." He is a physician employed by the German chemical producer, Bayer, whose US subsidiary Mobay makes pesticides, isocyanates, and other chemicals. Shortly after joining the TLV committee, Kimmerle was primarily responsible for the decision to double the TLV for one Mobay pesticide (fenthion). He then drafted documentations for new TLVs for three other pesticides made in the US solely by Mobay (fenamiphos, metribuzin, and sulprofos). The other five chemicals recorded as assigned to Kimmerle (amitrole, thiram, xylidine, perchloromethyl mercaptan, and phenylene diamine) are produced by Bayer in West Germany. Kimmerle's handling of TLV committee work, unlike his duties with the German MAK [Maximum Workplace Concentration] Commission, were not required to be handled as a confidential, separate matter from his job at Bayer.

In all, corporate representatives were given primary responsibility for developing TLVs on more than 100 substances between 1970 and 1988, including at least 36 classified as carcinogens by official bodies. (Complete information on the chemical assignments is not even available from ACGIH.) There is no question that the economic impact of the TLVs on the chemical industry generally and on Dow, DuPont, and Bayer in particular, has been enormous. There seems no reason to doubt that chemical industry employees working on the TLV committee were implementing corporate policies of their firms. This view is consistent with Dow's recommendations to OSHA to adopt the TLVs instead of stricter NIOSH recommendations for seven Dow products, at least six of which had been handled by Torkelson on the TLV committee.[5]

Industry employees aside, practically nothing has been disclosed about the documentations assigned to committee members who had part-time consulting relationships with chemical producers. ACGIH has never required members of the TLV committee who do corporate consulting to either disclose these business connections or excuse themselves from development of TLVs on chemicals of importance to their clients. The TLV booklets have listed such persons only by affiliations they had with universities.

TLV committee minutes fleetingly mention meetings of the committee and its subcommittees with dozens of representatives of companies and trade associations. Nothing in writing relating to most, if not all, of these meetings is in the chemical files at ACGIH. Robert Spirtas, a member of the committee since 1981, wrote

of his impression of these encounters in a 1987 letter to TLV Chairman E. Mastromatteo: "[P]resentations by outside groups have, in my experience, always been allied with the management point of view. The majority of the presentations have been personal interpretations of the published literature. In my opinion, these presentations have been attempts to lobby the committee, with very little new data." This state of affairs led ACGIH Secretary-Treasurer Philip Bierbaum to urge, in a 1988 memorandum to the ACGIH Board, that no presentations by outside groups to committee members be allowed unless they are publicly announced and open to the public.

As of late 1988, the TLV committee would not even permit interested scientists to attend its meetings as observers. Only after OSHA had proposed to adopt hundreds of the TLVs in 1988 did ACGIH allow researchers to examine relevant ACGIH files (eg, recent TLV committee minutes).

The TLV committee has stoutly refused to publicly disclose members' paid sources of corporate consulting work. This might be extensive, as the present 22-member committee includes only six full-time government employees. The TLV committee has also resisted recommendations by its only labor representative and members of the ACGIH Board that industry employee members of the committee be precluded from drafting TLV documentations.

Although some reforms may finally be instituted in 1989, the many TLVs just adopted as OSHA standards are a legacy of an earlier era. Former NIOSH director John Finklea has remarked that the TLVs were "the result of a process that would currently be viewed as seriously flawed."[23]

Medical Inadequacy of the TLVs

The information base upon which the TLVs were developed was severely limited. For standards intended for a potential lifetime of exposure, chronic data are critical. However, for at least 90% of the TLV chemicals, sufficient data on long-term effects are unavailable, either from animal studies or studies of industrial workers with long-term exposure to known concentrations of the substances.

The very concept of a *daily average* exposure limit has been attacked as being inconsistent with what is known about toxicity, and evidently originating more from economic than scientific considerations.[23,24] Atherley's analysis concluded that the time-weighted average index "cannot be viewed as a scientific idea underpinned by either empirical evidence or plausible scientific hypothesis."[24] In view of this, the TLV committee's deletion in 1984 to 1986 of most of the short-term exposure limits was particularly harmful. ("STELs" for nearly 200 substances were dropped prior to OSHA's adoption of the TLVs.)

The TLV committee's heavy reliance on animal data (mostly acute and subacute toxicity studies) raises a number of unavoidable problems. One cannot elicit a medical history from an animal, and symptom data can be missed that could be severe enough in a human to interfere with productive function at work. In addition, the animal data gathered were very limited in scope as well as duration. Typically, no study was done of neurologic and neurobehavioral function beyond meager observations of animal behavior such as lethargy, fighting, etc. Thus, animal studies are unable to evaluate cognitive changes such as we now know can occur from exposure to many solvents and other chemicals.

Animal studies also have not included an evaluation for pulmonary function, despite the fact that many chemicals are irritants and/or chemical allergens, and repeated exposure to such agents could well reduce pulmonary function, nor was immunologic function evaluated for the vast majority of chemicals. Endocrine function was at best evaluated by an occasional blood glucose test, typically ignoring the potential for endocrine alterations in other organs. Animal studies often did include information on the appearance of many but not all organs at death by gross and light microscopic analysis. However useful structural information is, though, it is not a substitute for evaluating the function of organs.

Another shortcoming of the TLVs was the frequent failure to use information that was available. For example, no systematic literature search was done in preparing documentations on hundreds of chemicals. References used are often very dated, and more recent information is often missing. Information in the international medical literature does not appear to have been reviewed for the vast majority of chemicals. In fact, little reference is made to the basic US medical literature in the TLV documentation. Thus, contrary to the TLV booklet's persistent claim, the TLVs are not "based on the best available information."

The medical inadequacy of the TLVs is evident from a review of four occupational medicine journals since the start of 1987 (Table). From this limited sampling, it would appear that further evidence of harm at and below the TLVs appears in the literature almost monthly. This review did not include industrial hygiene, toxicology, and general medical journals. Other scientists are encouraged to review these for sub-TLV effects.

The development of TLVs and evaluation of relevant scientific literature have mainly been done by industrial hygienists and other nonphysicians. Although industrial hygienists are vital to developing control strategies for chemicals, most lack training in the biomedical sciences to interpret health effects data reliably and independently. Yet this is exactly what they had to do as volunteers on the TLV committee. Copies of reviewed articles were generally not provided to the entire committee: the sole responsibility for accurate interpretation of the articles typically fell to the committee member assigned each chemical. The result was a list of exposure limits produced almost entirely by hygienists, chemists, and toxicologists, most of whom lacked the necessary training, let alone clinical experience with humans.

Toxic Torts and the TLVs

It is ironic that doctors may now be asked to confer legitimacy-in-retrospect on the TLVs.

TABLE
Health Effects at and below the TLVs*

Substance	Effects Reported/Exposure	TLV	Ref
Acetone	Neurobehavioral performance effects after 4 h at 250 ppm	750 ppm	25
Benzene	Bone marrow changes, leukemia, at or below 1 ppm	10 ppm	26, 27
Beryllium	Respiratory sensitization below 2 $\mu g/m^3$	2 $\mu g/m^3$	28
Cadmium	Changes in renal function at 0.007–0.039 mg/m^3	0.05 mg/m^3	29
	Changes in renal function at 0.003 mg/m^3		30
	Changes in renal function at cumulative exposures equal to 20–22 yr at 0.05 mg/m^3		31
2-Ethoxyethanol and 2-Methoxyethanol	Lowered sperm counts and reduced red and white (granulocytes) blood cell counts at combined exposure to 9.9 mg/m^3 2-EE and 2.6 mg/m^3 2-ME	19 mg/m^3 (2-EE) 16 mg/m^3 (2-ME)	32, 33
Ethylene diamine	Respiratory sensitization at 1–10 ppm	10 ppm	34
Ethylene oxide	Increase in sister chromatid exchanges in lymphocytes at 0.35 ppm	1 ppm	35
Formaldehyde	Respiratory cancer, allowing for 10 yr latency, 0.1–1 ppm	1 ppm (1.5 mg/m^3)	36
	Pathologic changes in nasal mucosa at 0.1–1.1 mg/m^3		37
Glutaraldehyde	Increased respiratory symptoms and headache below 0.04 mg/m^3	0.7 mg/m^3	38
Lead (naphthenate)	Blood lead concentrations over 60 $\mu g/dL$; mean ZPP† of 265 $\mu g/dL$, at 0.96 $\mu g/m^3$	150 $\mu g/m^3$	39
Manganese dust (inorganic)	Fatigue, trembling, tinnitus, irritability at 1 mg/m^3	5 mg/m^3	40
Mercury vapor	EEG changes at 25 $\mu g/m^3$	50 $\mu g/m^3$	41
Methyl chloroform (1,1,1-trichloroethane)	Behavioral performance deficits with 3 h at 175 ppm and 350 ppm	350 ppm	42
	Decreased DNA concentrations in the brains of gerbils after continuous exposure to 70 ppm for 3 mos		43
Oil mist, mineral	Cross-shift decline in 1-sec FEV at 0.2 mg/m^3	5 mg/m^3	44
Silica	Lung scarring in bricklayers exposed to dust (2.1% free silica) 0.5–2.0 mg/m^3	2 mg/m^3	45
Styrene	Occupational asthma at 62.7 mg/m^3	215 mg/m^3	46
Sulfur dioxide	Bronchoconstriction among asthmatics after 3–5 min at 0.5 ppm	5 ppm‡	47
Sulfuric acid mist	Laryngeal cancer at 0.2 mg/m^3	1 mg/m^3	48
Toluene	Neurobehavioral effects in rats exposed 20 min to 125 ppm	100 ppm; 150 ppm‡	49
	Impairment in human performance after 6–6.5 h at 100 ppm		50
	Increased fatigue, short-term memory changes, reduced concentration at 11.5 ppm and 41.8 ppm		51
	Neurobehavioral changes (visual vigilance) after 4 h at 100 ppm		52
Toluene diisocyanate	Asthma developed within 1 yr in 9 workers, at 0.002 ppm	0.005 ppm	53
Triethylamine	Blue haze (foggy vision), corneal edema, eye irritation at 18 mg/m^3	40 mg/m^3	54
Zinc oxide fume	Lung function changes in guinea pigs exposed 3 h on 6 consecutive days to 5 mg/m^3	5 mg/m^3	55

* This table was compiled from review of the contents of 33 months (January 1987 to September 1989) of 4 journals: *Journal of Occupational Medicine, American Journal of Industrial Medicine, Scandinavian Journal of Work Environment and Health,* and *British Journal of Industrial Medicine.*

† ZPP, Zinc protoporphyrin.

‡ Short-term exposure limit.

An increasing number of persons are appearing before the courts with conditions medically attributed to chemical exposures. The courts are interested in knowing the state of medical knowledge when these people's exposures to chemical products and wastes occurred. A rationale often used to parry charges of negligence and assessment of liability is known as the "TLV defense." This amounts to: We thought that the exposures here would be below the TLVs, and we also thought the TLVs were *safe*, so what happened is not our fault.

But although those in other professions may say, "we thought the TLVs were safe and sound," it is the opinion of the medical profession (ie, *not* the medical opinion of the industrial hygiene profession) that is most often sought to test such claims today. Consequently, doctors may be asked to appraise the TLV for one or more chemicals, the TLVs in general, and possibly even the TLV committee, too.

It is hard enough to look back on the withholding of medical expertise and medical knowledge that left so much to the TLV committee for so long. But it is professionally humiliating when doctors are asked to

dignify the medical stature and safety of guidelines that were never really a product of industrial medicine. Lawyers defending chemical liability cases may find that the TLV defense is easier for them to raise in an opening argument than it is to support with credible medical testimony.

Alternatives to the TLVs

There is an urgent need to compile the information that is available but has been ignored in the TLV development process. For example, the New Jersey Department of Health recently utilized chronic health effects data from the Environmental Protection Agency known as the Integrated Risk Information System (IRIS) data base. Workday air concentrations were calculated for noncarcinogens and carcinogens, reportedly corresponding to no risk of chronic health effects or (for carcinogens) a one-in-a-million lifetime risk of cancer. The resulting exposure limits, even for noncarcinogens, were markedly lower than the TLVs, not infrequently by 3 or more orders of magnitude (R.T. Zagraniski, 1988 testimony of the NJ Department of Health at informal hearings on OSHA's proposal to update permissible exposure limits for toxic substances). IRIS data exist on many more chemicals and could be used to supplement our understanding.

Further use needs to be made of the international literature, particularly the industrialized countries. Much information on chemical effects is available in English from the Scandanavian countries. In addition, the Soviet Union has exposure limits on more than 1400 chemicals. These limits were reportedly developed to prevent physiologic alteration, not just clinical disease. Critics of the Soviet exposure limits have sometimes raised a separate presumption that the Soviets in practice follow less stringent limits. But the medical issue is not the state of Soviet engineering practice. Physicians need to have as many data as possible on long-term effects of chemicals to understand what levels could cause harm. Philosophic and political differences have not prevented scientific cooperation in other health-related areas, and international relations now offer hope for expanded USA-USSR contact on matters of importance in industrial medicine.

Exposed workers themselves are a potentially vast source of data. The US experience in occupational health is that medical and environmental monitoring that is not legally required is often not conducted. We are thus missing an enormous amount of potentially useful health-effects data on early functional changes in workers. OSHA's expected medical and air monitoring standards may soon help stimulate industry to generate this dose-response data. However, doctors should not wait for legally mandated monitoring to begin to conduct medical evaluations for potential health effects below the TLVs.

Industry needs to provide adequate resources to allow physicians to visit workplace areas regularly, to monitor all exposed workers medically, and to update their knowledge about toxicologic effects regularly. Doctors need adequate computer and other literature access for all substances used, released, and produced in the workplace.

Doctors also need to be provided with sufficient time to do a thorough "review of systems." Experience has shown that a great deal of knowledge on chemical health hazards is not in the books, and clusters of adverse effects can be clinically identified sometimes before one of our busy medical colleagues has gotten the problem into print. Clinical cases are frequently the first evidence of occupational disease phenomena, and the patients themselves are an indispensable source of information. With the deficiency of published literature on the chronic effects of most chemicals in use, the need for doctors to take the time to listen to patients is underscored. Occupational medicine is a demanding field, and a full evaluation of a single person with illness potentially related to chemical exposure can take several hours.

Much better use can be made of industrial nurses, especially in small plants, where it is nurses who are the first to see problems and hear workers' health complaints. Industrial nurses and physician assistants, working with physicians, are capable of playing a more sophisticated role in occupational disease assessment than they have been offered in the past. To be most effective, however, these professionals will need to develop additional skills in occupational disease recognition. For example, they will require further training regarding the toxic effects of chemicals, taking medical and occupational exposure histories, and conducting physical examinations. Their preliminary assessments can then be useful in a team approach, working with the physician.

Industrial hygienists can expand their reconnaisance capability far beyond the generation of numbers on exposure levels. Industrial hygienists, as well as nurses and worker health and safety representatives, need specific training on the toxic effects of chemicals on the body and on how to interview workers for health effects in the intervals between medical monitoring. These health effects interviews, although not a substitute for medical evaluation, can nonetheless assist in the early detection of effects from irritants, sensitizers, and nervous system toxins.

The New Jersey Department of Health is developing a Guide to Workplace Inspection that could facilitate this process. That agency's Hazardous Substance Fact Sheets, now available for about 1000 chemicals, include target-organ toxicity information that can help to focus workplace health-effects interviews.

Because the TLVs lack scientific validity, the role of air monitoring should be a different one. A specific air concentration should never be relied upon as indicating safety. Rather, air monitoring should be used to assess the effectiveness of controls. In addition, because at this time there are no known safe exposure levels, physicians as part of the management team should insist on controls that reduce all exposures to the *maximum extent technically feasible.* To advocate a lesser degree of protection would violate the dictum to "do no harm."

Similarly, workplace inspectors may be better off not using the TLV booklet as now written, because of the misleading assertions stated in its preface. These inaccurate claims ("based on the best available information"; "nearly all workers may be repeatedly exposed day after day without adverse effect") provide a false sense of security to nonmedical personnel. Unless such claims are deleted from TLV booklets, industrial physicians would be prudent to instead obtain or encourage development of other sources of information.

Despite laws and regulations giving workers the "right to know," most hazard communication training programs are general and prepackaged, and do not address the specific toxic effects of the substances used in the workplace. If workers are not properly informed about such dangers, they will not be prepared to alert the medical department when early symptoms develop. Industrial physicians should ensure that all hazard communication training fulfills the legal requirement to include hazards of the specific chemicals used. The New Jersey Hazardous Substance Factsheets are particularly useful in this regard, as they discuss early symptoms and effects in lay English that the worker and supervisor can understand.

Of course, it is primarily industry's responsibility to provide and encourage adequate, coordinated occupational health programs. Just as management provides engineers with flow charts to monitor the industrial process, doctors need to be informed about the materials used and created in every department. It is management's responsibility to encourage cooperation between health professionals, to provide the resources and a framework for monitoring exposures and health of workers, and to grant industrial physicians the authority to fulfill their professional obligations to the people at work. Industrial physicians will not be able to do their job well unless and until industry respects the importance of industrial medicine and makes the commitment to prevent, not ignore, occupational diseases.

The judgment of how much exposure can cause disease in humans is ultimately a medical decision. Industrial physicians, as a profession and through the American College of Occupational Medicine, have the obligation to step forward and assert their responsibilities in assessing health hazards in industry. In fact, to not do so could be viewed as malpractice by some. Workers have been ill served by having critical decisions about their health delegated to engineers carrying TLV booklets.

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Leadership Style

Many modern managers are flexible about technology and organizational structure, but . . . they lack the quality of caring about people and their development. Only their economic values are articulated. For most managers, organizational development is evaluated solely in terms of productivity and profit. Paradoxically, this total concern with profit is what causes distrust and limits efficiency. People only trust leaders who articulate a moral code, who care about people and are competent in the exercise of power.

Here one may question whether these leaders are not limited by their unwillingness to sacrifice people for power, whether the same qualities that gain trust do not limit success in reaching the highest positions. . . .

There are two answers. One is that leadership is needed at different levels. All leaders do not need to reach the top. The second is that the new-style leaders must find allies and build coalitions. Given that they are less charismatic and narcissistic than past leaders and that people resent overbearing leadership, it is logical and necessary for new leaders to share the functions of leadership and thus increase their power, as they also increase the power of others who share their goals.

—From *The Leader* by Michael Maccoby, Simon and Schuster, New York, 1981, pp 222–223.

ANNEXE N°5

Article de:

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But They Are Not Thresholds: A Critical Analysis of the Documentation of Threshold Limit Values

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Threshold Limit Values (TLVs) represent conditions under which the TLV Committee of the American Conference of Governmental Industrial Hygienists (ACGIH) believes that nearly all workers may be repeatedly exposed without adverse effect. A detailed research was made of the references in the 1976 *Documentation* to data on "industrial experience" and "experimental human studies." The references, sorted for those including both the incidence of adverse effects and the corresponding exposure, yielded 158 paired sets of data. Upon analysis it was found that, where the exposure was at or below the TLV, only a minority of studies showed no adverse effects (11 instances) and the remainder indicated that up to 100% of those exposed had been affected (8 instances of 100%). Although, the TLVs were poorly correlated with the incidence of adverse effects, a surprisingly strong correlation was found between the TLVs and the exposures reported in the corresponding studies cited in the *Documentation*. Upon repeating the search of references to human experience, at or below the TLVs, listed in the more recent, 1986 edition of the *Documentation*, a very similar picture has emerged from the 72 sets of clear data which were found. Again, only a minority of studies showed no adverse effects and TLVs were poorly correlated with the incidence of adverse effect and well correlated with the measured exposure. Finally, a careful analysis revealed that authors' conclusions in the references (cited in the 1976 *Documentation*) regarding exposure-response relationships at or below the TLVs were generally found to be at odds with the conclusions of the TLV Committee. These findings suggest that those TLVs which are justified on the basis of "industrial experience" are not based purely upon health considerations. Rather, those TLVs appear to reflect the levels of exposure which were perceived at the time to be achievable in industry. Thus, ACGIH TLVs may represent guides of levels which have been achieved, but they are certainly not thresholds.

Key words: TLV, industrial experience, air contaminants, workplace exposures, irritation, health impairment, narcosis

INTRODUCTION

The list of Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH) has had a profound influence upon the

state of occupational hygiene in the U.S. and, indeed, throughout the world. Although intended as unofficial guides of acceptable exposure to chemical and physical agents in the workplace, these limits are widely applied as official limits by many states and countries. In point of fact, in the U.S., the Occupational Safety and Health Administration (OSHA) has twice adopted essentially the entire list of TLVs for Chemical Substances as enforceable limits: first the 1968 list under a one-time provision made for incorporating existing federal and national consensus standards (Sect. 6(a), OSH Act) [OSH Act, 1970], and recently the 1987/88 list in an unprecedented action [OSHA, 1989]. ACGIH TLVs formed the basis of the West German list of maximum workplace concentrations (MAKs) [Henschler, 1984], the British list of occupational exposure standards (OESs) [Health and Safety Executive, 1989], the Japanese list of maximum permissible exposure limits (PELs) [Toyama, 1985], the Swedish list of hygienic limit values (HLVs) [Nordberg et al., 1988], and many other lists.

The ACGIH defines TLVs for chemical substances as follows [ACGIH, 1988]: "Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect." This statement clearly implies that the TLVs are based primarily upon health considerations since "nearly all" workers exposed at the level of the TLV over a working lifetime would be protected. The current Chair of the Chemical Substances TLV Committee confirmed this when he stated that [Mastromatteo, 1988], "TLVs are health-based recommendations derived from assessment of the available published scientific information from studies in exposed humans and from studies in experimental animals. For each TLV, there has to be a published documentation supporting the committee recommendation."

Given these statements, it is not surprising that the various practitioners of occupational health generally believe that the TLVs afford substantial protection to the working population. Yet recently, both the process by which the TLVs have been established [Castleman and Ziem, 1988] and the data supporting the limits [Henschler, 1984; Zielhuis, 1988] have been called into question. Furthermore, each year, some of the values are changed, and in the majority of instances they are reduced, sometimes to one-half or one-tenth of their previous value. A past Chairman and TLV Committee member, in a robust defense of TLVs, remarked recently that ". . . throughout all the more than 40 years existence of threshold limit values, there has been no instance of serious health effects, provided exposures were kept at or below the TLVs." [Stokinger, 1988] Why then, it may be asked, have TLVs for such chemicals as benzene, vinyl chloride, and methyl chloride come down from early values of 100 ppm, 500 ppm and 20,000 ppm [Cook 1945] to current levels of 10 ppm, 5 ppm and 1000 ppm [ACGIH, 1988], respectively? Since most values are eventually reduced, one cannot help but wonder if the TLVs, indeed, protected nearly all workers during the transition period.

Resolution of this apparent contradiction in the meaning of TLVs can perhaps be resolved by examining more closely the key phrase, "nearly all workers." Here again the current Chairman of the Committee offered the following clarification [Mastromatteo, 1988]: "TLVs are based on the belief in a threshold or thresholds below which no adverse health effects would occur in workers . . . although . . . some workers with individual susceptibility may not be protected by the recommended TLVs." This notion that the TLVs protect all workers save, perhaps, a sensitive

subpopulation of persons especially susceptible on grounds of abnormal heredity, sensitization, disease, habits, sex, or reproductive status [de Silva, 1986], is reaffirmed annually by the ACGIH as follows [ACGIH, 1988]:

> Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

This statement indicates that a "small percentage" would experience discomfort, as perhaps would occur with a respiratory irritant, and that "a smaller percentage" might contract a chronic disease at or below the level of the TLV. To find further enlightenment as to what is meant by "small percentage" and "smaller percentage," it is necessary to analyze the documentation supporting the TLVs in detail and the references given therein. A separate companion piece to the TLV booklet is issued by the ACGIH under the title, *Documentation of the Threshold Limit Values and Biological Exposure Indices* [ACGIH, 1986]. In the TLV booklet the reader is urged to consult this *Documentation* when TLVs are being used [ACGIH, 1988].

When evaluating the evidence compiled in the *Documentation* it becomes clear that the TLV Committee has traditionally placed greatest importance upon studies involving human experience. This was stated unequivocally by a former Chairman of the Committee, H. Stokinger, about 20 years ago (see Stokinger, 1984] and supported more recently by Smyth [1984], who indicated that evidence based upon animal experiments must only serve until it can be replaced with documented human experience. Some 10 years ago one of us studied the references to human experience listed under each substance in the *1976 Documentation of the TLVs for Chemical Substances* [Roach, 1982]. We have recently analyzed the 1986 *Documentation* [ACGIH, 1986] to investigate whether the situation has changed since 1976, and in what follows we will summarize our findings from both investigations.

1976 DOCUMENTATION

In the 1976 list there were TLVs for 488 chemicals of which 225 TLVs were based at least in part on human experience. Copies of all the original published references to human experience were sought. The major references were the ones most easily located and contained the most useful information. Older and more abstruse references were progressively more difficult to obtain. The search was discontinued when the arbitrary target of 80% of the published references to human experience had been acquired.

References where the atmospheric exposure of the persons was doubtful or was not measured were put to one side. References in which there were doubts about the incidence of the effect the TLV was designed to prevent were also put aside as were those where the number of exposed persons was unclear. This left references to 70 substances which included data for 158 different groups of employees varying in size from one to 1,802 employees (median 10–11 employees). Information derived from these references is comprehensively compiled in Appendices A–C according to the measured exposure and the nature of the effect which served as the basis for the TLV

(impairment of health, irritation, or narcosis). The key references from which the data were extracted are also indicated.

The pertinent results are summarized in Table I where the incidence of adverse effects is given for persons exposed at or below the TLV. Some studies did show every employee to be free of adverse effects when exposed at or below the TLV (11 instances). However, scrutiny of Table I shows that most studies demonstrated an incidence of adverse effects which was substantially above zero at the TLV and which was even 100% in some cases (8 instances). This was particularly true regarding exposure to irritants, where 93 of 174 individuals exposed at or below the TLV experienced effects. At exposure levels above the TLVs, the incidence of adverse effects tended to be higher when the basis for the TLV was irritation or narcosis than when the basis was impairment of health. When all studies in Table I are combined, 17% of employees exposed to a concentration at or below the level of the 1976 TLV were adversely affected.

When exposure is expressed as a multiple of the TLV and related to the incidence of adverse effects, as in Figure 1, it is apparent that there was no correlation between the two variables ($r^2 = 0.005$: $p = 0.39$). On the other hand, the correlation between the TLV adopted for a substance and the concentrations reported in the corresponding studies listed in the *Documentation* was highly significant (Fig. 2: $r^2 = 0.26$: $p < 0.001$). The implications of these observations will be discussed later.

1986 DOCUMENTATION

It is well known that over the years TLVs tend to have been lowered, in stages, sometimes by large factors. On the other hand, TLVs have been developed for substances new to the list each year. Consequently, the overall picture may or may not be changing. In order to examine whether the situation has changed in 10 years the 1986 *Documentation* was analyzed. The labor of the exercise was reduced by limiting the analysis to those published references which, on reading the *Documentation*, appeared to contain data relating to atmospheric exposures at or below the 1986 TLV. The idea was that these particular references would be the ones to show that "nearly all" employees did not have adverse effects when exposed at these levels.

In the 1986 *Documentation* there were TLVs for 600 different chemicals of which 127 of the TLVs were based at least in part on human experience at or below the 1986 TLV. Published references to human experience for these chemicals were sought and assembled. As in the previous investigation, references were then put to one side where, on close examination, it was found that exposures were either not measured or were doubtful. References in which there were doubts about the incidence of the effect the TLV was designed to prevent were also put aside as were those where the number of exposed persons was unclear. This left references to 29 substances. Data were available for 72 different groups of individuals, exposed at or below the 1986 TLVs, varying in size from one to 1,182 people (median 9–10); a comprehensive listing of these data is provided in Appendices D and E that again includes the key references from which data were extracted.

Although the number of references investigated from the 1986 *Documentation* was smaller, the picture which emerged was substantially the same as for the 1976 *Documentation*. The incidence of adverse effects at the TLV again ranged from zero

TABLE I. Individuals Exposed at or Below 1976 TLVs

Effect	Chemical	Exposed	Affected	Exposure TLV	% affected
Impairment to health	Acetonitrile	3	1	1.00	33
	Asbestos	57	1	0.96[a]	2
	Asbestos	22	0	0.70	0
	Benzene	47	6	0.72	13
	Beryllium	372	93	> 1.00	25
	Carbon disulfide	16	16	1.00	100
	Carbon disulfide	100	39	< 0.53	39
	Carbon disulfide	100	53	0.73[a]	53
	Carbon tetrachloride	6	0	1.00	0
	Chlorine dioxide	12	7	< 1.00	58
	Chlorodiphenyl-42% cl	14	7	0.10	50
	Ethylene oxide	37	0	0.15[a]	0
	Fluoride	189	48	0.66[a]	25
	Lead	143	21	0.93	15
	Magnesium oxide fume	4	1	0.58	25
	Magnesium oxide fume	4	2	0.41	50
	Mercury	3	0	0.80	0
	Mercury	9	1	0.40	11
	Mica	109	1	0.10	92
	Mica	61	20	0.50	33
	2-Nitropropane	2	0	0.80[a]	0
	Sulfuric acid	15	0	0.43[a]	0
	Tetryl	1182	50	1.00	4
	Toluene	3	1	1.00	33
	Toluene	2	1	0.50	50
	Toulene 2,4 diisocyanate	12	0	1.00[a]	0
	Total:	2524	369		14.6
Irritation	Allyl alcohol	6	2	0.39	33
	Butyl alcohol	10	10	0.50	100
	Butyl alcohol	10	10	1.00	100
	Cyanogen	5	0	0.80	0
	Ethyl acetate	10	10	1.00	100
	Ethyl ether	10	10	0.75	100
	Propylene glycol monomethyl ether	1	0	0.47	0
	Propylene glycol monomethyl ether	6	4	0.95	67
	Selenium	62	9	0.15[a]	15
	Styrene monomer	6	3	0.99	50
	Styrene monomer	3	0	0.51	0
	Vanadium pentoxide	8	8	0.72	100
	Vanadium pentoxide	24	20	0.40[a]	83
	Vanadium pentoxide	5	5	0.40	100
	Vanadium pentoxide	2	2	0.20	100
	Vinyl chloride	6	0	0.30	0
	Total:	174	93		53.4
Narcosis	Perchloroethylene	8	2	0.96	25

[a]Exposure assigned at midpoint of range.

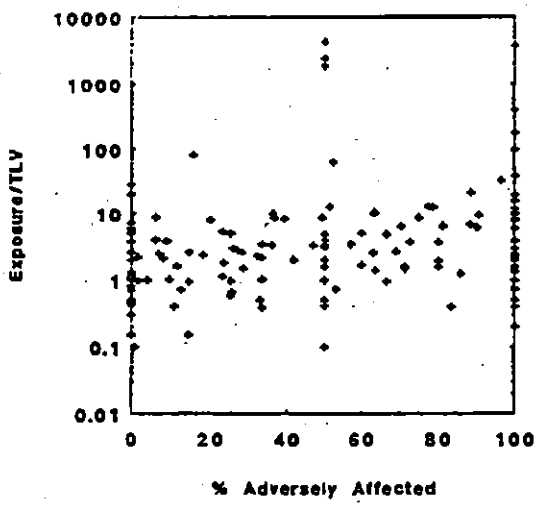

Fig. 1. Exposure expressed as a multiple of the TLV vs. the percent of individuals adversely affected. From references to human experience given in the 1976 *Documentation* of TLVs. (Data given in Appendices A–C.)

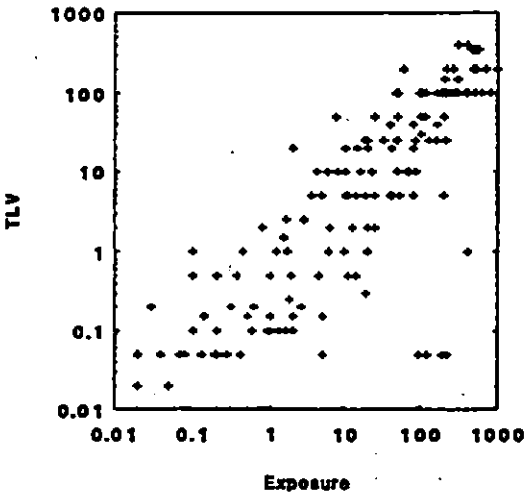

Fig. 2. TLV vs. the exposures reported in all studies for particular air contaminants. From references to human experience given in 1976 *Documentation* of TLVs. (Data given in Appendices A–C.)

(13 instances) to 100% (3 instances) and, as shown in Table II, it appeared that, overall, 14% of employees exposed at or below the 1986 TLV were adversely affected. Unlike the data gleaned from the 1976 *Documentation*, there was a weak but statistically significant linear correlation between exposure, expressed as a multiple of the TLV, and the percent of individuals affected (Fig. 3; $r^2 = 0.17$; $p = <0.001$).

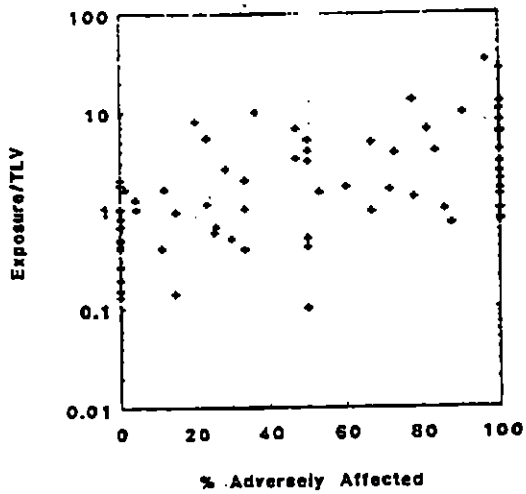

Fig. 3. Exposure expressed as a multiple of the TLV vs. the percent of individuals adversely affected. From references to human experience given in the 1986 *Documentation* of TLVs. (Data given in Appendices D, E.)

However, as shown in Figure 4, the correlation between the TLV adopted and the concentrations reported in the studies of particular contaminants was very strong ($r^2 = 0.61$; $p < 0.001$).

VALIDATION OF THE TLVS?

The above finding that, at or below the TLV, the incidence of adverse effects ranged from 0–100% and that overall one employee in 6 or 7 was adversely affected is clearly at odds with the official definition of TLVs. Indeed, we were so struck by this apparent contradiction arising from the very studies which were offered by the ACGIH as validation for its limits that we thought our results might have arisen from incorrect interpretations of the effects which the Committee intended to protect against with the TLVs. Thus, we returned to the 1976 *Documentation*, for which all references to human experience had been sought, and reexamined all of the papers which provided information about humans exposed *below* the 1976 TLV. Of these 40 papers, 70% were obtained which referred to 28 substances.

Upon reviewing each of the published articles, extracts were obtained which summarized the salient findings on these 28 substances. As far as possible the extracting was done without altering the words employed by the original authors. Statements about the effect(s) against which the 28 TLVs were meant to guard were also extracted from the 1976 *Documentation*. Both sets of statements are juxtaposed for quick reference in the following compilation. We added the words shown in italics to link pieces of information derived from portions of the papers.

TABLE II. Individuals Exposed at or Below 1986 TLVs

Effect	Chemical	Exposed	Affected	Exposure TLV	% affected
Impairment to health					
	Acetonitrile	3	1	1.00	33
	Carbon disulfide	100	39	< 1.00	39
	Chlorine dioxide	12	7	< 1.00	58
	Chlorodiphenyl-42% Cl	14	7	0.10	50
	Cyclonite	558	0	0.19	0
	Fluoride	189	48	0.66[a]	25
	Hexane	10	0	1.00	0
	Lead	143	21	0.93	15
	Magnesium oxide fume	4	1	0.58	25
	Magnesium oxide fume	4	2	0.41	50
	Mercury	18	0	0.26[a]	0
	Mercury	3	9	0.80	0
	Mercury	9	1	0.40	11
	Nitroglycerine	8	7	0.72	88
	Nitroglycerine	7	6	1.00	86
	Propylene glycol dinitrate	3	0	0.40[a]	0
	Quartz	784	233	0.50	30
	Sulfur dioxide	3	0	0.50	0
	Sulfur dioxide	3	0	0.15	0
	Sulfuric acid	15	0	0.43[a]	0
	Teryl	1,182	50	1.00	4
	Toluene	3	1	1.00	33
	Toluene	2	1	0.50	50
	Total:	3077	425		13.8
Irritation					
	Acetone	4	0	0.13	0
	Acetone	4	0	0.67	0
	Allyl alcohol	6	2	0.40	33
	Cyanogen	5	0	0.80	0
	Ethyl acetate	10	10	1.00	100
	Ethyl alcohol	3	3	0.79[a]	100
	Ethyl ether	10	10	0.75	100
	Propylene glycol monoethyl ether	6	4	0.95	67
	Selenium	62	9	0.14[a]	15
	1,1,2-Trichloro-1,2,2-trifluorethane	50	0	0.67	0
	Total:	161	38		23.6

[a]Exposure assigned at midpoint of range.

Acetaldeyde

Effect. "The TLV, 100 ppm, is recommended to prevent excessive eye irritation and potential injury to the respiratory tract." [ACGIH, 1976].

Validation? "Several *of 12 volunteers* objected . . . strenously even at 25 ppm . . . A majority . . . experienced . . . eye irritation at 50 ppm." [Silverman et al., 1946].

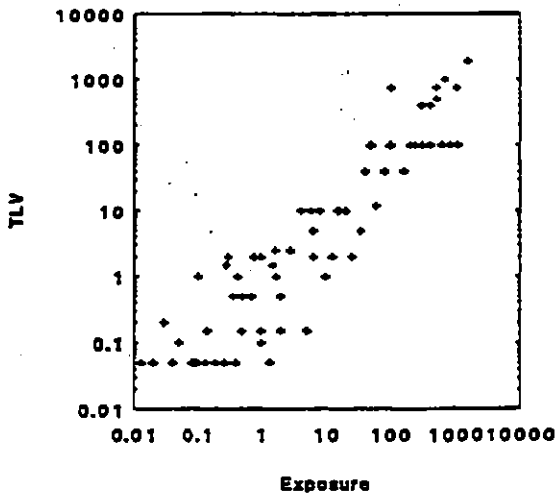

Fig. 4. TLV vs. the exposures reported in all studies for particular air contaminants. From references to human experience given in the 1986 *Documentation* of TLVs. (Data given in Appendices D, E.)

Acetone

Effect. "In view of the widespread use of acetone, its volatility and the paucity of reports of illness, it must be considered one of the least toxic of the common solvents. A limit of 1,000 ppm is recommended." [ACGIH, 1976].

Validation? "Acetone produced slight irritation at 300 parts per million, but 500 ppm was still tolerated by most *of 10* subjects." [Nelson et al., 1943].

Allyl Alcohol

Effect. "The threshold limit of 2 ppm would appear to provide protection against systemic effects and injury to superficial areas of the body, and to provide a reasonable freedom for most individuals from irritation." [ACGIH, 1976].

Validation? "Slight nose irritation *was* checked off by *2 of 6* volunteers exposed to *0.78 ppm* in an exposure room *which was* specially designed for the purpose." [Dunlap et al., 1958].

Allyl Propyl Disulfide

Effect. *TLV 2 ppm* "to minimize irritation and lacrimation." [ACGIH, 1976].

Validation? "Personal observation revealed that the general workroom atmosphere in the onion dehydration plant *where the concentration of allyl propyl disulfide was 1.7 ppm* caused marked irritation to the eyes, nose and throat . . ." [Feiner et al., 1946].

Asbestos

Effect. "On present evidence, this interim standard (5 fibers/ml longer than 5 microns) should afford protection against asbestosis and reduce to an acceptably low risk the development of neoplasms." [ACGIH 1976].

Validation? "In a recent study . . . of men from a factory processing chrysotile asbestos *none of* 22 exposed to a mean dust concentration *of* 3.5 fibres/cm^3 *had* basal rales, *which were* considered as the key symptom *of* the earliest demonstrable effects on the lung due to asbestos." [BOHS, 1968].

Benzene

Effect. "A TLV of 25 ppm is believed low enough to prevent serious blood changes." [ACGIH, 1976].

Validation? *In* "a study . . . of the benzene exposure of workers in the rubber coating industry . . . the *measured* benzene vapor concentrations *averaged 18 ppm* and *6 of 47* employees showed a lowered hemoglobin *of* below 13.5 grams." [Pagnotto et al., 1961].

2-Butanone

Effect. "A TLV of 200 ppm should prevent any injurious effects and minimize complaints about odor and irritation." [ACGIH, 1976].

Validation? "Butanone produced slight nose and throat irritation *in some of 10 volunteers* at 100 ppm." [Nelson et al., 1943].

Butyl Alcohol

Effect. "In view of the apparent potential of n-butyl alcohol to increase hearing loss in the younger age group of workers and to impair vestibular function at levels somewhat below 110 ppm, a TLV of 50 ppm as a ceiling value is recommended." [ACGIH 1976].

Validation? "Butyl alcohol, at 25 ppm *irritated the eyes, nose and throat of the majority of 10 volunteers* . . . At 50 ppm there was a unanimous feeling of pronounced throat irritation, *in 10 volunteers*." [Nelson et al., 1943].

Carbon Disulfide

Effect. "The limit, 20 ppm, although protecting against serious systemic effects, would appear to have little margin of safety, especially for those with mineral-deficient diets." [ACGIH, 1976].

Validation? *At a plant where* "concentrations of carbon disulfide . . . are less than 10 ppm for long exposures, with occasional scattered higher figures in some areas for short exposures . . . *in* a group of 100 employees . . . objective neurological signs were noted in 39 subjects who had one or more deviations from the average." [Rubin et al., 1950].

Chlorine Dioxide

Effect. "The recommended limit of 0.1 ppm is . . . to prevent irritation and possible bronchitis." [ACGIH, 1976].

Validation? "At a factory for the production of sulfite-cellulose . . . extensive investigations . . . showed the occurrence of slight bronchitis in 7 of 12 workers exposed to chlorine dioxide . . . *at* concentrations lower than 0.1 ppm." [Gloemme and Lundgren, 1957].

Chlorodiphenyl—42% Chlorine

Effect. "It is believed that this limit, 1 mg/m^3, will offer reasonably good protection against systemic intoxication but may not guarantee complete freedom from chloracne." [ACGIH, 1976].

Validation? "In a chemical plant concerned with organic chemical production *where* the chlorinated diphenyls in the actual breathing zones of the workers *were* 0.1 mg/m^3 of air . . . seven cases of mild to moderate chloracne of the face and head occurred among 14 chemical operators exposed . . ." [Meigs et al., 1954].

Cyanogen

Effect. " . . . to prevent irritation, as well as systemic effects, a TLV of 10 ppm is recommended." [ACGIH, 1976].

Validation? " . . . no effects from a concentration of eight ppm *were* experienced . . . by three males and two females . . . exposed in a sealed room." [McNerney and Schrenk, 1960].

Ethyl Acetate

Effect. "The threshold limit, 400 ppm, is believed to provide a level with a large safety factor from the standpoint of health, but may prove mildly irritating to some workers unaccustomed to the exposure." [ACGIH, 1976].

Validation? "Ethyl acetate at 200 ppm was objectionable to some *of 10 volunteers* because of the strong odor at that concentration." [Nelson et al., 1943].

Ethyl Ether

Effect. "Regular exposure at this concentration (400 ppm, the TLV) should cause no demonstrable injury to health nor produce irritation or signs of narcosis among workers." [ACGIH, 1976].

Validation? "Complaints of nasal irritation began at 200 ppm *in the majority of 10 volunteers.*" [Nelson et al., 1943].

Ethylene Oxide

Effect. "The results of these investigations of the chronic toxicity of ethylene oxide indicate that a threshold limit value of 50 ppm offers an adequate margin of safety from ostensible systemic effects." [ACGIH, 1976].

Validation? *At a* "plant *where* chemical operators engaged in the manufacture of ethylene oxide who had been exposed for many years to sub-threshold-limit-value (*TLV*) levels of this chemical . . . the general level of long-term exposure for the operators appeared to be in the order of 5 to 10 ppm . . . *A* thorough study of *the* over-all health level of . . . 37 individuals . . . failed to reveal evidence that the study group had suffered any ill effects from their exposure." [Joyner, 1964].

Fluoride as F

Effect. "The limit, 2.5 mg/m^3, is sufficiently low to prevent irritative effects and to protect against disabling bone changes." [ACGIH, 1976].

Validation? *At a factory where the concentration of fluorides ranged from 0.14 to 3.13 mg/m^3* "radiological examination revealed signs of osteosclerosis in *48 of 189 workers.*" [Largent, 1961].

Isopropyl Acetate

Effect. "The limit, 250 ppm, . . . is considered adequate to prevent significant irritation of the eyes and respiratory passages." [ACGIH, 1976].

Validation? "We found that at 200 ppm, the majority of . . . twelve subjects of both sexes . . . experienced some degree of eye irritation." [Silverman et al., 1946].

Magnesium Oxide Fume

Effect "The limit, 10 mg/m^3, is recommended on the basis that this value represents a maximal desirable limit for dusts of relatively minor hazard." [ACGIH 1976].

Validation? *In 1 of 4 subjects exposed to an average concentration of magnesium oxide of 5.8 mg/m^3 and in 2 of 4 subjects exposed to an average concentration of magnesium oxide of 4.1 mg/m^3* "was found . . . a leukocytosis and a fever resembling those caused by the heavy metals." [Drinker et al., 1927].

Mercury

Effect. "Following a study in the chlorine industry it was concluded in general that exposure at 0.1 mg/m^3 produced no significant incidence of mercury poisoning but contained little or no margin of safety." [ACGIH. 1976].

Validation? "Symptoms or signs of chronic mercury poisoning were found in *1 of 9 and in none of 3* men . . . engaged in repairing D.C. meters . . . *where* the concentration of mercury in the atmosphere *averaged 19 and 40 μg/m^3, respectively.*" [Bidstrup et al., 1951].

Mica

Effect. "The limits of 20 mppcf . . . should prevent disabling pneumoconiosis, but may not be sufficiently low to eliminate positive chest x-ray findings in workers with many years' exposure." [ACGIH. 1976].

Validation? "In mica factories . . . the exposure to dust is limited to muscovite mica only. . . . *which* contains less than 1% free silica. *When* the dust concentrations to which most workers were exposed ranged from 2 to 21 mppcf, with an average of 10 mppcf. . . . 27 *of 61* workers examined had ground-glass 2 readings *of their* chest x-rays." [Heimann et al., 1953].

Propylene Glycol Monomethyl Ether

Effect. "It can be concluded that the methyl ether of propylene glycol is low in systemic toxicity but that the vapors should be controlled to 100 ppm. . . . the TLVC, . . . to avoid complaints from the odor." [ACGIH. 1976].

Validation? "Upon entering the exposure chamber containing *47.3 ppm propylene glycol monomethyl ether* . . . a physician . . . perceived the odor to be moderately strong, not objectionable. When six subjects entered the chamber containing *95.0 ppm* . . . four immediately asserted that the odor was too strong to be tolerated and expressed a desire to promptly terminate the experiment." [Stewart et al., 1970].

Selenium

Effect. "The limit of 0.2 mg/m^3 for elementary selenium and its common inorganic compounds is believed low enough to prevent systemic toxicity and to minimize irritation of eyes and respiratory passages." [ACGIH, 1976].

Validation? *In the* "manufacture of rectifiers . . . conjuctivitis and slight tracheo-bronchitis were present in 9 of 62 workers . . . The atmospheric concentrations at different stages of the process varied from 0.007 to 0.05 mg/m^3, nowhere reaching the recommended MAC of 0.1 mg/m^3" [Kinningkeit, 1962].

Styrene (monomer)

Effect. "On the basis of human responses at the 100 ppm level. . . . mild, untoward, but transient subjective responses in half of those exposed . . . . a time-weighted average concentration of 100 ppm is recommended for a TLV." [ACGIH, 1976].

Validation? "Three of . . . six subjects exposed to 99 ppm styrene vapor . . . noted mild eye or throat irritation developing 20 minutes after the exposure had begun . . . No untoward subjective symptoms or objective signs of illness were noted during . . . the vapor exposure *to 51.4 ppm for 1 hour*." [Stewart et al., 1968].

Sulfuric Acid

Effect. "The TLV of 1 mg/m^3 is recommended to prevent irritation of respiratory passages and injury to the teeth." [ACGIH, 1976].

Validation? "Sulfuric acid mist . . . could not be detected by odor, taste or irritation . . . *by* 15 subjects *exposed* at 0.35 to 0.5 mg/m^3." [Amdur et al., 1952].

Toluene

Effect. "On the basis of the above data . . . human subjects exposed at 200 ppm suffered slight but definite changes in muscular coordination. . . . prolongation of reaction time, decrease in pulse rate and in systolic blood pressure. . . . a reduction in the TLV for toluene to 100 ppm is recommended." [ACGIH, 1976].

Validation? "During exposure to 100 parts per million of toluene in air . . . for 8 hours, . . . two (*of three*) subjects . . . had no subjective complaints except for moderate fatigue and sleepiness. . . . the third . . . complained of a slight headache, in addition to fatigue and sleepiness, on one occasion . . . With exposure to 50 parts per million of toluene in air . . . for 8 hours. . . . one (*of two*) subjects(s) had no subjective complaints, whereas the other complained toward the end of the experiment, of drowsiness and very mild headache." [von Oettingen et al., 1942].

Turpentine

Effect. "A TLV of 100 ppm is . . . recommended to prevent chiefly irritative effects." [ACGIH, 1976].

Validation? "Turpentine at 75 ppm, caused nose and throat irritation in several *of 10 volunteers*." [Nelson et al., 1943].

Vanadium Pentoxide Dust

Effect. "The ceiling limit of 0.5 mg/m^3 for the dust of V_2O_5 . . . is currently under review . . . in the light of the above reports. . . . of upper respiratory tract irritation in the form of persistent productive cough at an average concentration of 0.2 mg/m^3." [ACGIH, 1976].

Validation? "All five volunteers . . . exposed for an eight-hour period *at* 0.2 mg/m^3 . . . developed a . . . persistent . . . loose cough the following morning . . . When two . . . volunteers were subjected to an eight hour exposure of vanadium pentoxide dust at a concentration of 0.1 mg/m^3, a distinct clinical picture of pulmonary irritation appeared." [Zenz and Berg, 1967].

Vinyl Chloride

Effect. "A time-weighted average threshold limit value of 200 ppm vinyl chloride (with a few ppm vinylidene chloride) seems appropriate to prevent systemic effects from long-continued daily exposure." [ACGIH, 1976].

Validation? "No significant untoward effects were noted by . . . six subjects exposed to *a 59 ppm time weighted average concentration based on 7.5 hours including a 0.5-hour lunch period in an uncontaminated area* . . . The exposure had no noticeable effect on neurological responses, nor did it produce significant changes in the results of mental, coordination, or manual dexterity tests conducted during the exposure period. All clinical laboratory studies performed in the post exposure period were normal and not significantly different from pre-exposure values." [Baretta et al. 1969].

Even a cursory inspection of the quotations given above indicates that adverse effects had, in 1976, long since been reported in people exposed below the levels of 21 of 28 TLVs. Also, in one further case, carbon disulfide, exposure to the substance may have contributed to the signs reported and in one other, fluoride, the radiological effects may have been forewarnings of some risk of health. In the remainder, although only 5 substances, the conclusions of the original authors and of the TLV Committee appear to have been consistent. Among these 5 substances, it is interesting to note that to date, since 1976, three of the TLVs have come down (asbestos, ethylene oxide, and vinyl chloride), and 2 have remained the same (cyanogen and sulfuric acid), the latter being the only ones out of 28 to have retained their unequivocal validation.

DISCUSSION

Health-effects data from industrial surveys in which the environment and the health of employees were measured at the same time are notable for their paucity. Published survey data upon which TLVs are based refer to 200 or so substances but the total number of employees in all these surveys added together amounted to less than 10,000. Nonetheless, because the TLV Committee placed great weight upon such data when they were available, we felt compelled to conduct this investigation of the original references used by the Committee in assigning the limits.

Individual TLVs are supported by data obtained from such small numbers of persons that a single study showing alarmingly high prevalence of adverse effects could perhaps, by itself, be dismissed as a chance error lacking real significance. It is the multiplicity of such data sets among TLVs as a whole which is most disturbing and which requires explanation.

Three striking results emerged from this work, namely, that the TLVs were poorly correlated with the incidence of adverse effects (Figs. 1, 3), that the TLVs were well correlated with the exposure levels which had been reported at the time the limits were adopted (Figs. 2, 4), and that interpretations of exposure-response relationships were inconsistent between the authors of studies cited in the 1976 *Documentation* and the TLV Committee. Taken together these observations suggest that the TLVs could not have been based purely on considerations of health.

While factors other than health appear to have influenced assignments of particular TLVs, the precise nature of such considerations is a matter of conjecture. However, we note that one interpretation is consistent with the above results, namely, that the TLVs represent levels of exposure which were perceived by the Committee to be realistic and attainable at the time. Such an interpretation was voiced by the past chairman of the Committee, H. Stokinger. The most illuminating example of this is the following quotation from a 1968 paper [Stokinger, 1984]:

> Some TLVs . . . have been based on a decade or two of industrial experience (acetone, butanol and several other alcohols, many halogenated hydrocarbon solvents, several hydrocarbon solvents, lead, mercury, etc.). Clearly, such procedures can yield indisputable data on which realistic TLVs can be derived, unsurrounded by that uncertainty and doubt which requires incorporation of large safety factors, leading to wasteful over-engineering of plant processes.

Here the key word "realistic" suggests that such TLVs represent levels which had already been achieved in the industries which harbored the contaminants. In fact, Figures 2 and 4 indicate that the typical TLV was generally within a factor of 2 of the average exposure reported in studies cited in the *Documentation*. Consideration of feasibility in the setting of occupational limits is properly embodied in the OSH Act regarding the development of official standards [Rappaport, 1984]. However, we doubt whether, given its very limited resources, a voluntary body such as the ACGIH Chemical Substances TLV Committee is capable of accurately determining the levels of control which are achievable across the range of industries which experience a particular contaminant.

A past Chairman of the Committee, V. Carter, indicated that the TLV Committee ". . . must cooperate with and solicit information from all available sources including industry" [Carter, 1982]. Although it is difficult to argue with this position, one presumes that such cooperation would be restricted to the solicitation of data regarding exposures and health effects. Yet, Castleman and Ziem [1988] presented a more sinister role for industry by suggesting that industrial influence extended to the actual deliberations of the Committee. This view was recently, and surprisingly, supported by the reflections of a past Chairman of the Committee who hinted at "chicanery" on the part of industry consultants [Elkins, 1988]. While the extent to which such manipulations cannot be known, it is difficult to escape the implication that at least some TLVs have been influenced by vested interests.

Our conclusion is that TLVs for chemical substances are a compromise between health-based considerations and strictly practical industrial considerations, with the balance seeming to strongly favor the latter. In other words, most TLVs may represent guides of levels which have been achieved *but they are not thresholds*. We, therefore, regard the definition of the ACGIH TLV as incorrect and the term "threshold" in the name of the limits as singularly inappropriate.

In the days before the OSH Act, and similar pieces of legislation in other countries, the TLVs served as useful guidelines. Today, however, official governmental bodies, such as OSHA, set and enforce legal limits for exposure to chemicals. Thus, the TLV Committee has become an anachronism with no clear role to play in the development of exposure limits. The National Institute for Occupational Safety and Health (NIOSH), on the other hand, includes a full-time group, independent of industry and organized labor, charged with preparing Criteria Documents on hazardous chemicals. Each of 129 draft Criteria Documents prepared up to 1988 has been reviewed by experts representing affected industries, organized labor, and trade or health professionals with related experience in academia, government, or industry [Millar, 1988]. Since NIOSH appears to be the proper organization to develop criteria for chemical exposure in the U.S., we were concerned to see OSHA rely so heavily

upon the ACGIH TLVs, rather than information supplied by NIOSH, as the basis for recently updating its standards [OHSA, 1989].

The dependence of other countries on ACGIH TLVs should lessen as the particular counterparts to OSHA and NIOSH increasingly develop their own national limits appropriate to their economic and technical capabilities. International agencies such as the World Health Organization and the International Labor Office should be encouraged to develop exposure guidance for use in developing countries which are not currently able to generate their own limits.

RECOMMENDATION

Since so many TLVs for chemical substances appear to offer relatively little protection, we recommend that occupational hygienists and other health professionals routinely investigate the *Documentation* and, more importantly, the reference materials pertaining to particular contaminants rather than accepting on faith that every TLV provides the protection claimed by the ACGIH. This is in keeping with the sentiments expressed in the TLV booklet that " . . . the best practice is to maintain concentrations of all atmospheric contaminants as low as practical" [ACGIH, 1988]. Whenever possible, the exposure of employees in a particular process should be so controlled that during each work-shift the atmospheric exposure of nearly all the employees is kept below the TLV. As a general principle, it would be prudent to keep the average exposure of the employees below a small fraction of the TLV, say of 1/4 to 1/10. If this were done, and assuming exposure distributions to be quasi-lognormal, then fewer than 1–5% of exposures would be expected to exceed the TLV [Rappaport et al., 1988].

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APPENDIXES

APPENDIX A. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Impairment of Health"

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure:TLV)	Individuals affected	Organ affected
Acetonitrile[1]	160 ppm	40 ppm	4.0	1/2	Lungs
	80 ppm	40 ppm	2.0	0/2	Lungs
	40 ppm	40 ppm	1.0	1/3	Lungs
Aldrin[2]	1–2.6 mg/m³	0.25 mg/m³	4–10.4	0/34	—
Anisidine[3]	1.9 mg/m³	0.5 mg/m³	3.8	0/23	—
Antimony[4,5]	10.9 mg/m³	0.5 mg/m³	21.9	69/78	URT
	3.1–5.6 mg/m³	0.5 mg/m³	6.2–11.2	8/125	(Death)
	3.1–5.6 mg/m³	0.5 mg/m³	6.2–11.2	37/75	Heart
Arsine[6,7]	70–300 ppm	0.05 ppm	1,400–6,000	2/2	(Death)
	5 ppm	0.05 ppm	100	5/5	Blood
Asbestos[8]	11–27 f/cc	5 f/cc	2.2–5.4	14/153	Lungs
	11 f/cc	5 f/cc	2.2	1/58	Lungs
	3.5–6.0 f/cc	5 f/cc	0.7–1.2	1/57	Lungs
	3.5 f/cc	5 f/cc	0.7	0/22	—
Benzene[9–11]	208 ppm	25 ppm	8.3	130/332	Blood
	100–150 ppm	25 ppm	4.0–6.0	3/12	Blood
	0–100 ppm	25 ppm	2.8–4.0	2/4	Blood
	18 ppm	25 ppm	0.7	6/47	Blood
Beryllium[12,13]	0.018–0.060 mg/m³	0.002 mg/m³	9–30	0/50	—
	> 0.002 mg/m	0.002 mg/m³	> 1	93/372	Lungs
Cadmium cpds. dust[14,15]	0.02–0.24 mg/m³	0.05 mg/m³	0.4–4.8	12/19	Kidney/lungs
	0.13 mg/m³	0.05 mg/m³	2.5	4/27	Kidney/lungs
	0.07 mg/m³	0.05 mg/m³	1.4	14/22	Kidney/lungs

(continued)

APPENDIX A. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Impairment of Health" (continued)

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure TLV)	Individuals affected	Organ affected
Carbon disulfide[16,17]	20 ppm	20 ppm	1.0	16/16	CNS
	3–26 ppm	20 ppm	0.15–1.3	53/100	CNS
	< 10 ppm	20 ppm	< 0.5	39/100	CNS
Carbon tetrachloride[18,19]	85 ppm	10 ppm	8.5	4/4	Liver/kidney
	45–97 ppm	10 ppm	4.5–9.7	15/17	Liver/kidney
	49 ppm	10 ppm	4.9	3/6	Liver/kidney
	10 ppm	10 ppm	1.0	0/6	—
Chlordane[2]	14 mg/m³	0.5 mg/m³	28.0	0/22	—
Chlorine	0.2–ppm	0.1 ppm	0–20	25/69	Lungs
dioxide[20,21]	< 0.1 ppm	0.1 ppm	< 1.0	7/12	Lungs
Chlorodiphenyl-42% chlorine[22]	0.1 mg/m³	1 mg/m³	0.1	7/14	Skin/liver
Cobalt[23,24]	0.1–1.7 mg/m³	0.1 mg/m³	1.0–17.0	1.352/1.802	Lungs
	0.1–0.2 mg/m³	0.1 mg/m³	1–2	3/1.500	Lungs
Cotton	2.6 mg/m³	0.2 mg/m³	13.0	142/277	Lungs
dust[25–27]	0.6 mg/m³	0.2 mg/m³	3.0	203/793	Lungs
	0.3 mg/m³	0.2 mg/m³	1.5	160/566	Lungs
Ethylene chlorohydrin[28]	300–500 ppm	1 ppm	300–500	6/6	Liver/CNS
Ethylene oxide[29]	5–10 ppm	50 ppm	0.1–0.2	0.37	—
Fluoride[30,31]	2.81 mg/m³	2.5 mg/m³	1.1	17/74	Bones
	0.14–3.13 mg/m³	2.5 mg/m³	0.06–1.25	48/189	Bones
Fluorine[32]	1.2 ppm	1 ppm	1.2	0.61	—
Hexane[33]	500 ppm	100 ppm	5.0	0/10	—
Hydrogen selenide[34]	< 0.2 ppm	0.05 ppm	< 4.0	5/25	Lungs
Lead[35]	5.0 mg/m³	0.15 mg/m³	33	27/28	Blood/kidney
	2.0 mg/m³	0.15 mg/m³	13.3	24/31	Blood/kidney
	1.0 mg/m³	0.15 mg/m³	6.7	56/69	Blood/kidney
	0.14 mg/m³	0.15 mg/m³	0.93	21/143	Blood/kidney
	0.5 mg/m³	0.15 mg/m³	3.3	15/32	Blood/kidney
Magnesium	5.8 mg/m³	10 mg/m³	0.6	1/4	Lungs
oxide fume[36]	4.1 mg/m³	10 mg/m³	0.4	2/4	Lungs
Mercury	0.40 mg/m³	0.05 mg/m³	8.0	1/5	CNS
(Inorganic)[37]	0.27 mg/m³	0.05 mg/m³	5.4	6/26	CNS
	0.19 mg/m³	0.05 mg/m³	3.8	8/11	CNS
	0.13 mg/m³	0.05 mg/m³	2.6	9/32	CNS
	0.08 mg/m³	0.05 mg/m³	1.6	2/17	CNS
	0.04 mg/m³	0.05 mg/m³	0.8	0/3	CNS
	0.02 mg/m³	0.05 mg/m³	0.4	1/9	CNS
Methylene	985 ppm	200 ppm	4.9	2/3	CNS/blood
chloride[38]	690 ppm	200 ppm	3.5	1/3	CNS/blood
	515 ppm	200 ppm	2.6	0.8	—
	213 ppm	200 ppm	1.1	0/1	—
Mica[39,40]	80 mppcf	20 mppcf	4.0	3/47	Lungs
	42 mppcf	20 mppcf	2.1	1/12	Lungs
	10 mppcf	20 mppcf	0.5	20/61	Lungs
	2 mppcf	20 mppcf	0.1	1/109	Lungs

(continued)

APPENDIX A. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Impairment of Health" (continued)

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure/TLV)	Individuals affected	Organ affected
Nitrobenzene[1]	6 ppm	1 ppm	6.0	0.39	—
p-Nitrochlorobenzene[1]	20 mg/m³	1 mg m³	20	0/39	—
Nitrogen dioxide[41]	196 ppm	5 ppm	39	4/4	Lungs
	80 ppm	5 ppm	16	1/1	Lungs
2-Nitropropane[46]	20–45 ppm	25 ppm	0.8–1.8	5/5	CNS
	10–30 ppm	25 ppm	0.4–1.2	0/2	—
Phosphine[42]	3–35 ppm	0.3 ppm	10–120	35/67	Lungs
Picric acid[43]	0.009–0.194 mg/m³	0.1 mg m³	0.09–1.9	7/71	Skin
Platinum soluble salts[44,45]	0.007 mg/m³	0.002 mg/m³	3.5	52/91	Lungs
Silicon carbide[47]	100 mppcf	30 mppcf	3.3	19/53	Lungs
Sulfuric acid[48,49]	3–16.6 mg/m³	1 mg m³	3–17	57/63	Lungs/teeth
	< 0.8–2.5 mg m³	1 mg m³	0.8–2.5	9/15	Lungs/teeth
	0.35–0.5 mg/m³	1 mg m³	0.35–0.5	0/15	—
Tetrabromoethane[50]	< 14 ppm	1 ppm	< 14	6/6	Liver
1,1,2,2-Tetrachloroethane[51]	53 ppm	5 ppm	10.6	54/86	CNS
	43 ppm	5 ppm	8.6	39/107	CNS
	14 ppm	5 ppm	2.8	14/52	CNS
Tetryl[52]	1.5 mg/m³	1.5 mg m³	1.0	50/1,182	Skin
Toluene[53]	800 ppm	100 ppm	8.0	3/3	Blood/CNS
	600 ppm	100 ppm	6.0	3/3	Blood/CNS
	400 ppm	100 ppm	4.0	3/3	Blood/CNS
	300 ppm	100 ppm	3.0	3/3	Blood/CNS
	200 ppm	100 ppm	2.0	3/3	Blood/CNS
	100 ppm	100 ppm	1.0	1/3	Blood/CNS
	50 ppm	100 ppm	0.5	1/2	Blood/CNS
Toluene-2,4-diisocyanate (TDI)[54,55]	0.05 ppm	0.02 ppm	2.5	19/260	Lungs
	0.03–0.07 ppm	0.02 ppm	1.5–3.5	12/12	Lungs
	0.01–0.03 ppm	0.02 ppm	0.5–1.5	0/12	—

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APPENDIX B. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Irritation"

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure/TLV)	Individuals affected	Organ affected
Allyl alcohol[1]	25 ppm	2 ppm	12.5	5/5	Eyes/nose
	12.5 ppm	2 ppm	6.3	4/7	Eyes/nose
	6.25 ppm	2 ppm	3.1	3/6	Eyes/nose
	0.78 ppm	2 ppm	0.4	2/6	Eyes/nose
2-Butoxy ethanol[2]	195 ppm	50 ppm	3.9	3/3	Eyes/blood
	113 ppm	50 ppm	2.3	6/6	Eyes/blood
n-Butyl acetate[3]	300 ppm	150 ppm	2.0	10/10	Eyes/URT
	200 ppm	150 ppm	1.3	10/10	Eyes/URT
Butyl alcohol (n-butanol)[3]	50 ppm	50 ppm	1.0	10/10	Eyes/URT
	25 ppm	50 ppm	0.5	10/10	Eyes/URT
α-Chloroaceto-phenone[4]	213 ppm	0.05 ppm	4,260	2/4	Eyes
	119 ppm	0.05 ppm	2,380	2/4	Eyes
	93 ppm	0.05 ppm	1,860	2/4	Eyes
Chlorobenzilidene malonitrile[5]	0.2 ppm	0.05 ppm	4.0	4/4	Eyes/skin
Cyanogen[6]	16 ppm	10 ppm	1.6	7/7	Eyes/URT
	16 ppm	10 ppm	1.6	5/7	Eyes/URT
	8 ppm	10 ppm	0.8	0/5	—
Cyclohexanol[3]	100 ppm	50 ppm	2.0	10/10	Eyes/URT
Ethyl acetate[3]	400 ppm	400 ppm	1.0	10/10	Eyes
Ethyl ether[3]	300 ppm	400 ppm	0.75	10/10	URT

(continued)

APPENDIX B. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Irritation" (continued)

Substance	Air concentration		Exposure TLVs	Individuals affected	Organ affected
	Exposure	TLV			
Hydrogen sulfide[7,8]	50–80 ppm	10 ppm	5–8	88/125	Eyes
	18–28 ppm	10 ppm	1.8–2.8	25/78	Eyes
Iodine[9]	1.63 ppm	0.1 ppm	16.3	4/4	Eyes/URT
	0.57 ppm	0.1 ppm	5.7	0/4	—
Isoamyl alcohol[3]	200 ppm	100 ppm	2.0	10/10	Eyes/URT
Isophorone[10]	25 ppm	5 ppm	5.0	8/12	Eyes/URT
	10 ppm	5 ppm	2.0	5/12	Eyes/URT
Mesityl oxide[10]	50 ppm	25 ppm	2.0	6/12	Eyes/URT
Methyl-2-cyano-acrylate[11]	20 ppm	2 ppm	10	14/14	Eyes/URT
Osmium tetroxide[12]	0.1–0.6 mg/m³	0.002 mg/m³	50–300	7/7	Eyes/URT
Ozone[13,14]	2 ppm	0.1 ppm	20.0	1/1	Lungs
	0.8–1.7 ppm	0.1 ppm	8–17	11/14	Lungs
Propylene glycol monomethyl ether[15]	95 ppm	100 ppm	0.95	4/6	URT
	47 ppm	100 ppm	0.47	0/1	—
Selenium[16]	0.007–0.05 mg/m³	0.2 mg/m³	0.035–0.25	9/62	Eyes/URT
Stoddard solvent[17,18]	984–1,054 ppm	100 ppm	9.8–10.5	19/30	Eyes
	497–528 ppm	100 ppm	5.0–5.3	18/30	Eyes
	270 ppm	100 ppm	2.7	9/13	Eyes
	164–200 ppm	100 ppm	1.6–2.0	7/30	Eyes
	160 ppm	100 ppm	1.6	4/8	Eyes
Styrene monomer[19]	376 ppm	100 ppm	3.8	4/5	Eyes/CNC
	216 ppm	100 ppm	2.2	1/3	Eyes/CNC
	117 ppm	100 ppm	1.2	0/1	—
	99 ppm	100 ppm	1.0	3/6	Eyes/CNC
	51 ppm	100 ppm	0.5	0/3	—
Vanadium pentoxide dust[20,21]	1 mg/m³	0.5 mg/m³	2.0	2/2	URT
	0.36 mg/m³	0.5 mg/m³	0.7	8/8	URT
	0.1–0.3 mg/m³	0.5 mg/m³	0.20–0.6	20/24	URT
	0.20 mg/m³	0.5 mg/m³	0.4	5/5	URT
	0.1 mg/m³	0.5 mg/m³	0.2	2/2	URT
Vinyl chloride[22]	460–490 ppm	200 ppm	2.3–2.5	2/11	Eyes
	260 ppm	200 ppm	1.3	0/4	—
	60 ppm	200 ppm	0.3	0/6	—

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APPENDIX C. Documentation of 1976 TLVs Based Upon References to Human Experience: Hazard—"Narcosis"

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure/TLV)	Individuals affected	Organ affected
Chloroform[1]	77–237 ppm	25 ppm	3.1–9.5	9/10	Brain
	21–77 ppm	25 ppm	0.8–3.1	8/10	Brain
Methyl cellosolve[2]	61–3,960 ppm	25 ppm	2.4–158	6/38	Brain
Methyl chloroform[3]	560 ppm	350 ppm	1.6	4/5	Brain
	520 ppm	350 ppm	1.5	5/7	Brain
	490 ppm	350 ppm	1.4	7/7	Brain
	440 ppm	350 ppm	1.3	6/7	Brain
Perchloroethylene[4]	104 ppm	100 ppm	1.0	2/6	Brain
	96 ppm	100 ppm	1.0	2/8	Brain

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APPENDIX D. Documentation of 1986 TLVs Based Upon References to Human Experience: Hazard—"Impairment of Health"

Substance	Air concentration: Exposure	Air concentration: TLV	(Exposure:TLV)	Individuals affected	Organ affected
Acetonitrile[1]	160 ppm	40 ppm	4.0	1/2	Lungs
	80 ppm	40 ppm	2.0	0/2	—
	40 ppm	40 ppm	1.0	1/3	Lungs
Carbon disulfide[2,3]	20 ppm	10 ppm	2.0	16/16	CNS
	3–26 ppm	10 ppm	0.3–2.6	53/100	CNS
	< 10 ppm	10 ppm	< 1.0	39/100	CNS
Chlorine dioxide[4,5]	0–2 ppm	0.1 ppm	0–20	25/69	Lungs
	< 0.1 ppm	0.1 ppm	< 1.0	7/12	Lungs
Chlorodiphenyl[6]	0.1 mg/m³	1 mg/m³	0.10	7/14	Skin
Cyclonite[7]	0.28 mg/m³	1.5 mg/m³	0.19	0/558	—
Fluoride[8,9]	2.81 mg/m³	2.5 mg/m³	1.1	17/74	Bones
	0.14–3.13 mg/m³	2.5 mg/m³	0.6–1.25	48/189	Bones
Hexane[11]	500 ppm	500 ppm	1.0	0/10	—
Lead[10]	5.0 mg/m³	0.15 mg/m³	33	27/28	Blood/kidney
	2.0 mg/m³	0.15 mg/m³	13.3	24/31	Blood/kidney
	1.0 mg/m³	0.15 mg/m³	6.7	56/69	Blood/kidney
	0.5 mg/m³	0.15 mg/m³	3.3	15/32	Blood/kidney
	0.14 mg/m³	0.15 mg/m³	.93	21/143	Blood/kidney
Magnesium oxide fume[12]	5.8 mg/m³	10 mg/m³	0.6	1/4	Lungs
	4.1 mg/m³	10 mg/m³	0.4	2/4	Lungs
Manganese[13]	6.23 mg/m³	5 mg/m³	1.25	15/373	CNS
Mercury (Inorganic)[14–16]	0.09 mg/m³	0.05 mg/m³	1.6–2.0	0/21	—
	0.08 mg/m³	0.05 mg/m³	1.6	1/75	CNS
	0.004–0.022 mg/m³	0.05 mg/m³	0.2–0.6	0/18	—
	0.40 mg/m³	0.05 mg/m³	8.0	1/5	CNS
	0.27 mg/m³	0.05 mg/m³	5.4	6/26	CNS
	0.19 mg/m³	0.05 mg/m³	3.8	8/11	CNS
	0.13 mg/m³	0.05 mg/m³	2.6	9/32	CNS
	0.08 mg/m³	0.05 mg/m³	1.6	2/17	CNS
	0.04 mg/m³	0.05 mg/m³	0.8	0/3	CNS
	0.02 mg/m³	0.05 mg/m³	0.4	1/9	CNS
Nitroglycerin[17]	2.0 mg/m³	0.5 mg/m³	4.0	5/6	Headache/CVS
	0.7 mg/m³	0.5 mg/m³	1.4	10/10	Headache/CVS
	0.5 mg/m³	0.5 mg/m³	1.0	6/7	Headache/CVS
	0.36 mg/m³	0.5 mg/m³	0.72	7/8	Headache/CVS
Di-sec-octyl-phthalate[18]	1.7–66 mg/m³	5 mg/m³	0.34–13.2	69/147	CNS
Propylene glycol dinitrate[19]	1.35 ppm	0.05 ppm	27	6/6	CNS
	0.26 ppm	0.05 ppm	5.2	6/12	CNS
	0.1 ppm	0.05 ppm	2.0	1/3	CNS
	0.01–0.03 ppm	0.05 ppm	0.2–0.6	0/3	—
Quartz[20,21]	0.05 mg/m³	0.1 mg/m³	0.5	233/784	Lungs
Sulfur dioxide[22]	1 ppm	2 ppm	0.5	0/3	—
	0.3 ppm	2 ppm	0.15	0/3	—
Sulfuric acid[23,24]	3–16.6 mg/m³	1 mg/m³	3–17	57/63	Lungs/teeth
	< 0.8–2.5 mg/m³	1 mg/m³	0.8–2.5	9/15	Lungs/teeth
	0.35–0.5 mg/m³	1 mg/m³	0.35–0.5	0/15	—
Tetryl[25]	1.5 mg/m³	1.5 mg/m³	1.0	50/1,182	Skin
Toluene[26]	800 ppm	100 ppm	8.0	3/3	Blood/CNS
	600 ppm	100 ppm	6.0	3/3	Blood/CNS
	400 ppm	100 ppm	4.0	3/3	Blood/CNS

(continued)

APPENDIX D. Documentation of 1986 TLVs Based Upon References to Human Experience: Hazard—"Impairment of Health" (continued)

Substance	Air concentration		(Exposure TLV)	Individuals affected	Organ affected
	Exposure	TLV			
Toluene[20] (continued)	300 ppm	100 ppm	3.0	3:3	Blood:CNS
	200 ppm	100 ppm	2.0	3:3	Blood:CNS
	100 ppm	100 ppm	1.0	1:3	Blood:CNS
	50 ppm	100 ppm	0.5	1:2	Blood:CNS

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APPENDIX E. Documentation of 1986 TLVs Based Upon References to Human Experience. Hazard—"Irritation"

Substance	Air Concentration: Exposure	Air Concentration: TLV	(Exposure TLV)	Individuals affected	Organ affected
Acetone[1,2]	1,000 ppm	750 ppm	1.34	7:9	Eyes URT brain
	100 ppm	750 ppm	0.13	0:4	—
	500 ppm	750 ppm	0.67	0:4	—
Allyl alcohol[3]	25 ppm	2 ppm	12.5	5:5	Eyes·nose
	12.5	2 ppm	6.3	7:7	Eyes·nose
	6.25	2 ppm	3.1	3:6	Eyes·nose
	0.78	2 ppm	0.4	2:6	Eyes·nose
Camphor[4]	59 mg·m^3	12 mg·m^3	4.9	4:6	URT
Cyanogen[5]	16 ppm	10 ppm	1.6	7:7	Eyes/URT
	16 ppm	10 ppm	1.6	5:7	Eyes/URT
	8 ppm	10 ppm	0.8	0:5	Eyes/URT
Ethyl acetate[6]	400 ppm	400 ppm	1.0	10:10	Eyes/URT
Ethyl alcohol[7]	1,300–1,700 mg·m^3	1,900 mg·m^3	0.68–0.89	3:3	Eyes/URT
Ethyl ether[8]	300 ppm	400 ppm	0.75	10:10	URT
Propylene glycol monethyl ether[8]	95 ppm	100 ppm	0.95	4:6	URT
	47 ppm	100 ppm	0.47	0:1	URT
Selenium[9]	0.007–0.05 mg/m^3	0.2 mg·m^3	0.035–0.25	9:62	Eyes/URT
1,1,2-Trichloro-1,2,2,Trifluoroethane[10]	669 ppm	1000 ppm	0.67	0:50	—

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ANNEXE N°6

Documentation sur les *Health Based Exposure Limits*

Health-Based Exposure Limits

Draft 7 – October 23, 1993

by the Health-Based Exposure Limits Committee

Contents:

Acknowledgements for HBEL Booklet Draft 7 10/21/93

Special thanks to the members of the Health-Based Exposure Limits Subcommittee. This subcommittee was responsible for drafting this version. Members include Grace Ziem, MD, MPH, chairperson, and Jim Cone, MD, MPH; Barry Castleman, Ph.D.; Kathy Cunningham, Ph.D.; and David Egilman, MD, MPH. This subcommittee of the Exposure Limits Task Force was formed at the the Occupational Health and Safety Section meetings, 1989 at the annual meeting of the American Public Health Association. The opinions expressed in this draft are those of the individual members of the subcommittee, and not necessarily those of the Exposure Limits Task Force, APHA or the OH&S Section of APHA.

All HBEL's were calculated by Kathy Cunningham.

Requests for additional copies may be mailed to:

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Please enclose $5.00 for xeroxing, postage and handling.

THIS IS A DRAFT -- WE WELCOME YOUR COMMENTS!

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Introduction

Occupational exposure limits (OEL's) are maximum concentrations recommended for toxic substances in the air workers breathe. Many occupational exposure limits have been set near the maximum tolerable level, with little regard for the risks of long term harmful effects. The result has been widespread cancer and other diseases in workers.

Scientific studies show that, for some widely used chemicals, lifetime worker exposure at the allowed limits could lead to more than 1 worker in 10 dying from an occupational disease. For many more substances, to which millions of workers are exposed, working at current exposure limits is expected to cause death rates from occupational cancer greater than 1 per 100 and 1 per 1000 exposed (Alvanja 1990, Cunningham 1988).

Why a new booklet on exposure limits?

One goal of this booklet is to compare existing OEL's with levels that would virtually eliminate the risk of occupational disease, called "health–based" exposure limits. For each chemical, the worker exposure levels allowed in the U.S. and the strictest international governmental standard are compared with the level believed to correspond to very little or no known risk of disease. The differences are often enormous. For example, in the case of the cancer-causing agent benzene, the lowest OEL is 0.5 ppm (parts per million in air), or 1.6 mg/m3 but the exposure limit required to reduce a worker's risk of environmental cancer to as low as one in a million is 0.00021 ppm or 0.00063 mg/m3 (over 2000 times lower).

The low risk or "health–based" exposure limits in this booklet are calculated

from available data using standard risk evaluation techniques employed by the US Environmental Protection Agency. Even these numbers are based on limited knowledge about health effects. For example, studies used for this data often did not evaluate changes in the function of the lungs, the immune systems, the brain and nervous system, hormones, and effects on reproduction.

The Health Based Exposure Limits are typically too low to measure with current instrumentation. They are included to show the large gap between existing regulations and health protection. They show that there is a scientific basis for the industrial hygiene principle of lowering exposures as much as technologically possible.

Current Occupational Exposure Limits

A major reason for this booklet has been the disclosure that many old OEL's are tainted by corporate influence and based on shoddy scientific review. The OEL's in the US and other countries, since 1946, have been substantially based on the work of a private organization (called the American Conference of Governmental Industrial Hygienists or ACGIH). This group has had a committee of volunteers that recommended workplace exposure limits for hundreds of substances. Their limits were called **Threshold Limit Values** or TLV's.

In reality, the ACGIH does not represent a consensus of governmental industrial hygiene opininions. The minutes of the TLV committee show that, starting in 1970, employees of Dow Chemical, DuPont, and other companies have played central roles as committee members in developing TLV's for over 120 chemicals. This company role was not balanced by representatives of workers' interests, such as union representatives. Moreover, the stated basis for the TLV's of over 100 substances relies heavily on unpublished communications from corporations. No trace of most of these communications can be found today

(Castleman 1988, Ziem 1989). The TLV committee had no conflict of interest rules to prevent corporate employees and consultants on the committee from, in effect, prescribing allowable poisoning limits for exposure to chemicals used or produced by corporations hiring them. In 1989, weak conflict of interest rules were first adopted in response to public criticism and legal concerns.

Though the TLV booklet preface says the TLV's are adequate to protect "nearly all workers", close examination shows that to be untrue. The published reports of human data cited as the basis for the TLV's often reflect harmful effects at and below the TLV levels (Roach 1990). The literature used for the TLV's was sometimes misrepresented as showing no health problems when significant problems were present (Roach 1990). Current medical reports regularly show that work-related illness and death occur in workers exposed to toxic substances at levels lower than the TLV's (Ziem 1989).

The TLV booklet claim that TLV's are based on the "best available information" is also false. No complete literature searches were done in writing most TLV's. The effects of long term exposure was especially neglected. Much medical information was missed (Ziem 1989).

The TLV booklet implies that TLV's are updated yearly, which is misleading. Only a small number, a few dozen at most, are updated yearly. Some chemicals are not reviewed for many years. TLV's tend to justify long-existing levels of exposure to toxic substances in industry, rather than control exposures to levels below those shown to cause harm (Roach 1990, Tarlau 1990). In some cases, the TLV's were not even as strict as limits adopted internally by companies to prevent safety hazards that irritation, drowsiness, headache, visual disturbances and other ill effects can cause on the job.

The adoption of over 350 TLV's by OSHA in the last week of the Reagan Administration in 1989 came as a response to requests from

chemical companies. Unions, who have had no role in setting the TLV's for more than 40 years, criticized these limits as not protective. The National Institue for Occupational Safety and Health (NIOSH) charged that the TLV's were not adequately protective for 98 substances. In many cases, lower limits were urged by NIOSH but disregarded by the Occupational Safety and Health Administration (OSHA) (Robinson 1990). For example, the acceptable limits determined by NIOSH for carcinogens are as low as technically feasible, essentially zero. However, these union and NIOSH recommendations were ignored. The US Supreme Court ruled that the 1989 PEL's were invalid based on failure of OSHA to follow the procedures for standard setting outlined in OSHA Regulations.

Occupational exposure limits are the highest legally-permitted levels of human exposure to toxic substances. Environmental exposure of the public to the same air pollutants is regulated much more strictly. Workers exposure to toxic substances should be no greater in the workplace than in other regulated settings of human exposure to toxic substances.

Table 1: Comparative Exposure Limits

Substance Name	Chemical Abstracts Service Number	OSHA PEL (TLV) (mg/m3)	Lowest Occ. Exp. Level (mg/m3)	National Level Country Year	Health-Based Exposure Limit (mg/m3)
Acrylamide	19-06-1	0.03	0.03	Sweden	0.0000042*
Acrylic Acid	79-10-7	30 (6§)	5 ¶	USSR	0.0001
Acrylonitrile	107-13-1	4.3	0.5¶	USSR	0.000077
Aldrin	309-00-2	0.25	0.01	Poland, 1977	0.000001
Allyl Alcohol	107-18-6	5	2.4	Japan	0.053
Antimony	7440-36-0	0.5	0.2	USSR	0.0045
Arsenic	7440-38-2	4 (0.2§§)	0.01	Norway, 1989	0.0000012
Asbestos	133-22-14	0.2 f/cc	0.1f/cc	Norway, 1989	0.00003**
Benzene	71-43-2	3.2	1.6	Sweden 1990	0.00063
Beryllium	744-04-17	0.002	0.001¶	USSR, 1984	0.00022**
1,1-biphenyl	92-52-4	1	1	Norway, 1989	0.053
bis-(Chloro-methyl)ether	542-88-1	0.005	0.00025	Czech	0.000000083
1,3 butadiene	106-99-0	2200 (22)(4.4§§)	2.2	Norway, 1989	0.000019
Cadmium	7440-43-9	0.1fume	0.01	Denmark	0.0000029
Carbaryl	63-25-2	5	1	Poland	0.9
Carbon tetrachloride	56-23-5	12.6	1	Bulgaria, 1977	0.00035
Chlordane	57-74-9	0.5	0.01¶	USSR, 1977	0.000014
Chloroform	67-66-3	10	10	USA, 1989	0.00023
			10¶	Hungary	
ChromiumVI	7440-47-3	1(0.05)	0.001	Holland,1977	0.00000044

Table 1: Comparative Exposure Limits

Substance Name	Chemical Abstracts Service Number	OSHA PEL (TLV) (mg/m3)	Lowest Occ. Exp. (mg/m3)	National Level Country Year	Health-Based Exposure Limit (mg/m3)
Cresols	1319-77-3	22	5	Poland, 1977	0.53
Cyanogen	460-19-5	20	3	Romania, 1977	0.43
Dibutyl phthalate	84-74-2	5	4 0.5	France USSR, 1977	1.1
1,2-Dichloro-ethane	107-06-2	4(40)	4	Sweden, 1987	0.0002
1,1-Dichloro-ethylene	75-35-4	4(20)	4	Norway, 1989	0.00011
Epichlor-hydrin	106-89-8	8(0.38§)	1¶	USSR	0.0044
Ethyl benzene	100-41-4	435	100	Poland, 1977	0.35
Ethylene oxide	75-21-8	1.8	1¶	USSR, 1984	0.000053
Formalde-hyde	50-00-0	1.2 (0.3C§)	0.4 0.6	Denmark Sweden, 1987	0.00041
Formic acid	64-18-6	9	1¶	USSR, 1977	21.3
Heptachlor		0.5(0.05§)	0.01¶	USSR, 1977	0.0000041
Hexachloro-butadiene	87-68-3	0.24	0.24	Norway, 1989	0.00024
Hexachloro-cyclopenta-diene	77-47-4	0.1	0.01¶	USSR, 1977	0.000252

Table 1: Comparative Exposure Limits

Substance Name	Chemical Abstracts Service Number	OSHA PEL (TLV) (mg/m3)	Lowest Occ. Exp. (mg/m3)	National Level Country Year	Health-Based Exposure Limit (mg/m3)
Hexachloro-ethane	67-72-1	10	5	UK	0.0013
Hydrogen sulfide	7783-06-4	14	7	France	0.0031
Isophorone	78-59-1	23	1¶	USSR,1984	0.0044
Lindane	58-89-9	0.5	0.01	USSR, 1984	0.00052
Methylene chloride	75-09-2	500	10	Hungary	0.011
Methyl ethyl ketone	78-93-3	590	150	Sweden, 1987	1.0
Nitrobenzene	98-95-3	5	3	Italy, 1977	0.0069
Pentachloro-phenol	87-86-5	0.5	0.05	Germany	0.000022
Phenol	108-95-2	19	0.3¶	USSR, 1977	6.4
Phosphine	7803-51-2	0.4	0.1	USSR	0.0001
Strychnine	57-24-9	0.15	0.15	Australia,1977	0.0032
Styrene	100-42-5	215	30¶	USSR	0.0092
1,1,2,2-tetra-chloro-ethane	79-34-5	7	5	Poland	0.000091
Tetrachloro-ethylene	127-18-4	170 (340)	10¶	USSR, 1977	0.01
Tetraethyl Lead	78-00-2	0.075 (0.1)	0.005	USSR, 1984	0.0000018

Table 1: Comparative Exposure Limits

Substance Name	Chemical Abstracts Service Number	OSHA PEL (TLV) (mg/m3)	Lowest Occ. Exp. Level (mg/m3)	National Country Year	Health-Based Exposure Limit (mg/m3)
Toluene	108-88-3	375	50¶	USSR, 1984	21.3
1,2,4-trichlorobenzene	120-82-1	37C	10	USSR, 1977	0.03
1,1,2-trichloroethane	79-00-5	45	10	Hungary	0.00033
Trichloroethylene	79-01-6	270	10¶	USSR, 1977	0.0031
Trichlorofluoromethane	75-69-4	5600C	500	Poland, 1977	2.4
1,1,2-trichloro, 1,2,2-trifluoroethane	76-13-1	7600	2600	Yugosl.,1977	93.1
Vanadium pentoxide	1314-62-1	0.05	0.05¶	Sweden	0.096
Vinyl chloride		1.0	USSR		0.000053

KEY:

* from Alvanja 1990 ¶ Short Term Exposure Limit

** from OSHA, 1983 Temporary Emergency Standard

§ ACGIH Proposed level

§§ OSHA Proposed level

Health-based exposure limits (HBEL's): For carcinogens these are Occupa-

Notes for Exposure Limits Tables

Health-based exposure limits (HBEL's): For carcinogens these are Occupational Exposure Limits that yield one in a million lifetime risk of cancer; for noncarcinogens, the Occupational Exposure Limits correspond to estimated zero risk of known health effects over a lifetime of exposure. They are designed to be protective, not necessarily predictive. Hence the use of safety factors, and 95% confidence bounds.

Table 2. Estimated Lifetime Cancer Risk from Occupational Exposureto the TLV 8 hrs/day, 40 hrs/week, for a 40 year career

Substance	IARC Class	TLV µg/m3	Adjusted Unit Risk	Daily Exposure Associated With Risk of $1/10^6$	$1/10^3$	Estimated Cancer Risk@TLV
Acrylamide	2B	30	$2.4 \cdot 10^{-4}$	$2.4 \cdot 10^{-3}$	4.2	0.0072
Acrylonitrile	2A	4500	$1.3 \cdot 10^{-5}$	$7.7 \cdot 10^{-2}$	7.7•10	0.057
Benzene	1	30000	$1.5 \cdot 10^{-6}$	$6.7 \cdot 10^{-1}$	$6.7 \cdot 10^{2}$	0.044
Beryllium	2A	2	$4.5 \cdot 10^{-4}$	2.2•10	2.2	0.0009
1,3-Butadiene	2B	22000	$5.2 \cdot 10^{-5}$	$1.9 \cdot 10^{-2}$	$1.9 \cdot 10^{-2}$	0.68
Cadmium	2A	10	$3.3 \cdot 10^{-4}$	$3.0 \cdot 10^{-3}$	3.0	0.0033
CCl4	2B	30000	$2.8 \cdot 10^{-6}$	$3.6 \cdot 10^{-1}$	$3.6 \cdot 10^{2}$	0.081
Chloroform	2B	50000	$4.3 \cdot 10^{-6}$	$2.3 \cdot 10^{-1}$	$2.3 \cdot 10^{2}$	0.19
BCME	1	5	$1.2 \cdot 10^{-2}$	$8.3 \cdot 10^{-5}$	$8.3 \cdot 10^{-2}$	0.058
Chromium(VI)	1	50	$2.2 \cdot 10^{-3}$	$4.5 \cdot 10^{-4}$	$4.5 \cdot 10^{-1}$	0.10
Methylene Chloride	2B	175000	$7.6 \cdot 10^{-7}$	1.3	$1.3 \cdot 10^{3}$	0.12
Ethylene Oxide	2A	2000	$2.0 \cdot 10^{-5}$	$5.0 \cdot 10^{-2}$	5.0•10	0.039
Formaldehyde	2A	1500	$2.4 \cdot 10^{-6}$	$4.2 \cdot 10^{-1}$	$4.2 \cdot 10^{2}$	0.00098
Vinyl Chloride	1	10000	$1.3 \cdot 10^{-6}$	$7.7 \cdot 10^{-1}$	$7.7 \cdot 10^{2}$	0.013

From: Alvanja MCR, et. al.(1990). Risk assessment for carcinogens: A comparison of approaches of the ACGIH and the EPA. *Applied Occupational and Environmental Hygiene* 5:510-519.

TABLE 3-HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES (See Appendix 2 for calculation methods)

NAME	DATA SOURCE [a.]	STUDY EFFECT [b.]	RFD [c.] (mg/cubic meter)	HBEL [d.]
(Cancer statement is below name line)				
ACENAPHTHENE	I H	HEP	.06	.64
ACEPHATE	I H	NER	.004	.0426
2 yr mouse-liver (C) , HBEL = .002				
ACETONE	I H	HEP,NEP	.01	.1
ACETONE CYANOHYDRIN	H		.01*	.035
ACETONITRILE	I H	HEM,HEP	.05*	17
ACETOPHENONE	I H	CIR,HEP	.00002*	.000007

FOOTNOTES:

a. See abbreviations on page 51.

b. Effects reported in IRIS for reviewed studies, exposure route was via oral or gavage unless noted by * indicating inhalation route (see abbreviations, page 51)

c. RFD=Reference dose in mg/kg/day oral exposure; * indicates inhalation exposure in mg/m^3

d.Length of study, species, tumor site, EPA cancer status & risk per 1 mg/kg/d unless noted with * designating inhalation in mg/m^3 based on inhalation study or ** designating inhalation in mg/m^3 extrapolated from non-inhalation study by EPA.

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
ACIFLUORFEN, SODIUM	I	NEP	.013	.14
Carcinogenicity under evaluation				
ACROLEIN	I H	RES	.0001* (C)	.00035
ACRYLAMIDE	I H	NER	.0002	.021
2 year, rat-CNS, mam, thy, ut, oral cav,(B2) 0.0013**				
ACRYLIC ACID	I H	WT,TIS	.00003*	.0001
Carcinogenicity under evaluation				
ACRYLONITRILE	I			$7.7x10^{-5}$
human occ.-lung,(B1), 6.8 (-5)* (also oral rat, many sites)				
ALACHLOR	I H	HEM	.01	.10
B2 - IRIS input pending, 0.081, HBEL = 2.2×10^{-4}				
ALDICARB (D)	I H	NER	.00002	.0002
ALDRIN	I H	HEP	.00003	.00032
diet,2 years, mouse-liver, (B2), $4.9x10^{-3}$**, HBEL = 1×10^{-6}				
ALLYL ALCOHOL	I H	HEP,NEP	.005	.053
ALLYL CHLORIDE (C)	I H	NER	.001*	.0034
ALUMINUM PHOSPHIDE	I H	WT, M	.0004	.00043

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
AMDRO	I	WT	.0003	.0032
AMETRYN	I II	HEP	.009	.096
-AMINOPHENOL	II	THY,WT	.07	.75
4-AMINOPYRIDINE	I II	HEP,NER	.00002	.00021
AMMONIA	H	ODOR	.35*	1.21
AMMONIUM SULFAMATE	I	WT	.02	.21
ANILINE	I II	SPLEEN	.001*	.0035
2 year, rat-spleen, (B2), 5.7 (-3), HBEL = 3 (-3)				
ANTHRACENE	I II	none	.3	3.2

NOTE: FORM FOR ALL ANTIMONY IS POTASSIUM TARTRATE, THERE IS QUALITATIVE EVIDENCE OF CARCINOGENICITY.

ANTIMONY	I H	HEM	.0002*	.0007
ANTIMONY PENTOXIDE	I H	HEM	.00025*	.0009
ANTIMONY POTASSIUM TARTRATE	I H	HEM	.00045*	.0016

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
ANTIMONY TETROXIDE	I H	HEM	.0002*	.0007
ANTIMONY TRIOXIDE	I H	HEM	.0002*	.0007
APOLLO (3,6-BIS(2-CHLOROPHENYL)-1,2,4,5)TETRAZINE (C)	I		.0013	.014
ARAMITE	II	HEP	.05	.53
2 year, rat, liver, (B2), 7.1 (-6), HBEL = 7.2 (-4)				
ARSENIC	I H			
human, resp. tract, (A), 4.3 (-3)*, HBEL = 1.2 (-6)				
ASBESTOS - DONE WITHIN THE HBEL GROUP				
For reference from IRIS:(A) 2.3 (-1)fibers/ml*				
ATRAZINE	I II	REP,CARD	.005	.053
2 year, rat-mam & others, (C) .22, HBEL = 8.2 (-5)				
AZOBENZENE				
2 year, rat-abd. cav, (B2), 3.1 (-5)**, HBEL = 1.7 (-4)				
BANVEL (SEE DICAMBA)				
BARIUM (BaCO3,BaCl)	I H	REP,CIR	.0005	.0053

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
BISPHENOL A	I II	WT	.05	.53
BORON	II	REP	.09	.96
BROMODICHLORO-METHANE	I H	NEP	.02	.21
2 year mouse, liver, lg.intest, kidney, (B2), 1.3 (-1), HBEL = 1.4(-4)				
BROMOETHENE (VINYL BROMIDE)				
2 year rat-liver, (B2), 3.2 (-5)*, HBEL = 1.6 (-4)				
BROMOFORM	I H	HEP	.02	.21
2 year rat-large intest,(B2), 1.1 (-6)**, HBEL = 4.8(-3)				
BROMOMETHANE (METHYL BROMIDE)	I H	NER, HYP-EPI	.0006*	.00021
Cancer data pending				
BROMOPHOS	H	NER	.005	.053
BROMOXYNIL	I H	NONE	.02	.21
BROMOXYNIL OCTANOATE	I H	NONE	.02	.21

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
1,3-BUTADIENE				
mouse, rat-hem, Leydig cell, thy, (B2) 2.8 (-4)*, HBEL = 1.9(-5)				
1-BUTANOL (N-)	I II	HEM	.1	1.1
BUTYLATE	I II	HEP	.05	.53
BUTYL BENZYLPHTHALATE	I II	WT, REP,HEP,NEP	.2	2.1
preliminary evidence of cancer				
BUTYLPHTHALYL BUTYGLYCOLATE	I	NONE	1.0	10.7
CACODYLIC ACID (BASED ON ARSENIC EQUIVALENTS)	H	NONE	.003	.032
CADMIUM	I II			
human occ, resp.tract, (B1), 1.8 (-3)*, HBEL = 2.9 (-6)				
CALCIUM CYANIDE (CYANOGAS)	I II	WT, THY,NER	.011	.012
USED MORE RECENT LOEL WITH ADDED SF=10				
CAPROLACTAM	I II	REP (?)	.5	5.3

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
CAPTAFOL	I H	HEP, DLA	.002	.021
mouse, lymphosarcoma (C), 8.6 (-3),HBEL = 2.1(-3)				
CAPTAN	H			
limited data: B2, 3.5 (-3), HBEL = 5.2 (-3)				
CARBARYL	I H	NEP, HEP	.1	1.1
CARBAZOLE				
2 year mouse, liver, (B2) 2.2 (-2), HBEL = 8.2 (-4)				
CARBOFURAN (FURADAN)	I H	HEM, REP	.005	.053
CARBON DISULFUDE	I H	REP	.01	.11
CARBON TETRACHLORIDE	I H			
liver, (B2), 1.5 (-5), HBEL = 3.5(-4)				
CARBOSULFAN	I	WT. ACH, OTHER	.01	.11
CARBOXIN	I	ORGAN WT	.1	1.1
CHLORAL	I H	HEP	.002	.0213

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
CHLORANIL				
1.5 year, mouse-liver, lung (C), 4.0 (-1), HBEL = 4.5 (-5)				
CHLORAMBEN	I		.015	.16
Carcinogenicity under evaluation, + MOUSE LIVER STUDY				
CHLORDANE	I H			
mouse, liver, (B2), 3.7 (-4)** , HBEL = 1.4 (-5)				
CHLORINE CYANIDE (CYANOGEN CHLORIDE)	I H	WT, THY, NER	.07	.75
CHLOROACETIC ACID	H	MYOCARDITIS	.002	.0213
4-CHLOROANILINE (P-)	H	SPLEEN	.004	.0426
CHLOROBENZENE	I H	HEP, NEP	.02*	.021
CHLOROBENZILATE	I H	NONE	2	21.3
P-CHLOROBENZOIC ACID	H	NONE	.2	2.1
4-CHLOROBENZO-TRIFLUORIDE	H	NEP	.02	.21
2-CHLORO-1,3-BUTADIENE (CHLOROPRENE)	H	ALOPECIA	.1*	.345

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
1-CHLOROBUTANE	I H	GRO NER, HEM	.4	4.3
CHLORODIBROMOETHANE				
2 year mouse-liver (B2), 8.4 (-2), HBEL = 1.5(-6)				
CHLOROFORM	I H	HEP	.01	.11
2 year mouse, rat- liver, kidney, (B2), 2.3 (-5)*, HBEL = 2.3 (-4)				
CHLOROMETHANE				
2 year mouse-kidney, (C), 1.8 (-6)*, HBEL = 2.9(-3)				
4-CHLORO-2-METHYL-ANILINE				
1.5 year mouse-vascular hemangiomas and angiosarcomas, (B2), 5.8 (-1), HBEL = 3.1(-5), based on results from 4-chloro-2-2-methylaniline hydrochloride				
4-CHLORO-2-2-METHYLANILINE HYDROCHLORIDE				
1.5 years, mouse-vascular hemangiomas and angiosarcomas, (B2), 4.6 (-1), HBEL = 3.9(-5)				
CHLOROMETHYL METHYL ETHER (cmme)				
human-lung, (A), no risk values				
o-CHLORONITROBENZENE				
1.5 year mouse-liver, (B2), 2.5 (-2), HBEL = 7.3(-4)				
p-CHLORONITROBENZENE				
1.5 year mouse-vascular tumors, (B2), 1.8 (-2), HBEL = 1 (-3)				
2-CHLOROPHENOL	I H	REP	.005	.053
2-CHLOROPROPENE	H	HEP	.3*	1.0
CHLOROTHALONIL				
2.5 year rat-kidney (B2), 1.1 (-2), HBEL = 1.7(-3)				
0-CHLOROTOLUENE	I H	DECR WT GAIN	.02	.21
CHLORPYRIFOS	I H	NER	.003	.032

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
CHLORPYRIFOS-METHYL	H	REP, HEP	.01	.11
CHLORSULFURON	I	WT,HEM	.05	.53
CHLORTHALONIL	I H	HEP	.015	.16
CHLORTHIOPHOS	I H	NONE	.0008	.085
CHROMIUM III	I H	HEP,M	.000002*	2.1×10^{-5}
(FROM Cr IV AS CHROMIC ACID FROM HUMAN STUDIES)				
CHROMIUM IV	I H	HEP, M	.000002*	2.1×10^{-5}
(FROM Cr IV AS CHROMIC ACID FROM HUMAN STUDIES)				
human occ, lung, (A), 1.2 (-2)*, HBEL = 4.4(-7)				
COAL TARS				
human occ, lung, 6.2 (-4), HBEL = 2.9(-2)				
COPPER CYANIDE	I H	HEP, HEM NEP, WT	.005	.053
CRESOL (c) O, M, AND P-CRESOL				
ALL EVALUATED USING SAME STUDY AND WITH SAME RESULTS:	I H	WT, NER	.05	.53
CROTONALDEHYDE				
2 year, rat-liver, (C), 5.4 (-4)**, HBEL = 9.7(-6)				
CRYOMAZINE (VETRAZIN)	I	HEM	.00075	.008
CUMENE	I H	NER, IR NEP	.009*	.031
CYANAZINE	I H	WT, HEM	.002	.021
CYANIDE	I H	WT, THY NER	.03	.32
CYANOGEN	I H	WT, THY, NER	.04	.43

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
(CALCULATED BY ANALOGY TO FREE CYANIDE ADJUSTED FOR MOLECULAR WEIGHT.				
CYANOGEN BROMIDE	I H	WT,THY,NER	.09	.96
(CALCULATED BY ANALOGY TO FREE CYANIDE ADJUSTED FOR MOL.WT.)				
CYCLOHEXANONE	I	REPRO	2.0*	7.0
CYCLOHEXYLAMINE	I H	WT	.2	2.1
CYCLOPENTADIENE	H	HEP,NEP	(.3)*	1.0
DACTHAL (DCPA)	H	NEP,AD WT	.5	5.3
DALAPON	I H	NEP WT	.03	.32
DANITOL (FENPROPATHRIN)	I	RESP	.0005	.0053
2,4-D	I H	HEM,HEP NEP	.01	.11
2,4-DB	I H	HEMOR	.008	.085
DDD				
2 year, mouse-liver, (B2), 2.4 (-1), HBEL = 7.6(-5)				
DDE				
mouse, hamster-liver, (B2), 3.4 (-1), HBEL = 5.3(-5)				
DDT	I H	HEP	.0005	.0053
mouse, rat-liver, (B2), 9.7 (-5)**, HBEL = 5.4(-5)				
DECABROMODIPHENYL ETHER (C)	I H	HEP	.01	.01
(DBDPE) Preliminary cancer evidence so ADDED SF = 10				
DEMETON (SYSTOX)	I	ACH, ORGAN WTS, OPTIC, MANY OTHERS	.00004	.00042

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
DIALLATE				
1.5 year mouse-liver, (B2), 6.1 (-2), HBEL = 3.0(-4)				
DIAZINON	H	ACH	.0009	.0096
1,4-DIBROMO-BENZENE	I H	HEP	.01	.11
DIBROMOCHLORO-METHANE	I H	HEP	.02	.21
2 year mouse-liver, (C), 8.4 (-2), HBEL = 2.2(-4)				
1,2-DIBROMO-3-CHLOROPROPANE				
rat, mouse-lung, nas. cav., tongue, pharynx, adren. cortex,(B2), 6.3 (-3)*, HBEL = 8.4(-6)				
1,2-DIBROMOETHANE				
2 year rat-nasal cav., (B2) 2.2 (-4)*, HBEL = 2.4(-5)				
DIBUTYL-PHTHALATE (DBP)	I H	MORT REPRO	.1	1.1
DIBUTYLNITROSAMINE (DBN)				
mouse-bladder (B2), 1.6(-3), HBEL = 3.3(-6)				
DICAMBA (BANVEL)	I	REPRO	.03	.32
1,2-DICHLOROBENZENE	I H	WT,HEP	.2*	.69
p-(1,4)DICHLORO-BENZENE	H	HEP,NEP	.7*	2.4
2 year mouse-liver, (C), 2.4 (-2), HBEL = 7.6(-4)				
3,3-DICHLOROBENZIDINE				
2 year rat-mammary, (B2), 4.5 (-1), HBEL = 4.0(-5)				
1,4-DICHLORO-2-BUTENE				
90 day rat-nasal passages, (B2), 2.6 (-3)*, HBEL = 2.0(-6)				
DICHLORODIFLUORO				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
METHANE (FREON-12)	I H	RESP, HEP,WT	.2*	.69
1,1-DICHLORETHANE	H	NEP	.5*	1.7
rat-preliminary evidence of cancer - hemangiosarcoma				
1,2-DICHLOROETHANE				
rat-circ. sys., (B2),2.6 (-5)**, HBEL = 2.0 (-4)				
1,1-DICHLOROETHYLENE	I H	HEP		.009
1 year mouse-kidney, (C), 5.0 (-5)*, HBEL = 1.1(-4)				
1,2-C-DICHLORO-ETHYLENE	I H	HEM	.01	.11
1,2-T-DICHLORO-ETHYLENE	I H	M	.02	.21
DICHLOROMETHANE - SEE METHYLENE CHLORIDE				
2,4-DICHLORO-PHENOL	I H	IMM	.003	.032
1,2-DICHLOROPROPANE				
mouse-liver, (B2), 6.8 (-2), HBEL = 2.7(-4)				
1,3-DICHLOROPROPENE	I H	M, WT	.02*	
2 year mouse-lung, (B2), 3.7 (-5)*, HBEL = 1.4(-4)				
human: suspected lymphoma and leukemia				
DICYCLOPENTADIENE	H	NEP	.0002*	.00069
DIELDRIN	I H	HEP	.00005	.00053
mouse-liver, (B2), 4.6 (-3)**, HBEL = 1.1 (-6)				
DIETHYLENE GLYCOL	H	NEP	2	21
DIETHYLFORMAMIDE	H	NONE	.1	1.1
DIETHYLPHTHALATE	I H	WT	.8	8.5
DIETHYLSTILBESTEROL				
rat,mouse-mam, uter, cerv, (A), 1.4 (-1)**, HBEL = 3.8(-8)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
DIMETHIPIN	I	HEP	.02	.021
ADD SF=10 DUE TO POSITIVE CANCER STUDIES				
DIMETHOATE (PHOSPHAMID)	I	HACH HEM	.0002	.002
3-3'-DIMETHOXYBENZIDINE				
lifetime hamster-forestomach, (B2), 1.4 (-2), HBEL = 1.3 (-3)				
N,N-DIMETHYL-ANILINE	I H	SPLEEN	.002	.021
2,4-DIMETHYLANILINE and 2,4-DIMETHYLANILINE HYDROCHLORIDE				
1.5 year mouse-lung, (C), 7.5 (-1), HBEL = 2.4 (-5)				
study used HCl salt				
3,3-DIMETHYLBENZIDINE				
30 day rat-mam, (B2), 9.2 (0), HBEL = 2.0 (-6)				
N,N-DIMETHYL-FORMAMIDE	I H	HEP	.03*	.10
1,1-DIMETHYLHYDRAZINE				
lifetime mouse-vascular sys.(C), 8.7 (0), HBEL = 2.1 (-6)				
1,2-DIMETHYLHYDRAZINE				
1.5 year mouse-vascular sys. (B1), 1.4 (+3), HBEL = 1.3 (-8)				
2,4-DIMETHYL-PHENOL	I H	NER,HEM	.02	.21
2,6-DIMETHYL-PHENOL	I H	MANY	.0006	.0064

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
3,4-DIMETHYL-PHENOL	I H	WT,IRR	.001	.011
DIMETHYL PHTHALATE	H	NEP	1	11
DIMETHYL TEREPHTHALATE	IH	NEP	.1	1.1
M-DINITROBENZENE	I H	SPLEEN	.0001	.0011
DINITROBENZENE (o,p-)	H	SPLEEN	.0004	.0043
2,4-DINITROPHENOL	I H	THERAPUTIC CATARACT	.002	.021
2,4-DINITROTOLUENE AND 2,6-DINITROTOLUENE 2 year rat-liver, mam, (B2), 6.8 (-1), HBEL = 2.7 (-5) BASED ON A MIXTURE OF 2,4 AND 2,6 ISOMERS				
DI-N-OCTYL-PHTHALATE	H	HEP,NEP WT	.02	.21
DINOSEB	I H	REP	.001	.011
ADDED SF=1- FOR POSITIVE CARC STUDIES				
1,4-DIOXANE 2 year rat-nas. cav., liver, (B2), 1.1 (-2), HBEL = 1.7 (-3)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
DIPHENYLAMINE (DPA)	I H	WT, HEP & NEP WT	.025	.27
1,2-DIPHEYNLHYDRAZINE 2 year rat-liver,mam, ear, (B2), 2.2 (-4)**, HBEL = 2.4×10^{-5}				
DISULFOTON	I H	ACH, OPT	.00004	.00043
DYES: DIRECT BLACK 38 93 day rat-liverr, (A) 8.7 (0), HBEL = 2.1×10^{-6}				
DIRECT BLUE 6 91 days rat-liver, (A) 8.7 (0), HBEL = 2.1×10^{-6}				
DIRECT BROWN 95 91 day rat-liver (A), 9.3 (0), HBEL = 1.9×10^{-6}				
ENDOSULFAN	I H	NEP	.00005	.00053
ENDOTHALL	I H	STOMACH	.02	.21
ENDRIN	I H	HEP, CNS	.0003	.0032
EPICHLOROHYDRIN lifetime rat-resp. tract, (B2), 1.2 (-6)*, HBEL = 4.4×10^{-3}	I H	NEP,M	.0003*	.001
2-ETHOXYETHANOL	I H	HEM,WT	.2*	.69
ETHYL ACETATE	I H	MORT, WT	.9	9.6

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
ETHYL ACRYLATE				
lifetime rat-forestomach, (B2),.048, HBEL = 3.8×10^{-4}				
ETHYLBENZENE	I H	HEP, HEP, REP	.1*	.35
ETHYL CHLORIDE	H	REP	10*	34.5
EPTC	I H	CIR	.025	.27
ETHYLENE CHLORIDE - SEE 1,2-DICHLOROETHANE				
ETHYLENE CYANOHYDRIN	H	BRAIN WT, WT	.3	3.2
ETHYLENEDIAMINE	H	HEM, HEP	(.1)*	3.5
ETHYLENE DIBROMIDE - SEE 1,2-DIBROMOETHANE				
ETHYLENE GLYCOL	I H	HEP, NEP, MORT	2	21.3
ETHYLENE GLYCOL MONOBUTYL ETHER	H	HEM	.02*	.069
ETHYLENE OXIDE				
lifetime, rat-blood cells, brain, (B1), 1.0 (-4)*, HBEL = 5.3(-5)				
ETHYLENE THIOUREA				
lifetime, rat-thyroid, (B2), 3.6 (-2), HBEL = 5.0(-4)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
under review by CRAVE				
ETHYL ETHER	I H	HEP	.5	5.3
ETHYL METHACRYLATE	H	NEP	.09	.96
ETHYLPHALYL ETHYLGLYCOLATE (EPEG)	I		.3	3.2
FLUORANTHENE	I H	HEP, HEP, HEM	.04	.43
FLUORENE	I H	HEM	.04	.43
FLUORIDONE	I H	TEST, NEP	.08	.85
FOLPET	I H	HEM	.1	1.1
lifetime, mouse-digestive tract (B2), 3.5 (-3), HBEL = 5.2 (-3)				
FORMALDEHYDE				
lifetime rat-nasal cavity, (B1), 1.3 (-5)*, HBEL = 4.1 (-4)				
FORMIC ACID	H	GRO	2	21.3
FURAN	I H	HEP	.0001	.001
ADDED SF= 10 BASED ON INFO RE INHAL. RESPONSE				
FURAZOLIDONE				
one year rat-mammary, (B2), 3.8 (0), HBEL = 4.7 (-6)				
FURFURAL	I H	HEP, M	.05*	.017
FURIUM				
half-year, mouse-leukemia, (B2), 5.0(0), HBEL = 3.6 (-6)				
GLYCERALDEHYDE	I H	NEP, WT	.001*	.0035
70 week, rat-site not listed, (B2)				
HEPTACHLOR	I H	HEP WT	.0005	.0053

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
MALONONITRILE	H	HEP, SPLEEN	.00002	.00021
MANCOZEB	H	GOITER	.03	.32
MANEB	I H	THY WT	.05	.53
MANGANESE	I H	RESP,NER	.0004*	.0014
MEPHOSFOLAN	H	HEP, NEP,HEM,ACH	.00009	.00096
MERCURY (INORGANIC)	I H	NER, HEP	.0003*	.001
MERPHOS	I H	NER	.00003	.00032
MERPHOS OXIDE	I H	NER	.00003	.00032
METHACRYLONITRILE	I H	NER, HEP	.0007*	.0024
METHANOL	I H	HEP, NER WT	.5	5.3
METHOMYL	I H	NEP	.03	.32
METHOXYCHLOR	I H	REP	.005	.053
2-METHOXYETHANOL	H	TEST	.02*	.69
2-METHOXY-5-NITROANILINE				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
lifetime, rat-skin (note dietary exposure), (B2), 4.6 (-2), HBEL = 3.9(-4)				
METHYL ACETATE	H	HEP	1	10.7
METHYL ACRYLATE	H	NONE	CALCULATE*	
2-METHYLANILINE				
lifetime, rat-skin (note dietary exposure), (B2), 2.4 (-1), HBEL = 7.6(-5), BASED ON EXPOSURE TO HYDROCHLORIDE FORM				
2-METHYLANILINE HYDROCHLORIDE				
lifetime, rat-skin (note dietary exposure), (B2), 1.8 (-1), HBEL = 1 (-4)				
METHYL BROMIDE (SEE BROMOMETHANE)				
METHYL CHLORIDE (SEE CHLOROMETHANE)				
2-METHYL-4-CHLOROPHENOXY ACETIC ACID (MCPA)	I H	HEP	.0005	.0053
4-(2-METHYL-4-CHLOROPHENOXY)-BUTURIC ACID (MCPB)	I H	HEP, NEP, REP	.01	.11
PROPRIONIC ACID (MCPP)	I H	NEP	.001	.011

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
4,4-METHYLENE-BIS BENZELAMINE lifetime, rat-liver, no class, 2.5 (-1), HBEL = 7.2(-5)				
4,4-METHYLENE-BIS(2-CHLOROANILINE)	II	BLAD, HEP	.0007 .0075	
lifetime, rat-lung,(note dietary exposure), (B2), 3.7 (-5)**, HBEL = 1.4(-4)				
4,4-METHYLENE BIS (N,N,-DIETHYLANILINE) lifetime, rat-thyroid (B2), 4.6 (-2), HBEL = 3.9(-4)				
METHYLENE BROMIDE	H	HEM	CALCULATE	
METHYLENE CHLORIDE	H	HEP	3*	10.4
no term given, mouse-lung, (B2), 4.7 (-7)*, HBEL = 1.1 (-2)				
4,4-METHYLENEDIPHENYLISOCYANATE	II M		.00005*	.00017
METHYL ETHYL KETONE	I H	CNS,REP	.3*	1.0
METHYL HYDRAZINE lifetime, hamster-liver, no class, 1.1 (0), HBEL = 1.6 (-5)				
METHYL ISOBUTYL KETONE	I H	HEP, NEP	.08*	.028
METHYL MERCURY	H	CNS	.0003	.032
METHYL METHACRYLATE	II	NEP WT	.08	.85
2-METHYL-5-NITROANILINE lifetime, mouse-liver (C), 3.3 (-2), HBEL = 5.5 (-4)				
METHYL PARATHION	I II	HEM, ACH	.00025	2.6 (-3)
METHYL STYRENE (INDUSTRIAL MIXTURE)	II	IRR	.04*	.14
MIREX	I II	REP	.000002	.000021
lifetime, rat-liver, (B2), 1.8 (0), HBEL = 1 (-5)				
MOLYBDENUM	II	M	.004	.043
MOLINATE	I H	REP	.002	.021
MONOCHLOROBUTANES	H	MORT	.4	4.3
NAPHTHALENE	II	WT	.004	.043
NICKEL SULFATE	H	CANCER	.02	.021
nickel refinery dust- human-resp., (A), 2.4 (-4)*, HBEL = 2.2 (-5) nickel subsulfide- human-resp., (A), 4.8 (04)*, HBEL = 1.1 (-5)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
NITROBENZENE	II	HEM, NEP, HEP,AD	.002*	.0069
NITROFURANTOIN	H	TEST	.07	.75
NITROFURAZONE one year, rat-mammary, (B2), 1.5 (0), HBEL = 1.2 (-5)				
NITROGEN DIOXIDE	I H	RESP, HEM	.02*	.069
2-NITROPROPANE lifetime, rat-liver, (B2), 2.7 (-3)*, HBEL = 2.0(-6)	I H	HEP	.02*	.069
NITROTOLUENES(O,M,P)	II	SPLEEN	.01	.11
N-NITROSO-DI-N-BUTYLAMINE lifetime mouse-bladder, esophagus, (B2), 1.6 (-3)**, HBEL = 3.3 (-6)				
N-NITROSODIETHYANOLAMINE lifetime, rat-liver, (B2), 2.8 (0), HBEL = 6.4 (-6)				
N-NITROSODIETHYLAMINE (DIMETHYLNITROSAMINE) 6 and 12 months, rat-liver, (B2), 4.3 (-2)**, 1.2 (-7)				
N-NITROSODIMETHYLAMINE (DIETHYLNITROSAMINE) no term given, rat- liver, lung, skin, seminal vesicles, hem/lymph, (2), 1.4 (-2)**, HBEL = 3.8 (-7)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
N-NITROSODIPHENYLAMINE lifetime, rat-urinary bladder (B2), 4.9 (-3), HBEL = 3.7(-3)				
N-NITROSODI-N-PROPYLAMINE lifetime, rat-liver (B2), 7.0 (0), HBEL = 2.6 (-6)				
N-NITROSO-N-METHYL-ETHYLAMINE lifetime, rat-liver, (B2), 2.2 (+1), HBEL = 8.2 (-7)				
N-NITROSOPYRROLIDINE no term given, rat-liver, (B2), 6.1 (-4)**, HBEL = 8.6(-6)				
OBPDE	I	HEP	.00062	.0066
OCTABROMODIPHENYL ETHER	I H	HEP	.003	.032
OCTAMETHYLPYROPHOSPHORAMIDE	II	ACH	.002	.021
OXAMYL	I	ACH	.025	.27
PACLOBUTRAZOL	I	HEP, TERAT	.013	.14
PARAQUAT (C)	I	RESP	.00045	.005
PARATHION	II	ACH	.006	.064

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
PBBs see POLYBROMINATED BIPHENYLS				
PCBs see POLYCHLORINATED BIPHENYLS				
PEBULATE	H	HEM	.05	.53
PENDIMETHALIN	H	HEP	.04	.43
PENTABROMODIPHENYL ETHER	I H	HEP	.002	.021
1,2,3,4,5-PENTABROMO-6-CHLORO-CYCLOHEXANE lifetime, rat-large intest, (C) 2.3 (-2), HBEL=7.8(-4) based on alpha isomer				
PENTACHLOROBENZENE	I H	HEP, NEP	.0008	.0085
PENTACHLORONITROBENZENE 1.5 year, mouse-liver, (C), 2.6 (-1), HBEL = 6.9(-4)	I H	HEP	.003	.032
PENTACHLOROPHENOL lifetime, mouse-liver, adrenal, circ, (B2), 1.2 (-1), HBEL = 2.2 (-5),technical grade and Dow product	I H	NEP, HEP	.03	
PERMETHRIN	I	HEP.WT	.01	.11
PHENOL	I H	REP	.6	6.4

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
M-PHENYLENEDIAMINE	I H	HEP	.006	.064
o-PHENYLENEDIAMINE DIHYDROCHLORIDE 1.5 years, rat-liver, (B2), 4.7 (-2), HBEL = 3.8(-4)				
PHENYLMERCURIC ACETATE	I H	NEP	.00008	.00085
2-PHENYLPHENOL (SODIUM SALT) lifetime, rat-urinary bladder, (C), 1.9 (-3), HBEL = 9.5(-3)				
PHOSPHINE	I H	NEP	.00003*	.0001
P-PHTHALIC ACID	H	BLAD	1	10.7
PHTHALIC ANHYDRIDE	I H	RESP, NEP	2	21.3
POLYBROMINATED BIPHENYLS (Firemaster FF-1 tested for cancer) one year exposure & one year observation, rat-hepatocellular. carcinoma and neoplastic nodules, (B2), 8.9 (0),HBEL=2(-6)	H	HEP	.000007	.000075
POLYCHLORINATED BIPHENYLS (USED ARACHLOR 1260 FOR CANCER STUDY) no term givern, rat-liver, (B2), 7.7 (0),HBEL = 2.3(-6)				
POTASSIUM CYANIDE	I H	WT, THY, NER	.05	.53
POTASSIUM SILVER CYANIDE (CALCULATED BY ANALOGY TO FREE CYANIDE, ADJUSTED FOR MOL WT.)	I H	WT, THY, NER	.2	.21

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
PROFLURALIN	II	NONE	.006	.064
PRONAMIDE	I H	NONE	.08	.85
PROPACHLOR	I H	WT	.013	.14
PROPANIL	I	SPL,HEP	.005	.053
PROPAZINE	I II	WT,CARC	.002	.021
PROPOXUR (BAYGON)	I	ACH, NER	.004	.043
PROPYLENE GLYCOL	H	HEM	6*	20.7
PROPYLENE GLYCOL MONOETHYL ETHER	II	WT	.7	2.4
PROPYLENE GLYCOL MONOMETHYL ETHER	II	NER, HEP, NEP	.7*	7.5
PROPYLEN OXIDE	I H	IRR	.03*	1.0
lifetime, mouse0-nasal cavity, (B2), 3.7 (-6)*,HBEL=1.4(-3)				
PYDRIN (FENVALERATE)	I	NER, PIT.GL LYMPH.N, HEP, SPL,	.0025	.027
PYRENE	I H	NEP	.03	.32
PYRIDINE	I H	HEP WT	.001	.011
QUINALOPHOS	I		.0001	.001
QUINOLINE				
20-40 weeks, rat-liver, (C), 1.2 (+1), HBEL = 1.5(-6)				
RDX (CYCLONITE)	I II	HEM, M	.003	.032
lifetime, mouse-hepat. carc, and adenom., (C), 1.1 (-1). HBEL = 1.6 (-4)				
RONNEL	II	NEP, HEP	.05	.53
SELENIOUS ACID	I II	DERM	.003	.032
SELENIUM SULFIDE				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
lifetime, rat, mouse-liver, lung, (B2), number pending IRIS input pending				
SELENOUREA	II	no data	.005	.053
SETHOXYDIM	I	HEM, HEM, REPRO	.09	.96
SILVER CYANIDE	I II	WT, THY,NER	.1	1.1
(CALCULATED BY ANALOGY TO FREE CYANIDE ADJUSTED FOR molecular weight)				
SIMAZINE	I II	HEM, WT	.002	.021
limited data, (C), 1.2 (-1), HBEL = 1.5 (-4)				
SODIUM AZIDE	I	HEP.WT	.004	.043
SODIUM CYANIDE	I II	NER	.04	.43
(CALCULATED BY ANALOGY TO FREE CYANIDE ADJUSTED FOR molecular weight)				
SODIUM DIETHYL-DITHIOCARBAMATE	I II	HEM, NEP, WT	.03	.32
no term given, mouse-hepatoma, (C), 2.7 (-1), HBEL=6.7(-5)				
SODIUM METAVANADATE	II	NEP	.001	.011
STIROPHOS - SEE TETRACHLORVINPHOS				
STRYCHININE	I H	M	.0003	.0032
STYRENE	II	HEM, HEP	.2	2.1
20 month, rat-leukemia, (B2), 5.7 (-7)*, HBEL=9.2 (-3)				
2,3,7,8-TCDD				
no term given, rat-several, (B2), inhalation units unclear, possible picograms, use conversion from oral, 1.5 (+5), HBEL = 1.2(-10) NOTE: human cancer evidence is withmixture with chlorophenoxys or phenoxy herbicides.				
TEMEPHOS	II	NONE	.02	.21

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
TERBUFOS	II	NONE	.0001	.001
1,2,4,5-TETRACHLOROBENZENE	I H	NEP	.0003	.0032
1,1,1,2-TETRACHLOROETHANE				
lifetime, mouse-liver, (C), 7.4 (-6)**, HBEL=7.1(-4)				
1,1,2,2-TETRACHLOROETHANE (TCE)				
no term given, mouse-liver, (C_), 5.8 (-5)**, HBEL=9.1(-5)				
TETRACHLOROETHYLENE				
(PERCHLORETHYLENE)	I H	HEP	.01	.11
no term given, rat, mouse-leukemia, liver, (B2), 5.2 (-7)*, HBEL = 1 (-2)				
2,3,4,6-TETRACHLOROPHENOL	I H	HEP	.03	.32
p.a,a,a-TETRACHLOROTOLUENE				
no term given, mouse-lung, (B2),2.0 (+1),HBEL = 9 (-7)				
TETRACHLORVINPHOS(STIROFOS)	I H	HEP, NEP,WT, REPRO	.03	.32
1.5 year, mouse-liver, (C), 2.4 (-2), HBEL = 7.5 (-4)				
TETRAETHYL DITHIO-PYROPHOSPHATE	I H	HEM, ACH	.0005	.0053
TETRAETHYL LEAD	I H	HEP, THYMUS	1 (-7)	1.1(-6)
THALLIC OXIDE (III) AND THALLIUM IN SOLUABLE SALTS	H	HEP, M	.00007	.00075
(CALCULATED FROM THALLIUM SULFATE)				
THALLIUM(I)ACETATE AND THALLIUM (I) NITRATE, AND THALLIUM				
SELENITE	I H	HEP, M	.00009	.00096
(CALCULATED FROM THALLIUM SULFATE)				
THALLIUM(I)CARBONATE AND THALLIUM (I) SULFATE, AND THALLIUM (I)				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
CHLORIDE	I H	HEP, M	.00008	.00085
(CALCULATED FROM THALLIUM SULFATE)				
2-(THIOCYANOMETHYLTHIO)-BENZO				
THIAZOLE (TCMTB)	H	STOMACH	.03	.32
THIOFANOX	H	ACH	.0003	.0032
THIRAM	I H	REP	.006	.064
TIN & COMPOUNDS	H	HEP, NEP	.6	6.4
TOLUENE	I H	NER,IRR,NEP,HEP WT	2*	21.3
TOLUENE-2,4-DIAMINE				
lifetime, rat-mammary gland, (B2), 3.2 (0), HBEL = 5.6 (-6)				
TOLUENE-2,5-DIAMINE	H	NONE	.2	2.1
O-TOLUIDINE				
1.5 year rat-skin fibroma (note dietary exposure to sodium salt), (B2), 2.4 (-1), HBEL = 4.3 (-6)				
p-TOLUIDINE				
6 - 12 month, mouse-liver, (C), 1.9 (-1), HBEL = 3.4 (-6)				
TOXAPHENE				
lifetime, mouse-liver,(B2), 3.2 (-4)**, HBEL = 1.6(-5)				
TRIALLATE	I H	SPLEEN, HEP	.013	.14
1,2,4-TRIBROMOBENZENE	I H	HEP	.005	.053
2,4,6-TRICHLOROANILINE				
no term given, mouse-vasc. syst., (C), 3.4 (-2), HBEL=6(-7) exposure to sodium salt				

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
2,4,6-TRICHLOROANILINE HYDROCHLORIDE				
no term given, mouse-vasc. syst., (C), 2.9 (-2), HBEL = 5.2(-7),exposure to sodium salt				
1,2,4-TRICHLOROBENZENE	H	BLAD	.009*	.03
1,1,1-TRICHLOROETHANE	H	HEP	1*	3.45
1,1,2-TRICHLOROETHANE	I H	M	.004	.043
no term given, mouse-;liver, (C), 1.6 (-5)**, HBEL = 3.3(-4)				
TRICHOETHYLENE				
no term given, mouse-lung, (B2), 1.7 (-6)*, HBEL = 3.1 (-3) new values pending input to IRIS				
TRICHLOROFLUOROMETHANE (F-11)	I H	RESP, MORT	.7*	2.4
2,4,5-TRICHLORPHENOL	I H	HEP, NEP	.1	1.1
2,4,6-TRICHLOROPHENOL				
no term given, mouse-liver, (B2), 3.1 (-6)**, HBEL = 1.7 (-3)				
2,4,5-TRICHLOROPHENOXYACETIC ACID	I H	MORT	.01	.11
2(2,4,5-TRICHLOROPHENOXY)PROPIONIC ACID(SILVEX)	I H	HEP	.006	.064

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
1,1,2-TRICHLOROPROPANE	I H	HEP, NEP, THY	.005	.053
1,2,3-TRICHLOROPROPANE	I H	HEM, HEP, NEP, STO, SPL CARC UNDER EVALUATION	.006	.064
1,1,2-TRICHLORO-1,2,2,-TRI FLUOROETHANE	H	WT	UNDER REVIEW: 27*	93.1
-TRIFLURALIN	I H	HEP, HEM	.0075	.08
lifetime, rat-kidney, bladder, thyroid, (C), 7.7 (-3), HBEL = 2.3 (-3)				
TRIMETHYL PHOSPHATE				
10 week, mouse-uterus, (B2), 3.7 (-2), HBEL = 4.9 (-4)				
1,3,5-TRINITROBENZENE	I H	SPLEEN WT	.00005	.00053
TRINITROPHENYLMETHYLNITRAMINE	H	HEP, NEP, SPLEEN.	.01	.11
2,4,6-TRINITROTOLUENE	I H	HEP	.0005	.0053
lifetime, rat-urinary bladder, (C), 3.0 (-2), HBEL = 6 (-4)				
VANADIUM (SULFATE)	H	NONE	.007	.075

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL
VANADIUM PENTOXIDE	I H	NONE	.009	.096
VANADYL SULFATE	H	NONE	.02	.21
VERNOLATE(VERNAM)	I H	WT	.001	.011
VINYL BROMIDE - SEE BROMOETHANE				
VINYL ACETATE	I H	IRR	.2	2.1
VINYL CHLORIDE				
one year, rat-liver, (A), 8.4 (-5)*, HBEL = 5.3 (-5)				
VINYLIDENE CHLORIDE-SEE 1,1-DICHLOROETHYLENE				
WARFARIN	I	HEM	.0003	.0032
ZINC PHOSPHIDE	I H	WT, M	.0003	.0032
ZINEB	I H	THY	.05	.53

TABLE 3

HBELs DERIVED FROM ENVIRONMENTAL RISK VALUES

NAME	DATA SOURCE	STUDY EFFECT	RFD (mg/cubic meter)	HBEL

LIST OF ABBREVIATIONS

A	cancer classification indicating known human carcinogen
B1, B2	cancer classification indicating probable human carcinogen
C	cancer classification indicating suspected human carcinogen
ad	adrenal
ach	acetylcholinesterase
bla	bladder, urinary unless noted
carc	carcinogen, carcinoma
cav	cavity
card	cardiac
cerv	cervix
cir	circulatory
CNS	central nervous system
decr	decrease
derm	dermal
EPA	United States Environmental Protection Agency
esoph	esophagus
gl	gland
gro	growth
H	HEAST= Health Effects Assessment Summary Tables
HBEL	health based exposure limit
HEAST	health effects assessment summary tables (EPA)
hem	hematological
hemor	hemorage
hep	hepatic, liver
hyp epi	hyperplasia of epithelium
I	IRIS= Integrated Risk Information System
im	immune
incr	increase
inh	inhalation
intest	intestine
IRIS	Integrated Risk Information System
irr	irritation

LIST OF ABBREVIATIONS (continued)

kg	kilogram
lg	large
misc	miscellaneous,e.g.clinical parameters unspecified
mam	mammary
mg	milligram
ml	milliliter
mol	molecular
mort	mortality
nas	nasal
nep	nephrotic, kidney
ner	nervous system
opt	optic
pit	pituitary
PNS	peripheral nervous system
rep	reproductive
res	respiratory
RfC	reference concentration (airborne)
RfD	reference dose (contaminant/body weight/day)
SF	safety factors (see Technical Information)
spl	spleen
stom	stomach
sys	system
test	testes
thy	thyroid
tis	tissue
vasc	vascular
wt	weight (overall body unless organ specified)

LIST OF ABBREVIATIONS

A	cancer classification indicating known human carcinogen
B1, B2	cancer classification indicating probable human carcinogen
C	cancer classification indicating suspected human carcinogen
ad	adrenal
ach	acetylcholinesterase
bla	bladder, urinary unless noted
carc	carcinogen, carcinoma
cav	cavity
card	cardiac
cerv	cervix
cir	circulatory
CNS	central nervous system
decr	decrease
derm	dermal
EPA	United States Environmental Protection Agency
esoph	esophagus
gl	gland
gro	growth
H	HEAST= Health Effects Assessment Summary Tables
HBEL	health based exposure limit
HEAST	health effects assessment summary tables (EPA)
hem	hematological
hemor	hemorage
hep	hepatic, liver
hyp epi	hyperplasia of epithelium
I	IRIS= Integrated Risk Information System
im	immune
incr	increase
inh	inhalation
intest	intestine
IRIS	Integrated Risk Information System
irr	irritation

LIST OF ABBREVIATIONS (continued)

kg	kilogram
lg	large
misc	miscellaneous,e.g.clinical parameters unspecified
mam	mammary
mg	milligram
ml	milliliter
mol	molecular
mort	mortality
nas	nasal
nep	nephrotic, kidney
ner	nervous system
opt	optic
pit	pituitary
PNS	peripheral nervous system
rep	reproductive
res	respiratory
RfC	reference concentration (airborne)
RfD	reference dose (contaminant/body weight/day)
SF	safety factors (see Technical Information)
spl	spleen
stom	stomach
sys	system
test	testes
thy	thyroid
tis	tissue
vasc	vascular
wt	weight (overall body unless organ specified)

Appendix 2
Methodology for Calculating HBEL's

I. Introduction

IRIS and HEAST data were used to calculate air concentrations which should pose minimal cancer risk to workers (one in a million) and no risk of chronic health effects to workers. IRIS exposure guidelines and risk estimates were developed for chronic environmental exposures by EPA and were modified for application to chronic occupational exposures for use in this report.

Alternatives to the PELs and TLVs were considered necessary for numerous reasons: Most TLVs and PELs were developed prior to the availability of extensive chronic toxicity data for many chemicals, they were not based on a clear and consistent calculation methodology, they often lacked scientific documentation and they incorporated considerations of feasibility and cost. Many TLVs and PELs are based on effects of short-term expo sure such as skin or eye irritation.

The IRIS and HEAST guideline based on current toxicity data, uti lize state-of-the-art risk assessmer methodology which has gained a broad acceptance in the scientific community. They are derived fro systemic (non-carcinogenic) and ca cinogenic studies of chronic and su chronic exposure. Due to the chro ic nature of most occupational exposures, the air concentration guidelines calculated for this repo may be most appropriate. The com parison of occupational guidelines and standards with HBELS are us ful in identifying occupational limi

Appendix 2 (Continued)
Methodology for Calculating HBEL's

in need of substantial revision.

Reference Doses (RfD's) are maximum exposure recommendations developed by EPA for non-carcinogens found in air or water. RfDs are maximum recommended intakes per day in milligrams per kilogram body weight per day (mg/kg/d). The RfD is estimated to be the maximum lifetime daily exposure level at which no adverse non-carcinogenic effect is expected to occur. EPA's first priority in developing RfDs was to obtain values relevant to drinking water guidelines. Consequently, RfDs calculated for oral exposure were developed first and are the only values available for non-carcinogens as of this writing. The oral RfDs were adapted for the inhalation exposure route relevant to occupational settings for the HBEL's. In cases where RfDs were based upon inhalation studies, results were calculated directlyand are indicated in table 3 with an asterisk.

There is not considered to be a "safe" level of exposure to a carcinogen. Instead, EPA provides risk estimates, Unit Risks, expressed as the estimated cancer risks per microgram per cubic meter of air (ug/m3). These were converted to mg/m3 in this booklet.

The RfDs and Unit Risks were calculated by EPA using standard risk assessment methodology which introduces significant margins of safety. The margins of safety are reflected in the HBEL's. Consequently, the cancer risk es-

Appendix 2
Methodology for Calculating HBEL's

timates (e.g. individual cancer risk at a specific exposure level) are protective rather than predicitve. In most cases they represent the upper 95% confidence bound of the potential risk of exposure for a working lifetime of 40 years.

The HBELs are preliminary alternative exposure limits. They do not take into account significant considerations such as feasability, anecdotal reports of effects following human exposure, and routes of exposure other than inhalation. In spite of these constraints, the HBELs are preliminary health-based guidelines which are significantly safer for workers than current PELs and TLVs.

II. Methodology

Health-based exposure limits (HBEL) were calculated using methods which follow the federal Guidelines for Risk Assessment of Carcinogens (51 FR 33992-34003, Sept. 24, 1986. The methodology employed to develop the IRIS and HEAST values also follows the Federal guidelines and is explained in the IRIS Supplemental Documentation available from EPA.

Sources:

Standards, guidelines and Risk Assessment values (RFDs and NOELs) were obtained from the following sources:

1. **PELs:** 29 CFR, 1910.1000, Tables Z-1, Z-2, Z-3

2. **RELs:** MMWR Supplement, NIOSH Recommendations for Occupational Health and Safety Standards. 9/86, USDHHS.

3. **TLVs:** TLVs and Biological Exposure Indices for 1987 - 1988, ACGIH.

4. **NOELs, LOELs, RFDs, Slope Factors and Unit Risks:** IRIS Data Base, EPA Office of Research and Development, Washington, D.C. 1992.

HEAST: Health Effects Assessment Summary Tables, USEPA, 1992, Washington D.C.

Assumptions:

Numerous assumptions were required to calculate HBELs. The assumptions are listed below. As more information becomes available on topics such as dose rate and thresholds these assumptions may require modification. In addition to the assumptions required for the work done on this report, assumptions were required to develop the IRIS and HEAST values. These are discussed in the IRIS documentation available from EPA.

BREATHING RATE = 10 m3 per 8 hours work

BODY WEIGHT = 60 kg

WORKDAY= 8 hours

WORKDAYS PER YEAR = 240 days

WORKING LIFETIME = 40 years

1. Body Weight: The body weight used in all calculations is based on average female weight (IRCP, 1975). This was done to insure the group at greater risk was adequately considered. The total lung ventilation is very similar for men and women, 22.8 versus 21.2 for 24 hours and 9.6 versus 9.1 for light activity for 8 hours (ICRP,

Appendix 2 (Continued)

Appendix 2
Methodology for Calculating HBEL's

1975). Consequently, women's exposure per kilogram of body weight will result in a higher dose (in mg/kg) than men's. By using the lower (female) body weight in calculations, the HBELs incorporate considerations of womens' health concerns and increase the margin of safety for men.

2. Absorption: A variety of absorption factors have been used in risk assessments to adjust for differences in absorption via different routes of exposure or via the same route of exposure in different species. Absorption is most relevant to the non-carcinogen HBEL calculations which entailed a conversion from the oral to inhalation exposure route. Carcinogenic hazards are generally assumed to be similar via any route of exposure. Except in those rare cases where actual measurements have been made for a specific chemical, there is little scientific foundation for the selection of a particular absorption factor (Hallenbeck and Cunningham, 1986). Consequently, for this report, it was assumed that the proportion of a toxicant absorbed would be the same via oral or inhalation exposure and that it would be the same for study subjects (e.g., mice) and workers.

Whether it is assumed that 90% or 10% absorption occurs, the HBELs would not change as long as study subjects and workers are assumed to absorb the same percentage of the toxicant. Although differences in absorption do exist, detailed information on this is not

Appendix 2
Methodology for Calculating HBEL's

vailable for most chemicals. In most ases, changes in absorption factors ould result in minimalchanges in e final numbers.

3. Body weight versus target tisue mass: An adjustment is incorpoated into the HBELs derived from Ds based on oral exposure studies. his adjustment is equal to the ratio f body weight to the 2/3 power for uman versus animal exposures. It s discussed in the IRIS documentaon. An example of how this has een derived and used for a specific hemical along with a more detailed iscussion can be found in the Health ssessment Document for chloroform EPA, 1985, pages 8-76 to 8-87).

For inhaled toxins it was assumed hat the effective exposure of the target tissue in non-human species is similar to that of humans when corrected for body weight. This follows the approach taken in IRIS for inhaled toxins.

4. Thresholds: Thresholds are assumed to exist for non-carcinogenic effects. Cumulative exposure over long time periods contributes to the occurance of adverse health effects by aggregating chemical exposures to a level at which the effects occur. This may take place by increasing the body burden, incrementally increasing organ damage to a level where it can be ovserved, or through some other mechanism. Thresholds are assumed not to exist for carcinogens. Consequently, the aggregate exposure over a lifetime is relevant to the individual's cancer risk.

Appendix 2 (Continued)

5. Dose Rate: The rate at which a chemical exposure occurs may be a significant factor in the occurance of non-carcinogenic adverse health effects. There are clearly different effects observed following acute high level exposure and chronic low level exposure. However, this report deals with chronic exposures only. Consequently, the assumption is made here that low level environmental exposures which are dealt with in IRIS are very similar to low level occupational exposures and no adjustments were made to the HBELs for dose rate differences.

Some studies have been conducted which indicate cancer risks associated with low level exposure may vary with dose rate. For example, radiation induced cancer risks increase (a higher risk per unit of dose exists) at lower chronic exposure levels than at higher chronic exposure levels (Mays et al. 1978; BEIR, 1980; Upton, 1984; Charmeaud et al. 1977). Current knowledge of the impact of dose rate, continuous and intermittent exposure on risk is very limited. Consequently, no quantitative adjustments were made for these factors. As information becomes available on this topic, adjustments may be recommended to improve the accuracy of dose-response estimates.

CALCULATION OF HBELS

Different methods are used to calculate HBELs for carcinogens and non-carcinogens because they are based on different types of exposure and response data.

Appendix 2 (Continued)

NON-CARCINOGENS:

A "safe" threshold for working lifetime exposure was calculated using a previously estimated "safe" threshold for environmental exposures obtained. in most cases from USEPA. Air concentration guidelines (RfCs) were used when available; however, only oral intake guidelines (RfDs) were available for most chemicals. A route-to-route extrapolation was used to estimate "safe" air concentrations from RfD's.

1. WHEN AIR CONCENTRATION GUIDELINES WERE PROVIDED: the reference concentration (RfC) in mg/cubic meter was adjusted to account for work time exposure duration.
HBEL = RfC x 365/240 days per year x 20/10 cubic meters breathed
=RfC x 3.45

2. WHEN ORAL INTAKE GUIDELINES WERE PROVIDED: RfD in mg/kg/day was adjusted for work time exposure duration and body weight, and the units were converted to airborne exposure units.
HBEL = RfD x 365/240 days per year x 70 kg /10 cubic meters per day = RfD x 10.65

CARCINOGENS

An exposure level was calculated which is estimated to generate a maximum working lifetime risk of less than one in one million.
This was based on the unit risk (UR) obtained, in most cases from USEPA, expressed in lifetime risk per µg/cubic meter.

1. WHEN INHALATION UNIT RISKS WERE PROVIDED: the unit risk was adjusted to account for work time exposure duration and to derive a one in one million risk level.
HBEL = 1 x 10 (-6) x (U R x 1000 ug/mg x 240/365 days per year x 40/

Appendix 2 (Continued)

70 years x 10/20 cubic meters per day)

= 5.26 x 10 (-9) / U R

2. WHEN ORAL INTAKE GUIDELINES WERE PROVIDED: the unit risk was adjusted for work time exposure duration, the oral exposure units were converted to airborne exposure units, and to derive a one in one million risk level. This was divided into two steps:

a. - conversion to units of ug/ cubic meter URair = URoral x 20 cubic meters per day x .001mg/ug x 1/70 kg

= UR x 2.9 x 10 (-4)

b. - adjustment for occupational exposure duration using the same equation shown for inhalation unit risks:

5.26 x 10 (-9) / URair

A SIMPLIFIED APPROACH FOR CARCINOGENS COMBINING THE TWO EQUATIONS DIRECTLY ABOVE YIELDS:

HBEL = 1.8 x 10 (-5)/UR

Appendix 3
IARC Definite, Probable or Possible Human Carcinogens With OSHA Regulations or NIOSH recommended Standards (as of 1988)

Chemical name	IARC Vol:pg	Organ system definite carcinogens (probable carcinogens) [possible carcinogens] {animal carcingen, with human data lacking}	OSHA	NIOSH
Acrylonitrile	19:73	(Lung, trachea and bronchus) (Stomach;ProstateBrain;Lympopoietic)	X	
2-Acetylamino fluorine (Acetamide)	7:197	{Animal carcinogen}	X	
Adriamycin	10:43	(Leukemia, osteosarcoma)		
Aflatoxins	10:51	Liver		
Alcoholic beverages	44:259	Oral cavity; pharynx; larynx;Esophagus; liver		
Aluminum production	34:37	(Lung; Bladder)		
4-Aminobi- phenyl	1:74	Bladder	X	
Amitrole	7:31	(Lung, trachea and bronchus)		
Volatile Anesthetics	11:285	(Pancreas;lymphatic and hematopoietic)		
Analgesics w/ phenacetin	24:135	Renal pelvis (bladder,ureter)		
Arsenic & cpds.	23:39	Lung, trachea and bronchus Skin(Angiosarcoma of liver;lymphatic& hemat)	X	
Artificial sweeteners-cyclamates, -saccharin	22:171	(Bladder)		
Asbestos	14:	Mesothelioma of peritoneum Mesothelioma of pleura; Lung (GI tract;larynx)	X	
Auramine	1:69	(Bladder)		
Azathioprine	26:47	Lymphoma(liver;lung;thyroid;leukemia) (soft tissue sarcoma; skin; melanoma; bladder)		
Benzene	29:93	Leukemia	X	
Benzidine	29:149	Bladder	X	
Benzidine-based dyes				
•Direct Black 38	29:295	(Bladder)		
•Direct Blue 6	29:311	(Bladder)		
•Direct Brown 95	29:321	(Bladder)		
Benzo(a)pyrene	32:211			
Beryllium	29:321	(Lung)		X
Betel quid and tobacco	37:141	Oral		

Appendix 3 (Continued)
IARC Definite, Probable or Possible Human Carcinogens
With OSHA Regulations or NIOSH recommended Standards
(as of 1988)

Chemical name	IARC Vol:pg	Organ system definite carcinogens (probable carcinogens) [possible carcinogens] [animal carcingen, with human data lacking]	OSHA	NIOSH
N,N-Bis(2-chloroethyl)-2-naphthylamine	4:119	Bladder		
BCNU	26:79	(Leukemia)		
BCME,CMME	4:231	Lung	X	
Bleomycins	26:97	(Leukemia)		
4-Butanediol dimethane-sulfonate	4:247	Leukemia		
Cadmium	11:39	(Pharynx;colon;rectum) (lung,trachea and bronchus;prostate;kidney)	X	
Carbon black	33:35	[Animal carcinogen]		X
Carbon tet.	20:371	(Liver)		
ChemoRx (MOPP)	26:311	Leukemia (lymphoma)		
Chlorambucil	26:115	Leukemia		
Chloramphenicol	10:85	Leukemia		
Chlordane, heptachlor	20:45,129	(Neuroblastoma;leukemia)		
1-(2-chloroethyl)-3- cyclohexyl-1-nitrosourea	26:137	(Leukemia)		
Chlorinated toluene production:				
•Benzalchloride	29:49	(Lung)		
•Benzotrichloride	29:73	(Lung)		
• Benzylchloride	29:185	(Lymphoma)		
Chlorophenols	20:349	(Soft tissue sarcoma)		
Chlorophenoxy herbicides	41:319	(Soft tissue sarcoma; Lung, trachea & bronchus)		
Chloroprene	19:131	[GI tract;lung,trachea&bronchus] [Lymphatic&hematopoietic systems]		
Chromium VI	23:205	Lung, trachea & bronchus (GI tract; nose and nasal sinus)		X
Coke production	34:101	Skin, lung, trachea & bronchus		X
Cyclophosphamide	26:165	Bladder (skin;lymphatic;leukemia)		
Chrysene	32:247	[Animal carcinogen]		X
Coal tar	35:83	Skin		
2,4-D and esters	15:111	(Soft tissue sarcoma;lymphoma)		
Ortho- and para-Dichlorobenzenes	29:213	(Leukemia)		X
Diethyl sulfate	4:277	(Larynx)		
Dimethyl sulfate	4:271	(Lung, trachea & bronchus)		
Epichlorhydrin	11:131	(Lung, trachea & bronchus)		
Estrogens and Progestins:				
• contraceptives	21:103	(Liver; Breast;Cervix)		
•Diethylstilbestrol	21:173	Cervix; vagina (Breast;Endometrium;Ovary)		
Ethylene oxide	32:189	(Stomach; leukemia)		
Ethyleneimine	9:37	[Animal carcinogen]		X
Formaldehyde	29:345	(GI tract;skin;prostate;kidney;Brain;Hodgkin's)		
Hexachlorocyclo-hexanes	20:195	(Leukemia)		
Hydralazine	24:85	(Breast)		
INH	4:159	(Lung, trachea & bronchus)		
Iron&Steelfoundry	34:133	(Lung)		
Lead&cpds.	23:325	(Lung, trachea & bronchus)		
Leather goods mfg.	25:279	(Bladder;leukemia)		
Leather tanning and processing	25:201	(Bladder)		
Lumber and saw mills (including logging)	25:49	(Adenocarcinoma of nose & nasal sinus) (Soft tissue sarcoma;lymphoma) (Hodgkin's Disease)		
Man-made Mineral fibers: Glass,Rock,Slag wool				
•Slag wool	43:152	Lung		

Appendix 3 (Continued)
IARC Definite, Probable or Possible Human Carcinogens With OSHA Regulations or NIOSH recommended Standards (as of 1988)

Chemical name	IARC Vol:pg	Organ system definite carcinogens (probable carcinogens) [possible carcinogens] {animal carcingen, with human data lacking}	OSHA	NIOSH
Mfg. isopr. alcohol	15:223	Nose and nasal sinus (Larynx)		
Mfg. of magenta	4:57	(Bladder)		
Melphalan	9:167	Leukemia		
Methoxsalen +UVA(PUVA)	24:101	Skin		
MBOCA	4:73	[Animal carcinogen]		
Mineral oil	33:87	(Lung)		
Mustard gas	9:181	Lung, trachea & bronchus(pharynx;larynx)		
1-Naphthylamine	4:87	(Bladder)	X	
2-Naphthalamine	4:97	Bladder	X	
n-Nitrosodimethyl-amine	17:125	[Animal carcinogen]	X	
Nickel refining	11:75	Nose; Lung (Larynx)		X
Nickel and cpds.	11:75	(Nose; Lung;Larynx)		X
Nitrogen mustard	9:193	(Skin;Leukemia)		
Oxymethalone	13:131	(Liver)		
Pentachlorophenols	20:303	(Soft tissue sarcoma;Lymphoma;Leukemia)		
Phenacetin	24:135	(Bladder; renal pelvis)		
Phenobarbital	13:157	(Lung;Brain)		
Phenoxy herbicides	15:111,273	(Soft tissue sarcoma; Lymphoma)		
Phenylbutazone	13:183	(Leukemia)		
n-Phenyl-2-naphthylamine	16:325	(Bladder)		
Phenytoin	13:201	(Neuroblastoma; Neural crest;Lymphoma)		
PCB's	18:43	[GI tract;liver;pancreas; Melanoma; Lymph]		
Procarbazine	26:311	(Leukemia)		
B-Propiolactone	4:259	[Animal carcinogen]	X	
Propyl thiouracil	7:67	(Thyroid)		
Pulp and paper mfg.	25:157	(Lymphoma; Hodgkin's Disease)		
Radon	43:241	Lung		
Reserpine	24:211	(Breast)		

Appendix 3 (Continued)
IARC Definite, Probable or Possible Human Carcinogens With OSHA Regulations or NIOSH recommended Standards (as of 1988)

Chemical name	IARC Vol:pg	Organ system definite carcinogens (probable carcinogens) [possible carcinogens] {animal carcingen, with human data lacking}	OSHA	NIOSH
Rubber mfg.	28:	Bladder; leukemia (Esophagus;stomach;colon;pancreas) (Lung, trachea & bronchus; thyroid) (Skin;testis;brain)		
Shale oils	35:761	Skin		
Silica (crystalline)	42:39	(Lung;GI)		
Soots, tars	3:22	Skin (GI tract;larynx; Lung; Bladder)		
Styrene	19:231	(Lymphoma; myeloma; leukemia)		
2,4,5-T and esters	15:273	(Soft tissue sarcoma;lymphoma)		
Tobacco smoke	38:37	Lung, trachea & bronchus; pancreas; Renal pelvis; oral; oropharynx; hypopharynx Larynx; esophagus;bladder		
Tris(1-aziridinyl)-phosphine sulfide	9:85	(Leukemia)		
Treosulfan	26:341	Leukemia		
Underground hematite mining (exposure to radon)	1:29	Lung, trachea & bronchus		
Vinblastine	26:349	(Leukemia)		
Vincristine	26:365	(Leukemia)		
Vinyl chloride	19:377	Angiosarcoma of liver (GI tract; Lung; Brain; Lymph)	X	

[Adapted from Cone J, Rosenberg J. Medical Surveillance and Biomonitoring for Occupational Cancer Endpoints. Occupational Medicine: State of the Art Reviews 1990;5: 563-581.]

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American Conference of Governmental Industrial Hygienists (1989). Threshold limit values and biological exposure indices for 1989-1990. Cincinnati: ACGIH.

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Cunningham K (1988). A comparison of PEL's and TLV's to health based exposure limits derived from the IRIS data base. Report to OSHA by the New Jersey Department of Health, October 5, 1988.

IRIS Database 1993: Integrated Risk Information System, USEPA, on line via TOXNET, also via National Technical Information Service, Washington, D.C.

Roach SA, Rappaport SM (1990). But they are not thresholds: A critical analysis of the documentation of the threshold limit values. Am J of Industrial Medicine 17:727-753.

Robinson JC, Paxman DG, Rappaport SM. Implications of OSHA's reliance on TLV's in Developing the Air Contaminants Standard. Am J Ind Med 1991;19:3-13.

Tarlau ES (1990). Industrial hygiene with no limits. Am Ind Hyg Assoc J 51:A-9.

Ziem GE, Castleman BI (1989). Threshold limit values: Historical perspectives and current practice. J Occ Med 31:910-918.

Lowest Occupational Exposure Levels have been revised based on:

International Labor Organization, International Exposure Limits for Airborne Toxic Substances, Geneva, 3rd Ed., 1991.

Cook W. Occupational Exposure Limits – Worldwide. AIHA, 1987.

ANNEXE N°7

Méthode utilisée par le Dr.K.Cunningham (communication personnelle)

DRAFT

A COMPARISON OF PEL'S AND TLV'S TO HEALTH-BASED EXPOSURE LIMITS DERIVED FROM THE IRIS DATA BASE

Kathleen Cunningham, Ph.D.

New Jersey Department of Health

Occupational Health Service

July 8, 1988

file: iris.tlv

Original work c/o (NE) HEAST - has explanation
Contains IRIS & methods discussion & Appendices

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Introduction

The following report contains a comparison of the maximum levels of occupational exposure recommended by ACGIH's Threshold Limit Values (TLV's) and NIOSH's Permissible Exposure Limits (PEL's) to exposure limits derived from USEPA's (EPA) Integrated Risk Information System (IRIS) for 49 chemicals including suspected or known carcinogens. IRIS data were also used to calculate air concentrations which should pose no risk of chronic health effects and minimal cancer risk (one in a million) to workers. Brief summaries are included of systemic and carcinogenic toxciology data used as the basis for the comparisons and air concentration recommendations for each chemical.

IRIS exposure guidelines and risk estimates were developed for chronic environmental exposures by EPA and were modified for application to chronic occupational exposures for use in this report. A comparison of occupational standards and guidelines to IRIS based guidelines was considered useful for two reasons. The IRIS guidelines are based on current toxicity data, are extensively peer reviewed and utilize state-of-the-art risk assessment methodology which has gained a broad acceptance in the scientific community. (Appendix A contains a detailed explaination of the methodology.) Most TLV's and PEL's were developed prior to the availability of extensive chronic toxicity data for many chemicals, were not based on a clear and consistent calculation methodology, often lacked documentation and may incorporate considerations of feasibility and cost. Secondly, IRIS values are based on systemic (non-carcinogenic) and carcinogenic effects of chronic and subchronic exposure. Many of the TLV's and PEL's are based on effects of short-term exposure such as skin or eye irritation. Due to the chronic nature of most occupational exposures, the air concentration guidelines

derived for this report from the IRIS values may be more appropriate. The comparison of occupational guidelines and standards with IRIS values could be useful in identifying occupational limits in need of substantial revision.

IRIS maximum exposure recommendations were developed by EPA for non-carcinogens which the general population would be exposed to (e.g. via air or water pollution). They are given in the form of Reference Doses (RfD's) which are maximum recommended intakes per day in miligrams per kilogram body weight per day (mg/kg/d). The RfD is estimated to be the maximum lifetime exposure level at which no adverse systemic (non-carcinogenic) effect is expected to occur. EPA's first priority in developing IRIS RfD's was to obtain values relevant to drinking water guidelines; consequently, RfD's calculated for oral exposure were developed first and are the only values available for non-carcinogens as of this writing. The oral RfDs' were adapted for the inhalation exposure route relevant to occupational settings for purposes of this report. In cases where RfD's were based upon inhalation studies, both results calculated directly from the studies and from the oral RfD's are given in this report.

For carcinogens, IRIS does not provide a relevant RfD, since there is not considered to be a "safe" level of exposure to a carcinogen. Instead, risk estimates are provided: Slope Factors which give the estimated cancer risks per mg/kg/day and Unit Risks which give the estimated cancer risks per microgram per cubic meter of air (ug/m3). These were used to calculate the estimated individual cancer risks based on a working lifetime of exposure for this report. Slope Factors and Unit Risks are defined in detail in the Key and methods used in IRIS to calculate these values are presented in Appendix A. For potentially carcinogenic chemicals which do not have IRIS

cancer risk values, but which have other EPA carcinogenic risk estimates, the alternative cancer risk data are listed with their sources.

The RfD's and Unit Risks were calculated using standard risk assessment methodology which introduces significant margins of safety. The margins of safety are reflected in the worker risk levels and exposure limit recommendations calculated for this report. Consequently, the risk estimates (e.g. individual cancer risk at a specific exposure level) are protective rather than predictive. In most cases they represent the upper 95% confdidence bound of the potential risk of exposure for a working lifetime of 40 years.

RfD's and Unit Risks were used to calculate a Workday Ambient Air Concentration (WAC) in mg/m3 for this report. By modifying the exposure duration parameters used by EPA to compute RfD's and Unit Risks, WAC's could be calculated to estimate the maximum exposure level which would pose no risk of systemic health effects for non-carcinogens or a minimal risk of cancer (one in a million) for carcinogens to a worker exposed for a working lifetime (40 years). Adjustments were made to convert exposures from a lifetime of 70 years used by IRIS to a working lifetime exposure period.

The WAC's are not recommended exposure limits because they do not take into account numerous significant considerations including feasability, anecdotal reports of effects following human exposure, routes of exposure other than inhalation, and other critical information. Also, the WAC's for non-carcinogens are based primarily on oral exposure studies. In some cases there may be inhalation studies which are more appropriate for use in setting an occuptaional exposure guideline, but which were not discussed in IRIS due to their focus on the oral exposure route. In spite of these constraints, the WAC's may be considered preliminary health-based guidelines

which are useful as indicators that current PEL's and TLV's may need reevaluation.

To compare the occupational guidelines and standards with the environmental (IRIS) recommendations, a Risk Factor (RF) was calculated which reflects the degree to which the TLV and PEL for a chemical exceeds the WAC. For example, the PEL for allyl alcohol is 111 times greater than the WAC so the RF is 111. The comparison between the recommended health-based exposure limit and the limit which is recommended as safe for workers has different implications for carcinogens than for non-carcinogens. If the WAC is based upon non-carcinogeni effects, it is assumed to be at the threshold for adverse effects, with safety factors built in for individual and species differences in response. Exposure at levels which exceed the WAC may, therefore, result in adverse effects in some workers. It is likely that the proportion of workers affected increases with increases above that concentration; although the statistical nature of the increase is not well understood and may differ for different compounds (e.g. the distribution of responses may be normal, log-normal, etc.). If the WAC is based on carcinogenic responses the WAC has been calculated to generate a risk of one per million. Consequently, a risk factor of 1000 would increase the estimated risk by a factor of 1000 to one in one thousand. As the exposure levels increase the validity of the Unit Risk which was used to calculate the WAC and Risk Factor decreases so that the risk factor is less reliable.

For carcinogens a Worker Risk Level (WRL) was calculated which estimates the individual lifetime cancer risk to a worker exposed at the TLV or PEL based on the IRIS Unit Risk and WAC. The risk is expressed as a probability (e.g. .04 or four out of one hundred) of cancer. The WRL is an 95% upper bound on risk and is a protective estimate rather than a

predictive one. As the cumulative exposure level increases the Unit Risk, which was used to calculate the Worker Risk Level, is less reliable. Information is provided in IRIS regarding the limits of reliability of their risk estimates. The reader is refered to the IRIS documentation for more detailed information on this.

WRL's were not calculated for non-carcinogens because no Unit Risks have been calculated. For non-carcinogens the occurance of systemic health effects are not considered to be probabilistic. The expectation is that they will occur if exposure exceeds a specific threshold. Although individual differences are acknowledged, the likelihood of being affected is not considered to be a random event. Consequently, no probability of effect is assigned to exposure at the TLV or PEL for non-carcinogens. Athough there is no currently accepted risk assessment methodology to calculate the risk of adverse effect for non-carcinogens the Risk Factor indicates the degree to which the occupational guidelines and standards exceed the health-based WAC.

A summary of information on each chemical is provided which contains the following: IRIS RfD for non-carcinogens or Slope Factor and Unit Risk for carcinogens for each chemical, the type of study which the IRIS numbers or the EPA carcinogen classification was based upon and health effects observed in the study, the WAC calculated for this report and any special modification needed to carry out the calculations, the TLV, PEL, and NIOSH recommendations if available, the Risk Factor at the TLV and PEL, the Worker Risk Level at the TLV and PEL for carcinogens, a summary of the carcinogenicity, mutagenicity, chronic toxicity and teratogenicity determinations provided in the Hazardous Substance Fact Sheets, and additional information which may be relevant to evaluation of this chemical.

Methodology

Three types of values were calculated for this report: workday ambient air concentrations (WAC) which are working lifetime exposure levels in mg/m3 are estimated to pose no systemic health effects risk or negligible carcinogenic risk (one in a million) derived from IRIS data, risk factors (RF) which are the ratios of WAC's and either TLV's or PEL's, and worker risk levels (WRL) which are the individual cancer risks for lifetime exposure at the TLVs' and PEL's. The methods follow the Guidelines for Risk Assessment of Carcinogens (51FR 33992-34003, Sept. 24, 1986) and the approach taken for IRIS.

The values calculated for this report are based upon IRIS Reference Doses (RfD's), Unit Risks, and in a few cases, studies selected for use in IRIS. Consequently, the methods used for IRIS are critical to the results obtained for this work. The methodology employed to develop the IRIS values is explained in the IRIS Supplemental Documentation in Appendix A. It is necesary to review the documentation to gain a complete understanding of how the results were obtained.

Chemicals were selected for evaluation based on the availability of both IRIS data and PEL's and TLV's. An attempt was made to match all chemicals listed in the March 1986 IRIS Documentation, Volume II, Chemical Files with current TLV's and PEL's using the sources listed below. Those chemicals which matched were included in the evaluation. In addition, the 4/15/88 list: Chemicals on the Integrated Risk Information System from EPA were reviewed. All designated carcinogens were also searched for a match with current TLV's and PEL's. CAS numbers were matched in all cases. A very small number of chemicals were eliminated from the evaluation due to a lack of matching between CAS numbers or incomplete data.

SOURCES:

Standards, guidelines and Risk Assessment values (RFD's and NOEL's) were obtained from the following sources:

PEL's: NIOSH/OSHA Pocket Guide to Chemical Hazards. 9/85. USDHHS, PHS, CDC, NIOSH, DHEW (NIOSH) Publ. No. 78-210

REL's: MMWR Supplement, NIOSH Recommendations for Occupational Health and Safety Standards. 9/86, USDHHS.

TLV's: TLV's and Biological Exposure Indices for 1987 - 1988, ACGIH.

NOEL's, LOEL's, RFD's, Slope Factors and Unit Risks: IRIS Data Base, EPA Office of Research and Development, Washington, D.C. 1988.

I. ASSUMPTIONS

Numerous assumptions were required to calculate WAC's, Risk Factors and Worker Risk Levels. The assumptions are listed below. As more information becomes available on topics such as dose rate and thresholds these assumptions may require modification. In addition to the assumptions required for the work done on this report, assumptions were required to develop the IRIS values. These are discussed in the IRIS documentation provided in Appendix A.

BREATHING RATE	10 m3 per 8 hours work
BODY WEIGHT	60 kg
WORKDAY	8 hours
WORKDAYS PER YEAR	240
WORKING LIFETIME	40 years

The body weight used in all calculations is based on average female weight (IRCP, 1975). This was done to insure the group at greater risk was adequately considered. The total lung ventilation is very similar for men and women, 22.8 versus 212.1 for 24 hours and 9.6 versus 9.1 for light activity for 8 hours (ICRP, 1975). Consequently, women's exposure per kilgoram of body weight will result in a higher dose (in mg/kg) than for males. By using the lower (female) body weight in calculations, the Workday Ambient Air Concentrations, Risk Factors, and Worker Risk Levels incorporates considerations of womens health concerns and increases the margin of safety for men.

Absorption: A variety of absorption factors have been used in risk assessments to adjust for differences in absorption via different routes of eposure or via the same route of exposure in different species. Absorption is most relevant to the non-carcinogen WAC and Risk Factor calculations which entailed a conversion from the oral to inhalation eposure route. Carcinogenic hazards are <u>generally</u> assumed to be similar via any route of eposure. Except in those rare cases where actual measurements have been made for a specific chemical, there is little scientific foundation for the selection of a particular absorption factor. Consequently, for this report, is was assumed that the proportion of a toxicant absorbed would be the same via oral or inhalation exposure and that it would be the same for all species. Although differences do exist, other assumptions can not be supported without detailed information and analysis which is not available for most chemicals. In most cases absorption factors would result in minimal changes in the final numbers.

Body weight versus target tissue mass: No additional adjustments were made, in addition to those incorporated into the IRIS values, for intraspecies variation in body weight and target tissue mass to calculate dose. An adjustment is incorporated into the WAC's derived from RfD's which are based on oral exposure studies. This adjustment is equal to the ratio of body weight to the 2/3 power for human versus animal exposures. It is discussed in the IRIS documentation provided in Appendix A. An example of how this has been derived and used for a specific chemical along with a more detailed discussion can be found in the Health Assessment Document for chloroform (EPA, 1985, pages 8-76 to 8-87).

For inhaled toxins it was assumed that the effective exposure of the target tissue in non-human species is similar to that of humans when corrected for overall body weight. This follows the approach taken in IRIS for inhaled toxins.

Thresholds: Thresholds are assumed to exist for non-carcinogenic effects. Cumulative exposure over long time periods contributes to the occurance of adverse health effects by aggregating chemical exposures to a level at which the effect occur. This may take place by increasing the body burden, incrementally increasing organ damage to a level where it can be observed, or through some other mechanism. Thresholds are assumed not to exist for carcinogens. Consequently, the aggregate exposure over a lifetime is relevant to the individual's cancer risk. This assumption is further discussed in the Guidelines for Cancer Risk Assessment in Appendix A.

Dose Rate : The rate at which chemical exposure occurs may be a significant factor in the occurance of non-carcinogenic adverse health effects. There are clearly different effects observed following acute high level exposure versus chronic low level exposure; however, this report is dealing with chronic exposures only. Consequently, assumption is made here that low level environmental exposures which are dealt with in IRIS are very similar to low level occupational exposures and no adjustments were made to the WAC's for dose rate differences. This follows the approach of most risk assessment methods including those discussed in the IRIS documentation and the Guidelines for Risk Assessment contained in Appendix A.

Some studies have been conducted which indicate cancer risks associated with low level exposure may vary with dose rate. For example, radiation induced cancer risks increase (a higher risk per unit of dose exists) at lower chronic exposure levels than at higher chronic exposure levels (Mays, 1978, BEIR, 1980, Upton, 1984, Charmeaud, 1977). Current knowledge of the impact of dose rate, continuous and intermittent exposure on risk is very limited. Consequently, no quantitative adjustments were made for these factors for this report. As information becomes available on this topic adjustments may be recommended to improve the accuracy of dose-response estimates.

II. CALCULATION OF WORKDAY AMBIENT AIR CONCENTRATION (WAC)

Different methods are used to calculate WAC's for carcinogens and non-carcinogens because they are based on different types of information in IRIS.

Non-carcinogens

The WAC for non-carcinogens is based upon the Reference Dose (RfD). Two modifications must be made to most RfD's to adapt them to occupational exposure situations. The exposure is modified to reflect 240 days worked per year, and 10 m3 of air breathed per 8 hour workday rather than continuous (365 days per year) exposure which was used to calculate the IRIS RfD's. By using the volume breathed during a workday and an estimated worker body weight of 60kg, the second adjustment is incorporated to change the exposure units from mg/kg/day to mg/m3. The following equation was used to calculate WAC's from IRIS RfD's:

$$\text{WAC} = \frac{\text{RfD} \times 240/365 \text{ days per year} \times 60 \text{ kg}}{10 \text{ m3 air breathed per day}}$$

The simplified equation is WAC = RfD x 9.

For non-carcinogens the cumulative exposure over long time periods is relevant to the health effects observed, so an adjustment was made for days exposed per year. A threshold for toxicity is assumed to exist and the cumulative exposure over a year, rather than over the entire lifetime is significant to the observation of a health effect.

EXAMPLE: allyl alcohol

An IRIS RfD is provided for this chemical because it was determined to be a systemic (non-carcinogenic) toxicant.

IRIS RfD: .005 mg/kg/day

WAC = .005 x 9 = .045 mg/m3

In some cases modification of this method were necessitated by the type of data that was available (e.g. an inhalation study). When the WAC was calculated directly from study data, the same method of calculation was used in this report as was used for IRIS. In those cases the method used to calculate the WAC is presented with the information on the chemical. The methodology discussed in IRIS documentation provided in Appendix A should be refered to for an explaination of safety factors and other calculation parameters.

Carcinogens

The WAC for carcinogens is based upon the Unit Risk (UR) which gives the estimated cancer risk for a lifetime of exposure at 1 ug/m3. An adjustment to the Unit Risk was made for exposure duration and to convert the units from ug/m3 to mg/m3. A factor for the proportion of air breathed by workers versus environmentally exposed individuals dealth with in the IRIS Unit Risk (10 versus 20 liters/day) was used. This was considered more accurate than using the number of hours exposed per day since the hours per day do not reflect the variation in breathing rate with variations in activity level over 24 hours.

An equality was set up to identify the air concentration which would yield an estimated individual risk of one in a million:

$$\text{Unit Risk/1 ug/m3} = 10\ (-6)\ \text{risk/ WAC}$$

This equality, with the adjustments dicsussed above yields the following equation for WAC:

$$\text{WAC} = \frac{1 \times 10\ (-6)}{\text{UR risk/ug/m3} \times 1000 \times \frac{240}{365}\ \text{days/year} \times \frac{40}{70}\ \text{years} \times \frac{10}{20}\ \text{m3 air breathed per day}}$$

The simplified calcualtion is WAC = 5.26 x 10 (-9)/Unit Risk.

The risk level of one in a million was chosen because it can be considered a minimal risk. This risk level was recently incorporated into law by the New Jersey legislature to be used as a health-based guideline in the devlopment of standards for the maximum allowable contamination of drinking water. Occupational risks are not usually targeted to this low level. However, considering the numerous potentially hazardous workplace materials individual workers may be exposed to, the author considered it reasonable for purposes of this report.

EXAMPLE: acrylonitrile

An IRIS Unit Risk is given for this chemical because it was determined to be a carcinogen.

IRIS Unit Risk: 6.8 x 10 (-5) risk per ug/m3

WAC = 5.26 x 10 (-9)/6.8 x 10 (-5) = 7.74 x 10 (-5) mg/m3

In some cases modifications of this method were necessitated by the type of data that were available (e.g. a cancer risk estimate from the Air Toxics Branch of EPA rather than IRIS). In those cases the method used to calculate the WAC is presented with the information on the chemical. It is very similar to the method presented above and all necessary assumptions (e.g. amount of water consumer per day) are discussed in the IRIS documentation in Appendix A.

III. CALCULATION OF RISK FACTORS

Risk Factors were calculated directly from the WAC's. They are the ratio of the occupational standard (PEL) or guideline (TLV) and the WAC. They indicate the degree to which the PEL or TLV exceed the health-based WAC. The following equation was used:

Risk Factor = TLV or PEL/ WAC

EXAMPLE: allyl alcohol

WAC: .045 mg/m3

TLV and PEL: 5 mg/m3

Risk Factor = 5/.045 = 111

EXAMPLE: acrylonitrile

WAC: 7.74 x 10 (-5) mg/m3

TLV and PEL: 4.5 mg/m3

Risk Factor = 4.5 / 7.74 x 10 (-5) = 58,140

IV. CALCULATION OF WORKER RISK LEVELS

As discussed in the Introduction, Worker Risk Levels (WRL) are only calculated for carcinogens because probabilistic risk estimates are only relevant to carcinogenic responses. The Unit Risk (individual cancer risk per ug/m3 lifetime exposure) was multiplied by the TLV or PEL, with modifications for exposure duration to obtain the estimated risk for a working lifetime of exposure at the TLV or PEL. An adjustment was made to convert the units for Unit Risk (ug) to the units used in TLV's and PEL's (mg). The following equation was used:

$$WRL = \text{Unit Risk}(1000) \times \frac{240 \text{ days/year}}{365} \times \frac{40 \text{ years}}{70} \times \frac{10 \text{ m3 air breathed}}{20} \times \text{TLV per day}$$

The simplified equation is WRL = Unit Risk x 19 x TLV

EXAMPLE: acrylonitrile

Unit Risk = 6.8 x 10 (-5)

TLV = 4.5 mg/m3

WRL = 6.8 x 10 (-5) x 190 x 4.5 = .058

V. DATA FROM THE HAZARDOUS SUBSTANCES HEALTH FACT SHEETS

Data on chronic health effects from the Hazardous Substance Fact Sheets was summarized in a brief paragraph at the end of each chemical information sheet. If the Fact Sheets indicated evidence of mutagenicity, carcinogenicity, decreased fertility, or organ damage the paragraph includes a statement that the chemical may be mutagen or may cause cancer, decreased fertility, or organ damage. If the Fact Sheets indicated evidence of teratogenicity, fetotoxicity, embryotoxicity, or fetal mortality the paragraph states fetal damage may occur. The reader is refered to the Hazardous Substances Fact Sheets for detailed information on acute and chronic health effects, methods of worker protection, and current standards and guidelines. The Fact Sheets can be obtained from the New Jersey Department of Health, Occupational Health Service, Right to Know Program, Fact Sheet Unit and from ...THIS PAGE GIVEN TO YVES MIKOL FOR COMMENT AND REVIEW.

FORMAT

The following format is used for each chemical evaluated. Terms are described in the KEY and calculation methods in Methods and Appendix A.

CHEMICAL CAS Number

IRIS (date evaluation was completed by EPA)

Non-carcinogenic Effects:

NOEL, Safety Factor(SF), Modifying Factor (MF), and study type

Reference Dose (RfD), health effects basis

Workday Acceptable Ambient Concentration (WAC)

Scientific Support

Other Relevant Data

Carcinogenic Effects:

Basis for risk calculations and carcinogenic classification

Method of Extrapolation

Slope Factor for inhalation exposure

Unit Risk for inhalation exposure

Workday Ambient Air Concentration (WAC)

TLV: ppm (mg/m3), target tissue

Risk Factors

Worker Risk Levels (carcinogens)

PEL: ppm (mg/m3), target tissue

Risk Factors

Worker Risk Levels

ADDITIONAL INFORMATION

NIOSH recommendations are listed here.

HAZARDOUS SUBSTANCES FACT SHEETS: chronic health effects and mutagenicity data are summarized followed by the Fact Sheet number in parenthesis.

KEY

Definitions of terms and units of numerical values are given below in the order that they appear on the chemical information sheet and Format. Calculation methods are described in Methods and Appendix A.

NOEL — No Observable Effect Level obtained from an animal or human study. Determined by EPA. Units: mg/kg body weight/day unless otherwise noted.

Study Type — The study subjects (e.g. rats, mice), route of exposure, and length of the study (e.g. chronic, subchronic) are listed. These determine which safety factors are used and indicate the relevance to occupational settings (e.g. an oral study is less relevant than an inhalation study for most compounds).

LOEL — Lowest Observable Effect Level obtained from an animal or human study and used when a NOEL is unavailable. Determined by EPA. Units: mg/kg body weight/day unless otherwise noted.

RfD — Reference Dose is the maximum intake per day which is estimated to cause no adverse effects to humans. Calculated by EPA. RfD's are calculated for non-carcinogens only because it is assumed that there is no safe level of exposure to a carcinogen. Calculated by EPA for IRIS from the NOEL or LOEL. The health effects listed are adverse effects noted by IRIS usually in the study which the LOEL or NOEL was based upon obtained. If no effects were observed in the cited study, effects observed in other studies cited in IRIS are listed. Units: mg/kg body weight/day

KEY

WAC	Workday Ambient Air Concentration. Calculated for this report. For non-carcinogens WAC is the maximum time weighted average air concentration which is expected to cause no adverse health effects in humans with a working lifetime of exposure (40 years). Calculated from the RfD or directly from study data used to derive the RfD using durations of exposure and inhalation volumes relevant to the workplace (e.g. 8 hours instead of 24 hours).
AWAC	Alternative Workday Ambient Air Concentration. Calculated for this report. Similar to WAC and uses IRIS data, but provides a better basis for exposure guidelines and risk factors because it employs either a more standard method or a more relevant study than IRIS. Units: mg/m3
Risk Factor	Multiplication factor by which occupational standard or guideline for a non-carcinogen exceeds the safe exposure level derived from IRIS. Calculated for this report. Based on the equations: WAC/PEL, TLV, or REL. No units
Basis	The results of carcinogenicity studies which were used to form the basis of the classification of a compound's carcinogenicity status. NOT necessarily the basis of the risk calculations. Calculations may utilize aggregate information from a number of studies. The USEPA classification is listed followed in parenthesis by the alpha-numeric designation of its carcinogenicity status (e.g. B1). The meaning and derivation of their classification system is discussed in the IRIS documentation contained in Appendix A.

KEY

Method	The risk assessment method used to extrapolate the cancer risk to humans from either animal or epidemiological data. The methods used for IRIS are discussed in Appendix A.
Slope Factor	Cancer risk per mg/kg/day assuming a lifetime of exposure. Calculated by EPA for IRIS utilizing stanadard risk assessment methods (in most cases the linearized multistage model). The values given usually represent the upper 95% confidence bound on risk. Consequently, they represent a protective estimate rather than a predictive one. Units: individual cancer risk, e.g. .009 or 9 per thousand
Unit Risk	Individual cancer risk per ug/m3 air concentration assuming a lifetime of exposure. Calculated by EPA for IRIS utilizing stanadard risk assessment methods (in most cases the linearized multistage model). The values given usually represent the upper 95% confidence bound on risk. Consequently, they represent a protective estimate rather than a predictive one. Units: individual cancer risk, e.g. .009 or 9 per thousand
WAC	Workday Ambient Air Concentration. Calculated for this report. For <u>carcinogens</u> it is the maximum time weighted average concentration which is expected to incur a lifetime cancer risk no greater than one in a million (10 x -6). It was calculated for this report from the IRIS Unit Risk with adjustments for working lifetime exposure. Units: mg/m3

KEY

Worker Risk Level	Upper bound (usually 95%) of lifetime cancer risk estimated to be incurred from a working lifetime (40 years, 240 days per year, 8 hours per day, 10 m3 per air breathed per day) of exposure at the TLV, PEL or REL listed. Calculated from the Unit Risk for this report. Units: individual cancer risk
TLV	Threshold Limit Values set by the American Conference of Governmental Industrial Hygienists (ACGIH). Unless otherwise noted they are 8 hour time weighted averages (TWA). Target tissues and carcinogenicity evaluation cited with the TLV are listed. Units: ppm followed by mg/m3 in parenthesis.
PEL	Permissible Exposure Limits set by the Occupational Safety and Health Administration (OSHA). Unless otherwise noted they are 8 hour time weighted averages (TWA). Target tissues and carcinogenicity evaluation cited with the PEL are listed. Units: ppm followed by mg/m3 in parenthesis
REL	Recommended Exposure Limit set by National Institute for Occupational Safety and Health (NIOSH). Unless otherwise noted they are 10 hour TWA. Target tissues and carcinogenicity evaluation cited with the REL are listed. Units: ppm followed by mg/m3 in parenthesis.

Results

Table I summarizes the quantitative results obtained in this report. The current TLV's and PEL's are listed along with the IRIS-based WAC's. The comparison of current occupational guidelines and standards with WAC's are expressed in terms of Risk Factor. Where an Alternative WAC was calculated, the Risk Factor derived from comparison with the AWAC is given in parenthesis. When both PEL's and TLV's were available, the Risk Factor obtained from the TLV comparison is listed first followed by a slash (/) and the PEL Risk Factor.

The WAC's are health-based estimates of exposure limits which would pose minimal risks to workers, are significantly lower than current PEL's and TLV's for most chemicals considered. Most are in the range of micrograms or nanograms per cubic meter (ng/m3), with a low value of .4 ng/m3 for chromium VI. All but three WAC's are lower than 1 mg/m3. This is in contrast to current TLV's and PEL's for which 31 of the 49 chemicals evaluated have limits greater than 1 mg/m3 and 14 of these are greater than 100 mg/m3.

The WAC's calculated for carcinogens are lower than those for noncarcinogens in most cases. This results both from the risk assessment method used (linearized multistage) and the level of individual worker risk which was defined as acceptable for this raport (one in a million). The effects of using a carcinogen risk assessment approach versus a threshold non-carcinogen approach can be seen in the results obtained for three chemicals: chloroform, tetrachloroethylene, and trichlorofluoromethane. WAC's and Risk Factors for each of these were calculated from both a Unit Risk based upon a cancer study with a multistage extrapolation and on an RfD based on a non-cancer study with a threshold and safety factor

extrapolation. For chloroform the non-cancer based WAC is 391 times higher than the cancer based WAC. For tetrachloroethylene there is a 20 fold difference and for trichlorofluoromethane there is a 27,000 fold difference.

Risk Factors range from .5 for formic acid to 56,000,000 for trichlorofluoromethane. The TLV's and PEL's exceed the WAC's for all chemicals considered except formic acid which has a TLV and PEL of 18 mg/m3 and a WAC of 9 mg/m3. For 50% of the chemicals the Risk Factors are greater than 1901 (the median value), indicating that the PEL and/or TLV are more than 1900 times the WAC or AWAC.

Carcinogenic risks calculated from the IRIS Unit Risks and modified for occupational exposures are listed as Worker Risk Levels. As with the Risk Factors the TLV derived risks are listed first followed by a slash and the PEL derived risk. The risks are upper bound estimates based, in most cases, on a linearized multistage model. Carcinogenic risk, which is estimated for individual workers exposed at the TLV or PEL for 40 years, range from .001 for hexachlorobutadiene to levels approaching 1 for 5 chemicals (1,3-butadiene, chloroform, methylene chloride, and trichlorofluoromethane).

Table 1 provides a summary of the quantitative data; for more qualitative information on each chemical and an explaination of the calculation methods for chemicals with Alternative WAC's the reader is refered to the Individual Chemical Information Sheets. A review of the qualitative data on individual chemicals demonstrates that for most chemicals designated as carcinogens by IRIS the basis of the current TLV or PEL is not carcinogenic effects. However, even for those which have an indication of carcinogeni potential in the TLV or PEL guidebooks (see Sources in Methodology section) such as cadmium, benzene and acrylonitrile, the current occupational expposure limits exceed health-based WAC's very

significantly, by factors of 68,493 (PEL), 47,000 (TLV and PEL) and 58,140 (TLV and PEL) respecively.

The chemical information sheets also indicate frequent differences in target tissues cited by IRIS and the TLV and PEL guidebooks, especially for the non-carcinogens. For example, skin is the only target tissue listed for 15 of the 49 chemicals. This may indicate a focus on obvious and acute effects in the limit setting process, although the effects listed did not necessarily form the basis of the limits. For a thorough discussion of the basis of the TlV's see Castleman and Ziem, 1988. More serious chronic health effcets are noted as the basis of IRIS values and are also noted in the New Jersey Department of Heatlh Hazardous Substances Fact Sheet summaries.

A review of the summaries of chronic health effects from the Hazardous Substances Fact Sheets indicates that in a majority of cases Fact Sheet information supports the IRIS RfD or cancer classification. The Fact Sheet data, like the IRIS data, incorporates current toxicological and epidemiological data. The Fact Sheets should be consulted for detailed information on health effects, worker protection information and other types of data.

TABLE 1. SUMMARY OF RESULTS Results of comparison of IRIS (WAC), TLV, and PEL exposure guidelines and risk evaluations.

CHEMICAL NAME	OCCUPATIONAL GUIDELINE TLV/PEL in mg/m3	IRIS-BASED GUIDELINE Workday Ambient Air Concentration (WAC) or Alternative (AWAC) in mg/m3	COMPARISON Risk Factor(RF) based on WAC or AWAC (in paren) and TLV/PEL	CARCINOGENIC RISKS Worker Risk Level (WRL)
acrylic acid	30	.72(.24)	42(125)	-
proposed TLV	6	same	8(25)	-
acrylonitrile	4.5	7.7 x 10 (-5)	58,140	.058
aldrin	.25/.25	1.1 x 10 (-6)	232,992	.23
allyl alcohol	5/5	.045	111	-
antimony	.5/.5	.0045	111	-
arsenic, inorganic	.2/.01	1.2 x 10 (-6)	163,532/8,177	.163/.008
benzene	30/30	6.3 x 10 (-4)	47,000	.047
1,1-biphenyl	2.5	.45	5.5	-
1,3-butadiene	22/220	1.9 x 10 6(-5)	1,157,895/ 11,578,947	1
cadmium (dust)	.05/.2	2.9 x 10 (-6)	17,123/68,493	.017/.0684
proposed TLV	.01	same	3,425	.0034
carbaryl	5/5	.9(.10)	5.6(50)	
carbon tetrachloride	30/63	3.5 x 10 (-4)	85,714/180,000	.0855/.0171

TABLE 1. (continued)

CHEMICAL NAME	TLV/PEL	WAC(AWAC)	RF	WRL
chlordane	.5/.5	1.42 X 10 (-5)	35,211	.035
chloroform	50/240	.09	556/2,667	-
cancer-based		.00023	217,391/1,043,477	.22/1
chromium(VI)water soluble	.05/1	4.4 x 10 (-7)	114,155/2,283,105	.114/1
water insoluble	.005	same	11,416	.014
cresols	22/22	(.0009)	24,444	-
cyanogen	20	.36	56	-
dibutyl phthalate	5/5	.9	5.6	-
1,2-dichloroethane	40/200	2.02 x 10(-4)	198,020/990,100	.2/1
1,1-dichloroethylene	.2	1.1 x 10 (-4)	1,901	.0019
epichlorohydrin	10/19	4.4 x 10 (-3)	2,283/4,338	.0023/.0043
ethylbenzene	435/435	.9	483	-
formic acid	9/9	18	.5	-
heptachlor	.5/.5	4.1 x 10 (-6)	123,579	.1235
hexachlorobutadiene	.24	2.4 x 10 (-4)	1,004	.001
hexachlorocyclopentadiene	.1	.063(.002)	1.6(44.8)	-
hexachloroethane	100/10	1.3 x 10 (-3)	76,046/7,605	.076/.0076
proposed TLV	10		7,605	.0076
hydrogen cyanide	11/5	.18(.018)	61(611)/28(278)	-
hydrogen sulfide	14/28	.027	519/1,037	-
isophorone	25/140	1.35	19/104	-
lindane	.5/.5	.0027(.00052)	185(958)	-

TABLE 1. (continued)

CHEMICAL NAME	TLV/PEL	WAC(AWAC)	RF	WRL
methylene chloride	350/1750	1.3 x 10 (-3)	273,438/1,367,188	.27/1
methyl ethyl ketone	590/590	.45(.693)	1,311(851)/1,311(851)	-
nitrobenzene	5/5	.000625(.0025)	8,000(1,667)	-
pentachlorophenol	.5/.5	.27	1.9	-
phenol	19/19	.36(.036)	53(530)	-
phosphine	.4/.4	.0027	148	-
styrychnine	.15/.I5	.0027	56	-
styrene	215/430	1.8	119/239	-
1,1,2,2-tetrachloroethane	7/35	9.1 X 10 (-5)	77,178/385,888	07714/.3857
tetrachloroethylene(perc)	335/670	.18(.475)	1,861(705)/3,722(1410)	-
cancer based:		9.1 x 10 (-3)	37,222/74,444	.037/.074
tetraethyl lead	.1/.075	1.8 x 10 (-6)	55,556/41,667	-
toluene	375/750	(.376)	997/1,995	-
1,2,4-trichlorobenzene	40	.18(.009)	222(4,444)	-
1,1,2-trichloroethane	45/45	3.3 x 10 (-4)	136,778	.1368
trichloroethylene	270/538	4.1 x 10 (-3)	66,667/133,333	.06/.133
trichlorofluoromethane	5600	2.7	2,074	-
cancer based:		1.0 x 10 (-4)	56,000,000	1
1,1,2-trichloro-trifluoroethane	7600/7600	5358	1.14	-
vanadium pentoxide	.05/	.18(.0001)	.28(500)/	-
	.5 (dust)		2.8 (5,000)	-
	.1 (fume)		.56 (1,000)	-

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