



# Toxicological Profile for Glutaraldehyde

July 2017



U.S. Department of Health and Human Services  
Agency for Toxic Substances and Disease Registry

## **DISCLAIMER**

Use of trade names is for identification only and does not imply endorsement by the Agency for Toxic Substances and Disease Registry, the Public Health Service, or the U.S. Department of Health and Human Services.

## UPDATE STATEMENT

A Toxicological Profile for Glutaraldehyde, Draft for Public Comment was released in December 2015. This edition supersedes any previously released draft or final profile.

Toxicological profiles are revised and republished as necessary. For information regarding the update status of previously released profiles, contact ATSDR at:

Agency for Toxic Substances and Disease Registry  
Division of Toxicology and Human Health Sciences  
Environmental Toxicology Branch  
1600 Clifton Road NE  
Mailstop F-57  
Atlanta, Georgia 30329-4027

This page is intentionally blank.

## FOREWORD

This toxicological profile is prepared in accordance with guidelines\* developed by the Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency (EPA). The original guidelines were published in the *Federal Register* on April 17, 1987. Each profile will be revised and republished as necessary.

The ATSDR toxicological profile succinctly characterizes the toxicologic and adverse health effects information for these toxic substances described therein. Each peer-reviewed profile identifies and reviews the key literature that describes a substance's toxicologic properties. Other pertinent literature is also presented, but is described in less detail than the key studies. The profile is not intended to be an exhaustive document; however, more comprehensive sources of specialty information are referenced.

The focus of the profiles is on health and toxicologic information; therefore, each toxicological profile begins with a public health statement that describes, in nontechnical language, a substance's relevant toxicological properties. Following the public health statement is information concerning levels of significant human exposure and, where known, significant health effects. The adequacy of information to determine a substance's health effects is described in a health effects summary. Data needs that are of significance to the protection of public health are identified by ATSDR.

Each profile includes the following:

- (A) The examination, summary, and interpretation of available toxicologic information and epidemiologic evaluations on a toxic substance to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects;
- (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure that present a significant risk to human health of acute, subacute, and chronic health effects; and
- (C) Where appropriate, identification of toxicologic testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.

The principal audiences for the toxicological profiles are health professionals at the Federal, State, and local levels; interested private sector organizations and groups; and members of the public.

This profile reflects ATSDR's assessment of all relevant toxicologic testing and information that has been peer-reviewed. Staffs of the Centers for Disease Control and Prevention and other Federal scientists have also reviewed the profile. In addition, this profile has been peer-reviewed by a nongovernmental panel and was made available for public review. Final responsibility for the contents and views expressed in this toxicological profile resides with ATSDR.



Patrick N. Breyse, Ph.D., CIH  
Director, National Center for Environmental Health and  
Agency for Toxic Substances and Disease Registry  
Centers for Disease Control and Prevention

### \*Legislative Background

The toxicological profiles are developed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA or Superfund). CERCLA section 104(i)(1) directs the Administrator of ATSDR to "...effectuate and implement the health related authorities" of the statute. This includes the preparation of toxicological profiles for hazardous substances most commonly found at facilities on the CERCLA National Priorities List and that pose the most significant potential threat to human health, as determined by ATSDR and the EPA. Section 104(i)(3) of CERCLA, as amended, directs the Administrator of ATSDR to prepare a toxicological profile for each substance on the list. In addition, ATSDR has the authority to prepare toxicological profiles for substances not found at sites on the National Priorities List, in an effort to "...establish and maintain inventory of literature, research, and studies on the health effects of toxic substances" under CERCLA Section 104(i)(1)(B), to respond to requests for consultation under section 104(i)(4), and as otherwise necessary to support the site-specific response actions conducted by ATSDR.

## QUICK REFERENCE FOR HEALTH CARE PROVIDERS

Toxicological Profiles are a unique compilation of toxicological information on a given hazardous substance. Each profile reflects a comprehensive and extensive evaluation, summary, and interpretation of available toxicologic and epidemiologic information on a substance. Health care providers treating patients potentially exposed to hazardous substances may find the following information helpful for fast answers to often-asked questions.

---

### *Primary Chapters/Sections of Interest*

**Chapter 1: Public Health Statement:** The Public Health Statement can be a useful tool for educating patients about possible exposure to a hazardous substance. It explains a substance's relevant toxicologic properties in a nontechnical, question-and-answer format, and it includes a review of the general health effects observed following exposure.

**Chapter 2: Relevance to Public Health:** The Relevance to Public Health Section evaluates, interprets, and assesses the significance of toxicity data to human health.

**Chapter 3: Health Effects:** Specific health effects of a given hazardous compound are reported by type of health effect (e.g., death, systemic, immunologic, reproductive), by route of exposure, and by length of exposure (acute, intermediate, and chronic). In addition, both human and animal studies are reported in this section.

**NOTE:** Not all health effects reported in this section are necessarily observed in the clinical setting. Please refer to the Public Health Statement to identify general health effects observed following exposure.

**Pediatrics:** Four new sections have been added to each Toxicological Profile to address child health issues:

<b>Chapter 1</b>	<b>How Can (Chemical X) Affect Children?</b>
<b>Chapter 1</b>	<b>How Can Families Reduce the Risk of Exposure to (Chemical X)?</b>
<b>Section 3.8</b>	<b>Children's Susceptibility</b>
<b>Section 6.6</b>	<b>Exposures of Children</b>

### **Other Sections of Interest:**

<b>Section 3.9</b>	<b>Biomarkers of Exposure and Effect</b>
<b>Section 3.12</b>	<b>Methods for Reducing Toxic Effects</b>

---

### *ATSDR Information Center*

**Phone:** 1-800-CDC-INFO (800-232-4636) or 1-888-232-6348 (TTY)

**Internet:** <http://www.atsdr.cdc.gov>

The following additional materials are available online:

*Case Studies in Environmental Medicine* are self-instructional publications designed to increase primary health care providers' knowledge of a hazardous substance in the environment and to aid in the evaluation of potentially exposed patients (see <https://www.atsdr.cdc.gov/csem/csem.html>).

*Managing Hazardous Materials Incidents* is a three-volume set of recommendations for on-scene (prehospital) and hospital medical management of patients exposed during a hazardous materials incident (see <https://www.atsdr.cdc.gov/MHMI/index.asp>). Volumes I and II are planning guides to assist first responders and hospital emergency department personnel in planning for incidents that involve hazardous materials. Volume III—*Medical Management Guidelines for Acute Chemical Exposures*—is a guide for health care professionals treating patients exposed to hazardous materials.

*Fact Sheets (ToxFAQs™)* provide answers to frequently asked questions about toxic substances (see <https://www.atsdr.cdc.gov/toxfaqs/Index.asp>).

---

### ***Other Agencies and Organizations***

*The National Center for Environmental Health (NCEH)* focuses on preventing or controlling disease, injury, and disability related to the interactions between people and their environment outside the workplace. Contact: NCEH, Mailstop F-29, 4770 Buford Highway, NE, Atlanta, GA 30341-3724 • Phone: 770-488-7000 • FAX: 770-488-7015 • Web Page: <https://www.cdc.gov/nceh/>.

*The National Institute for Occupational Safety and Health (NIOSH)* conducts research on occupational diseases and injuries, responds to requests for assistance by investigating problems of health and safety in the workplace, recommends standards to the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA), and trains professionals in occupational safety and health. Contact: NIOSH, 395 E Street, S.W., Suite 9200, Patriots Plaza Building, Washington, DC 20201 • Phone: 202-245-0625 or 1-800-CDC-INFO (800-232-4636) • Web Page: <https://www.cdc.gov/niosh/>.

*The National Institute of Environmental Health Sciences (NIEHS)* is the principal federal agency for biomedical research on the effects of chemical, physical, and biologic environmental agents on human health and well-being. Contact: NIEHS, PO Box 12233, 104 T.W. Alexander Drive, Research Triangle Park, NC 27709 • Phone: 919-541-3212 • Web Page: <https://www.niehs.nih.gov/>.

---

### ***Clinical Resources (Publicly Available Information)***

*The Association of Occupational and Environmental Clinics (AOEC)* has developed a network of clinics in the United States to provide expertise in occupational and environmental issues. Contact: AOEC, 1010 Vermont Avenue, NW, #513, Washington, DC 20005 • Phone: 202-347-4976 • FAX: 202-347-4950 • e-mail: [AOEC@AOEC.ORG](mailto:AOEC@AOEC.ORG) • Web Page: <http://www.aoec.org/>.

*The American College of Occupational and Environmental Medicine (ACOEM)* is an association of physicians and other health care providers specializing in the field of occupational and environmental medicine. Contact: ACOEM, 25 Northwest Point Boulevard, Suite 700, Elk Grove Village, IL 60007-1030 • Phone: 847-818-1800 • FAX: 847-818-9266 • Web Page: <http://www.acoem.org/>.

*The American College of Medical Toxicology (ACMT)* is a nonprofit association of physicians with recognized expertise in medical toxicology. Contact: ACMT, 10645 North Tatum Boulevard,



Suite 200-111, Phoenix AZ 85028 • Phone: 844-226-8333 • FAX: 844-226-8333 • Web Page:  
<http://www.acmt.net>.

*The Pediatric Environmental Health Specialty Units (PEHSUs)* is an interconnected system of specialists who respond to questions from public health professionals, clinicians, policy makers, and the public about the impact of environmental factors on the health of children and reproductive-aged adults. Contact information for regional centers can be found at <http://pehsu.net/findhelp.html>.

*The American Association of Poison Control Centers (AAPCC)* provide support on the prevention and treatment of poison exposures. Contact: AAPCC, 515 King Street, Suite 510, Alexandria VA 22314 • Phone: 701-894-1858 • Poison Help Line: 1-800-222-1222 • Web Page:  
<http://www.aapcc.org/>.

This page is intentionally blank.

## CONTRIBUTORS

### CHEMICAL MANAGER(S)/AUTHOR(S):

Susan Zells Ingber, A.B., M.S.P.P.  
Sharon Wilbur, M.A.  
Carolyn Harper, Ph.D.  
Eugene Demchuk, Ph.D.  
ATSDR, Division of Toxicology and Human Health Sciences, Atlanta, GA

David W. Wohlers, Ph.D.  
Mario Citra, Ph.D.  
Mary Kawa, M.A.  
SRC, Inc., North Syracuse, NY

### THE PROFILE HAS UNDERGONE THE FOLLOWING ATSDR INTERNAL REVIEWS:

1. Health Effects Review. The Health Effects Review Committee examines the health effects chapter of each profile for consistency and accuracy in interpreting health effects and classifying end points.
2. Minimal Risk Level Review. The Minimal Risk Level Workgroup considers issues relevant to substance-specific Minimal Risk Levels (MRLs), reviews the health effects database of each profile, and makes recommendations for derivation of MRLs.
3. Data Needs Review. The Environmental Toxicology Branch reviews data needs sections to assure consistency across profiles and adherence to instructions in the Guidance.
4. Green Border Review. Green Border review assures the consistency with ATSDR policy.

This page is intentionally blank.

## PEER REVIEW

A peer review panel was assembled for glutaraldehyde. The panel consisted of the following members:

1. Dr. H.M. Bolt, M.D., Ph.D., Leibniz Research Centre for Working Environment and Human Factors, Ardeystraße 67, D-44139 Dortmund;
2. Barbara Shane, Ph.D., 205 Landreth Court, Durham, North Carolina; and
3. Dr. Errol Zeiger, Ph.D., J.D., A.T.S., Errol Zeiger Consulting, 800 Indian Springs Road, Chapel Hill, North Carolina.

These experts collectively have knowledge of glutaraldehyde's physical and chemical properties, toxicokinetics, key health end points, mechanisms of action, human and animal exposure, and quantification of risk to humans. All reviewers were selected in conformity with the conditions for peer review specified in Section 104(I)(13) of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended.

Scientists from the Agency for Toxic Substances and Disease Registry (ATSDR) have reviewed the peer reviewers' comments and determined which comments will be included in the profile. A listing of the peer reviewers' comments not incorporated in the profile, with a brief explanation of the rationale for their exclusion, exists as part of the administrative record for this compound.

The citation of the peer review panel should not be understood to imply its approval of the profile's final content. The responsibility for the content of this profile lies with the ATSDR.

This page is intentionally blank.

## CONTENTS

DISCLAIMER .....	ii
UPDATE STATEMENT .....	iii
FOREWORD .....	v
QUICK REFERENCE FOR HEALTH CARE PROVIDERS .....	vii
CONTRIBUTORS .....	xi
PEER REVIEW .....	xiii
CONTENTS .....	xv
LIST OF FIGURES .....	xix
LIST OF TABLES .....	xxi
1. PUBLIC HEALTH STATEMENT FOR GLUTARALDEHYDE .....	1
2. RELEVANCE TO PUBLIC HEALTH .....	7
2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO GLUTARALDEHYDE IN THE UNITED STATES .....	7
2.2 SUMMARY OF HEALTH EFFECTS .....	8
2.3 MINIMAL RISK LEVELS (MRLs) .....	10
3. HEALTH EFFECTS .....	13
3.1 INTRODUCTION .....	13
3.2 DISCUSSION OF HEALTH EFFECTS BY ROUTE OF EXPOSURE .....	13
3.2.1 Inhalation Exposure .....	14
3.2.1.1 Death .....	14
3.2.1.2 Systemic Effects .....	15
3.2.1.3 Immunological and Lymphoreticular Effects .....	43
3.2.1.4 Neurological Effects .....	45
3.2.1.5 Reproductive Effects .....	46
3.2.1.6 Developmental Effects .....	47
3.2.1.7 Cancer .....	47
3.2.2 Oral Exposure .....	48
3.2.2.1 Death .....	48
3.2.2.2 Systemic Effects .....	49
3.2.2.3 Immunological and Lymphoreticular Effects .....	66
3.2.2.4 Neurological Effects .....	66
3.2.2.5 Reproductive Effects .....	67
3.2.2.6 Developmental Effects .....	67
3.2.2.7 Cancer .....	68
3.2.3 Dermal Exposure .....	70
3.2.3.1 Death .....	70
3.2.3.2 Systemic Effects .....	70
3.2.3.3 Immunological and Lymphoreticular Effects .....	76
3.2.3.4 Neurological Effects .....	82
3.2.3.5 Reproductive Effects .....	82
3.2.3.6 Developmental Effects .....	82
3.2.3.7 Cancer .....	82
3.2.4 Other Routes of Exposure .....	82
3.3 GENOTOXICITY .....	82
3.4 TOXICOKINETICS .....	90
3.4.1 Absorption .....	90

3.4.1.1	Inhalation Exposure .....	90
3.4.1.2	Oral Exposure .....	91
3.4.1.3	Dermal Exposure .....	91
3.4.1.4	Other Routes of Exposure .....	92
3.4.2	Distribution .....	92
3.4.2.1	Inhalation Exposure .....	92
3.4.2.2	Oral Exposure .....	92
3.4.2.3	Dermal Exposure .....	93
3.4.2.4	Other Routes of Exposure .....	93
3.4.3	Metabolism .....	94
3.4.4	Elimination and Excretion .....	96
3.4.4.1	Inhalation Exposure .....	96
3.4.4.2	Oral Exposure .....	96
3.4.4.3	Dermal Exposure .....	96
3.4.4.4	Other Routes of Exposure .....	97
3.4.5	Physiologically Based Pharmacokinetic (PBPK)/Pharmacodynamic (PD) Models .....	98
3.5	MECHANISMS OF ACTION .....	99
3.5.1	Pharmacokinetic Mechanisms .....	99
3.5.2	Mechanisms of Toxicity .....	99
3.5.3	Animal-to-Human Extrapolations .....	101
3.6	HAZARD IDENTIFICATION AND MINIMAL RISK LEVELS .....	101
3.6.1	Hazard Identification .....	101
3.6.2	Minimal Risk Levels (MRLs) .....	102
3.6.2.1	Inhalation MRLs .....	102
3.6.2.2	Oral MRLs .....	108
3.7	TOXICITIES MEDIATED THROUGH THE NEUROENDOCRINE AXIS .....	113
3.8	CHILDREN'S SUSCEPTIBILITY .....	114
3.9	BIOMARKERS OF EXPOSURE AND EFFECT .....	116
3.9.1	Biomarkers Used to Identify or Quantify Exposure to Glutaraldehyde .....	118
3.9.2	Biomarkers Used to Characterize Effects Caused by Glutaraldehyde .....	118
3.10	INTERACTIONS WITH OTHER CHEMICALS .....	118
3.11	POPULATIONS THAT ARE UNUSUALLY SUSCEPTIBLE .....	118
3.12	METHODS FOR REDUCING TOXIC EFFECTS .....	119
3.12.1	Reducing Peak Absorption Following Exposure .....	119
3.12.2	Reducing Body Burden .....	120
3.12.3	Interfering with the Mechanism of Action for Toxic Effects .....	120
3.13	ADEQUACY OF THE DATABASE .....	120
3.13.1	Existing Information on Health Effects of Glutaraldehyde .....	120
3.13.2	Identification of Data Needs .....	122
3.13.3	Ongoing Studies .....	134
4.	CHEMICAL AND PHYSICAL INFORMATION .....	135
4.1	CHEMICAL IDENTITY .....	135
4.2	PHYSICAL AND CHEMICAL PROPERTIES .....	135
5.	PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL .....	139
5.1	PRODUCTION .....	139
5.2	IMPORT/EXPORT .....	139
5.3	USE .....	140
5.4	DISPOSAL .....	145



6. POTENTIAL FOR HUMAN EXPOSURE .....	147
6.1 OVERVIEW .....	147
6.2 RELEASES TO THE ENVIRONMENT .....	148
6.2.1 Air .....	149
6.2.2 Water .....	149
6.2.3 Soil .....	151
6.3 ENVIRONMENTAL FATE .....	152
6.3.1 Transport and Partitioning .....	152
6.3.2 Transformation and Degradation .....	152
6.3.2.1 Air .....	153
6.3.2.2 Water .....	153
6.3.2.3 Sediment and Soil .....	154
6.3.2.4 Other Media .....	155
6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT .....	155
6.4.1 Air .....	155
6.4.2 Water .....	156
6.4.3 Sediment and Soil .....	156
6.4.4 Other Environmental Media .....	157
6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE .....	157
6.6 EXPOSURES OF CHILDREN .....	159
6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES .....	160
6.8 ADEQUACY OF THE DATABASE .....	160
6.8.1 Identification of Data Needs .....	160
6.8.2 Ongoing Studies .....	162
7. ANALYTICAL METHODS .....	163
7.1 BIOLOGICAL MATERIALS .....	163
7.2 ENVIRONMENTAL SAMPLES .....	164
7.3 ADEQUACY OF THE DATABASE .....	170
7.3.1 Identification of Data Needs .....	170
7.3.2 Ongoing Studies .....	171
8. REGULATIONS, ADVISORIES, AND GUIDELINES .....	173
9. REFERENCES .....	179
10. GLOSSARY .....	205
APPENDICES	
A. ATSDR MINIMAL RISK LEVELS AND WORKSHEETS .....	A-1
B. FRAMEWORK FOR ATSDR'S SYSTEMATIC REVIEW OF HEALTH EFFECTS DATA FOR GLUTARALDEHYDE .....	B-1
C. USER'S GUIDE .....	C-1
D. ACRONYMS, ABBREVIATIONS, AND SYMBOLS .....	D-1

This page is intentionally blank.

## LIST OF FIGURES

3-1. Levels of Significant Exposure to Glutaraldehyde – Inhalation.....	24
3-2. Exposure-Response Array of Selected Glutaraldehyde-Induced Respiratory Effects Following Acute-, Intermediate-, or Chronic-Duration Inhalation Exposure.....	40
3-3. Levels of Significant Exposure to Glutaraldehyde – Oral.....	60
3-4. Proposed Metabolic Scheme for Glutaraldehyde .....	95
3-5. Conceptual Representation of a Physiologically Based Pharmacokinetic (PBPK) Model for a Hypothetical Chemical Substance .....	100
3-6. Existing Information on Health Effects of Glutaraldehyde.....	121

This page is intentionally blank.

**LIST OF TABLES**

2-1. Minimal Risk Levels (MRLs) for Glutaraldehyde .....	11
3-1. Levels of Significant Exposure to Glutaraldehyde – Inhalation.....	16
3-2. Reported Respiratory Responses in Humans Exposed to Glutaraldehyde Vapor .....	27
3-3. Incidences of Male and Female F344/N Rats with Selected Histopathologic Lesions in the Nasal Vestibule Following Exposure to Glutaraldehyde Vapor 6 Hours/Day, 5 Days/Week for up to 13 Weeks in the Time-Course Study .....	32
3-4. Incidences of Male and Female B6C3F1 Mice with Selected Histopathologic Lesions in the Nasal Vestibule Following Exposure to Glutaraldehyde Vapor 6 Hours/Day, 5 Days/Week for up to 13 Weeks in the Time-Course Study .....	34
3-5. Incidences of Male and Female F344/N Rats with Selected Histopathologic Lesions in the Nasal Vestibule Following Exposure to Glutaraldehyde Vapor 6 Hours/Day, 5 Days/Week for up to 2 Years.....	37
3-6. Incidences of Male and Female B6C3F1 Mice with Selected Histopathologic Lesions in the Nasal Vestibule Following Exposure to Glutaraldehyde Vapor 6 Hours/Day, 5 Days/Week for up to 2 Years.....	38
3-7. Levels of Significant Exposure to Glutaraldehyde – Oral.....	50
3-8. Levels of Significant Exposure to Glutaraldehyde – Dermal .....	71
3-9. Summarized Results from Studies Designed to Evaluate Glutaraldehyde-Induced Dermal Hypersensitivity.....	77
3-10. Genotoxicity of Glutaraldehyde In Vitro.....	83
3-11. Genotoxicity of Glutaraldehyde In Vivo .....	87
4-1. Chemical Identity of Glutaraldehyde.....	136
4-2. Physical and Chemical Properties of Glutaraldehyde.....	137
5-1. FDA-Cleared Glutaraldehyde-Containing Disinfectants for Medical Devices .....	141
7-1. Analytical Methods for Determining Glutaraldehyde in Environmental Samples.....	165
8-1. Regulations, Advisories, and Guidelines Applicable to Glutaraldehyde.....	175