

# Chlorine

## Health Hazard Information Sheet

### What is chlorine?

In meat, poultry and egg products establishments, the term “chlorine” is commonly used to describe a variety of different chemicals which contain chlorine. These chemicals are also generically known as “bleach”. “Bleach” refers to chlorine-based compounds which have strong bactericidal properties and are commonly used as disinfectants.

The purest form of chlorine is a greenish-yellow gas with a strong, pungent, irritating odor. This form of chlorine is known as elemental chlorine (two chlorine atoms bound together) or chlorine gas. When used in industry, chlorine gas is compressed into a liquid and stored in metal cylinders.

In addition to chlorine gas, the most common chemicals which are referred to as “chlorine”, are either a liquid chlorine solution called “sodium hypochlorite” or a solid chlorine powder called “calcium hypochlorite”. Liquid sodium hypochlorite is the most widely used form of chlorine and is frequently referred to as just “bleach”. Calcium hypochlorite is the major component of “bleaching powder” and is generally found in the form of tablets that are then dissolved in water. While chlorine gas (elemental chlorine) may be still be in use at some establishments, many are currently using the liquid and solid forms of chlorine due to the significant safety and health hazards associated with the transport, storage and handling of pure chlorine gas.

### What happens when chlorine is added to water?

When chlorine (as chlorine gas, sodium hypochlorite or calcium hypochlorite) is added to water it immediately begins to react with the other chemicals and materials found in the water and with the water itself. Some of the results of these reactions are desirable producing a residual chlorine solution (such as hypochlorous acid) that is able to kill microorganisms. Some reactions are not desirable producing odorous and irritating chemicals which have little to no disinfecting properties (such as nitrogen trichloride, hydrochloric acid, sulfuric acid and hydrogen sulfide). The type of chemicals formed depend on many variables including the composition of the source water, the amount of organic material in the water, the amount of chlorine used, and the pH of the water. This can vary widely from day to day and requires that the chlorination process is carefully monitored and controlled.

The basic reaction of chlorine with water produces hypochlorous acid (HOCl) and hydrochloric acid (HCl). Hypochlorous acid is the most effective form of free chlorine residual for disinfection. Depending on pH, hypochlorous acid may break down further into a hydrogen ion and a hypochlorite ion. Hypochlorite ions are much less efficient disinfectants. A higher pH favors the formation of more hypochlorite ions and results in less hypochlorous acid in the water, so disinfection is more efficient at a lower pH rather than a high pH.

Many chemicals are used to “acidify chlorinated water” to produce more hypochlorous acid. These include carbonic acid (carbon dioxide), acetic acid, peroxyacetic acid, and citric acid.

These chemicals must be carefully controlled in a relatively narrow pH range (6.0 to 7.0) as lower pHs (less than 4.0 to 5.0) can produce odorous and irritating gases. This is especially critical when the source water used by the establishments contains high amounts of nitrogen or is treated with chlorine and ammonia (known as chloramination) by the public water supply facility prior to on-site chlorination by the establishment. Chlorine and ammonia/nitrogen react to form a number of new compounds, depending on water temperature, chlorine/ammonia concentrations, and pH. The main reaction produces a group of chemicals known as chloramines. These include monochloramine (NH<sub>2</sub>Cl), dichloramine (NHCl<sub>2</sub>), and trichloramine (nitrogen trichloride) (NCl<sub>3</sub>). Depending on changes in pH one or all of these compounds may be formed. Nitrogen trichloride is very irritating to the eyes and lungs and when conditions favor its formation, is thought to be one of the main causes of these symptoms in poultry plants as opposed to chlorine gas.

### **How are FSIS employees exposed to chlorine in their workplaces?**

Chlorine is used as an antimicrobial treatment, sanitizer and cleaner in meat, poultry and egg product establishments. It is commonly found in poultry chillers and spray cabinets, and also as a sanitizing spray or rinse on processing equipment. In much of the United States, very low concentrations are used to treat drinking water supplies.

As previously discussed, the addition of chlorine to water can produce many different chemical by-products (disinfection by-products), some of which may off-gas or evaporate from the treated water causing eye, nose and throat irritation if proper process controls are not in place and monitored. In addition, chlorinated water can be found as a mist around spray nozzles and as large droplet splashes from chillers and evisceration equipment. Chlorinated water may also cause irritation to the eyes, nose and throat by direct contact with mists and droplets.

### **What are the health effects of exposure to chlorine?**

Exposure to chlorine gas can cause upper respiratory (nose, sinuses, throat) and eye irritation depending on the concentration in air to which a person is exposed, the duration of the exposure and the frequency of exposure. These symptoms usually improve upon leaving the exposure environment. Some health effects associated with airborne exposure concentration levels in parts per million (ppm) are:

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| <b>0.5 ppm</b>      | Burning of eyes is noticeable by some individuals                                    |
| <b>0.5 to 1 ppm</b> | Some studies have indicated reduction in pulmonary function and increased discomfort |
| <b>1 ppm</b>        | Eye and respiratory irritation in 30 minutes or less                                 |
| <b>5 ppm</b>        | Respiratory symptoms, inflammation of mucous membranes and erosion of teeth          |
| <b>10 ppm</b>       | Considered to be "Immediately Dangerous to Life and Health" (IDLH)                   |

In addition, direct contact with droplets and mists of chlorinated water, such as splashes from a chiller or overspray from a cabinet, can cause eye and mucous membrane irritation.

Chlorine's distinctive odor does not present any health hazards on its own. Some people will smell chlorine long before it could cause any irritation, but others may not. The odor threshold for chlorine has been reported to range widely from 0.02 to 3.5 ppm. While odors may indicate that chlorine is present, they cannot be used as a precise indicator that hazardous conditions exist or do not exist. All three forms of "chlorine" (chlorine gas, sodium hypochlorite and calcium hypochlorite) will give off a bleach-like odor when exposed to air.

Concentrated chlorine-based chemicals (prior to dilution with water to the use concentration) may cause severe irritation to the eyes, skin and respiratory system, as well as chemical burns or serious respiratory damage. Concentrated solutions are not suitable for use on meat and poultry, and should not be stored or used in food production areas. It is unusual for an IPP to be exposed to the concentrated solutions because most chemical storage and mixing stations are typically located in a separate room from inspection, or in a locked cage outside of the building.

The health hazards of exposure to chlorine containing compounds formed during water treatment and disinfection have not been determined for inhalation exposures although it is assumed that they would have similar irritation effects especially upon direct contact. Nitrogen trichloride (trichloramine) is a known respiratory and eye irritant and is the primary chemical considered responsible for swimming pool health hazard exposures.

### **What are the Occupational Exposure Limits for chlorine?**

The Occupational Safety and Health (OSHA) Permissible Exposure Limit (PEL) for chlorine gas (as elemental chlorine) is 1 ppm, as a "ceiling" concentration (i.e., a level that should never be exceeded). This limit was selected to prevent acute irritation episodes. Some states, such as California, have stricter limits: 0.5 ppm as a full-shift (8-hour time-weighted average), with 15-minute short term exposures of up to 1.0 ppm allowed. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value (TLV) of 0.5 ppm (as a full shift, 8-hour TWA) and 1 ppm as a Short Term Exposure Limit (STEL) averaged over a 15 minute exposure period. These values were selected to reduce the risk of irritation and pulmonary function decline, and to minimize subjective complaints of irritation. Over the past few years, it has become standard to use an exposure threshold of 0.5 ppm as good management practice.

There are no airborne Occupational Exposure Limits (OEL) for exposures to the other chlorine containing compounds formed during water treatment and disinfection. In general the limit of 0.5 ppm has been used to monitor and evaluate exposures to all inorganic chlorine-containing chemicals.

### **How are occupational exposures to chlorine monitored or measured?**

There are a variety of validated air sampling methods for measuring chlorine gas. These include both OSHA and NIOSH laboratory analytical methods and direct reading instruments. However, these methods can only be used for measuring chlorine gas as elemental chlorine and cannot be used to specifically detect, identify or quantify hypochlorous acid, hypochlorite ion, chloramines or mixtures of chlorine-based compounds. Air sampling methods have not been fully developed or validated for any of these chemicals. All air sampling methods are for measuring a specific chemical only and are subject to interferences from similar compounds present in the air, which can result in a falsely low or falsely high reading. There are also no viable air sampling methods to determine the identity of an “unknown contaminant”.

In addition most of the available methods cannot test for chlorine that is present as water droplets or mists (only chlorine in the gas form). Another issue is that most electronic direct reading instruments use electrochemical sensor cells which are sensitive to contact with water, temperature changes, and other oxidizing compounds in the air (e.g. chlorine dioxide and ozone) and therefore not always suitable for establishment environments.

FSIS, OSHA, and NIOSH have collected hundreds of air samples in poultry establishments over the past 25 years and have only found a few instances where concentrations of chlorine gas exceeded an OEL. In most cases, sample results for chlorine in air are found to be “non-detectable or zero”, even if employees are experiencing visible signs of irritation. This is because the many other chlorine species that can be formed during chlorine water treatment can cause irritation and are not measureable by existing methods.

In some cases, a direct reading (color indicating) instrument like a Drager Chip Measurement System or detector tubes show greatly elevated readings on chlorine chips and tubes. However, it is not known exactly what chlorine compound(s) the equipment is responding to (e.g. reading is generally too high to be just chlorine or color change is not the same as what is expected). Manufacturers of this type of equipment have not evaluated or quantitated them for chemicals other than elemental chlorine gas. These readings however should be interpreted to mean that there is an elevated level of a chlorine based chemical in the air for which corrective actions should be evaluated, especially if there are concurrent employee symptoms. It has been found that when corrective actions (such as enclosure, ventilation or pH control) are implemented, the readings will decrease. Therefore, these instruments can be used qualitatively to determine the effectiveness of corrective actions. In summary, unfortunately a “zero” air sampling reading in the presence of employee irritation, does not necessarily mean that there are no chlorine based air contaminants present which could be causing the irritation. However, an elevated reading of any kind over normal conditions or background levels usually indicates that there is a contaminant issue that should be addressed.

## **What safety precautions can be followed to protect FSIS employees against exposure to chlorine?**

The following recommendations are primarily targeted at controlling airborne exposures at their source. FSIS Supervisors should use these suggestions to explore corrective actions with establishment management.

1. The most effective ways to prevent over-exposure to chlorine and chlorine-based compounds is to ensure that the antimicrobial application systems are operated in accordance with their approved specifications (especially ranges for chlorine and pH). These limits should be identified and carefully monitored. Establishments should provide these results to FSIS supervisors as needed.
2. If an acidification system is required for effective disinfection, it should be designed by a water quality engineer to ensure correct delivery of the acid to the water and that it has a monitoring system for measuring and maintaining the desired pH. (Low pH, starting at around 5.0-5.5 may produce odorous and irritating gases under certain conditions.)
3. If the source water provided to the establishment is either chloraminated (treated with chlorine and ammonia) by the municipal water supply facility or from surface (lake) water or well water, a water quality engineer should determine if excess ammonia/nitrogen or organic materials may be the cause of odorous or irritating gas especially after the establishment has added additional chlorine to the water (called super-chlorination).
4. Any process water containing chlorine-based solutions should not be allowed to mix with strong acids in open floor trenches. If redundant antimicrobial systems are used, these chemicals needed to be evaluated together to ensure that mixing does not result in adverse chemical reactions and off-gassing. If there are plans to add a new system in addition to an existing one, the chemical supplier should be required to evaluate the potential interactions between all systems and provide information on control measures to be implemented.
5. If a system or process variable cannot be identified as a potential cause of airborne irritation, then equipment (e.g. chillers, spray cabinets) should be contained/enclosed as much as possible and a determination of the need for local exhaust ventilation or increased general ventilation should be completed to capture contaminants at their source and remove them from the workplace air. (Note: Personal fans or air movers at individual inspection stations are not likely to provide relief from gases, since they only move air around within the plant. Exhaust fans in the walls or roof designed with appropriate make-up air supplies can draw air out of the area, limiting the amount of contaminant in the air.)
6. Containment and ventilation should also be used to prevent chlorinated water mists or droplets from coming in contact with employees. If possible, spray cabinets should be located far enough from inspectors that visible clouds of mist do not reach the inspection stations and nearby surfaces do not become wet from the mist. Cabinets should discharge into fast-moving floor drains or be recirculated.

7. On a temporary basis, while investigations are being conducted or corrective actions are in progress, FSIS supervisors may request acid gas disposal respirators (mask) for IPP. Contact your Occupational Safety and Health Specialist for further information.

**Where can FSIS employees turn for information on chlorine?**

OSHA requires that chemical containers are labeled with hazard warnings and that Safety Data Sheets (SDSs) are available to employees upon request.

**How should training for this Health Hazard Information Sheet be recorded?**

Per requirements found in FSIS Directive 4791.1 Section IX, all occupational health and safety training is to be recorded using either AgLearn or FSIS form 3530-12. Training records are to include the topics covered, date, and employee name. The Agency is to retain all training records for a minimum of five years.”

**About the ESHG**

The FSIS Environmental Safety and Health Group (ESHG) is devoted to providing a safe and healthful work environment for FSIS employees. More information on safety topics can be found on the intranet site <http://www.tinyurl.com/FSIS-ESHG> or by email [askemployeesafety@fsis.usda.gov](mailto:askemployeesafety@fsis.usda.gov)