IMMEDIATELY DANGEROUS to LIFE or HEALTH

IDLH

VALUE PROFILE

Hydrogen Bromide
CAS® No. 10035-10-6

U.S. Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH) VALUE PROFILE

HYDROGEN BROMIDE

[CAS® No. 10035-10-6]

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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On June 22, 2023, NIOSH published a request for public review in the Federal Register [88 FR 40826] on the draft versions of the Immediately Dangerous to Life or Health Values for Hydrogen Bromide and Hydrogen Iodide. We invited comments from manufacturers, distributors/vendors, healthcare providers, government agencies, academia, professional organizations, non-government organizations, and members of the public. NIOSH did not receive public comments on the draft document for hydrogen bromide.

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June 2025

Summary of changes: updated authorship and acknowledgements.

Worker Summary of the NIOSH Immediately Dangerous to Life or Health (IDLH) Value Profile for Hydrogen Bromide

CAS Number: 10035-10-6
IDLH Value: 35 parts per million (ppm) or 116 milligrams per cubic meter (mg/m^3)

General Substance Information

Other names:
- HBr
- Hydrobromic acid
- Bromane

HBr:
- is a colorless to yellow/brown gas with strong, irritating smell
- is corrosive
- is **not** flammable
- is used for dissolving substances and speeding up chemical reactions
- is stored as liquid or compressed gas
- liquid gives off strong fumes that sink in air

Health Effects of HBr

Short-term exposure to dangerous levels causes:
- eye irritation (stinging and burning)
- coughing
- difficulty breathing
- symptoms get worse as exposure continues

As HBr levels increase:
- nose and throat pain
- asthma-like symptoms
- lung injury and fluid in lungs

For more information on HBr visit: LINK TO CHEMICAL DOCUMENT

What is an IDLH Value?

NIOSH develops IDLH values for workplace conditions carrying immediate, unacceptable risks. As a safety margin, IDLH values are based on the effects that might occur from 30-minute exposures. Workers should not stay in an IDLH environment longer than absolutely necessary. **EVERY EFFORT SHOULD BE MADE TO EXIT IMMEDIATELY!** Short exposures to highly concentrated chemicals in the air can quickly overwhelm workers and harm worker health. Harmful effects may include:
- Long-term health issues
- Inability to escape the area
- Death

Workers should **never** be exposed to air concentrations that exceed the IDLH value without proper respiratory protection. NIOSH sets IDLH values to make sure that a worker can escape **immediately** from an area before severe injuries occur.

Employers must require workers to wear a NIOSH Approved® full facepiece self-contained breathing apparatus (SCBA) or a combination supplied air respirator with SCBA when entering IDLH conditions. These respirators deliver clean air to the worker in dangerous conditions, and these provide the greatest protection.

NIOSH Approved is a certification mark registered in the United States and several international jurisdictions.

Basis for IDLH Value: In an experiment done in mice, HBr gas caused severe breathing problems and death after exposure to increasingly high concentrations. The concentration at which these effects occurred in mice was used to estimate an IDLH value for humans. Because humans could be more sensitive than mice, the IDLH concentration was divided by an uncertainty factor to account for the expected difference. This IDLH value was calculated to be 35 ppm. Reports reviewed by NIOSH indicate that people exposed to this concentration may experience burning sensations in the nose and throat. Continuous exposure to this concentration is expected to cause corrosive injury to the airways and lungs.

For more information on HBr visit: NIOSH POCKET GUIDE

Foreword

Chemicals are a frequent component of the modern workplace. Occupational exposures to chemicals have long been recognized as having the potential to adversely affect the lives and health of workers. Acute or short-term exposures to high concentrations of some airborne chemicals can quickly overwhelm workers, affecting their ability to escape from the exposure environment. These exposures can result in a range of negative health outcomes—from eye and respiratory tract irritation to severe, irreversible health effects—and in extreme cases, death.

Airborne concentrations of chemicals capable of causing such adverse health effects or impeding escape from high-risk conditions may come from a number of nonroutine workplace situations affecting workers. These may include special work procedures (e.g., in confined spaces), industrial incidents (e.g., chemical spills or explosions), and chemical releases into the community (e.g., during transportation incidents or other uncontrolled-release scenarios).

This technical report presents the scientific basis, toxicologic data, and risk assessment methodology used to derive a health-based immediately dangerous to life or health (IDLH) value for hydrogen bromide (CAS No. 10035-10-6). The IDLH values are based on the scientific rationale and logic outlined in *Current Intelligence Bulletin (CIB) 66: Derivation of Immediately Dangerous to Life or Health Values* [NIOSH 2013].

This approach is intended to (1) update the scientific basis and risk assessment methodology used to derive IDLH values from quality toxicity and human health effects data and (2) provide transparency behind the rationale and derivation process for IDLH values. The IDLH value for hydrogen bromide has been established through the approach outlined in CIB 66. This value is intended to protect against health effects that impair escape, are irreversible, or result in death from exposures of 30 minutes or less.

John Howard, M.D.
Director
National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention

Contents

Abbreviations*

ACGIH®	American Conference of Governmental Industrial Hygienists
AEGLs	acute exposure guideline levels
AIHA®	American Industrial Hygiene Association
atm	atmosphere (a unit of pressure)
BMC	benchmark concentration
BMCL	benchmark concentration lower confidence limit
BMD	benchmark dose
BMR	benchmark response
C	ceiling value
°C	degrees Celsius
CAS®	chemical abstracts service
CIB	Current Intelligence Bulletin
ERPGs™	Emergency Response Planning Guidelines
°F	degrees Fahrenheit
HBr	hydrogen bromide
HCl	hydrogen chloride (hydrochloric acid)
HF	hydrogen fluoride
hr	hour
IDLH	immediately dangerous to life or health
IFA	Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung v(Institute for Occupational Safety and Health of the German Social Accident Insurance)
LC	lethal concentration
LC_{01}	1% lethal concentration
LC_{50}	median lethal concentration
LC_{LO}	lowest concentration that caused death in humans or animals
LD_{50}	median lethal dose
LD_{LO}	lowest dose that caused death in humans or animals
LEL	lower explosive limit
LOAEL	lowest observed adverse effect level
mg/m^3	milligram(s) per cubic meter
min	minutes
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
NLM	National Library of Medicine
NOAEL	no observed adverse effect level
NRC	National Research Council
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration

PEL	permissible exposure limit
POD	point of departure
ppm	parts per million
RD_{50}	concentration of a chemical in the air that is estimated to cause a 50% decrease in the respiratory rate
REACH	Registration, Evaluation, Authorization, and Restriction of Chemicals (European Union regulatory program)
REL	recommended exposure limit
RfC	reference concentration
STEL	short-term exposure limit
TEEL	temporary emergency exposure limit
TERA	Toxicology Excellence for Risk Assessment
TLV®	threshold limit value
TWA	time-weighted average
UEL	upper explosive limit
UF	uncertainty factor
WEELs®	Workplace Environmental Exposure Levels

**Abbreviations listed are based on recurring use in IDLH documents and do not necessarily indicate usage in this assessment*

Glossary

Acute exposure: Exposure by the oral, dermal, or inhalation route for 24 hours or less.

Acute exposure guideline levels (AEGLs): Threshold acute exposure limits for the general public, applicable to exposure periods ranging from 10 minutes to 8 hours. AEGL-1, AEGL-2, and AEGL-3 values for individual chemicals are developed for reversible and nondisabling, irreversible or disabling, and lethal effects, respectively. Five values at each severity level are developed for 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours [NRC 2014]. AEGLs are intended to be guideline levels used during rare events or single once-in-a-lifetime exposure to airborne concentrations of acutely toxic, high-priority chemicals [NRC 2014]. AEGLs are designed to protect the general population, including the elderly, children, and other potentially sensitive groups who are generally not considered in the development of workplace exposure recommendations. (Additional information is available at https://www.epa.gov/aegl.)

Acute reference concentration (Acute RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure for an acute duration (24 hours or less) of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors (UFs) generally applied to reflect limitations of the data used. Generally used in EPA noncancer health assessments [EPA 2022].

Acute toxicity: Any poisonous effect produced within a short period of time following an exposure, usually 24 to 96 hours [EPA 2022].

Adverse effect: A substance-related biochemical change, functional impairment, or pathologic lesion that affects the performance of an organ or system or alters the ability to respond to additional environmental challenges.

Benchmark dose/concentration (BMD/BMC): A dose or concentration that produces a predetermined change in response rate of an effect (called the benchmark response, or BMR) compared with background [EPA 2022]. (Additional information is available at https://www.epa.gov/bmds.)

Benchmark response (BMR): An adverse effect, used to define a benchmark dose from which a reference dose or concentration can be developed. The change in response rate over background of the BMR is usually in the range of 5%–10%, which is the limit of responses typically observed in well-conducted animal experiments [EPA 2022].

Benchmark concentration lower confidence limit (BMCL): A statistical lower confidence limit on the concentration at the BMC [EPA 2022].

Bolus exposure: A single, relatively large dose.

Ceiling value ("C"): Term in occupational exposure indicating the airborne concentration of a potentially toxic substance that should never be exceeded in a worker's breathing zone.

Chronic exposure: Repeated exposure for an extended period of time. Typically, exposures are more than approximately 10% of life span for humans and >90 days to 2 years for laboratory species.

Critical study: The study that contributes most significantly to the qualitative and quantitative assessment of risk [EPA 2022].

Dose: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism [EPA 2022].

Emergency Response Planning Guidelines (ERPGs™): Maximum airborne concentrations below which nearly all individuals can be exposed without experiencing health effects for a 1-hour exposure. ERPGs are presented in a tiered fashion, with health effects ranging from mild or transient to serious, irreversible, or life threatening (depending on the tier). ERPGs are developed by the American Industrial Hygiene Association [AIHA 2016].

Endpoint: An observable or measurable biological event or sign of toxicity, ranging from biomarkers of initial response to gross manifestations of clinical toxicity.

Exposure: Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

Extrapolation: An estimate of the response at a point outside the range of the experimental data, generally through the use of a mathematical model, although qualitative extrapolation may also be conducted. The model may then be used to extrapolate to response levels that cannot be directly observed.

Hazard: A potential source of harm. Hazard is distinguished from risk, which is the probability of harm under specific exposure conditions.

Immediately dangerous to life or health (IDLH) condition: A condition that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment [NIOSH 2004, 2013].

IDLH value: A maximum (airborne concentration) level above which only a highly reliable breathing apparatus providing maximum worker protection is permitted [NIOSH 2004, 2013]. IDLH values are based on a 30-minute exposure duration.

LC_{01}: The statistically determined concentration of a substance in the air that is estimated to cause death in 1% of test animals.

LC_{50}: The statistically determined concentration of a substance in the air that is estimated to cause death in 50% of test animals; median lethal concentration.

LC_{LO}: The lowest lethal concentration of a substance in the air reported to cause death, usually for a small percentage of the test animals.

LD_{50}: The statistically determined lethal dose of a substance that is estimated to cause death in 50% of the test animals, i.e., the median lethal concentration.

LD_{LO}: The lowest dose of a substance that causes death, usually for a small percentage of test animals.

Lethality: Pertaining to or causing death; fatal; referring to the deaths resulting from acute toxicity studies. May also be used in a lethality threshold to describe the point of sufficient substance concentration to begin to cause death.

Lower explosive limit (LEL): The minimum concentration of a gas or vapor in air, below which propagation of a flame does not occur in the presence of an ignition source.

Lowest observed adverse effect level (LOAEL): The lowest tested dose or concentration of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Mode of action: The sequence of significant events and processes that describes how a substance causes a toxic outcome. By contrast, the term "mechanism of action" implies a more detailed understanding on a molecular level.

No observed adverse effect level (NOAEL): The highest tested dose or concentration of a substance that has been reported to cause no harmful (adverse) health effects in people or animals.

Occupational exposure limit (OEL): Workplace exposure recommendations developed by governmental agencies and nongovernmental organizations. OELs are intended to represent the maximum airborne concentrations of a chemical substance below which workplace exposures should not cause adverse health effects. OELs may apply to ceiling limits, STELs, or TWA limits.

Peak concentration: Highest concentration of a substance recorded during a certain period of observation.

Permissible exposure limits (PELs): Occupational exposure limits developed by OSHA (29 CFR § 1910.1000) or MSHA (30 CFR § 57.5001) for allowable occupational airborne exposure concentrations. PELs are legally enforceable and may be designated as ceiling limits, STELs, or TWA limits [OSHA 2019].

Point of departure (POD): The point on the dose–response curve from which dose extrapolation is initiated. This point can be the lower bound on dose for an estimated incidence or a change in response level from a concentration-response model (BMC). It can also be a NOAEL or LOAEL for an observed effect selected from a dose evaluated in a health effects or toxicology study.

RD_{50}: The statistically determined concentration of a substance in the air that is estimated to cause a 50% decrease in the respiratory rate.

Recommended exposure limit (REL): Recommended maximum exposure limit to prevent adverse health effects, based on human and animal studies and established for occupational (up to 10-hour shift, 40-hour week) inhalation exposure by NIOSH. RELs may be designated as ceiling limits, STELs, or TWA limits.

Short-term exposure limit (STEL): An exposure concentration limit that shall not be exceeded at any time during a workday, usually based on a 15-minute time-weighted average unless otherwise noted.

Target organ: Organ in which the toxic injury manifests in terms of dysfunction or overt disease.

Threshold limit values (TLVs®): Recommended guidelines for occupational exposure to airborne contaminants, published by the American Conference of Governmental Industrial Hygienists (ACGIH®). TLVs refer to airborne concentrations of chemical substances and represent condi-

tions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse effects. TLVs may be designated as ceiling limits, STELs, or 8-hour TWA limits [ACGIH 2021].

Time-weighted average (TWA): A worker's 8-hour (or up to 10-hour) time-weighted average exposure concentration that shall not be exceeded during an 8-hour (or up to 10-hour) work shift of a 40-hour week. The average concentration is weighted to take into account the duration of different exposure concentrations [ACGIH 2021].

Toxicity: The degree to which a substance can cause an adverse effect on an exposed organism.

Uncertainty factors (UFs): Mathematical adjustments applied to the POD when developing exposure limits or IDLH values. The UFs for IDLH value derivation are determined by considering the study and effect used for the POD, with further modification based on the overall database.

Workplace Environmental Exposure Levels (WEELs®): Exposure levels developed by the American Industrial Hygiene Association (AIHA®) that provide guidance for protecting most workers from adverse health effects related to occupational chemical exposures, expressed as TWA or ceiling limits.

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Krystin Carlson, PhD (formerly of the Division of Science Integration) also contributed to earlier versions of this document.

IDLH Value for Hydrogen Bromide

IDLH Value: 35 ppm (116 mg/m^3)

Basis for IDLH Value: The immediately dangerous to life or health (IDLH) value for hydrogen bromide (HBr) is based on lethality. MacEwen and Vernot [1972] reported a one-hour LC_{50} of 814 ppm in mice, which is the lower of two LC_{50} values available for HBr. Lethality in mice was accompanied by severe dyspnea and respiratory distress. A 30-minute (min) adjusted equivalent concentration of 1,026 ppm was derived using the ten Berge method. An uncertainty factor (UF) of 30 was applied to extrapolate the risk of immediately dangerous effects to human workers in an emergency scenario. The calculated limit value of 34 ppm was rounded to 35 ppm for the final IDLH value. This updates the previous IDLH value of 30 ppm that was based on a 10-fold extrapolation from the NIOSH REL for hydrogen bromide of 3 ppm.

1 Introduction

1.1 Purpose

This *Immediately Dangerous to Life and Health (IDLH) Value Profile* presents (1) a brief summary of technical data associated with acute inhalation exposures to hydrogen bromide (HBr) and (2) the scientific rationale behind the IDLH value for HBr. IDLH values are developed based on the scientific rationale and logic outlined in the C*urrent Intelligence Bulletin (CIB) 66: Derivation of Immediately Dangerous to Life or Health (IDLH) Values* [NIOSH 2013]. NIOSH performed in-depth literature searches (outlined generally in CIB 66 and further described in Section 1.2 of this document) to ensure that all relevant data from human and animal studies with acute exposures to the substance were identified. The data identified in this literature search were evaluated for relevance by considering the methods used in the studies (i.e., species, study protocol, exposure concentration, and duration), the health endpoint(s) evaluated, and the critical effect levels (e.g., NOAELs, LOAELs, LC_{50} values).

1.2 How IDLH Values Are Set

An IDLH situation is one that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment [NIOSH 2004]. An IDLH value is a maximum (airborne concentration) level above which only a highly reliable breathing apparatus providing maximum worker protection is permitted [NIOSH 2004]. IDLH values are based on a 30-minute (min) exposure duration and signal that every effort should be made to evacuate the area. These values are designed to protect workers from acute or short-term exposures to high concentrations of airborne chemicals that could quickly overwhelm them, affecting their ability to escape. These exposures could result in a range of undesirable outcomes from eye and respiratory tract irritation to severe irreversible health effects, and in extreme cases, death. IDLH values also protect workers against non-toxicological safety hazards, including deprivation of oxygen, impairment of visibility, and ignition in the air.

1.2.1 Health Effects Considered

For the purposes of setting an IDLH value, NIOSH typically considers health effects data for the following acute health endpoints [NIOSH 2013]:

- Lethality/death

- Acute deficits in neurological and/or psychomotor functions that impair escape by interfering with workers' ability to recognize escape routes and any actions needed to get away through those routes, such as the operation of lifts, elevators, and door mechanisms
- Eye irritation severe enough to affect workers' ability to see adequately and escape the area
- Respiratory irritation severe enough to impair breathing, assuming a non-rest scenario, or that results in long-term respiratory complications
- Cardiac and hematological effects, including cardiac sensitization
- Any other specific target organ effects that are incapacitating and escape impairing or have the potential for long-term injury, disability, or deficits in function

1.2.2 Time Scaling

Effect levels for acute exposures are adjusted to 30-min effect levels when needed using the ten Berge et al. [1986] method, where a "k" constant value is calculated from concentration (C) and time (t) using the equation $C^n \times t = k$. When the value of the exponent *n* can be derived from data, the data-based *n* is used. Otherwise, default values of 1 for adjusting from a shorter exposure to 30 min and 3 for adjusting from longer exposures are used as described in CIB 66. For effects that are understood to occur based on threshold concentration regardless of exposure duration, time scaling may not be required.

1.2.3 Uncertainty Factor Considerations

The time-scaled effect levels for immediately dangerous health effects are modified by an uncertainty factor (UF) to estimate the concentration correlating to an unacceptable risk of immediately dangerous health effects in workers and account for the possibility of underestimating the degree of risk. When estimating an overall UF, NIOSH considers the following types of uncertainty and variability (NIOSH 2013, 2020):

- Interspecies differences in sensitivity: When the effect level is obtained from animal data, the potential difference between animal and human responses should be accounted for. When data specific to the chemical are available, a factor may be calculated based on the known magnitude of toxicokinetic and/or toxicodynamic differences. If chemical-specific data are not available, NIOSH typically selects a value between 1 and 10 depending on the expectation of animal-to-human differences in toxic susceptibility.
- Human variability in sensitivity: To account for potential differences in sensitivity between individuals, NIOSH typically selects a value between 1 and 10 depending on the mode-of-action considerations in humans and, in cases where IDLH values are based directly on human subject data, whether variability among workers can be assessed from the experimental sample population. Because NIOSH generally assumes workers to be adults and in reasonable health, UFs for IDLH values generally do not account for particularly sensitive subgroups such as those with preexisting conditions.
- Severity of effect: A UF may be applied when the IDLH is based on health effects severe enough that overestimation of the threshold of immediately dangerous or lethal effects in workers becomes a concern. This may be done to ensure that the IDLH is sufficiently protective of workers' health when the boundary between adverse and immediately dangerous risk is difficult to interpret.
- Other factors or database deficiencies: If gaps in the database create the possibility of significantly overestimating the IDLH value, UFs may be used to account for this. In addition, in special cases other factors may arise that warrant inclusion of a UF.

1.3 Literature Search

Primary Literature Search

NIOSH performed an initial broad literature search and screened literature during November 2022 as outlined in NIOSH Current Intelligence Bulletin 66: Derivation of immediately dangerous to life or health (IDLH) values [NIOSH 2013]. This included several public databases consisting of non-peer reviewed literature that were reviewed for toxicity information on HBr.

For searching the peer-reviewed primary literature, the following literature databases were used based on relevance and current availability. They were searched without limitations on publication date and were most recently queried in December 2024:

- PubMed/Medline
- Scopus
- Embase

Search terms used to search the primary literature for effect level data for animal and human endpoints relevant to the IDLH assessment are given in Table 1.1. These terms were used in conjunction with the chemical identifiers of "hydrogen bromide" or "hydrobromic acid." The search terms were selected to best reflect the body of literature specific to HBr and most effectively retrieve relevant toxicity data.

Table 1.1: Search Terms Used to Find Human and Animal Acute Toxicity Data

Acute	Symptoms	Accident
Irritation	Lethality	Confusion
Behavioral	LC_{50}	Toxicity
Neuro*	RD_{50}	Occupational
Psycho*	Poisoning	Volunteers
Subjects	Clinical	Animal
Inhalation	ppm	Fatality

*Denotes terms searched as prefixes

Tree Search for Government Reports and Non-peer Reviewed Literature

In addition to primary literature searches, NIOSH reviewed references cited in authoritative reviews and other literature to identify relevant toxicity data. NIOSH primarily used acute exposure guideline level (AEGL) documentation for HBr [NRC 2014]. The REACH chemical information dossier for HBr [ECHA 2022] was also reviewed for toxicity data. All datasets identified through these means were reviewed by NIOSH to identify effect levels from endpoints relevant to the IDLH assessment.

Screening Methods and Study Inclusion Criteria

NIOSH used the following inclusion criteria to screen for relevant datasets:

- Populations included in the review were human adults, workers, and mammalian test species.
- Exposures included in the review were acute exposures, meaning less than ~1 day for reports and <8 hour (hr) for experiments by any route where dose/concentration is known or estimated. Reports were excluded when the exposure concentration and/or duration were not estimated or reported.

- Comparators/controls included any comparisons between known doses/concentrations including comparisons between non-exposed, lower-exposed, and baseline prior to acute exposure.
- Outcomes included escape-impairing signs, symptoms, and endpoints in humans or animals; persistent adverse signs or symptoms in humans; persistent adverse effects in any organ/species; lethality; or RD_{50} values. For the purposes of the IDLH assessment, "escape-impairing" endpoints include acute neurological symptoms (e.g., recognition of letters and numbers, reaction time, psychomotor performance), irritation of the eyes and/or airways, or self-reported symptoms of the same.

2 General Substance Information

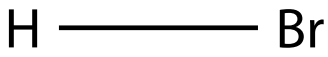
Chemical: Hydrogen Bromide

CAS No: 10035-10-6

Synonyms: HBr, anhydrous hydrogen bromide, aqueous hydrogen bromide (hydrobromic acid)*

Chemical category: Bromine compounds, inorganic; inorganic acids†

Structural formula*:



References: *[NLM 2022] †[IFA 2019]

Hydrogen bromide (HBr) is a colorless, corrosive, nonflammable gas with an acrid, irritating odor. It is commercially available as an aqueous solution or as a compressed gas. HBr is used in the organic synthesis of bromine-containing compounds, as a mineral ore solvent or mineral residue cleaner, and as an alkylation catalyst [ACGIH 2021]. High exposures to HBr have also been observed following the inadvertent hydrolysis of brominated compounds including fire extinguisher compounds and fumigants containing brominated hydrocarbons. Aqueous HBr (hydrobromic acid) forms corrosive vapors that are heavier than air and may flow along the ground [ACGIH 2021]. Table 2.1 summarizes the physicochemical properties of HBr relevant to IDLH conditions.

Several agencies and other safety and health organizations have developed OELs based on the human health effects of aqueous HBr exposure. Existing exposure limits for HBr are given in Table 2.2. These range from OELs for daily 8-hr exposures (NIOSH REL, OSHA PEL, ACGIH TLV) to short-term acute exposures (AIHA ERPGs). Limit values estimated for shorter exposure periods are typically at higher concentrations than those estimated for longer periods. Some limit values are expressed as ceiling limits that should not be exceeded at any time during the workday. IDLH values differ from ceiling limits in that ceiling limits protect workers from adverse effects arising from peaks in exposure concentration and apply to normal workday routines. IDLH values are meant only to protect workers from severe or catastrophic effects in the course of responding to a potential workplace emergency. The NIOSH IDLH value is estimated for a 30-min exposure period to give workers time to leave an area as quickly and safely as possible.

AEGL values are emergency safety limits developed by the National Research Council and designed to protect members of the general public from adverse health effects from airborne chemicals for periods ranging from 10 min to 8 hr. AEGL values are estimated for three ranges of effects: nondisabling (AEGL-1), disabling (AEGL-2), and lethal (AEGL-3). The AEGL value most analogous to the IDLH is the 30-min AEGL-2 value, which is estimated to protect people from irreversible, serious, or escape-impairing effects, including in susceptible individuals. The AEGL values for HBr are listed in Table 2.3.

Table 2.1: Physiochemical Properties of Hydrogen Bromide

Property	Value
Molecular weight	80.9
Description	Colorless gas
Odor	Sharp, irritating
UEL	Not flammable
LEL	Not flammable
Vapor pressure	20 atm
Flash point	Not flammable
Ignition temperature	Not flammable
Solubility in water	49%
Relative gas density	2.81
Incompatibilities and reactivities	Strong oxidizer, strong caustics, moisture, copper, brass, zinc (Note: hydrobromic acid is highly corrosive to most metals)

UEL: upper explosive limit; LEL: lower explosive limit
Reference: NIOSH [2020b]

Table 2.2: Exposure Values and Limits for Hydrogen Bromide

Organization	Value (ppm)
NIOSH REL*	3 ppm (10 mg/m^3), ceiling
OSHA PEL†	3 ppm (10 mg/m3), TWA
ACGIH TLV®‡	2 ppm (6.6 mg/m3), ceiling
AIHA ERPG§	None

References: †Recommended Exposure Limit, NIOSH [2020b]; ‡Permissible Exposure Limit, OSHA [2019]; Threshold Limit Value, ACGIH [2021]; §Emergency Response Planning Guideline, AIHA [2016]

Table 2.3: Acute Exposure Guideline Level Values for Hydrogen Bromide

Classification	10-min	30-min	1-hr	4-hr	8-hr	Endpoint (Reference)
AEGL-1 (Nondisabling)	1.0 ppm 3.3 mg/m^3	1.0 ppm 3.3 mg/m^3	1.0 ppm 3.3 mg/m^3	1.0 ppm 3.3 mg/m^3	1.0 ppm 3.3 mg/m^3	Threshold of nasal irritation in humans [CT Dept of Health,1955, as cited in ACGIH 2021; NRC 2014]
AEGL-2 (Disabling)	250 ppm 827 mg/m^3	83 ppm 275 mg/m^3	40 ppm 132 mg/m^3	10 ppm 33 mg/m^3	5 ppm 17 mg/m^3	One third of AEGL-3 values [NRC 2014]
AEGL-3 (Lethal)	740 ppm 2449 mg/m^3	250 ppm 8279 mg/m^3	120 ppm 397 mg/m^3	31 ppm 103 mg/m^3	15 ppm 50 mg/m^3	Threshold for lethality in rats [MacEwen and Vernot 1972; NRC 2014]

Reference: NRC [2014]

3 Health Effects of Hydrogen Bromide

Overview of Health Effects: Hydrogen halides such as HBr form corrosive gases and are eye and respiratory tract irritants. As a chemical class, they are highly soluble and rapidly absorbed in the upper airways. HBr has an odor threshold reported between 2 ppm and 12 ppm [Amoore and Hautala 1983]. Information on the immediately dangerous effects of HBr gas is available from experimental data in animals and limited experimental and case report data in humans.

3.1 Physical Safety

HBr is noncombustible on its own and ignition is not a safety hazard at any concentration.

3.2 Lethality

3.2.1 Overview

Reports of lethality caused by acute exposure to HBr are limited to experimental reports in rats and mice. The lowest LC50 value identified was 814 ppm derived from a 1-hr exposure in mice [MacEwen and Vernot, 1972]. Death in animals was accompanied by severe dyspnea, and some deaths were not immediate and occurred over the following hours or days.

3.2.2 Human Data

No reports of deaths in humans due to HBr exposure were identified.

3.2.3 Animal Data

MacEwen and Vernot [1972] exposed groups of 10 male CFE (Sprague-Dawley derived) rats to 2,205 ppm; 2,328 ppm; 2,759 ppm; 3,253 ppm; 3,711 ppm; or 3,822 ppm of HBr for 1 hr and male CF1 (non-Swiss albino) mice to 507 ppm; 875 ppm; 1,036 ppm; or 1,163 ppm for 1 hr. Concentrations were monitored in real time. The study reported a 1-hr LC_{50} of 2,858 ppm for rats and 814 ppm for mice, with no mortality observed at 507 ppm for mice. The next highest concentration of 875 ppm caused death in the majority (7/10) of animals, thus the lowest observed lethal concentration fell above the calculated median lethal estimate for this particular study. Nose and eye irritation, labored breathing, gasping, and convulsions were observed in exposed animals, but the concentrations at which these effects occurred were not reported. During the 14-day post-exposure period, the surviving animals were prostrate and most lost weight. Delayed deaths were observed. Burns accompanied by autolysis were observed on exposed areas of the skin, such as feet, tails, scrotum, and ears. Severe liver and lung congestion with pulmonary edema was reported in rats exposed to 3,822 ppm. The authors also reported that rats exposed to 2,205 ppm had necrotic lesions on their feet and tails for up to 14 days. The only gross pathological effect in mice that survived the 14-day post-exposure period was tail necrosis. The authors also reported milky cornea opacity in both rats and mice that resolved by 24-hr post-exposure. In an additional study, Kusewitt et al. [1989] reported no deaths in F344 rats exposed to up to 1,000 ppm HBr for 30 min. An examination of respiratory tract histology at 8 hr and 24 hr following exposure showed corrosive damage limited to the nasal region.

Table 3.1 summarizes the LC data identified in animal studies.

Table 3.1. Lethal Concentration Data for Hydrogen Bromide

Species	LC_{50} (ppm)	Time (min)
Mouse	814	60
Rat	2,858	60

Reference: MacEwen and Vernot [1972]

3.3 Neurotoxicity

No evidence indicates neurological effects are a human health hazard of acute exposure to HBr.

3.4 Respiratory and Eye Irritation

3.4.1 Overview

Halogen acids such as HBr are rapidly absorbed by airway surfaces and cause damage and corrosive injury to tissue in addition to causing typical sensory irritation symptoms (e.g., coughing, dyspnea, stinging/burning of eyes). Reports of human and animal exposures to gases or vapors of HCl indicate that eye and airway irritation symptoms are immediate, and symptoms can continue to develop after exposure to sufficiently high concentrations [NIOSH 2025].

Regarding eye irritation, data in guinea pigs reported by Burleigh-Flayer et al. [1985] and reviewed in the documentation of the NIOSH IDLH value for HCl indicated that corneal opacity occurred following a 30-min exposure to 680 ppm HCl with a no-effect level of 320 ppm. This is consistent with the report by MacEwen and Vernot [1972], reporting corneal opacity following a one-hr exposure to 507 ppm HBr in mice. The authors reported this effect resolved within 24 hrs. Victims of incidental high exposures in reports reviewed below describe eye irritation symptoms in several cases, but the reports do not indicate that victims experienced escape-impairing eye effects even at levels resulting in severe respiratory effects [Burns and Linden 1997; Feng et al. 2006; Miller et al. 1961; Orlando et al. 1997]. These data suggest that concentrations of HBr causing escape-impairing or irreversible eye effects in humans during or following a 30-min exposure are likely in the range of several hundred ppm.

Regarding respiratory irritation, data specific to HBr is limited. The study in rats by Stavert et al. [1991], summarized below, is the only animal study identified for HBr exposure. Reports of humans incidentally exposed to dangerous HBr levels indicate that the airways are a critical target of acute exposure to HBr gas. People exposed to high HBr levels gas in home and workplace incidents reported chest tightness, burning, and shortness of breath that can be persistent, but reliable estimates of exposure thresholds for these outcomes are sparse [Burns and Linden 1997; Feng et al. 2006; Miller et al. 1961; Orlando et al. 1997]. There are no rodent RD_{50} values available for HBr, but the Stavert et al. [1991] study demonstrated that respiratory damage induced by inhaled HBr gas was highly regionalized and reflected the chemical's rapid absorption in the airways, similar to the effects of HCl. HCl is the closest chemical analogue to HBr. The most sensitive rodent RD_{50} value identified for HCl was reported to be 309 ppm in mice [Barrow et al. 1977]. These data give some idea of the respiratory potency of HBr but no data are available to support an IDLH value based directly on respiratory irritation endpoints.

3.4.2 Human Data

The human toxicity data available for HBr consists of one human subject study reported by the Connecticut State Department of Health in 1955 [as cited in ACGIH 2021] and several case reports from incidental exposures, some of which allow for a rough estimation of exposure

levels [Burns and Linden 1997; Feng et al. 2006; Miller et al. 1961; Orlando et al. 1997]. Overall, these reports indicated that HBr has a distinctive odor at concentrations below those that cause escape-impairing effects. With increasing dose, exposed humans were reported to first experience an irritating sensation in the nose, followed by throat irritation and eventually tissue damage to the lower airways (chemical pneumonitis). From these reports, irritating sensations in the nose and throat preceded escape-impairing effects such as eye irritation and cough. Data from reports on irritation effects in humans exposed to HBr were not suitable for quantitatively estimating an IDLH value based on respiratory irritation endpoints.

In the 1955 human subject study, the Connecticut State Department of Health reported on six volunteers exposed to 2, 3, 4, 5, or 6 ppm HBr gas for "several minutes" [as cited in ACGIH 2021]. With irritation effects being classified as subjective reports of "slight, stinging sensation to a definite feeling of irritation," subjects reported nose and throat irritation beginning at 3 ppm and 4 ppm. At 6 ppm, subjects did not report eye irritation despite all reporting nose irritation. One out of six subjects reported throat irritation at each dose level from 3–6 ppm. All subjects reported odor at all exposure levels. It was not clear from the available summary whether this study was done in a continuous escalation format or used a recovery period or whether the same volunteers were exposed to each exposure level. HBr at exposure levels up to 6 ppm for several minutes were not reported to affect sight or breathing in a way that would impair escape.

Miller et al. [1961] reported a case where HBr gas was generated in a home by interaction of a gas pilot light and fumigated methyl bromide. Family members in the home reported significant eye and upper respiratory tract irritation. Based on a reconstruction of the exposure, the authors estimated a peak concentration of 72 ppm HBr in the home. The effects were immediate and poorly tolerated by the family, who vacated the house as a result.

Burns and Linden [1997] reported two separate cases of reactive airway distress syndrome after exposure to HBr and bromine gas in an indoor hot tub for 5 min and 10 min, respectively. No air concentrations were estimated but the patients reported severe irritation and an acrid odor. The authors surmised that the gas was generated by a combination of bromine being used as a disinfectant along with low pH and high temperature. Symptoms of dyspnea and burning sensation in the airways were persistent in both cases a year following the incidents.

Orlando et al. [1997] reported a case of a 37-year-old male manufacturing worker who worked in the vicinity of a circuit-board-stripping machine that generated vapors of hydrobromic acid for approximately 3.5 hr, at which point the worker left due to throat irritation and cough. The patient was seen clinically for persistent nonatopic cough and dyspnea that were triggered by nonspecific exposure to chemicals, fumes, and fragrances. The patient's obstructive symptoms worsened over several months, resulting in disability. The concentration of HBr gas inhaled was not known, but a subsequent examination of the workplace indicated vapors of HBr, and lesser amounts of HF and hydrogen phosphide.

Feng et al. [2006] reported on the outcome of a workplace incident during which 44 workers were exposed to HBr and bromine gas. All 44 workers were affected with respiratory symptoms including sore throat, chest tightness, and wet and dry rales/coarse breathing; 26 workers were hospitalized for severe effects. From this report, the extent of eye irritation and/or immediate breathing difficulty the workers experienced was not evident, but the report emphasized that the pungent odor alerted the workers and prompted the decision to evacuate the area. The level of HBr in the workplace was not measured contemporaneously and no exposure reconstruction was available to estimate the exposure concentration.

3.4.3 Animal Data

MacEwen and Vernot [1972] reported temporary corneal opacity following a one-hour exposure to 507 ppm HBr in mice. Respiratory irritation studies in animals were limited.

Ivanov et al. [1976] exposed groups of eight rats to a range of HBr concentrations for 4 hours and measured respiratory function along with several other endpoints. The summary reported respiratory depression and olfactory desensitization in rats exposed to HBr with the most sensitive effect threshold calculated to be 26 mg/m^3 (8 ppm). This was the lowest effect level of HBr measured in the experiment, with the next most sensitive effects being subtle changes in body temperature and neurophysiology occurring at 66 mg/m^3 (20 ppm).

Stavert et al. [1991] exposed male F344 rats (5–9/group) to 1,300 ppm HF, HCl, or HBr for 30 min via nose-only or orotracheal (where trachea is intubated through the mouth) inhalation. Lung function (frequency, minute volume, and tidal volume) was monitored during exposure, and body weights, lung weights, and full respiratory tract pathology were assessed 24 hr following exposure. During exposure, breathing frequency, minute volume, and tidal volume in HBr-exposed nose-only rats decreased by mean percentages of ~5%, ~25%, and ~19%, respectively, over a 30-min exposure. Minute volume decreased immediately at the onset of exposure and appeared to recover within several minutes.

Ventilation effects in the HCl-exposed group followed a similar profile. No effects were seen in orotracheally-intubated rats exposed to HBr or HCl, despite inhaling 39% and 23% higher doses than nose-only rats as estimated by the authors. Histopathological lesions 24 hr following HBr or HCl exposure consisted of necrosis, exudation, and submucosal inflammation. In nose-breathing animals, these lesions were limited to the nasal cavity. In orotracheally-intubated animals, these lesions were present in the trachea and conducting airways, and some inflammation was present in the lung. Overall, results of this study indicate that HBr is rapidly absorbed in the airway, and that respiratory irritation effects can vary based on airway anatomy. The study was conducted at a concentration far above the HCl RD_{50} values reported in rats [Barrow et al. 1977; Hartzell et al. 1985]. Therefore, the ventilation data generated in this study are not likely to be useful for predicting rodent ventilation effects at exposure levels that would normally be used to derive a candidate IDLH value.

3.5 Cardiac and Hematological Effects

No evidence was identified that indicated direct cardiac or hematological effects from HBr exposure.

3.6 Other Relevant Health Effects

No other target organ effects resulting from acute exposure to HBr were identified.

4 Determination of IDLH Value

4.1 Selection of Critical Data

Immediately dangerous effects of acute exposure to HBr shown in available data consist of respiratory and eye irritation and death. HBr exposure is not an explosive or asphyxiant hazard and does not induce any other immediately dangerous or irreversible health effects. HBr is a corrosive irritant gas and directly damages exposed tissues on contact. Similar to HCl gas [Kaplan et al. 1985], the respiratory and eye irritant effects of HBr are not necessarily escape-impairing but result in acute necrotic and denuding effects in airways that can result in prolonged respiratory distress [Feng et al. 2006]. Though no reports of human fatalities were identified, lethal exposures in animals indicate that massive acute damage to the airways and lungs is the cause of death in fatal exposures to HBr gas. Data were not available to derive an IDLH value from respiratory irritation data. NIOSH considered candidate IDLH values based on eye irritation and lethality:

Eye Irritation: MacEwen and Vernot [1972] reported temporary corneal opacity in mice exposed to 507 ppm HBr for 1 hr. The study did not find a no-effect level, but the study by Burleigh-Flayer et al. [1985] observed corneal opacity in guinea pigs following a 30-min exposure to 640 ppm HCl with a no-effect level of 320 ppm. This is the lowest reported no-effect level for corneal opacity identified in the available literature for HCl. Because the effects of HCl on the eyes are expected to approximate those of HBr, and the lowest adverse effect levels for corneal opacity are similar between the HBr study in rats and the HCl study in guinea pigs, the no-effect level of 320 ppm from the Burleigh-Flayer et al. [1985] study in guinea pigs was used as a read-across no-effect level for corrosive eye irritation induced by exposure to HBr gas. Test concentrations from these studies were nominal, but authors reported analytical monitoring of concentrations in both cases.

Lethality: The rodent lethality study by MacEwen and Vernot [1972] provides the only quantitative lethality data available for HBr. The study found 1-hr LC_{50} values of 814 ppm in mice and 2,858 ppm in rats. There were no deaths in mice exposed to 507 ppm. The more sensitive of the two LC_{50} values was used to derive a candidate IDLH value. The calculated LC_{50} was used instead of an estimate of lethality threshold (i.e., a LC_{LO} or BMCL value) because this was considered the most quantitatively robust metric available. In particular, the sharp increase in lethal incidence between the no-effect and lowest-observed effect concentrations made estimates of a true sub-lethal concentration too uncertain or dependent on choice of model.

4.2 Application of Time Scaling

The no-effect level for corneal opacity to derive an IDLH value based on eye irritation was taken from a 30-min exposure study and did not need adjustment.

The LC_{50} value of 814 ppm is adjusted from 60 to 30 min using the ten Berge equation (see Section 1.2.2). A data-driven n exponent value was not available for HBr. The exponents derived for the two closest analogues were 1.0 for HCl and 2.0 for HF [ten Berge et al. 1986]. Because an exponent for HBr could not be clearly extrapolated from these, the default values were used for HBr:

$$(814\ ppm)^3 \times 60\ minutes = (C)^3 \times 30\ minutes$$

$$C = 1{,}026\ ppm\ adjusted\ value$$

4.3 Application of Uncertainty Factors

The UF for eye irritation is based on corneal opacity being a direct effect caused by the corrosivity of HCl (in lieu of HBr) with no biotransformation or other biological steps needed to mediate

the outcome. Therefore, variability in responses between individuals or between animals and humans are expected to be minimal. To account for greater sensitivity humans could potentially have when compared with eye effects in guinea pigs, a UF of 3 was applied.

The UF for the candidate IDLH based on lethality is based on the severity of the effect and extrapolation from mouse to human. Animals exhibited severe dyspnea prior to death when exposed to lethal concentrations of HBr, indicating gross damage to airways and lungs. Although pharmacokinetic differences between mice and humans are not expected to play a role in the lethal effects of HBr gas, differences in rodent airway physiology create a considerable area of uncertainty when extrapolating to human risk, so a factor of 10 is applied (NIOSH 2013). In addition, Malek and Alarie [1989] demonstrated that increased ventilation brought on by physical exertion exacerbated the lethality of halogen halide gas. To account for the likelihood that the exertion of escaping a workplace emergency may increase the susceptibility of workers to severe effects from HBr, an additional modifying factor of 3 was applied for a total UF of 30.

Table 4.1: Potential IDLH Values Based on Immediately Dangerous Health Outcomes of Hydrogen Bromide Exposure

Health outcome	Immediately dangerous effect level (ppm)		30-Min adjusted value (ppm)	Uncertainty factor	Candidate IDLH value (ppm)
Eye irritation	320	NOAEL	320	3	107
Lethality	814	LC_{50}	1,026	30	34

4.4 Final IDLH Calculation

Table 4.1 summarizes the immediately dangerous health outcomes of HBr exposure and potential IDLH values. After applying UFs, NIOSH set the IDLH value based on the 34 ppm limit value for lethality. This value was chosen over the value based on eye irritation because it is substantially more protective and also does not rely on data from a chemical analogue. Furthermore, reports of human exposures support respiratory distress rather than eye irritation as the primary hazard in acute HBr exposure [Feng et al. 2006; Orlando et al. 1997]. Based on the limited amount of human exposure data that was identified, the 34 ppm value based on the lethality value approximates a concentration that would be noticeably uncomfortable in both odor and pungency, but not so severe as to result in lasting injury. The IDLH for HBr is set at a rounded value of 35 ppm.

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