Chlorine:
Effects on Health and The Environment

Edition Three includes a one-page addition on steps to be taken during a chlorine incident and first aid for chlorine exposure.

THE CHLORINE INSTITUTE, INC.

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Purpose

The purpose of this publication is to provide quick access to information about the effects of chlorine on human health and the environment. It is part of the Chlorine Institute's support of the chlor-alkali industry and service to the public.

The Chlorine Institute, Inc.

The Chlorine Institute, Inc. is a non-profit trade association of chlorine manufacturers, distributors, users, and many related companies whose business interest is safety in the manufacture, transport, and use of chlorine and related products. The membership of nearly 210 companies includes the producers of more than 98 percent of North America's chlorine. The Institute's concerns focus on enhancements to chlorine container design, safe transportation of chlorine, employee health and safety, the elimination of chlorine releases to the environment, control of chlorine emergencies, and product/process specifications.

Legal Notice

Information in this brochure is drawn from Chlorine Institute Pamphlet 90, *Molecular Chlorine: Health and Environmental Effects*, and other sources believed to be reliable. The Chlorine Institute and its members, jointly and severally, make no guarantee and assume no liability in connection with any of this information. Moreover, it should not be assumed that the information is comprehensive or complete, or that in future circumstances it may not change, which may render this description obsolete or inaccurate.

Additional Information

Additional information about molecular chlorine and the many ways the chlor-alkali industry practices responsible stewardship of this important chemical can be found on the Chlorine Institute's Internet web site: http://www.CL2.com.

Information about the benefits of chlorine chemistry to society and our qualtiy of life, and research into the impact of chlorine chemistry on health and the environment will find reports, resources, and references on the Internet web sites of the Chemical Manufacturers Association (CMA) and the Chlorine Chemistry Council (CCC). Respectively, those sites are: http://www.cmahq.com and http://c3.org.

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Background

Because of its reactivity, chlorine gas is almost never found in nature. Approximately two percent of the earth's surface materials is chlorine which is mostly in the form of sodium chloride in sea water and in natural deposits as carnallite ($KMgCl_3 \cdot 6H_2O$) and as sylvite (KCl). Active volcanoes emit some chlorine, and it has been detected coming from the decomposition of sea salt. For the purposes of this brochure, transportation containers and chlorine production, storage, repackaging, and user facilities are considered to be the only potential sources from which chlorine gas would enter the environment.

Chlorine is made through one of the most basic and simple of chemical processes. Electricity is used to break down salt water into chlorine, sodium hydroxide (also called caustic soda or lye) and hydrogen. The salt water used in this process either is drawn from underground brine fields or is made at manufacturing locations from sodium chloride and water. The chlorine gas produced is either used on site to produce other chemicals or chilled into a liquid to facilitate storage and transport.

Chlorine generally is transported and stored as a liquified compressed gas. Other than at large production facilities, chlorine will most likely be contained in 100- and 150-pound cylinders, one-ton containers, or 55- and 90-ton rail tank cars.

In the event of a chlorine release, the concentration is highest at the leak source. The concentration of the gas then diminishes at various distances from the leak, depending on a number of factors. These factors include the release volume, whether it is in the liquid or gas form, and the weather conditions (temperature, humidity, wind direction, and velocity). For example, chlorine dissipates more rapidly on a warm, windy day than on a cold, calm one.

Trained Chlorine Emergency Plan (CHLOREP) teams throughout North America are available for advice at the onset of an incident. If necessary, the teamswill respond to the scene with equipment and tools to help control an incident.

Safety: The First Priority

Safety has been of paramount importance since the North American chlorine industry developed on a large scale during the early 1900s. In March 1924, chlorine producers from the U.S. and Canada organized the Chlorine Institute as their safety and technical information center. The Institute exists to support the chlor-alkali industry and serve the public by fostering continuous analysis of and enhancements to safety and the protection of human health and the environment during the production, distribution and use of its mission chemicals.

The chlor-alkali industry is one of America's safest. Through the Institute, the industry has set as a main goal the elimination of uncontrolled chlorine releases into the environment. Until that goal is achieved, the industry has in place the Chlorine Emergency Plan (CHLOREP) to minimize and mitigate the effects of any release.

Acute Health Effects

Liquid chlorine in contact with any part of the body will result in a freeze burn of varying severity depending on the length of exposure. Immediate first aid (discussed on page 7) is needed to reduce the severity of the burn. Since chlorine vaporizes quickly under normal atmospheric conditions, liquid chlorine can be found only at the source of the leak. Therefore, it is very unlikely the public will come in contact with liquid chlorine.

Chlorine gas is a respiratory irritant. The distinctive odor similar to household bleach is detectable easily at very low concentrations, e.g., 0.2-0.4 parts per million (ppm) –the "odor threshold." For example, the concentration over a laundry tub where bleach is being used is around one part chlorine per one million parts of air. Most people can smell it very readily at that level. Chlorine concentrations above five parts per million (ppm) are irritating to the nose, throat, and eyes. In concentrations around the 1-3 ppm, chlorine causes mild eye and respiratory-tract irritation after several hours.

Inhaling the gas at almost any noticeable concentration causes coughing, tears, a "running nose," and breathing difficulties. These symptoms result from chlorine combining with moisture in the eyes, nose, throat, and lungs forming a weak acid.

If levels of chlorine become severely irritating or dangerous, people voluntairly will try to seek a safer location. As concentration and duration increase, so does the level of irritation and discomfort. The affected individual may become apprehensive and restless with coughing accompanied by throat irritation, sneezing, and excess salivation. The very young, the elderly, and people with other health problems are most susceptible to the effects of chlorine exposure.

If a person is trapped for a long period in a high-chlorine-concentration atmosphere, loss of consciousness and possibly death can result. It is important during a chlorine emergency to leave the contaminated area if possible. If that is not possible, sheltering in place can reduce considerably the chlorine exposure level.

Symptoms are reversible if an exposed person quickly is removed from the contaminated area and given prompt medical attention (see First Aid on page 7). Complete recovery is normal.

Effects of Chlorine Exposure

The effects of various levels of chlorine inhalation vary with the individuals involved. The following list, taken from the Chlorine Institute's *Pamphlet 90, Molecular Chlorine: Health and Environmental Effects*, is a compilation of chlorine exposure thresholds and reported responses in humans:

- 0.2-0.4 ppm: threshold of odor perception with considerable variation among subjects (a decrease in odor perception occurs over time);
- 1-3 ppm: mild, mucous membrane irritation, tolerated for up to one hour;
- 5-15 ppm: moderate irritation of the respiratory tract;
- 30 ppm: immediate chest pain, vomiting, dyspnea, and cough;
- 40-60 ppm: toxic pneumonitis and pulmonary edema;
- 430 ppm: lethal over 30 minutes;
- 1000 ppm: fatal within a few minutes.

To receive a lethal exposure, a person would have to remain near a leak source, within a chlorine cloud, and without respiratory protection.

Animal Studies on Chronic Toxicity

A pair of studies have been conducted to assess chlorine's ability to damage the reproductive system. Rabbits exposed by inhalation to concentrations of up to 1.5 ppm displayed no adverse reproductive effects. Neither did rats force-fed highly chlorinated water daily.

No increased tumor incidence was observed in a study to evaluate chlorine's ability to cause cancer in laboratory animals. For the study, several generations of rats were force-fed highly chlorinated water daily.

Rabbits and guinea pigs exposed to 1.7 ppm for nine months showed weight loss and a decreased resistance to disease.

In December 1993, the Chemical Industry Institute of Toxicology issued its report on a study on the chronic inhalation of chlorine in rats and mice. Rats and mice were exposed to chlorine gas at 0.4, 1.0 or 2.5 ppm for up to 6 hours a day and 3-5 days/week for up to 2 years. There was no evidence of cancer. Exposure to chlorine at all levels produced nasal lesions. However, because rodents can breath only through their noses, how these results should be interpreted for humans is not clear.

Rhesus monkeys were exposed to concentrations of up to 2.3 ppm for six hours a day, five days a week for one year. The researchers concluded that 2.3 ppm acts as an eye and respiratory irritant in monkeys, while lower exposures induced changes of questionable significance. They also said the monkey appears to be less sensitive than the rat to chlorine.

Numerous other chronic toxicity studies have been conducted on animals having basically the same physiological response mechanisms as humans. Results have varied, but no serious problems have been discovered.

Chronic Human Health Effects

Most studies indicate no significant connection between chronic exposure to low concentrations of chlorine and adverse health effects. A 1983 Finnish study did show an increase in chronic coughs and a tendency for hyper-secretion of mucous among workers. However, these workers showed no abnormal pulmonary function in tests or chest x-rays.

One of the most comprehensive studies, involving 300 chlorine plant workers chronically exposed to 0.006 to 1.42 ppm, showed no statistically significant increase in abnormal chest x-rays, electrocardiograms, or pulmonary function tests.

Other studies of workers in the chlor-alkali industry have resulted in similar observations. *No significant effects have been indicated for chlorine levels normally found in work places where chlorine is handled.* Those levels typically are well below one ppm.

As for the air breathed by the general population, chlorine levels in ambient air are so low that they are either unmeasurable or of no toxicological importance.

Chlorine in the Atmosphere

What becomes of chlorine gas that is released to the air? Clearly, it does not remain very long as molecular chlorine, which is a gas under ordinary conditions. This is known because under normal circumstances chlorine levels in air are so low they are undetectable or insignificant. While scientists have not yet answered all of the possible questions concerning chlorine's atmospheric chemistry, abundant research has enabled some predictability of behavior.

When the gas enters the air as chlorine molecules, each molecule consists of two chlorine atoms. As wind disperses and dilutes the gas, a relatively few chlorine molecules react with water vapor, oxygen, or other substances in the three-to-four mile near-earth atmosphere (troposphere). The products of these reactions have little, if any, environmental effect.

Much of this chlorine eventually reacts with hydrogen to form hydrogen chloride gas, which is either washed out of the air by rainfall, or it combines with fine, solid or liquid particles that fall to earth through gravity.

Some of the remaining atomic chlorine probably is involved in both forming and destroying

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Chlorine In The Atmosphere (Continued from bottom of page five)

tropospheric ozone, the principal component of urban smog. Ozone forms through a complex chemical mechanism involving a variety of emissions from natural and manmade sources. Most notable of these is the internal combustion engine. Whether atomic chlorine adds to or detracts from near-earth ozone and urban smog still is open to question. Available evidence suggests the overall effect is negligible.

A release of elemental chlorine plays no role in the depletion of the ozone layer. As stated earlier, molecular chlorine is cleansed from the air in the troposphere before it can reach the ozone layer in the stratosphere, about seven miles above the earth's surface.

Scientists have concluded that ozone layer damage apparently is caused by certain highly stable compounds which contain chlorine. Before their phase-out in many parts of the world in the mid-1990s, chlorofluorocarbons (CFCs) used in air conditioning and refrigeration were one such class of compounds.

Because of the negligible presence of chlorine in the atmosphere, neither chlorine nor its reaction products have any known toxic effects on land animals or plants.

Because chlorine is a respiratory irritant at higher concentrations, animals in the path of a significant amount of chlorine are affected the same way humans are (see previous section on human health effects).

Plants in the path of a chlorine release may be damaged. Chlorine will bleach leaves. Pine trees and mature leaves of deciduous trees are most susceptible to damage. Leaves may turn brown and fall off because chlorine stops the plant from producing chlorophyll. Healthy plants recover over time, although yield and growth rate may be retarded.

When the chlorine molecules which become hydrogen chloride gas (see earlier section) are washed out of the air by rainfall, the hydrogen chloride makes a minor contribution to acid rain – about one percent, at most. Major contributors to acid rain are sulphur dioxide and nitrogen oxides.

Chlorine In Water

The U.S. Environmental Protection Agency (EPA) regulates the amount of chlorine that may be present in treated wastewater discharges. At allowable levels, chlorine does not significantly affect flora or fauna. If an excess amount of chlorine is released by accident into a lake or stream, it may harm aquatic plants and animals until it is diluted to a harmless level. It is not likely to cause permanent environmental damage.

Since it is only slightly water soluble, very little chlorine gas that escapes into the air enters bodies of water, and therefore does little, if any, harm to aquatic life. Chlorine could enter natural waters in combination with other chemicals in the form of acid participation. However, as we have mentioned, the amount of chlorine released into the air is so small that any acid precipitation containing only chlorine compounds has no detectable effect.

Avoiding Chlorine Releases At Home

Here are three ways to avoid releasing chlorine gas in and around the home:

- When using a dry, chlorine-based swimming pool sanitizer, *always add the sanitizer to the pool water.* ***Never mix water into pool treatment chemicals.***
- ***Never mix different types of swimming pool treatment chemicals together.***
- ***Never mix household chlorine compounds*** (bleach, cleansers) ***with ammonia or with acid-based household chemicals*** like toilet-bowl cleaners.

Getting Help During A Chlorine Emergency

The Chlorine Institute has a committee which coordinates an industry-wide chlorine emergency response program, primarily for transportation emergencies. The program is called the Chlorine Emergency Plan or CHLOREP.

Throughout the U.S. and Canada, there are regional sectors where chlorine emergency teams from producer, packager, and consumer facilities are on constant alert to handle threatened or actual chlorine emergencies.

During a chlorine emergency, any carrier, customer, or civil authority can obtain basic emergency information and be put in contact with the closest chlorine emergency group by phoning CHEMTREC in the U.S. [800-424-9300] or CANUTEC in Canada [613-996-6666].

First Steps During A Chlorine Incident

As soon as there is any indication of a chlorine release, immediate steps must be taken to correct the situation. Chlorine leaks can get progressively worse if they are not promptly corrected. When a chlorine leak occurs, authorized, trained personnel equipped with respiratory and appropriate other personal protective equipment (PPE) should investigate and take prescribed actions. People should not enter into atmospheres containing concentrations of chlorine in excess of the Immediately Dangerous to Life and Health Concentration (IDLH) of 10 ppm without appropriate PPE and back-up personnel. Unnecessary people should be kept away and the hazard area should be isolated. People potentially affected by a chlorine release should be evacuated or sheltered in place as circumstances warrant.

If near a fixed facilities, area chlorine monitors and wind direction indicators can supply timely information (e.g., escape routes) to help determine whether people are to be evacuated or sheltered in place.

When evacuation is used, potentially exposed persons should move to a point upwind of the release. Because chlorine is heavier than air, higher elevations are preferable. To escape in the shortest time, people already in a potentially affected area should move crosswind.

When inside a building and sheltering in place is selected, shelter by closing all windows, doors and other openings, and turning off air conditioners and air intake systems. People should move to the side of the building furthest from the release.

Position potentially affected people so they have an excape route. A safe position may be made hazardous by a change in wind direction or by the release becoming larger.

If fire is present or imminent, chlorine containers and equipment should be moved to a safe location, if possible. Non-leaking containers or equipment that cannot be moved should be kept cool by the application of water. This should continue until well after the fire has been extinguished and the containers are cooled. Containers exposed to excessive heat should be isolated until an examination can be conducted by the supplier.

Water should not be used directly on a chlorine leak. Chlorine and water react forming acids which could make the leak worse. However, where several containers are involved and some are leaking, it may be prudent to use a water spray to help prevent over-pressurization of the non-leaking containers.

First Aid for Chlorine Inhalation

Prompt action is essential. Remove the exposed person to fresh air and summon professional medical assistance immediately. If breathing has ceased, begin artificial respiration. Trained personnel should administer oxygen as soon as possible.

If breathing, the person should be placed in a comfortable position, either seated in a chair or, in severe cases, lying down with the head and body trunk elevated at a 45- to 60-degree angle. Encourage the person to take slow, deep, regular breaths. Administer oxygen as soon as possible. Keep the person warm and at rest.

Mission Statement

The Chlorine Institute, Inc. exists to support the chlor-alkali industry and serve the public by fostering continuous improvements to safety and the protection of human health and the environment connected with the production, distribution and use of chlorine, sodium and potassium hydroxides, and sodium hypochlorite; and the distribution and use of hydrogen chloride. This support extends to giving continued attention to the security of chlorine handling operations.

The Institute strives to meet these obligations by maintaining a scientific and technical organization that fully meets the needs and expectations of its members and the public. The Institute works with governmental agencies, its members, and other stakeholders to encourage the use of credible science and proven technology in the development of voluntary actions and regulations to enhance safety and security in operations involving its Mission chemicals.

The Institute believes that its Mission chemicals are essential to society and can be produced and used safely.

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