PENGAD-Bayonne, N.J.
PLAINTIFF'S EXHIBIT
841

DOCUMENTATION

OF THE

THRESHQLD LIMIT VALUES

for

Substances

in

Workroom Air

WITH
SUPPLEMENTS FOR THOSE SUBSTANCES
ADDEDORCHANGED
SINCE 1971

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

Third Edition 1971

4TH PRINTING 1977

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by

American Conference of Governmental Industrial Hygienists

First Edition 1962
Second Edition 1966
Third Edition 1971
Third Edition, Second Printing 1974
Third Edition, Third Printing 1976
Third Edition, Fourth Printing 1977

This document may be ordered from the
American Conference of Governmental Industrial Hygienists,
P. O. Box 1937, Cincinnati, Ohio45201

PRICE $20.00

PREFACE TO THIRD EDITION

The issuance in 1971 constitutes the third edition of the Documentation of .the Threshold Limit Values for Substances in Workroom Air. The second edition (1966) comprised 367 substances; this edition contains almost 500. The documentation for each substance has been updated and expanded to include information through 1970, selected from the scientific literature for its relevance to the TLVs. The general format of the 1966 edition has been retained, but chemical formulae have been added for precise identification of each substance, more than 100 substances have been cross referenced, and the size of the substances' captions has been greatly enlarged for more ready reference. Specific statements on the toxicity and hazard, culled from the literature, or from the collective experience of the TLV Committee members, have been referenced for further examination and a clear, summarizing statement on precisely what basis the TLV has been selected is included in most documentations. This latter has been felt by the Committee to be a highly important adjunct for industrial hygienists administering the TLVs.

This edition was placed in the capable hands of Dr. Hervey B. Elkins, Director, Massachusetts Division of Occupational Hygiene, and long-time member of the TLV Committee of the American Conference of Governmental Industrial Hygienists. Although the minutiae of the editorial work was entrusted to Andrew D. Hosey, much devotedcare and attention to proper arrangement and content was given by TLV Committee recording secretary, William D. Wagner, and my secretary Eileen Fangmeyer.

H. E. Stokinger, Ph.D. Chairman
Threshold Limits Committee

PREFACE -- SECOND PRINTING

This second printing, three years after publication of the third edition, was occasioned by the relatively large number (72) new additions or updating of old documentations. The printing thus contains all the documentations of the third edition and as a supplement, the new and revised documentations since 1971. These revisions are noted by a *preceding the name of a substance in the main text. The additions or revisions are also arranged alphabetically as in the main body of this *text.*

H. E. Stokinger, Ph.D. Chairman
Threshold Limits Committee

PREFACE - THIRD PRINTING

The double star ★★ preceding the name of a substance in the main body of the text or the supplement for 1971–1973 indicates that this documentation has been revised and is to be found in the 1974–1975 supplement. The supplemental documentations are arranged alphabetically as in the main text.

William G. Frederick, Ph.D.
Chairman
Threshold Limits Committee

PREFACE - FOURTH PRINTING

This Fourth Printing of the Third Edition is necessitated by the significant volume of sales of the third printing. This publication contains those documentations available for the year 1976. A dagger † preceding the name of a substance in the main body or the first two supplements indicates that this documentation has been revised and is to be found in the 1976 Supplement.

Hervey B. Elkins, Ph.D.
Chairman
Threshold Limits Conimittee

GENERALREFERENCES

The following references are quoted as sources of recommended **TLVs** (or MACs):

Listing	Reference
Cook (1945)	**Cook, W.A.:** Ind. Med. **14,** 936.
Smyth (1656)	Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. **17,** 129 (Comments on **TLV** list of that date).
Elkins (1959)	Elkins, H.B.: Chemistry *of* Industrial Toxicology, 2nd Ed., p. **248,** Wiley & Sons, New York.
ANSI	American National Standards Institute (formerly American Standards Association); recommendation of acceptable time-weighted average concentration assuming **an** eight-hour work day, Z37 series of standards.
U.S.S.R. (Soviet) (1959)	Smelyanskiy, Z.B., Ulanova, I.P.: Ind. Hyg. & Occ. Dis. (Moscow) 5, **7;** cited by Elkins, H.B.: Arch. Env. Health 2, 45 (1961).
U.S.S.R. (Soviet) (1966)	Mimeographed undated table entitled: Standards **for** Permissible Level of Toxic Gases, Vapors and Dust in the Air of Industrial Premises to 1966. **U.S.S.R.**
U.S.S.R. (Soviet) (1967)	Letavet, A.A., Korbakova, A.I.: Zhurnal Vsesoyuznogo Khimicheskogo Obshchestva imeni Mendeleeva **12, 242;** trans. by William **F.** Kelly.
Czechoslovakia (1969)	Documentation of **MAC** in Czechoslovakia, Czechoslovak Committee of MAC, Prague.

OTHER REFERENCE **NOT** UTILIZED

Permissible Limits for Toxic Substances in the Working Environment and Criteria for Their Assessment, Document prepared **by** the Occupational Safety and Health Branch of the I.L.O., Geneva, 1970.

★★C BENZENE - Skin

C_6H_6

25 ppm (Approximately 80 mg/m^3)

Benzene as an acute posion produces narcotic effects comparable to those of toluene. Chronic intoxication by benzene is by far the most serious disease caused by the common hydrocarbon solvents. Its action is primarily on the bone marrow resulting in numerous blood changes and, in serious Cases, aplastic anemia, with a frequently fatal outcome. It is unique among the hydrocarbons as a myelotoxicant, according to Gerarde(1). Elkins(2) stated that more than 140 fatal cases of benzene poisoning had been recorded prior to 1959. Vigliani and Saita(3) listed 26 deaths from chronic benzene poisoning in two provinces in Italy between 1960 and 1963. Eleven of these cases were diagnosed as leukemia, which frequently develops several years after cessation of exposure to benzene.

Many of the deaths from benzene have resulted from exposures of the order of 200 ppm or more. Bowditch and Elkins(4) estimated that of eleven fatal cases, three resulted from concentrations in excess of 200 ppm, four from concentrations between 100 and 200 ppm, and three from concentrations judged to be below 100 ppm (but not measured). Greenburg et al.(5) described nine cases, with one death, in the rotogravure printing industry. Of 48 air analyses, 20 showed less than 100 ppm, and 15 more than 200 ppm. Savilahti(6) found that 107 of 147 workers in a shoe factory revealed blood abnormalities. The source of the benzene was cement, and concentrations were reported to have ranged from 318 to 470 ppm (these seem high for shoe cementing operations). One death occurred.

Winslow(7), however, reported blood changes in workers where concentrations of benzene vapor below 100 ppm were found. Heimann and Ford(8) found one death and three cases with blood changes where air analysis for benzene showed a concentration of 105 ppm. Wilson(9) reported three fatal cases in a plant where the average concentration of benzene vapor was 100 ppm. Hardy and Elkins(10) recorded one death and several cases of blood changes in a plant where repeated air analyses indicated benzene vapor concentrations of about 60 ppm.

Blaney(11) found little evidence of benzene intoxication in a group of 90 workers regularly exposed to benzene for about 13 years. Concentrations were generally low, but urinary phenol measurements indicated some exposures of the order of 25 ppm(12). Pagnotto et al.(13) found rubber spreaders exposed to benzene vapor concentrations ranging for the most part between 6 and 25 ppm. A limited number of blood studies showed some abnormalities but no apparent correlation with exposure. So far as is known, none of this group developed serious blood dyscrasias.

A TLV of 25 ppm is believed low enough to prevent serious blood changes, but this limit should be considered a ceiling and exposure to higher concentrations not permitted.

Other recommendations: Cook (1945) 50 ppm; Smyth (1956) 35 ppm; Elkins (1959) 25 ppm: ANSI (1969) 10 ppm; U.S.S.R. (1967) 6 ppm; Czechoslovakia (1969) 16 ppm.

References:

1. Gerarde, H.W.: Toxicology and Biochemistry of Aromatic Hydrocarbons, Elsevier Publishing Co., New York (1960).
2. Elkins, H.B.: Chemistry of Industrial Toxicology, p. 103, Wiley & Sons, New York (1959).
3. Vigliani, E.C., Saita, G.: New Eng. J. of Med. 271, 872 (1964).
4. Bowditch, M., Elkins, H.B.: J. Ind. Hyg. & Tox. 21, 321 (1939).
5. Greenburg, L., Mayers, M.R., Goldwater, L., Smith, A.R.: J. Ind. Hyg. & Tos. 21, 395 (1939).
6. Savilahti, M.: Arch. Gewerbepath. u. Gewerbehyg. 15, 147 (1956).
7. Winslow, C.E.A.: J. Ind. Hyg. 9, 69 (1927).
8. Heimann, H., Ford, C.B.: N.Y. Ind. Hyg. Bull. p. 224 (Nov. 1940).
9. Wilson, R.H.: J. Lab. Clin. Med. 27, 1517 (1942).
10. Hardy, H.L., Elkins, H.B.: J. Ind. Hyg. & Tox. 30, 196 (1948).
11. Blaney, L.: Ind. Med. & Surg. 19, 227 (1950).
12. Walkley, J.E., Pagnotto, L.D., Elkins, H.B.: Am. Ind. Hyg. Assn. J. 22, 362 (1961)
13. Pagnotto, L.D., Elkins, H.B., Brugsch, H.G., Walkley, J.E.: Am. Ind. Hyg. Assn. J. 22, 417 (1961).

SUPPLEMENTS

FOR THOSE SUBSTANCES

ADDED OR CHANGED

YEARS 1974 and 1975

Occupational exposures solely to As_2O_3 have been reported to result in contact dermatitis and sensitization, conjunctivitis, and ulceration and perforation of the nasal septum(1,3); cancers from exposure to arsenic have followed 1) the internal use of Fowlers Solution(4), an aromatic solution of potassium arsenite, 2) inhalation and skin contact exposure to sheep-dip dust(5) 'a mixture of sodium arsenite and sulfur, or 3) the combined inhalation of As_2O_3, sulfur dioxide and minor amounts of heavy metal oxides(1,2,6,7). Experimental cancers in animals have not been produced from As_2O_3 despite several attempts(8,9,10), and the conclusion has been reached after an extensive. review that "it is improbable that arsenic (per se) plays a significant role in the generation of cancer(10)."

A search of the world literature reveals no reports of industrial or experimental exposures solely to As_2O_3, which contain both environmental and toxicologic criteria from which a TLV can be unequivocally based. However, information helpful in arriving at a TLV for As_2O_3 on a reasonable basis is available by estimating the exposure levels from the urinary arsenic values in smelter workers(2). [In this calculation, it is assumed that arsenical dermatitis, and not cancer, is the response from As_2O_3 alone.] Total urinary As values among smelter workers averaged 0.8 mg/day over a period of years. If 12 to 14% of this value is dietary As, or 0.7 mg, and that, of the 8 m^3 of air inhaled during a'workshift, 50% is deposited in the body, and of that, 50% is retained in the tissues or excreted in the feces, a TLV of 0.25 mg As/m^3 as a TWA is estimated to be a reasonable air limit. Reduction from the previous TLV of 0.5 mg/m^3 seems warranted on the possibility that airborne As_2O_3 contributed to the arsenical dermatitis reported(2).

References:

1. Pinto, S. S., McGill, C. M.: Ind. Med. & Surg. 22, 281 (1953).
2. Pinto, S. S., Bennett, B. M.: Arch. Envir. Hlth. 7, 583 (1963).
3. Birmingham, D. J. et al.: Arch. Derm. 91, 457 (1965).
4. Graham, J. H. et al.: J. Invest. Derm. 37,317 (1961).
5. Hill, A. B., Faning, E. L.: Brit. J. Ind. Med. 5(1), 6(1948).
6. Milham, S. Jr., Strong, T.: Envir. Res. (1974).
7. Lee, A. M., Fraumeni, J. F. Jr.: J. Natl. Cancer Inst. 42, 1045 (1969).
8. Hueper, W. C., Payne, W. W.: Arch. Envir. Hlth. 5, 44571962).
9. Baroni, C. et al.: ibid. 7, 668 (1963).
10. Vallee, E. L. et al.: Arch. Ind. Hlth., 21, 132 (1960).

BENZENE - Skin

C_6H_6

TLV, 10 ppm (Approximately 30 mg/m^3)

Benzene as an acute poison produces narcotic effects comparable to those of toluene. Chronic intoxication by benzene is by far the most serious disease caused by the common hydrocarbon solvents. Its action is primarily on the bone marrow resulting in numerous blood changes and, in serious cases, aplastic anemia, with a frequently fatal outcome. It is unique among the hydrocarbons as a myelotoxicant, according to Gerarde(1). Elkins(2) stated that more than 140 fatal cases of benzene poisoning had been recorded prior to 1959. Vigliani and Saita(3) listed 26 deaths from chronic benzene poisoning in two provinces in Italy between 1960 and 1963. Eleven of these cases were diagnosed as leukemia, which frequently develops several years after cessation of exposure to benzene.

Many of the deaths from benzene have resulted from exposures of the order of 200 ppm or more. Bowditch and Elkins(4) estimated that of eleven fatal cases, three resulted from concentrations in excess of 200 ppm, four from concentrations between 100 and 200 ppm, and three from concentrations judged to be below 100 ppm (but not measured). Greenburg et al.(5) described nine cases, with one death. in the rotogravure printing industry. Of 48 air analyses, 20 showed less than 100 ppm, and 15 more than 200 ppm. Savilahti(6) found that 107 of 147 workers in a shoe factory revealed blood abnormalities. The source of the benzene was cement, and concentrations were reported to have ranged from 318 to 470 ppm (these seem high for shoe cementing operations). One death occurred.

Winslow(7), however, reported blood chances in workers where concentrations of benzene vapor below 100 ppm were found. Heimann and Ford(8) found one death and three cases with blood changes where air analysis for benzene showed a concentration of 105 ppm. Wilson(9) reported three fatal cases in a plant where the average concentration of benzene vapor was 100 ppm. Hardy and Elkins(10) recorded one

death and several cases of blood changes in workers in a plant where repeated air analyses indicated benzene vapor concentrations of about 60 ppm.

Blaney(11) found little evidence of benzene intoxication in a group of 90 workers regularly exposed to benzene for about 13 years. Concentrations were generally low, but urinary phenol measurements indicated some exposures of the order of 25 ppm(12). Pagnotto et al.(13) found rubber-spreaders exposed to benzene concentrations ranging for the most part between 6 and 25 ppm. A limited number of blood studies showed some abnormalities, but no apparent correlation with exposure. So far as is known, none of this group developed serious blood dyscrasias. Deichmann et al.(14) found that rats exposed 5 hours per day, 5 days per week for from 5 to 8 weeks to benzene at concentrations of 44 and 47 ppm developed a moderate degree of leukopenia, but no leukopenia when exposed at concentrations of from 15 to 31 ppm, thus establishing an approximate threshold for this blood dyscrasia for rats, at least under these conditions, of some level between 31 ppm and 44 ppm.

Some substantiation for these findings was reported by Nau et al.(15) who found a decrease in the number of white blood cells of rats which had been exposed to benzene at 50 ppm for 756 hours on an exposure schedule of 8 hours per day, 5 days per week. The rats also showed reduced amounts of DNA in the white cells, a depression in myelocytic activity, and an increase in the relative number of red cell precursors in the bone marrow.

Considering the borderline changes in the formed elements of the blood in both man and animals that occurred from not excessively long periods of exposure at levels only slightly above that of the 1973 TLV of C 25 ppm, a TLV of 10 ppm as a time-weighted average is recommended with a ceiling value of 25 ppm.

Other recommendations: Cook (1945) 50 ppm; Smyth (1956) 35 ppm; Elkins (1959) 25 ppm; ANSI (1969) 10 ppm; USSR (1972) 3 ppm; Czechoslovakia (1969) 16 ppm.

References:

1. Gerarde, H. W.: Toxicology and Biochemistry of Aromatic Hydrocarbons, Elsevier Publishing Co., NY (1960).
2. Elkins, H. B.: Chemistry of Industrial Toxicology, p. 103, Wiley & Sons, NY (1959).
3. Vigliani, E. C., Saita, G.: New Eng. J. of Med. 271, 872 (1964).
4. Bowditch, M., Elkins, H. B.: J. Ind. Hyg. & Tox. 21, 321 (1939).
5. Greenburg, L., Mayers, M. R., Goldwater, L., Smith, A. R.: J. Ind. Hyg. & Tox. 21, 395 (1939).
6. Savilahti, M.: Arch. Gewerbepath. u. Gewerbehyg. 15, 147 (1956).
7. Winslow, C. E. A.: J. Ind. Hyg. 9, 69 (1927).
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9. Wilson, R. H.: J. Lab. Clin. Med. 27, 1517 (1942).
10. Hardy, H. L., Elkins, H. B.: J. Ind. Hyg. & Tox. 30, 196 (1948).
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13. Pagnotto, L. D., Elkins, H. B., Brugsch, H. G., Walkley, J. E.: Am. Ind. Hyg. Assn. J. 22, 417 (1961).
14. Deichmann, W. B., et al.: Tox. Appl. Pharm. 5, 201 (1963).
15. Nau, C. A., et al.: Arch. Environ. Hlth. 12, 382 (1966).

BORATES, TETRA, SODIUM SALTS

SODIUM TETRABORATE DECAHYDRATE (Borax),	$Na_2B_4O_7 \cdot 10H_2O$	TLV 5 mg/m^3	SKIN
SODIUM TETRABORATE PENTAHYDRATE,	$Na_2B_4O_7 \cdot 5H_2O$	TLV 1 mg/m^3	SKIN
SODIUM TETRABORATE, ANHYDROUS,	$Na_2B_4O_7$	TLV 1 mg/m^3	SKIN

The three forms of sodium tetraborate have the following properties:

	ANHYDROUS	PENTAHYDRATE	DECAHYDRATE
Molecular Weight	201.3	291.4	381.4
Specific Gravity	2.367	1.815	1.73
Melting Point	740°C	200°C	62°C
Boiling Point	1575°C	--	--
Water Solubility	2.5g/100g(20°C)	3.82g/100g(20°C)	5.93 '100g(25°C)