



# Sodium Hypochlorite

## Toxicological Overview

### Key Points

#### Health effects of acute exposure

- ingestion of sodium hypochlorite may cause burns to the mouth and throat, gastrointestinal irritation, nausea, vomiting and diarrhoea
- inhalation and ocular exposure to chlorine gas, produced when sodium hypochlorite is mixed with acidic or alkaline solutions, results in burning of throat and lungs, eye and nose irritation, chest tightness, coughing and sore throat
- exposure to higher concentrations of chlorine may lead to tachypnoea, cyanosis, swelling of the airway and, in severe cases, pulmonary oedema and respiratory failure
- sodium hypochlorite is corrosive and may irritate the skin or cause burning pain, inflammation and blisters
- ocular exposure may cause irritation, pain, lacrimation, photophobia and retinitis

#### Health effects of chronic exposure

- chronic skin exposure may cause skin irritation, pain, inflammation and blisters
- the International Agency for Research on Cancer (IARC) classified sodium hypochlorite as a category 3 carcinogen, ie not classifiable as to the carcinogenicity to humans
- sodium hypochlorite is not considered to be a reproductive toxin

## Summary of Health Effects

Sodium hypochlorite itself may be toxic if ingested, or by dermal or ocular exposure. If mixed with acidic solutions chlorine gas is produced, and mixing with ammonia-based solutions gives rise to chloramine solution, both of which contribute to toxic effects.

Ingestion of small volumes of sodium hypochlorite causes burns to the mouth and throat, gastrointestinal irritation, nausea and vomiting. Ingestion of any amount of industrial strength bleach (>10% sodium hypochlorite) or large amounts (approximately 300 mL in adults; 100 mL in children) of household bleach (<10% sodium hypochlorite) may cause abdominal and retrosternal pain and diarrhoea. Aspiration of liquid may lead to pulmonary complications such as acute respiratory distress syndrome (ARDS).

Inhalation of chlorine gas causes burning of the throat and lungs, eye and nose irritation, chest tightness and coughing. At higher levels of exposure, tachypnoea, cyanosis and swelling of the airway may occur. Pulmonary oedema and respiratory failure may arise in severe cases, the onset of which may take up to 36 hours.

Sodium hypochlorite is corrosive and may irritate the skin or cause burning, pain, inflammation and blisters. Ocular exposure can cause irritation, pain, lacrimation and photophobia.

Hypochlorite salts have been classified as group 3 by the International Agency for Research on Cancer (IARC), ie compounds that are not classifiable as to their carcinogenicity in humans.

## Sources and Route of Human Exposure

In children the main route of exposure to sodium hypochlorite solution is by accidental ingestion, while in adults ingestion is relatively rare. In adults, inhalation of gases formed by the mixing of sodium hypochlorite with acidic or alkaline solutions is the most frequent route of exposure. Dermal or ocular exposure may also occur [1-3].

Sodium hypochlorite is commonly used as a general disinfectant and bleaching agent. Household bleach may contain up to 10% sodium hypochlorite, while industrial bleaches may be more concentrated (up to 50%) [2]. Due to inappropriate mixing of domestic cleaning products or incorrect use of swimming pool disinfectants, accidental domestic exposures to chlorine are relatively common.

## Health Effects of Acute/Single Exposure

### Human data

#### General toxicity

Although sodium hypochlorite solution itself is only moderately toxic, it liberates chlorine gas when acidified, eg if mixed with acidic cleaning agents. Mixing sodium hypochlorite with ammonia-based solutions gives rise to chloramine compounds. Both chlorine and chloramines are strong respiratory irritants hence contribute to toxic effects [1, 3, 4].

Symptoms of sodium hypochlorite exposure may be immediate, or may be delayed for several hours [4].

#### Inhalation

Intoxication following the inhalation of sodium hypochlorite vapours is extremely rare as chlorine gas is not released by bleach solutions in appreciable amounts under normal conditions. The toxicity of sodium hypochlorite solution by inhalation is predominantly due to the mixing of bleach with acids and the release of highly irritant gases [1]. Metabolic acidosis may occur in rare cases following significant inhalation of sodium hypochlorite [5].

Mixing sodium hypochlorite with acids releases chlorine gas, although in most cases the concentration of chlorine liberated is not sufficient to cause adverse health effects. In rare cases, inhalation of chlorine gas, produced from mixing sodium hypochlorite with acid, causes immediate burning of the throat and lungs, eye and nose irritation, chest tightness, coughing, sore throat, wheezing and dyspnoea [3-5]. In severe cases, bronchospasm, pneumonitis, upper airway oedema, pulmonary oedema or oedema of the glottis may develop [5].

Mixing sodium hypochlorite with ammonia-based solutions results in the formation of monochloramine and dichloramine, both of which are respiratory irritants [4].

In most cases respiratory irritation occurs immediately, followed by a latent period of 5 minutes to 15 hours, after which time breathlessness and bronchospasm may occur [1]. In most cases symptoms are usually resolved in 1–4 weeks [4, 6]. However, in some instances pulmonary damage may lead to long-term reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma following an acute respiratory exposure to an irritant gas [3, 6]. In addition, ARDS as a result of pneumonitis, has been reported in patients following inhalation of chlorine following the mixing of bleach and other hydrochloric acid [5, 6].

#### Ingestion

At low concentrations (up to 10%), such as those used for household bleach, sodium hypochlorite is a mild to moderate irritant that rarely produces necrosis or significant mucosal injury. Ingestion is not expected to cause severe or permanent damage of the

gastrointestinal tract and recovery is usually rapid. At higher concentrations (>10%) it is corrosive. The critical pH for corrosivity is thought to be 12.5 [1, 7].

Ingestion of small volumes (up to 200 mL in adults; 50 mL in children) of sodium hypochlorite solution (<10%) usually causes minimal health effects. In some cases it may cause burns to the mouth, throat, oesophagus and stomach, pharyngeal pain and inflammation, gastrointestinal irritation, nausea and vomiting [2, 3, 5, 8]. Dysphagia, stridor, drooling, abdominal pain and dyspnoea may also occur [7, 9]. Severe irritation is uncommon unless contact is prolonged or a large volume is ingested [2].

Ingestion of any amount of industrial strength bleach (>10% sodium hypochlorite) or large amounts (approximately 300 mL in adults; 100 mL in children) of household bleach (<10% sodium hypochlorite) may cause corrosive oesophagitis, haematemesis, abdominal and retrosternal pain, diarrhoea and, in some cases, melaena and metabolic acidosis [3, 5, 8]. Symptoms other than vomiting do not strongly correlate with the amount of sodium hypochlorite ingested [7]. In rare cases, the gastrointestinal mucosa may become haemorrhagic, ulcerated and perforated, leading to shock [8].

Hypernatraemia, hyperchloraemia, hypotension and cardiovascular collapse may rarely develop after ingestion of extremely large volumes of sodium hypochlorite (volumes not stated) [5].

Aspiration of sodium hypochlorite or aspiration of contaminated vomit may occur. This secondary source of pulmonary exposure may lead to ARDS [1-3].

### Dermal/ocular exposure

Sodium hypochlorite itself is corrosive and may irritate the skin or cause burning pain, inflammation and blisters. Skin damage may not be immediately apparent and may continue to develop over time [3].

Ocular exposure to household bleach can cause mild irritation and temporary discomfort if eyes are washed immediately [1]. Irritation becomes more severe and prolonged if eyes are not washed. More concentrated solutions can cause pain, blepharospasm, lacrimation, conjunctivitis, photophobia, necrosis and chemosis of the cornea, clouding of the cornea, iritis, cataract formation and retinitis [3, 8].

### Delayed effects following an acute exposure

Most children who ingest bleach swallow only small amounts and experience only vomiting and gastrointestinal irritation. Pulmonary complications such as ARDS result from aspiration [2]. A study of 19 children who ingested household bleach showed no short or long-term sequelae [7, 10]. In contrast, severe respiratory sequelae were reported in a toddler [10].

Potential sequelae following ingestion of sodium hypochlorite solution include bleeding, perforation, scarring and stricture formation following corrosive injury to the mouth, throat,

oesophagus and stomach, oesophageal obstruction, pyloric stenosis and vocal cord paralysis [3].

Chlorine was used as a chemical warfare agent during World War I, hence it has been widely documented. In follow-up studies of survivors there was no evidence of permanent lung damage following inhalation of chlorine gas. Most studies indicated acute respiratory disease but fewer chronic sequelae [4]. In contrast, more recent reports have suggested that chronic sequelae following acute exposure may be more prevalent than previously thought, such as toxic pneumonitis with respiratory compromise [4, 10].

There is some evidence to suggest that exposure to chlorine may also be associated with long-term neuropsychological changes [11].

## Health Effects of Chronic/Repeated Exposure

### Human data

#### Dermal/ocular exposure

Chronic dermal exposure to sodium hypochlorite solution may cause skin irritation [3]. Cases of allergic contact dermatitis have been reported in the literature [12]. However, the cases are isolated and often poorly reported, therefore sodium hypochlorite is not considered to be a skin sensitisation hazard [13].

#### Carcinogenicity

No data was available from studies in humans on the carcinogenicity of hypochlorite salts and there was inadequate evidence for the carcinogenicity of hypochlorite salts in experimental animals. Overall, IARC assigned hypochlorite salts to group 3, ie compounds that are not classifiable as to their carcinogenicity in humans [14].

#### Reproductive and developmental toxicity

There are no studies on the effect of direct exposure to sodium hypochlorite bleach in pregnancy [15].

There is limited data on the effects of exposure to sodium hypochlorite in drinking water. This data does not provide evidence of an increased risk of congenital malformations [15]. However, there is some evidence of other outcomes including an increased risk of pre-term delivery, reduced fetal head circumference and decreased body length [15].

### Animal and in-vitro data

#### Genotoxicity

Sodium hypochlorite has been shown to have some mutagenic activity in both bacterial and mammalian cells in vitro [4]. Chromosomal aberrations were induced in Chinese hamster ovary cells exposed to 0.5 mg/mL sodium hypochlorite in the presence of S9 mix, although it was questioned whether such clastogenic effects were due to cytotoxicity. Chromosomal aberrations were also demonstrated in Chinese hamster cells treated with 500 g/mL sodium hypochlorite without metabolic activation [4]. Sodium hypochlorite was weakly genotoxic in human leukocytes in vitro at concentrations similar to those used in disinfection processes, as measured by the Comet assay, or at concentrations five- to ten-fold higher than those used for water disinfection, measured by *Saccharomyces cerevisiae* strain D7 [16].

There is no evidence for activity in vivo [4]. Oral administration of chlorine at pH 8.5 (where hypochlorite predominates) did not induce chromosomal aberrations or micronuclei in bone marrow of CD-1 mice [17].

## Carcinogenicity

The carcinogenicity of sodium hypochlorite was investigated in rats treated with 500 or 1000 mg/L sodium hypochlorite for 104 weeks; no tumours were attributed to sodium hypochlorite exposure [4]. Studies on female mice suggested that sodium hypochlorite could act as a tumour promoter, although it largely depended on the initiator used [4].

Several in-vivo studies have been carried out to assess the carcinogenicity of sodium hypochlorite. Male and female mice and rats were orally administered sodium hypochlorite for 2 years; two strains of female mice had dermal application of sodium hypochlorite; sodium hypochlorite was tested for its promoting effects in two strains of female mice following initiation with 7,12-dimethylbenz[a]anthracene and 4-nitroquinoline 1-oxide, respectively; male and female rats were administered sodium hypochlorite in drinking water in a multigenerational study. All studies reported negative results. However, none of the studies evaluated was considered adequate by IARC to draw definite conclusions [14].

Hypochlorite was classified in category 3 by IARC (not classifiable as to carcinogenicity in humans); animal studies indicate that solutions of chlorine in water are not carcinogenic [14].

The US National Toxicology Program (NTP) investigated the carcinogenicity of chlorine (up to 275 ppm) and chloramine (up to 200 ppm), dissolved in drinking water, in a 2-year carcinogenicity bioassay in mice and rats. There was no evidence of carcinogenic activity of chlorinated or chloraminated drinking water in male rats or male and female mice [18].

## Reproductive and developmental toxicity

Sperm-head abnormalities in rats were increased (the significance of which is unknown) following oral administration of 4 and 8 mg/kg of bw per day sodium hypochlorite prepared from chlorine gas for 5 weeks [17]. However, no such effects were reported in another study in male rats treated for 56 days prior to mating and no adverse effects in reproductive outcome were observed in female rats treated 14 days prior to mating and through gestation [4]. Furthermore, animal studies have demonstrated no reproductive or teratogenic effect of chlorine exposure [4].

Various in-vivo studies have indicated no reproductive or developmental effects due to exposure to chloramines [4].

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