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Guide to Occupational Exposure Values

Compiled by
ACGIH®

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Defining the Science of Occupational and Environmental Health®

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INTRODUCTION

The *Guide to Occupational Exposure Values* is a readily accessible reference for comparison of published values from ACGIH®; the U.S. Occupational Safety and Health Administration (OSHA); the U.S. National Institute for Occupational Safety and Health (NIOSH); Deutsche Forschungsgemeinschaft (DFG), Federal Republic of Germany, Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area; the American Industrial Hygiene Association (AIHA); and Occupational Alliance for Risk Science (OARS). Provided below are the sources of the values cited in this *Guide*, including publication dates, and the uniform resource locator (URL) if verified online (Reviewed 2019).

- ACGIH® Threshold Limit Values (TLVs®) for Chemical Substances
  - *2021 TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. ACGIH®, Cincinnati, OH (2021).
- OSHA Permissible Exposure Limits (PELs)
  - Occupational Safety and Health Administration (OSHA): Occupational Safety and Health Standards, Toxic and Hazardous Substances, Limits for Air Contaminants. Specified in Tables Z-1, Z-2, and Z-3. Title 29 CFR 1910.1000–1910.1200. Reviewed at: https://www.osha.gov/dsg/annotated-pels/index.html.
- NIOSH Recommended Exposure Limits (RELs)
  - NIOSH Pocket Guide to Chemical Hazards: Introduction. Available online at: http://www.cdc.gov/niosh/npg/pgintrod.html (Reviewed 2020).
  - *See also*: Ludwig HR; Cairelli SG; Whalen JJ (Eds): Documentation for Immediately Dangerous to Life or Health Concentrations (IDLH): Introduction. NTIS Pub. No. PB-94-195047 (1994). Available online at: http://www.cdc.gov/niosh/idlh/idlhintr.html.
  - *See also*: Wittaker C; Rice F; McKernan L; et al.: Current intelligence bulletin 68: NIOSH chemical carcinogen policy. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH), DHHS, Publication No. 2017-100 (2017). Available online at: https://www.cdc.gov/niosh/docs/2017-100/pdf/2017-100.pdf.
- DFG Maximum Concentrations at the Workplace (MAKs)
  - List of MAK and BAT Values 2020: Maximum Concentrations and Biological Tolerance Values at the Workplace. Report No. 54. Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, FRG (2020).
- AIHA Workplace Environmental Exposure Levels (WEELs™)
- OARS Workplace Environmental Exposure Levels (WEELs™)
  - Occupational Alliance for Risk Science (OARS) Workplace Environmental Exposure Levels (WEELs™) managed by Toxicological Excellence for Risk Assessment (TERA), Cincinnati, OH. Available online at tera.org/OARS/index.html (Reviewed 2021).

The *Guide* also includes those carcinogens found in the occupational environment that are identified by the above organizations and by the U.S. Environmental Protection Agency (EPA), the International Agency for Research on Cancer (IARC), and the U.S. National Toxicology Program (NTP). In addition to those sources cited above, the following were also used in preparing this *Guide* (Reviewed 2021).

- U.S. EPA Integrated Risk Information System (IRIS) database. A–Z List of Substances. Online at: https://cfpub.epa.gov/ncea/iris2/atoz.cfm.
- Agents Classified by the IARC Monographs, Volumes 1–124. IARC, Lyon, France (1987–2020). Available online at: http://monographs.iarc.fr/agents-classified-by-the-iarc/ (Reviewed 2020).
- Report on Carcinogens, 14th Ed., U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, Research Triangle Park, NC (2016). Available online at: http://ntp.niehs.nih.gov/pubhealth/roc/index-1.html (Reviewed 2016).

The *Guide to Occupational Exposure Values* is intended as a companion document to the ACGIH® annual *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* (*TLVs® and BEIs®*) book, specifically the section on TLVs® for Chemical Substances in the Work Environment.

The following pages provide "Definitions, Abbreviations, Terms, and Coding," the MAK "Peak Exposure Limitation Categories," the MAK "Pregnancy Risk Group Classifications," and the MAK "Germ Cell Mutagens Classifications."

Editor's note: The double entries that were previously included in this publication were eliminated effective with the 2006 edition. The entry in this publication will correspond to that carried in the *TLVs® and BEIs®* book, e.g., 2-butoxyethanol rather than ethylene glycol monobutyl ether. When ACGIH® does not recommend a TLV® and two or more jurisdictions (e.g., MAK and IARC) list a chemical substance with separate synonyms, ACGIH® will generally use the ChemIDplus database available on the ToxNet website (http://toxnet.nlm.nih.gov/) maintained by the U.S. National Library of Medicine. ChemIDplus is a database of over 370,000 chemicals, which contains names and synonyms as well as chemical formulae and structures. Whichever synonym ChemIDplus uses as the primary name attached to a specific CAS number is the name generally listed in this publication. In all cases, the removed synonym is listed with its primary entry and with its respective CAS number in the CAS Number Index section of this publication.

Carcinogenicity Categories

U.S. Environmental Protection Agency (EPA)

NOTE: The rationale and methods used to develop the carcinogenicity classifications EPA-A through EPA-E are found in the 1986 *Risk Assessment Guidelines* (EPA/600/8-87/045). The categories, EPA-K, EPA-L, EPA-CBD, and EPA-UL, were developed under the 1996 *Proposed Guidelines for Carcinogen Risk Assessment* (*Federal Register* 61[79]:17960-18011, April 23, 1996). Further to its updating of risk assessment guidelines, EPA issued a revised draft *Guidelines for Carcinogen Risk Assessment* (NCEA-F-0644; July 1999), which resulted in slightly different descriptors. In 2005, the agency published the final version of *Guidelines for Carcinogen Risk Assessment* (EPA/630/P-03-001 B), which contained refined descriptors for summarizing weight of evidence for human carcinogenic potential. All four risk assessment guidelines may be found online at: **http://www.epa.gov/risk**. In all instances, the user is referred to the online IRIS Guidance Documents found on the EPA website: **http://www.epa.gov/iris** and the online Toxicological Reviews and Support Documents available at: **http://cfpub.epa.gov/ncea/iris** for further carcinogenicity discussion and for information on long-term toxic effects other than carcinogenicity. In all cases, the most current carcinogenicity assessment will be listed in this publication.

EPA-A: Human Carcinogen — Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer.

-B: Probable Human Carcinogen — Weight of evidence of human carcinogenicity based on epidemiologic studies is limited; agents for which weight of evidence of carcinogenicity based on animal studies is sufficient.

Two subgroups:

-B1: Limited evidence of carcinogenicity from epidemiologic studies.

-B2: Sufficient evidence from animal studies; inadequate evidence or no data from epidemiologic studies.

-C: Possible Human Carcinogen — Limited evidence of carcinogenicity in animals in the absence of human data.

-D: Not Classifiable as to Human Carcinogenicity — Inadequate human and animal evidence of carcinogenicity or no data are available.

-E: Evidence of Noncarcinogenicity for Humans — No evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiologic and animal studies.

Under the 1996 Draft Guidelines, when the available tumor effects and other key data are adequate to demonstrate carcinogenic potential convincingly for humans, EPA-K or EPA-L are appropriate descriptors.

EPA-K: Known Human Carcinogens — Agents *known* to be carcinogenic in humans based on either epidemiologic evidence or a combination of epidemiologic and experimental evidence, demonstrating causality between human exposure and cancer;

OR

Agents that should be treated *as if* they were *known* human carcinogens, based on a combination of epidemiologic data showing a plausible causal association (not demonstrating it definitively) and strong experimental evidence.

-L: Likely to Produce Cancer in Humans — Agents that are *likely* to produce cancer in humans due to the production or anticipated production of tumors by modes of action that are relevant or assumed to be relevant to human carcinogenicity. Modifying descriptors for particularly high or low ranking in the "known/likely" group can be applied based on scientific judgment and experience and are as follows:

- Agents that are *likely* to produce cancer in humans based on data that are at the high end of the weights of evidence typical of this group.
- Agents that are *likely* to produce cancer in humans based on data that are at the low end of the weights of evidence typical of this group.

-CBD: Cannot Be Determined — This descriptor is appropriate when available tumor effects or other key data are suggestive or conflicting or limited in quantity and, thus, are not adequate to convincingly demonstrate carcinogenic potential for humans. In general, further agent specific and generic research and testing are needed to be able to describe human carcinogenic potential. The descriptor *cannot be determined* is used with a subdescriptor that captures the rationale:

- Agents whose carcinogenic potential *cannot be determined*, but for which there is suggestive evidence that raises concern for carcinogenic effects.
- Agents whose carcinogenic potential *cannot be determined* because the existing evidence is composed of *conflicting data* (e.g., some evidence is suggestive of carcinogenic effects, but other equally pertinent evidence does not confirm any concern).
- Agents whose carcinogenic potential *cannot be determined* because there are inadequate data to perform an assessment.
- Agents whose carcinogenic potential *cannot be determined* because no data are available to perform an assessment.

-NL: Not Likely to be Carcinogenic in Humans — This descriptor is appropriate when experimental evidence is satisfactory for deciding that there is no basis for human hazard concern, as follows (in the absence of human data suggesting a potential for cancer effects):

- Agents *not likely* to be carcinogenic to humans because they have been evaluated in at least two well-conducted studies in two appropriate animal species without demonstrating carcinogenic effects.
- Agents *not likely* to be carcinogenic to humans because they have been appropriately evaluated in animals and show only carcinogenic effects that have been shown not to be relevant to humans (e.g., showing only effects in the male rat kidney due to accumulation of α_2u-globulin).
- Agents *not likely* to be carcinogenic to humans when carcinogenicity is dose or route dependent. For instance, not likely below a certain dose range (categorized as *likely* above that range) or *not likely* by a certain route of exposure (may be categorized as likely by another route of exposure). To qualify, agents will have been appropriately evaluated in animal studies and the only effects show a dose range or route limitation or a route limitation is otherwise shown by empirical data.

Under the 1999 revised draft Guidelines, the following descriptors were issued; however, the descriptors are only presented in the context of a weight-of-evidence-narrative. [*Editor's note*: The "short hand" used within this *Guide* (e.g., EPA-K) to indicate descriptors used within the 1996 and 1999 draft Guidelines were developed to accommodate the page format only.] The reader is referred to the current EPA evaluation for a complete discussion of substance in question.

EPA-CaH: Carcinogenic to Humans — This descriptor is appropriate when there is convincing epidemiologic evidence demonstrating causality between human exposure and cancer. This descriptor is also appropriate when there is an absence of conclusive epidemiologic evidence to clearly establish a cause and effect relationship between human exposure and cancer, but there is compelling evidence of carcinogenicity in animals and mechanistic information in animals and humans demonstrating similar mode(s) of carcinogenic action. It is used when all of the following conditions are met:

- There is evidence in a human population(s) of association of exposure to the agent with cancer, but not enough to show a causal association;
- There is extensive evidence of carcinogenicity;
- The mode(s) of carcinogenic action and associated key events have been identified in animals; and
- The key events that precede the cancer response in animals have been observed in the human population(s) that also show evidence of an association of exposure to the agent with cancer.

-L: Likely to be Carcinogenic to Humans — This descriptor is appropriate when the available tumor effects and other key data are adequate to demonstrate carcinogenic potential to humans. Adequate data are within a spectrum. At one end is evidence for an association between human exposure to the agent and cancer and strong experimental evidence of carcinogenicity in animals; at the other, with no human data, the weight of experimental evidence shows animal carcinogenicity by a mode or modes of action that are relevant or assumed to be relevant to humans.

-S: Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential — This descriptor is appropriate when the evidence from human or animal data is suggestive of carcinogenicity, which raises a concern for carcinogenic effects but is judged not sufficient for a conclusion as to human carcinogenic potential. Examples of such evidence may include: a marginal increase in tumors that may be exposure-related, or evidence is observed only in a single study, or the only evidence is limited to certain high background tumors in one sex of one species. Dose–response assessment is not indicated for these agents. Further studies would be needed to determine human carcinogenic potential.

-I: Data are Inadequate for an Assessment of Human Carcinogenic Potential — This descriptor is used when available data are judged inadequate to perform an assessment. This includes a case when there is a lack of pertinent or useful data or when existing evidence is conflicting, e.g., some evidence is suggestive of carcinogenic effects, but other equally pertinent evidence does not confirm a concern.

-NL: Not Likely to be Carcinogenic to Humans — This descriptor is used when the available data are considered robust for deciding that there is no basis for human hazard concern. The judgment may be based on the following:

- Extensive human experience that demonstrates lack of carcinogenic effect (e.g., phenobarbital).
- Animal evidence that demonstrates lack of carcinogenic effect in at least two well-designed and well-conducted studies in two appropriate animal species (in the absence of human data suggesting a potential for cancer effects).
- Extensive experimental evidence showing that the only carcinogenic effects observed in animals are not considered relevant to humans (e.g., showing only effects in the male rat kidney due to accumulation of α_2u-globulin).
- Evidence that carcinogenic effects are not likely by a particular route of exposure (Section 2.3.3.).

- Evidence that carcinogenic effects are not anticipated below a defined dose range.

Under the 2005 *Guidelines for Carcinogen Risk Assessment* (EPA/630/P-03/001 B), the following descriptors were issued; however, the descriptors are only presented in the context of a weight-of-evidence-narrative. [*Editor's note*: The "short hand" (e.g., EPA-CaH) used within this *Guide* to indicate the 2005 descriptors was developed to accommodate the page format of this *Guide* only.] The reader is referred to the individual IRIS evaluation for a complete discussion of the substance in question.

EPA-CaH: Carcinogenic to Humans — This descriptor indicates strong evidence of human carcinogenicity. It covers different combinations of evidence.

- This descriptor is appropriate when there is convincing epidemiologic evidence of a causal association between human exposure and cancer.
- Exceptionally, this descriptor may be equally appropriate with a lesser weight of epidemiologic evidence that is strengthened by other lines of evidence. It can be used when all of the following conditions are met: (a) there is strong evidence of an association between human exposure and either cancer or the key precursor events of the agent's mode of action but not enough for a causal association, and (b) there is extensive evidence of carcinogenicity in animals, and (c) the mode(s)of carcinogenic action and associated key precursor events have been identified in animals, and (d) there is strong evidence that the key precursor events that precede the cancer response in animals are anticipated to occur in humans and progress to tumors, based on available biological information. In this case, the narrative includes a summary of both the experimental and epidemiologic information on mode of action and also an indication of the relative weight that each source of information carries, e.g., based on human information, based on limited human and extensive animal experiments.

-L: Likely to Be Carcinogenic to Humans — This descriptor is appropriate when the weight of the evidence is adequate to demonstrate carcinogenic potential to humans but does not reach the weight of evidence for the "Carcinogenic to Humans" descriptor. Adequate evidence consistent with this descriptor covers a broad spectrum. As stated previously, the use of the term "likely" as a weight of evidence descriptor does not correspond to a quantifiable probability. The examples below are meant to represent the broad range of data combinations that are covered by this descriptor; they are illustrative and provide neither a checklist nor a limitation for the data that might support use of this descriptor. Moreover, additional information, e.g., on mode of action, might change the choice of descriptor for the illustrated examples. Supporting data for this descriptor may include:

- an agent demonstrating a plausible (but not definitively causal) association between human exposure and cancer, in most cases with some supporting biological, experimental evidence, though not necessarily carcinogenicity data from animal experiments;
- an agent that has tested positive in animal experiments in more than one species, sex, strain, site, or exposure route, with or without evidence of carcinogenicity in humans;
- a positive tumor study that raises additional biological concerns beyond that of a statistically significant result, for example, a high degree of malignancy, or an early age at onset;
- a rare animal tumor response in a single experiment that is assumed to be relevant to humans; or
- a positive tumor study that is strengthened by other lines of evidence, for example, either plausible (but not definitively causal) association between human exposure and cancer or evidence that the agent or an important

metabolite causes events generally known to be associated with tumor formation (such as DNA reactivity or effects on cell growth control) likely to be related to the tumor response in this case.

-S: Suggestive Evidence of Carcinogenic Potential — This descriptor of the database is appropriate when the weight of evidence is suggestive of carcinogenicity; a concern for potential carcinogenic effects in humans is raised, but the data are judged not sufficient for a stronger conclusion. This descriptor covers a spectrum of evidence associated with varying levels of concern for carcinogenicity, ranging from a positive cancer result in the only study on an agent to a single positive cancer result in an extensive database that includes negative studies in other species. Depending on the extent of the database, additional studies may or may not provide further insights. Some examples include:

- a small, and possibly not statistically significant, increase in tumor incidence observed in a single animal or human study that does not reach the weight of evidence for the descriptor "Likely to Be Carcinogenic to Humans." The study generally would not be contradicted by other studies of equal quality in the same population group or experimental system (*see* discussions of *conflicting evidence* and differing results, below);
- a small increase in a tumor with a high background rate in that sex and strain, when there is some but insufficient evidence that the observed tumors may be due to intrinsic factors that cause background tumors and not due to the agent being assessed. (When there is a high background rate of a specific tumor in animals of a particular sex and strain, then there may be biological factors operating independently of the agent being assessed that could be responsible for the development of the observed tumors.) In this case, the reasons for determining that the tumors are not due to the agent are explained;
- evidence of a positive response in a study whose power, design, or conduct limits the ability to draw a confident conclusion (but does not make the study fatally flawed), but where the carcinogenic potential is strengthened by other lines of evidence (such as structure-activity relationships); or
- a statistically significant increase at one dose only, but no significant response at the other doses and no overall trend.

-I: Inadequate Information to Assess Carcinogenic Potential — This descriptor of the database is appropriate when available data are judged inadequate for applying one of the other descriptors. Additional studies generally would be expected to provide further insights. Some examples include:

- little or no pertinent information;
- conflicting evidence, that is, some studies provide evidence of carcinogenicity but other studies of equal quality in the same sex and strain are negative. *Differing results*, that is, positive results in some studies and negative results in one or more different experimental systems, do not constitute *conflicting evidence*, as the term is used here. Depending on the overall weight of evidence, differing results can be considered either suggestive evidence or likely evidence; or
- negative results that are not sufficiently robust for the descriptor, "Not Likely to Be Carcinogenic to Humans."

-NL: Not Likely to Be Carcinogenic to Humans — This descriptor is appropriate when the available data are considered robust for deciding that there is no basis for human hazard concern. In some instances, there can be positive results in experimental animals when there is strong, consistent evidence that each mode of action in experimental animals does not operate in humans. In