

HPA Compendium of Chemical Hazards

Arsine and Stibine

Key Points

Fire

- Extremely flammable
- Arsine and stibine react with strong oxidants. Stibine reacts with chlorine and concentrated nitric acid
- Arsine decomposes on heating, in light and with moisture producing arsenic fumes. Stibine decomposes to produce metallic antimony and hydrogen gas
- In the event of a fire involving arsine or stibine, use fine water spray and liquid and gas tight chemical protective clothing with breathing apparatus

Health

- Toxic following inhalation
- Arsine is very toxic, stibine is harmful
- The health effects of arsine and stibine are similar
- The characteristic toxic effect of both arsine and stibine is haemolysis (rupture of red blood cells)
- The onset of symptoms following short-term exposure may be delayed for several hours
- Short-term inhalation of arsine or stibine may cause weakness, headache, drowsiness, sickness, anaemia, abdominal pain, dyspnoea, jaundice of the skin and mucous membranes and red urine
- The effect of long-term exposure is thought to cause similar symptoms as short-term exposure
- Arsine is not thought to cause damage to the unborn child

Environment

- Dangerous for the environment
- Inform Environment Agency of substantial releases

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Arsine and Stibine

General information

Key Points

Fire

- Extremely flammable
- Arsine and stibine react with strong oxidants. Stibine reacts with chlorine and concentrated nitric acid
- Arsine emits toxic fumes of arsenic when heated to decomposition
- In the event of a fire involving arsine or stibine, use fine water spray and liquid and gas tight chemical protective clothing with breathing apparatus

Health

- Toxic by inhalation
- Arsine is very toxic, stibine is harmful
- The health effects of arsine and stibine are similar and are characterised by damage to the red blood cells (haemolysis)
- The onset of symptoms following short-term exposure may be delayed for several hours
- Short-term inhalation of arsine or stibine may cause weakness, headache, drowsiness, sickness, anaemia, abdominal pain, shortness of breath, yellow skin and eyes and red urine
- The effect of long-term exposure is thought to cause similar symptoms as short-term exposure
- Arsine is not thought to cause damage to the unborn child

Environment

- Dangerous for the environment
- Inform Environment Agency of substantial incidents

Background

Arsine is a colourless, non-irritating gas with a mild garlic-like odour. It is formed when arsenic or arsenic-containing compounds react with acid or water. Arsine is extremely flammable and is soluble in water. Other names for arsine include arsenic hydride or arsenic trihydride.

Stibine is also a colourless gas with a disagreeable odour that resembles rotten eggs. It is produced when antimony or antimony-containing compounds react with an acid or water. Other names for stibine include antimony hydride or antimony trihydride.

Both arsine and stibine are used in the semiconductor industry to manufacture microchips. Industrial processes, including welding, soldering, refining, galvanising and etching may lead to the accidental formation of arsine or stibine. Overcharging of lead storage batteries can also lead to the production of arsine and stibine.

Exposure to arsine or stibine is most likely to occur in an occupational setting where they are used or accidentally formed during industrial processes. Arsine and stibine are not used domestically; therefore exposure in the home is unlikely.



When breathed in, arsine and stibine enter the blood via the lungs, where they damage red blood cells. Symptoms may be delayed for several hours. Short term exposure to low to moderate levels may cause weakness, headache, drowsiness, sickness, abdominal pain, shortness of breath, yellow skin and eyes and red urine.

Exposure to high concentrations can result in loss of consciousness and death.

People who survive a short-term exposure may suffer from long term health effects including kidney damage, confusion, memory loss, and numbness and pain in the extremities.

The effects of long term exposure are similar to those observed following short term exposure.

Arsine is unlikely to cause damage to the unborn child.



Production and Uses

Key Points

- Arsine and stibine are used the semiconductor industry to produce microchips

Arsine is prepared for industrial use by the reaction of aluminium arsenide with water or hydrochloric acid. It is also formed by treating arsenic compounds with acid and then subjecting them to electrolytic action. Stibine is prepared in a similar way, but the process involves using antimony compounds.

Arsine and stibine are extensively used in the semiconductor industry as doping agents. Arsine is also used as an agent in the manufacture of light-emitting diodes and glass dyes.

Frequently Asked Questions

Arsine

What is arsine?

Arsine is a colourless, non-irritating, flammable, toxic gas that has a mild garlic odour.

What is arsine used for?

Arsine is used in the semiconductor industry in the production of microchips.

How does arsine get into the environment?

Small amounts of arsine may be produced and released into the environment from natural processes involving bacteria and fungi. Arsine is also released into the air from human activities including welding and soldering.

How could I be exposed to arsine?

Exposure is most likely to occur in the workplace where arsine is used or accidentally formed.

If there is arsine in the environment will I have any adverse health effects?

The presence of arsine in the environment does not always lead to exposure. Clearly, in order for it to cause any adverse health effects you must come into contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact. Following exposure to any chemical, the adverse health effects you may encounter depend on several factors, including the amount to which you are exposed (dose), the way you are exposed, the duration of exposure, the form of the chemical and if you were exposed to any other chemicals.

Minor to moderate exposures may result in weakness, fatigue, headache, drowsiness, shortness of breath, sickness, abdominal pain, yellow skin and eyes and red urine. Exposure to a high concentration of arsine may cause fitting loss of consciousness and may even death. Symptoms of poisoning usually develop within 1 – 24 hours following the exposure to arsine. Severely exposed individuals who survive the initial exposure may experience long term health effects including kidney damage, memory loss, confusion, and numbness and pain in the extremities.

Can arsine cause cancer?

There are no data available to assess the carcinogenicity of arsine itself. It is broken down in the body to a number of compounds some of which are recognised by the International Agency for Research on Cancer (IARC) as known human carcinogens. Prolonged exposure may therefore result in an increase in risk of cancer.

Does arsine affect children or damage the unborn child?

There is no evidence to suggest that arsine, at concentrations that do not affect the mother, can affect the health of the unborn child. However, exposure to arsine during pregnancy should be avoided because of its general toxic effects.

What should I do if I am exposed to arsine?

It is very unlikely that the general population will be exposed to a level of arsine high enough to cause adverse health effects.

Stibine

What is stibine?

Stibine is a colourless gas with a disagreeable odour that resembles rotten eggs.

How does stibine get into the environment?

Stibine is released into the air from human activities including welding and soldering.

How will I be exposed to stibine?

Exposure is most likely to occur in the workplace where stibine is used or accidentally formed.

If there is stibine in the environment will I have any adverse health effects?

The presence of stibine in the environment does not always lead to exposure. Clearly, in order for it to cause any adverse health effects you must come into contact with it. You may be exposed by breathing, eating or drinking the substance or by skin contact. Following exposure to any chemical, the adverse health effects you may encounter depend on several factors, including the amount to which you are exposed (dose), the way you are exposed, the duration of exposure, the form of the chemical and if you were exposed to any other chemicals.

The adverse health effects associated with exposure to stibine are thought to resemble those associated with short-term exposure to arsine. Symptoms include weakness, fatigue, headache, drowsiness, shortness of breath, sickness, abdominal pain, yellow skin and eyes and red urine. Exposure to a high concentration of stibine may lead to loss of consciousness, fitting and in severe cases may lead to death.

Can stibine cause cancer?

There are no data available to assess the carcinogenicity of stibine.

Does stibine affect children or damage the unborn child?

There are no data available to assess the reproductive and developmental effects of stibine. Exposure to arsine during pregnancy should be avoided because of its general toxic effects.

What should I do if I am exposed to stibine?

It is very unlikely that the general population will be exposed to a level of stibine high enough to cause adverse health effects.

Arsine and Stibine

Incident management

Key Points

Fire

- Extremely flammable
- Arsine and stibine react with strong oxidants. Stibine reacts with chlorine and concentrated nitric acid
- Arsine decomposes on heating, in light and with moisture producing arsenic fumes. Stibine decomposes to produce metallic antimony and hydrogen gas
- In the event of a fire involving arsine or stibine, use fine water spray and liquid and gas tight chemical protective clothing with breathing apparatus

Health



- Toxic by inhalation
- The health effects of arsine and stibine are similar
- Arsine is very toxic, stibine is harmful
- The onset of symptoms is often delayed for several hours
- Inhalation of arsine or stibine may cause headache, malaise, thirst, dizziness and breathlessness followed by abdominal pain, nausea, vomiting and diarrhoea leading to hypovolaemic shock
- Myocardial depression and cardiovascular collapse may also occur
- 24-48 hours after inhalation, fever, tachycardia, severe haemolytic anaemia, jaundice, pulmonary oedema, acute hepatic and renal failure may occur.

Environment

- Dangerous for the environment
- Inform Environment Agency of substantial releases

Hazard Identification

Standard (UK) Dangerous Goods Emergency Action Codes^(a)



UN		2188	Arsine	
EAC		2PE^b	Use fine water spray. Wear liquid-tight chemical protective clothing in combination with breathing apparatus *. Danger that the substance can be violently or explosively reactive. Spillages and decontamination run-off may be washed to drains with large quantities of water. Due care must however still be exercised to avoid unnecessary pollution to watercourses. There may be a public safety hazard outside the immediate area of the incident**.	
APP		A(cf)	Gas-tight chemical protective suit with breathing apparatus *. Fire kit intended to protect against liquefied flammable gas with a boiling point below -20 °C.	
Hazards	Class	2.3	Toxic gases	
	Sub risks	2.1	Flammable gases	
HIN		-		

UN – United Nations number; EAC – Emergency Action Code; APP – Additional Personal Protection; HIN - Hazard Identification Number

^a Dangerous Goods Emergency Action Code List, HM Fire Service Inspectorate, Publications Section, The Stationery Office, 2004.

^b Not applicable to the carriage of dangerous goods under the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID) or the European Agreement Concerning the International carriage Dangerous Goods by Road (ADR)

Standard (UK) Dangerous Goods Emergency Action Codes^(a)

UN		2676	Stibine	
EAC		2PE^b	Use fine water spray. Wear liquid-tight chemical protective clothing in combination with breathing apparatus *. Danger that the substance can be violently or explosively reactive. Spillages and decontamination run-off may be washed to drains with large quantities of water. Due care must however still be exercised to avoid unnecessary pollution to watercourses. There may be a public safety hazard outside the immediate area of the incident**.	
APP		A(f)	Gas-tight chemical protective suit with breathing apparatus *. Fire kit intended to protect against flammable gas.	
Hazards	Class	2.3	Toxic gases	
	Sub risks	2.1	Flammable gases	
HIN		-		

UN – United Nations number; EAC – Emergency Action Code; APP – Additional Personal Protection; HIN - Hazard Identification Number

*Liquid-tight chemical protective clothing (BS 8428) in combination with self-contained open circuit positive pressure compressed air breathing apparatus (BS EN 137).





** People should stay indoors with windows and doors closed, ignition sources should be eliminated and ventilation stopped. Non-essential personnel should move at least 250 m away from the incident.

^a Dangerous Goods Emergency Action Code List, HM Fire Service Inspectorate, Publications Section, The Stationery Office, 2004.

^b Not applicable to the carriage of dangerous goods under the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID) or the European Agreement Concerning the International carriage Dangerous Goods by Road (ADR)



Chemical Hazard Information and Packaging for Supply Classification

Arsine^(a)

Classification	F+	Extremely flammable	
	T+	Very toxic	
	Xn	Harmful	
	N	Dangerous for the environment	
Risk phrases	R12	Extremely flammable	
	R26	Very toxic by inhalation	
	R48/20	Harmful: danger of serious damage to health by prolonged exposure through inhalation	
	R50/53	Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	
Safety phrases	S1/2	Keep locked up and out of the reach of children	
	S9	Keep container in a well-ventilated place	
	S16	Keep away from sources of ignition - No smoking	
	S28	After contact with skin, wash immediately with plenty of ... (to be specified by the manufacturer)	
	S33	Take precautionary measures against static discharges	
	S36/37	Wear suitable protective clothing and gloves	
	S45	In case of accident or if you feel unwell seek medical advice immediately (show the label where possible)	
	S60	This material and its container must be disposed of as hazardous waste	
S61	Avoid release to the environment. Refer to special instructions/safety data sheet		

^a European Chemicals Bureau, Classification and Labelling, Annex I of Directive 67/548/EEC; <http://ecb.jrc.it/classification-labelling/> (accessed 02/2007).

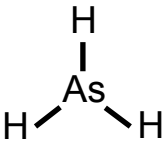
Stibine^(a)

Classification	Xn	Harmful	
	N	Dangerous for the environment	
Risk phrases	R20/22	Harmful by inhalation and if swallowed	
	R50/53	Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	
Safety phrases	S2	Keep out of the reach of children	
	S61	Avoid release to the environment. Refer to special instructions/safety data sheet	

^a European Chemicals Bureau, Classification and Labelling, Annex I of Directive 67/548/EEC; <http://ecb.jrc.it/classification-labelling/> (accessed 02./2007).

Physicochemical Properties

Arsine

CAS number	7784-42-1
Molecular weight	78
Empirical formula	AsH ₃
Common synonyms	Arsenic hydride; Arsenic trihydride; Hydrogen arsenide
State at room temperature	Gas
Volatility	Vapour pressure 11,000 mm Hg at 25°C
Specific gravity	2.7 at 20°C (air = 1)
Flammability	Extremely flammable
Lower explosive limit	4.5%
Upper explosive limit	78.0%
Water solubility	Low solubility in water, 280 mg L ⁻¹ at 20°C. Soluble in chloroform, benzene. Slightly soluble in ethanol
Reactivity	Reactive. Arsine reacts with strong oxidants, causing risk of explosion. May explosively decompose upon shock or friction
Reaction or degradation products	Decomposes on heating and in the presence of light and moisture, producing toxic fumes of arsenic
Odour	Garlic
Structure	

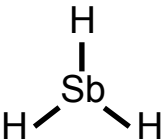
References^(a,b,c)

^a Arsine (HAZARDTEXT® Hazard Management). In: Klasco RK (Ed): TOMES® System. Thomson Micromedex, Greenwood Village, Colorado (accessed 02/2007).

^b The Merck Index (14th Edition). Entry 809: Arsine, 2006.

^c The Dictionary of Substances and their Effects. Ed. S Gangolli. Second Edition, Volume 2, 1999.

Stibine

CAS number	7803-52-3
Molecular weight	125
Empirical formula	SbH ₃
Common synonyms	Antimony hydride
State at room temperature	Gas
Volatility	Vapour pressure >760mm Hg at 20°C
Specific gravity	4.4 at 15°C (air = 1)
Flammability	Extremely flammable
Lower explosive limit	Limits not known
Upper explosive limit	Limits not known
Water solubility	Solubility in water, 4.1g L ⁻¹ at 0°C. Soluble in ethanol, carbon disulphide and other organic solvents
Reactivity	Reactive. Stibine reacts violently with chlorine, concentrated nitric acid and ozone causing risk of fire and explosion. Reacts with oxidisers and acids
Reaction or degradation products	Decomposes slowly at room temperature but quickly when heated to 200°C, to form metallic antimony and hydrogen gas
Odour	Resembles rotten eggs (hydrogen sulphide)
Structure	

References^(a,b)

^a Stibine (HAZARDTEXT® Hazard Management). In: Klasco RK (Ed): TOMES® System. Thomson Micromedex, Greenwood Village, Colorado (accessed 02/2007).

^b The Merck Index (14th Edition). Entry 8811: Stibine, 2006.

Threshold Toxicity Values

Arsine

EXPOSURE VIA INHALATION		
ppm	mg m⁻³	SIGNS AND SYMPTOMS
3 – 10	10 – 32	Exposure may result in symptoms within a few hours
25 – 50	81 – 162	Lethal (30 minute exposure)
250	810	Instantly lethal

Reference^(a)

Note: The effects of stibine are likely to be similar to those of arsine but not necessarily at the same concentrations

^a International Programme on Chemical Safety, Poisons Information Monographs 044: Arsine.

Published Emergency Response Guidelines

Emergency Response Planning Guideline (ERPG) Values^(a)

<i>Arsine</i>	Listed value (ppm)	Calculated value (mg m ⁻³)
ERPG-1*	-	-
ERPG-2**	0.5	1.6
ERPG-3***	1.5	4.8

<i>Stibine</i>	Listed value (ppm)	Calculated value (mg m ⁻³)
ERPG-1*	-	-
ERPG-2**	0.5	2.6
ERPG-3***	1.5	7.7

* Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour.

** Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

*** Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

Acute Exposure Guideline Levels (AEGs)^(b)

<i>Arsine</i>	ppm				
	10 min	30 min	60 min	4 hr	8 hr
AEGL-1 [†]	-	-	-	-	-
AEGL-2 ^{††}	0.30	0.21	0.17	0.04	0.02
AEGL-3 ^{†††}	0.91	0.63	0.50	0.13	0.06

<i>Stibine</i>	ppm				
	10 min	30 min	60 min	4 hr	8 hr
AEGL-1 [†]	Data not available				
AEGL-2 ^{††}					
AEGL-3 ^{†††}					

[†] The level of the chemical in air at or above which the general population could experience notable discomfort.

^{††} The level of the chemical in air at or above which there may be irreversible or other serious long-lasting effects or impaired ability to escape.

^{†††} The level of the chemical in air at or above which the general population could experience life-threatening health effects or death.

^a American Industrial Hygiene Association (AIHA). Emergency Response Planning Guideline Values and Workplace Environmental Exposure Level Guides Handbook, Fairfax, VA, 2005.

^b U.S. Environmental Protection Agency. Acute Exposure Guideline Levels, <http://www.epa.gov/oppt/aegl/pubs/chemlist.htm> (accessed 02/2007).

Exposure Standards, Guidelines or Regulations

Occupational standards

Arsine

WEL^(a)	LTEL(8 hour reference period): 0.5 ppm (0.2 mg m ⁻³)
	STEL(15 min reference period): No guideline value specified

Public health guidelines

DRINKING WATER QUALITY GUIDELINE	No guideline value specified
AIR QUALITY GUIDELINE	No guideline value specified
SOIL GUIDELINE VALUE AND HEALTH CRITERIA VALUES	No guideline value specified

WEL – Workplace exposure limit; LTEL - Long-term exposure limit; STEL – Short-term exposure limit

^a Health & Safety Executive. EH40/2005 Workplace Exposure Limits 2005. The Stationery Office, London, 2005.

Health Effects

Major route of exposure^(a)

- Toxic via inhalation

Immediate signs or symptoms of acute exposure^(b)

- Early features of arsine or stibine exposure: the onset is often delayed for several hours. Initial features include headache, malaise, thirst, dizziness and breathlessness followed by abdominal pain, nausea, vomiting and diarrhoea leading to hypovolaemic shock.
- Weakness with muscle cramps may occur as well as myocardial depression and cardiovascular collapse.
- Painless, dark red urine develops 4-6 hours post exposure. Red staining of the conjunctiva and sclera may occur.
- After 24-48 hours: fever, tachycardia, severe haemolytic anaemia, jaundice, hyperkalaemia, pulmonary oedema, T wave changes on ECG, leucocytosis and reticulocytosis. Acute hepatic and renal failure may occur.

TOXBASE - <http://www.toxbase.org>

^a TOXBASE: Arsine, 2003.

^b TOXBASE: Arsine – features and management, 2003.

Decontamination and First Aid

Important Notes

- Ambulance staff, paramedics and emergency department staff treating chemically-contaminated casualties should be equipped with Department of Health approved, gas-tight (Respirex) decontamination suits based on EN466:1995, EN12941:1998 and prEN943-1:2001, where appropriate.
- Decontamination should be performed using local protocols in designated areas such as a decontamination cubicle with adequate ventilation.
- Flammability warning: prevent exposure to all sources of ignition such as naked flames, electrical equipment, oxidising chemicals and the smoking of tobacco products.

Dermal exposure

- Not applicable

Ocular exposure^(a)

- Remove patient from exposure.
- Remove contact lenses if present and immediately irrigate the affected eye thoroughly with water or 0.9% saline for at least 10-15 minutes.
- Patients with corneal damage or those whose symptoms do not resolve rapidly should be referred for urgent ophthalmological assessment.

Inhalation^(a)

- Remove patient from exposure.
- Ensure a clear airway and ensure adequate ventilation.
- Give humidified oxygen.
- Monitor pulse, blood pressure, oxygen saturation, respiratory rate and cardiac rhythm.
- Apply other supportive measures as indicated by the patient's clinical condition.

Ingestion

- Not applicable

TOXBASE - <http://www.toxbase.org>

^a TOXBASE: Arsine – features and management, 2003.

Arsine and Stibine

Toxicological overview

Key Points

Kinetics and metabolism

- Arsine and stibine are readily absorbed following inhalation
- Following absorption arsine and stibine are distributed to organs including blood, liver, kidneys and spleen
- Arsine is oxidised to trivalent arsenic as well as pentavalent arsenic
- Arsine metabolites are predominantly excreted in the urine

Health effects of acute exposure

- The health effects of arsine and stibine are similar
- The characteristic toxic effect of both arsine and stibine is haemolysis (rupture of red blood cells)
- The onset of symptoms may be delayed for several hours
- Inhalation of arsine or stibine may cause headache, malaise, weakness, dizziness, dyspnoea, anaemia, red staining of the conjunctiva, dark red urine, abdominal pain, nausea and vomiting. Renal failure, liver damage and pulmonary oedema may occur 24 – 48 hours post exposure. Exposure to high concentrations may lead to death.

Health effects of chronic exposure

- The effect of chronic exposure to arsine is expected to be similar to acute exposure
- There is no data available regarding chronic exposure to stibine
- There is no evidence to suggest that arsine is a reproductive or developmental toxicant
- There are no data on the carcinogenicity of arsine itself, but it is metabolised to inorganic compounds that are recognised human carcinogens
- The carcinogenicity and reproductive effects of stibine have not been studied

Toxicological Overview

Summary of Health Effects

Arsine

Following acute inhalation of arsine the onset of effects may be delayed for several hours. Effects include headache, malaise, weakness, dizziness, dyspnoea, red staining of the conjunctiva, abdominal pain, nausea and vomiting. A characteristic effect is damage to red blood cells resulting in the release of haemoglobin. Dark red urine (due to the presence of haemoglobin) generally develops within 4 – 6 hours post exposure. Anaemia, renal failure, liver damage and pulmonary oedema may occur 24 – 48 hours post exposure. Exposure to high concentrations can lead to death. Peripheral neuropathy may develop over the first months following acute exposure to arsine. The effects of chronic exposure to arsine are similar to those observed following acute exposure.

The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as known human carcinogens (Group 1). However, there are no data available on the carcinogenicity of arsine *per se*.

Stibine

The toxic effects of acute exposure to stibine are thought to resemble those associated with arsine exposure. Effects include headache, nausea, weakness, abdominal and lumbar pain, haematuria and haemolytic anaemia. There is currently no data available on the effects of chronic exposure to stibine in humans.

Kinetics and metabolism

Arsine

Arsine is readily absorbed by the lungs and mucous surface of the respiratory tract following inhalation [1]. It is lipid soluble therefore it diffuses rapidly across the alveolar and capillary membranes of the lungs and the red blood cell membrane [2]. Following exposure to arsine, the concentration in the blood increases rapidly, where it is preferentially bound to the red blood cell membrane. Distribution to the liver, kidneys, spleen and other organs is much slower [1].

Following absorption, arsine is oxidised to trivalent arsenic as well as pentavalent arsenic. Trivalent arsenic is subsequently methylated to monomethylarsonate and dimethylarsinate [1].

Arsine metabolites are predominantly excreted in the urine [1, 2]. The highest urinary excretion occurred within the first five days following an acute occupational exposure to arsine [1].

Stibine

Stibine is readily absorbed following inhalation. Following exposure, stibine has been detected in blood, liver, lungs, kidneys, thyroid, adrenals, and pancreas [3].

Sources and route of human exposure

Arsine

Inhalation of arsine is the major route of exposure. Arsine is formed whenever nascent hydrogen is generated in the presence of arsenic or when water reacts with metallic arsenides [4].

Many industrial processes including the smelting and refining of metals, plating, galvanising and soldering can lead to the accidental formation and liberation of arsine fumes [2]. Very small amounts of an arsenic impurity can lead to the formation of highly toxic levels of arsine. Occupational exposure may also occur in the lead acid battery industry or the semiconductor industry where arsine is extensively used as a doping agent. Arsine can be generated from other arsenic compounds (arsenites and arsenates) by some fungi and bacteria [1, 4]. Arsine formation is also thought to occur in the environment in places such as hazardous waste deposits [1].

Following exposure to light or when it comes into contact with moisture in the air arsine decomposes quickly, depositing shiny black arsenic. When exposed to water it rapidly hydrolyses to other arsenic compounds [1].

Stibine

Inhalation of stibine is the major route of exposure. Stibine is formed when alloys containing antimony are treated with acid and subjected to electrolytic action, when antimony compounds are treated with steam or whenever nascent hydrogen comes into contact with metallic antimony or a soluble antimony compound [3, 5]. Stibine is also generated during lead battery manufacture or results from overcharging of lead storage batteries. Exposure may also occur in the semiconductor industry where stibine is used as a doping agent [3].

Health Effects of Acute / Single Exposure

Human Data

General toxicity

Arsine

Arsine primarily targets the erythrocyte (red blood cell) and rapidly induces intravascular haemolysis. Secondary effects resulting from haemolysis include haemolytic anaemia, hepatic and renal damage. The exact mechanism by which arsenic causes erythrocytes to rupture is not known, but it is believed to be due to either oxidative damage or reaction with sulphhydryl groups [1].

Stibine

Stibine is a powerful haemolytic agent. There are limited data available on the toxicity of stibine following acute exposure. The toxic effects of acute exposure to stibine are thought to resemble those associated with arsine exposure [5].

Inhalation

Arsine

Symptoms of arsine poisoning develop within 1 – 24 hours (usually within a few hours) after the exposure, depending upon the concentration and duration of exposure [1]. Exposure to 10 – 32 mg m⁻³ of arsine may cause symptoms within a few hours. Symptoms of arsine toxicity have been observed following a brief exposure to 100 mg m⁻³. A 30 minute exposure to 80 – 160 mg m⁻³ is considered lethal and inhalation of 800mg m⁻³ is instantly lethal [2, 4].

Initial symptoms include headache, malaise, weakness, dizziness, dyspnoea, red staining of the conjunctiva, abdominal pain, nausea and vomiting. Dark red urine due to the presence of haemoglobin generally develops within 4 – 6 hours post exposure [1].

Haematological changes reported in humans following an acute exposure to arsine include anaemia, leukocytosis, increased plasma free haemoglobin, iron and potassium concentrations. Damage to red blood cells (such as basophilic stippling, Heinz bodies, anisocytosis, poikilocytosis, red blood cell fragments and ghost cells) may also be observed [1, 6].

Renal failure secondary to haemolysis, if left untreated, is often the cause of death following arsine exposure. In severe cases oliguria or anuria may develop within 2 days after the exposure [1]. Free haemoglobin, erythrocytes, proteins, casts and methaemoglobin have been found in the urine of individuals acutely exposed to arsine [1, 4].

Jaundice of the skin and mucous membranes is observed at 24 – 48 hours following the exposure [1]. Serum bilirubin and lactate dehydrogenase levels are usually elevated and the liver is often enlarged and tender. However, severe liver damage has rarely been reported following arsine exposure [6].

Toxic pulmonary oedema or acute circulatory failure has been reported as the cause of death in some cases of arsine poisoning. Tachycardia and ECG abnormalities, including alterations in the S-T segment and elevation of the T-wave, have been reported [1, 2, 7]. In some cases, ECG abnormalities have lasted for several months after the exposure [1, 4].

Stibine

Several cases of poisoning have been reported following occupational exposure to a mixture of gases including stibine. Headache, nausea, weakness, abdominal and lumbar pain, haematuria and haemolytic anaemia were observed in workers exposed to a mixture of stibine, arsine and hydrogen sulphide [5].

Delayed effects following an acute exposure

Arsine

Peripheral neuropathy may develop over the first months following exposure to arsine [2]. Neuropsychological symptoms including irritation, confusion, memory loss, agitation and disorientation have also been reported in individuals acutely exposed to arsine [1]. Vertical white lines on the nails (Mee's lines) may appear 2 – 3 weeks after the exposure [6].

Animal and In-Vitro Data

Inhalation

Arsine

Ten minute LC₅₀ values have been reported as 390, 250, and 650 mg m⁻³ in the rat, mouse and rabbit, respectively. The 50 minute and 24 hour LC₅₀ was 100 and 25 mg m⁻³, respectively in the mouse [1].

In an arsine lethality study LC₅₀'s of 898, 577 and 146 mg m⁻³ (240, 178 and 45 ppm) were reported in rats exposed for 30 minutes, 1 hour and 4 hours, respectively. Rats in the group exposed for 30 minutes generally died within 3 days following exposure. Dyspnoea was observed during exposure and a concentration-related increase in haematuria was recorded post-exposure [6].

Stibine

In an acute inhalation study rats and guinea pigs were exposed to 1395 or 799 mg m⁻³ antimony as stibine, for 30 minutes. Renal tubular dilation was observed in the rats and guinea pigs exposed to 799 mg m⁻³ antimony. Exposure to 1395 mg m⁻³ antimony resulted in the development of pulmonary oedema and death [7].

Health Effects of Chronic / Repeated Exposure

Human Data

Arsine

Inhalation

The effects of chronic exposure to arsine are similar to those observed following acute exposure. The main difference from acute exposure is the longer period of latency [1, 4]. The symptoms of chronic arsine inhalation include shortness of breath on exertion, malaise, headache, nausea, anorexia, paresthesia and muscle pain. Peripheral neuropathy, liver and kidney impairment, anaemia and basophilic stippling have been reported in individuals occupationally exposed to arsine [1, 4, 10]. In an occupational study the degree of anaemia in workers chronically exposed to arsine was proportional to the duration of exposure to arsine [1, 4].

Genotoxicity

There are currently no data available regarding the genotoxicity of arsine in humans.

Carcinogenicity

There are no studies in the literature regarding the carcinogenicity of arsine *per se* [1]. Arsine is however metabolised to inorganic arsenic compounds which are recognised human carcinogens (IARC Group 1) [8].

Reproductive and developmental toxicity

There are limited data on the reproductive and developmental effects of arsine in humans. A few occupational studies have reported an increase in the rate of miscarriage among women who work in the semiconductor industry, where arsine is used to produce microchips [2, 9, 10]. The studies had several limitations, including small sample size and exposure to multiple chemicals. Therefore, it was not possible to determine the role of arsine in the observed increase in rate of miscarriage [10].

Stibine

There are currently no data available on the effects of chronic exposure to stibine in humans.

Animal and In-Vitro Data

Arsine

Inhalation

Repeated exposure studies in the rat, mouse and hamster indicate that there were no quantitative differences in the toxic effects seen. The most sensitive endpoint related to effects on the haematopoietic system namely haemolysis, abnormal red blood cell morphology and increased spleen weight (due to increased removal of damaged red blood cells and increased splenic haematopoiesis).

In hamsters, a significant increase in relative spleen weight was noted following exposure to $\geq 8.1 \text{ mg m}^{-3}$ arsine, 6 hours day^{-1} , 5 days week^{-1} for 28 days [1, 9]. A number of studies have reported increases in spleen weights in rats and mice exposed to arsine concentrations of 0.08 mg m^{-3} and above, 6 hours day^{-1} for up to 13 weeks [9]. Anaemia (reduced haemoglobin, haematocrit, red cell count) was reported in rats and mice exposed to arsine concentrations of 1.6 mg m^{-3} and above, 6 hours day^{-1} , 5 days week^{-1} for up to 90 days [1].

Increased susceptibility to bacterial infection and a reduction of T lymphocytes in the spleen were observed in mice exposed to 1.6 , 8.1 and 16 mg m^{-3} arsine, 6 hours day^{-1} for 14 days [10, 13].

Genotoxicity

There are currently no data available regarding the genotoxicity of arsine.

Carcinogenicity

There are currently no data available regarding the carcinogenicity of arsine.

Reproductive and developmental toxicity

There are limited data on the reproductive and developmental effects of arsine in animals.

In an inhalation study rats and mice were exposed to 0.08 , 1.6 or 8.1 mg m^{-3} arsine 6 hours day^{-1} on gestation days 6 to 15. In mice, the dams exposed to 8.1 mg m^{-3} had significantly enlarged spleens, but no developmental toxicity was observed. In rats, the dams exposed to 8.1 mg m^{-3} arsine also had significantly enlarged spleens and a significant increase in fetal body weight was observed. No other developmental or reproductive effects were noted [9, 10].

Stibine

There are currently no chronic animal or *in-vitro* data available.

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This document will be reviewed not later than 3 years or sooner if substantive evidence becomes available