# Hydrogen chloride / hydrochloric acid

# Toxicological overview

## Key Points

### *Kinetics and metabolism*

- Hydrogen chloride rapidly dissociates into hydrogen and chloride ions
- Upon contact with water hydrogen chloride forms hydrochloric acid

### *Health effects of acute exposure*

- The main routes of exposure to hydrogen chloride are via inhalation, or skin or eye contact and exposure to hydrochloric acid is predominantly by ingestion, or skin or eye contact
- Inhalation may cause irritation to nose and upper respiratory tract, ulceration, coughing, chest tightness and shortness of breath. Higher concentrations cause tachypnoea, pulmonary oedema and suffocation
- Ingestion may cause corrosion of lips, mouth, oesophagus and stomach, dysphagia and vomiting
- Pain, eye ulceration, conjunctival irritation, cataracts and glaucoma may occur following eye exposure
- Erythema and skin irritation, as well as chemical burns to skin and mucous membranes may arise following skin exposure

### *Health effects of chronic exposure*

- Inhalation may cause pulmonary function deficits, bronchial inflammation and nasal ulceration
- Ingestion may cause inflammation of the mouth or mucous membranes and dental enamel erosion
- Hydrogen chloride could not be classified as to its carcinogenicity in humans

**Prepared by S Bull**
**CHAPD HQ, HPA**
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# Toxicological Overview

## *Summary of Health Effects*

Hydrogen chloride is irritating and corrosive to any tissue with which it comes into contact. It is highly soluble in water, producing hydrochloric acid.

The main routes of exposure to hydrogen chloride are via inhalation, or skin or eye contact. Exposure to hydrochloric acid is predominantly by ingestion, or skin or eye contact.

As it is highly soluble in water, following acute inhalation hydrogen chloride is deposited in the nose and upper respiratory tract, causing irritation and ulceration, coughing, chest tightness, shortness of breathing and choking. At higher concentrations, hydrogen chloride may cause tachypnoea, swelling of the throat leading to suffocation, as well as pulmonary oedema. Reactive Airway Dysfunction Syndrome (RADS), a chemical-induced type of asthma, may also occur.

Acute ingestion of hydrochloric acid may cause burns to the lips, mouth, throat, oesophagus and stomach, dysphagia, nausea and vomiting.

Skin exposure to low concentrations of hydrogen chloride gas or hydrochloric acid causes erythema and inflammation of the skin whereas high concentrations can cause severe chemical burns to the skin and mucous membranes.

Acute eye exposure causes stinging pain, ulceration, conjunctival irritation and corneal damage at lower concentrations and at higher concentrations corneal necrosis, cataracts and glaucoma may occur.

Chronic inhalation exposure to hydrogen chloride gas or mist may result in decreased pulmonary function, inflammation of the bronchi and nasal ulceration.

Chronic ingestion may cause discolouration and erosion of dental enamel.

The International Agency for Research on Cancer (IARC) has designated hydrochloric acid as being not classifiable as to its carcinogenicity to humans. i.e. category 3; there was inadequate evidence in humans or experimental animals.

## *Kinetics and metabolism*

Hydrogen chloride vapour or aerosols of hydrochloric acid are readily inhaled. It rapidly dissociates into hydrogen and chloride ions. Inhaled hydrogen chloride is partially neutralised by naturally occurring ammonia gas in the respiratory system, before it reaches the upper respiratory tract [1].

## *Sources and route of exposure*

Hydrogen and chlorine, which form hydrogen chloride, are commonly found in the environment.

The main routes of exposure to hydrogen chloride are via inhalation, or skin or eye contact. Exposure to hydrochloric acid is predominantly by ingestion, or skin or eye contact.

Due to its widespread use, hydrogen chloride is released into the air from anthropogenic activities such as waste incinerators or chemical plants and is formed in large quantities when materials such as plastics or polyvinyl chloride (PVC) are burnt. Volcanic eruptions also contribute to environmental levels of hydrogen chloride [1]. Humans and other mammals secrete gastric juice containing approximately 0.17 N hydrochloric acid into the stomach cavity [1].

As hydrogen chloride is used in a number of industrial processes occupational exposure is widespread. However, due to its irritating and corrosive properties, protective equipment is recommended to reduce exposure [1].

Hydrogen chloride that exists in the atmosphere can be inhaled by the general public, albeit at very low concentrations. Indirect exposure may also occur via drinking water or food. However, due to the low concentrations and the buffering capacity of the environment, significant health effects are not expected [1].

In an occupational setting, inhalation or eye exposure to the gaseous form of hydrogen chloride are the most likely routes of exposure. Upon contact with water hydrogen chloride forms hydrochloric acid for which skin or eye exposure or ingestion is most common.

# Health Effects of Acute / Single Exposure

## *Human Data*

### General toxicity

Hydrogen chloride is irritating and corrosive to any tissue with which it comes into contact. On exposure to air, hydrogen chloride gas forms dense white vapour due to condensation with moisture in the air. It dissolves rapidly in water to form hydrochloric acid, affecting moist areas e.g. mucous membranes.

### Inhalation

Inhalation is a main route of exposure to hydrogen chloride [2]. It is a sensory and respiratory irritant, the primary targets being the eyes, skin, nose, mouth, pharynx, larynx and trachea [3, 4]. The severe irritating effects of hydrogen chloride are usually sufficient to cause the workers to withdraw from exposure before severe damage can occur [1, 4].

Exposure to 0.2 – 10 ppm hydrogen chloride does not appear to cause adverse respiratory effects in humans. Irritation to the nose and throat, causing coughing, pain, inflammation and oedema of the upper respiratory tract was reported following inhalation of 5 ppm hydrogen chloride. Exposure to 50 – 100 ppm was barely tolerable for 1 hour.

Since it is highly water soluble, effects on the upper respiratory tract predominate following inhalation. In one study short term exposure to approximately 35 ppm produced sneezing, laryngitis, chest pain, hoarseness and a feeling of suffocation. This concentration was reported to be below the threshold for taste or eye irritation. Exposure can also produce ulceration of the nasal septum. Other effects that have been noted included headache, palpitations, shock, tachypnoea, tachycardia and circulatory collapse [2, 4].

At high concentrations it can cause corrosive burns to the eyes, mouth, nose and throat, nasoseptal perforation, constriction of the larynx and bronchi, necrosis of the bronchial epithelium, immediate onset of tachypnoea, blue colouration of skin, narrowing of bronchioles and rapid swelling and spasm of the throat, leading to suffocation. Chemical pneumonitis and pulmonary oedema may also occur [2, 4, 5]. However, tolerance may occur and it has been reported that some individuals are capable of enduring short term exposure to concentrations as high as 670 – 1250 ppm hydrogen chloride [3].

Inhalation of hydrogen chloride may also lead to Reactive Airway Dysfunction Syndrome (RADS), which is a chemical-induced type of asthma [2, 5].

Following inhalation of hydrogen chloride, nephritis and renal failure, liver damage and metabolic acidosis may also occur [4].

### Ingestion

Ingestion of concentrated hydrochloric acid at concentrations sufficient to produce mucosal irritation, can cause severe corrosive injury to lips, mouth, throat, oesophagus and stomach, pain, irritation, dysphagia, nausea, vomiting, thirst, salivation, chills, fever, shock and renal

failure as well as burns, ulceration and perforation of the gastrointestinal tract. Peritonitis or oesophageal, gastric or pyloric strictures may also occur [2, 4].

Internal bleeding in the gastrointestinal tract or fluid displacement may result in hypotension [2].

Circulatory shock, with weak and rapid pulse, or myocardial infarction may occur following hydrochloric acid ingestion [4]. Asphyxia due to laryngeal or glottal oedema, or stomach perforation with peritonitis, gastric haemorrhage and infection may lead to death [4].

### Dermal / ocular exposure

Hydrogen chloride is not absorbed through the skin. However, on contact with moisture on the skin hydrochloric acid is formed. Exposure to low concentrations (concentrations not stated) of hydrogen chloride vapour or hydrochloric acid causes erythema, irritation, inflammation, pain, dermatitis and ulceration of the skin. High concentrations (not stated) of hydrochloric acid or hydrogen chloride gas can cause severe chemical burns to the skin and mucous membranes [2-4]. Contact with refrigerated liquid may cause frostbite [2, 6]. Studies in human volunteers indicated that a 10 % solution should be classified as a skin irritant whereas a 4 % solution was only slightly irritating [1].

Extensive skin exposure to concentrated hydrochloric acid or hydrogen chloride vapour may cause hypotension, due to internal bleeding in the gastrointestinal tract or fluid displacement [2].

Acute eye exposure to low concentrations of hydrogen chloride vapour or hydrochloric acid causes stinging pain, ulceration, conjunctivitis and corneal damage. Higher concentrations cause corneal necrosis, cataracts and glaucoma [2-4]

### Delayed effects following an acute exposure

Potential sequelae following ingestion of hydrochloric acid include perforation, scarring of the oesophagus or stomach and stricture formation causing dysphagia or gastric outlet obstruction. In some cases, RADS may develop. Respiratory symptoms may take up to 36 hours to develop [2].

# Health Effects of Chronic / Repeated Exposure

## *Human Data*

### Inhalation

Chronic exposure to hydrogen chloride gas or mist may result in decreases in pulmonary function, inflammation of the bronchi, dermatitis, conjunctivitis, upper respiratory tract abnormalities and nasal ulceration. Symptoms may be delayed for 1-2 days [4, 7]. Symptoms similar to those of acute viral infections of the upper respiratory tract may also occur [2]. Inhalation also causes a transitory constriction of the respiratory tract, which lessens on prolonged exposure [3].

### Ingestion

Chronic exposure may result in discolouration and erosion of dental enamel [2-4, 7].

### Genotoxicity

Little data are available regarding the genotoxicity of hydrogen chloride in humans [3].

### Carcinogenicity

The International Agency for Research on Cancer (IARC) concluded that there is inadequate evidence for the carcinogenicity of hydrochloric acid in humans and in experimental animals. Therefore, IARC has designated hydrochloric acid as being not classifiable as to its carcinogenicity to humans. i.e. category 3 [8].

This conclusion was based on the assessment of several studies in battery plants and steel mills where workers were exposed to acid mists. Industry-based case-control studies could not show an association between exposure to hydrogen chloride and preleukaemia, lung cancer, intercranial neoplasms or renal cancer [1, 8]. In contrast, an increased risk of lung cancer and laryngeal cancer was observed in steel pickling workers exposed primarily to hydrochloric acid, although analysis was not carried out on workers exposed only to hydrochloric acid [1, 8]. A population based case control study of workers exposed to hydrochloric acid reported an increase risk of oat cell carcinoma, but not other types of lung cancer [1, 8].

### Reproductive and developmental toxicity

Little data are available regarding the reproductive and developmental toxicity in humans [3].

## *Animal and In-Vitro Data*

### Genotoxicity

Hydrogen chloride would not be expected to react with DNA.

A number of studies have been carried out to assess the mutagenicity of hydrogen chloride. Negative results were obtained for the Ames test, as well as for a mitotic recombination test using *S. cerevisiae* and Rec asay using *E. coli*. [1, 8]

Hydrogen chloride-induced chromosomal aberrations were reported in Chinese hamster ovary cells and in the mammalian cell gene mutation assay using mouse lymphoma L5178Y cells. However such positive results were observed at cytotoxic conditions and thought to be artefacts due to low pH [1, 8].

Positive results were reported in a Sex Linked Recessive Lethal assay with *D. melanogaster.* No mammalian *in vivo* studies were available [1].

Overall, it can be assumed that hydrogen chloride does not have any significant mutagenic potential.

### Carcinogenicity

Mice given repeated subcutaneous injections of hydrogen chloride for 18 months developed local sarcoma at the site of injection. However, due to the wide range of chemicals able to induce such an effect this study could not be used to assess the oncogenic potential of hydrogen chloride [3].

In a 128-week inhalation study, male rats were exposed to 10 ppm hydrogen chloride gas, no pre-neoplastic or neoplastic nasal lesions were observed in the treated animals. This dose level produced irritant effect on the respiratory tract and the group size used was appropriate for a carcinogenicity assay. This study provided evidence to support the conclusion that hydrogen chloride dose not have any significant carcinogenic potential [1].

### Reproductive and developmental toxicity

Limited data is available regarding the reproduction and development of animals following oral, dermal or inhalation exposure to hydrogen chloride or hydrochloric acid [1].

Few reliable studies have been reported regarding the reprotoxicity and development of animals following ingestion, inhalation or dermal exposure to hydrogen chloride or hydrochloric acid. Protons and chloride ions both exist as normal constituents of body fluid in animals, hence low concentrations of hydrogen chloride appear not to cause adverse effects in animals. Cells of gastric glands secrete hydrochloric acid into the stomach cavity. Administration of sulphuric acid, which resulted in a change in pH, did not cause developmental toxicity in animals. Therefore, hydrogen chloride or hydrochloric acid is not expected to cause developmental toxicity. In addition, after a 90 day inhalation study with up to 50 ppm hydrogen chloride no effects on the gonads were reported [1].

Female rats inhaling hydrogen chloride (450 mg $m^{-3}$ hr) 1 day prior to mating caused lung and kidney damage in the offspring [4]. Pregnant rats appeared to have an increased tolerance to hydrogen chloride compared to non-pregnant rats [4].

## References

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