

Chlorine

Toxicological overview

Key Points

Health effects of acute exposure

- Due to its gaseous nature inhalation and ocular exposure are most likely, resulting in lung and eye irritation
- Exposure to higher concentrations of chlorine may lead to coughing and breathing difficulties due to the development of pulmonary or laryngeal oedema

Health effects of chronic exposure

- Chronic inhalation exposure may result in impaired pulmonary function
- Chlorine was found to be non-carcinogenic in animal studies, and hypochlorite salts were not classifiable as to their carcinogenicity in humans
- Animal studies demonstrated no reproductive or teratogenic effects of chlorine

Toxicological Overview

Summary of Health Effects

Exposure of unprotected personnel to chlorine gas may initially result in eye and lung irritation, the severity of which will be dependent on the concentration and duration of contact.

Relatively minor exposures may result in sensory irritation such as burning of the eyes and throat. These initial symptoms are caused by free-radicals, hypochlorous or hypochloric acid formed by the reaction of chlorine with water in lung or eye tissues.

More significant exposures may lead to coughing and breathing difficulties due to the development of pulmonary and/or laryngeal oedema.

Clearly, exposure to a large concentration of chlorine in an enclosed or poorly ventilated area may cause asphyxiation as a result of decreased oxygen availability.

There is some evidence to suggest that acute exposure may result in long-term pulmonary sequelae (reactive airways dysfunction; RADs) in a small proportion of individuals.

Sources and route of human exposure

Due to its gaseous nature, inhalation and ocular exposure are most likely. Dermal features usually occur only from exposure to concentrated chlorine gas or in the immediate vicinity of a release of pressurised liquid. Significant ingestion is unlikely because chlorine is a gas at room temperature.

Deliberate release of chlorine occurred during World War I. Up to 2000 UK personnel died and approximately 165,000 were injured [1].

A significant occupational setting for chlorine exposure has been within the pulp and paper industry, hence the term “bleachery disease” to describe the pulmonary effects of chronic chlorine exposure.

Exposure of the general public to chlorine may arise through accidental release during road or rail transport. Globally, acute incidents have led to 73 deaths and 3,549 injuries since 1974 [2].

A number of accidental domestic exposures to chlorine arise each year through the inappropriate mixing of domestic cleaning products or incorrect use of swimming pool disinfectants.

Health Effects of Acute / Single Exposure

Human Data

Inhalation

Immediate symptoms following inhalation include a burning sensation in the eyes and pain or burning of the lungs during respiration. Sufficient exposure may induce reflex cholinergic bronchoconstriction with associated signs of coughing, wheezing and dyspnoea. Exposure to a sufficiently high dose may result in pulmonary oedema and respiratory failure, the onset of which may be delayed by up to 36 hours. In extreme cases, pulmonary haemorrhage may also occur [3]. There is some evidence to suggest that exposure to chlorine may be associated with long-term neuropsychological changes [4], although further studies are required to confirm this hypothesis.

Table 1: Summary of acute toxic effects in relation to approximate (air) concentration of chlorine [5]. Concentration (mg m^{-3}) are approximate conversions from the corresponding ppm value.

Concentration		Signs and symptoms
ppm	mg m^{-3}	
1 – 3	3 – 10	Mild mucous membrane irritation
5 – 15	15 – 45	Moderate irritation of upper respiratory tract
30	90	Immediate chest pain, vomiting and coughing
40 – 60	115 – 175	Toxic pneumonitis and pulmonary oedema
430	1250	Lethal after 30 minutes exposure
1000	2900	Lethal in minutes

Delayed effects following an acute exposure

Most studies of survivors of World War I gassing incidents have reported a high incidence of acute respiratory damage and a lower incidence of chronic sequelae following acute exposure [6]. Similar sequelae have also been reported for individuals following acute exposure to the accidental release of chlorine gas, with the most consistently reported chronic effect being a reduction in the forced expiratory volume (FEV) [7]. A relatively recent report relating to accidental exposure to chlorine gas suggests that chronic sequelae following acute exposure may be more frequent than previously anticipated: a follow-up study in July 1999 on twenty individuals (previously exposed in 1995) indicated that 75% had residual lung volumes below 80% of their predicted value and nearly half the subjects tested for airway reactivity to methacholine had a greater than 15% decline in FEV [8]. There is some evidence to suggest that a single, acute exposure to chlorine gas may cause reactive airways dysfunction syndrome (RADS), also known as irritant-induced asthma [6, 9].

Health Effects of Chronic / Repeated Exposure

Human Data

Inhalation

There is some evidence to suggest that chronic, occupational exposure to chlorine may result in impaired pulmonary function as demonstrated by a decrease in FEV₁, FVC and FEF₂₅₋₇₅ [9].

Genotoxicity

No data are available on the mutagenicity of chlorine gas *per se*, although the mutagenicity of solutions of chlorine in water (hypochlorite and its salts) has been investigated. Sodium hypochlorite has been shown to have some mutagenic activity *in vitro* (both bacterial and mammalian cells) that may be due to the generation of reactive oxygen species. However, there is no evidence for activity *in vivo* [7]. Negative results were obtained in bone marrow assays for clastogenicity (chromosome aberrations and micronuclei) in mice [10]. The negative results reported in the carcinogenicity bioassays also support the view that hypochlorite does not have any significant mutagenic potential *in vivo*.

Carcinogenicity

Negative results were obtained when chlorine (dissolved in drinking water) was investigated in a National Toxicology Program (NTP) carcinogenicity bioassay in rats and mice; concentrations of up to 275 ppm chlorine were used [11]. Previously, the International Agency for Research on Cancer (IARC) had evaluated the carcinogenicity of hypochlorite salts [12] and concluded that there was no data available from human studies and that the data from experimental studies in animals was inadequate. Therefore, hypochlorite salts were assigned to Group 3, i.e., compounds that are not classifiable as to their carcinogenicity in humans.

Reproductive and developmental toxicity

In general, animal studies have demonstrated no reproductive or teratogenic effects of chlorine [7]. The effects of water chlorinated to a level of 150 mg L⁻¹ were investigated in rats over 7 generations. No effects were observed on fertility, growth or survival [13].

References

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