

Agent Characteristics	<p>Agent Classification: Choking/pulmonary agent and Toxic Industrial Chemical; CAS: 7782-50-5; Formula: Cl₂; Molecular Weight: 70.9 g/mol.</p> <p>Description: Chlorine (CL) is a greenish-yellow gas at room temperature with a pungent, irritating odor. Under increased pressure or at temperatures below -30°F (-34°C), CL is a clear, amber-colored liquid. CL causes health effects through corrosion and oxidation. Most people can smell CL well below toxic levels, but olfactory fatigue greatly decreases this safeguard. CL can be generated from hypochlorites (e.g., household bleach) at low pHs. CL will react rapidly with atmospheric moisture to form hydrochloric acid (HCl) and hypochlorous acid (HOCl). CL is a strong oxidizer and may react explosively or form explosive compounds with many common substances such as acetylene, ether, turpentine, ammonia, fuels, hydrogen, many other chemicals, and metal shavings. Toxic environmental breakdown products of CL can include HCl, HOCl, and numerous organochlorine compounds.</p> <p>Persistence: CL is considered "non-persistent." Vapor: minutes to hours; liquid: rapidly evaporates at ambient temperatures and pressures. Persistence will depend upon amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. CL will react with many materials resulting in damage that greatly shortens their usable life (e.g., reduction of metal corrosion resistance).</p>																																
	<p>Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.344; mg/m³ = ppm x 2.90. NA = not applicable.</p> <table border="1"> <thead> <tr> <th>Vapor Density</th> <th>Vapor Pressure</th> <th>Volatility</th> <th>Boiling Point</th> <th>Freezing Point</th> <th>Flash Point</th> <th>Liquid Density</th> <th>Aqueous Solubility</th> <th>Non-aqueous Solubility</th> </tr> </thead> <tbody> <tr> <td>2.5 (air =1)</td> <td>5,830 mm Hg (77°F/25°C)</td> <td>very high, limited by mass transfer</td> <td>-30°F/-34°C</td> <td>-150°F/-101°C</td> <td>NA, not combustible</td> <td>1.409 g/mL (68°F/20°C)</td> <td>7 g/L (77°F/25°C)</td> <td>Bases, chlorides, alcohols</td> </tr> </tbody> </table>									Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility	2.5 (air =1)	5,830 mm Hg (77°F/25°C)	very high, limited by mass transfer	-30°F/-34°C	-150°F/-101°C	NA, not combustible	1.409 g/mL (68°F/20°C)	7 g/L (77°F/25°C)	Bases, chlorides, alcohols						
Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility																									
2.5 (air =1)	5,830 mm Hg (77°F/25°C)	very high, limited by mass transfer	-30°F/-34°C	-150°F/-101°C	NA, not combustible	1.409 g/mL (68°F/20°C)	7 g/L (77°F/25°C)	Bases, chlorides, alcohols																									
Release Scenarios	<p>AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.</p> <p>Open Areas: Due to its volatility, CL is relatively easy to disperse as a gas, and the primary release/attack scenario is an airborne release. CL is expected to disperse or to degrade by reaction with encountered surfaces/materials. However, an unreacted cloud of CL (typically greenish-yellow) can migrate several miles from the site of release by the wind while maintaining very dangerous concentrations. CL is heavier than air and can accumulate in lower terrains.</p> <p>Water/Water Systems: CL released into or over natural waters or water systems can dissolve within seconds and form HCl and HOCl, which are corrosive and may exert toxic effects if present in high concentrations. If a large cloud of CL is released, not all CL may dissolve before the CL cloud leaves the vicinity of the water.</p> <p>Indoor Facility: Due to its volatility, CL could potentially be dispersed inside a building or facility; HVAC systems could be impacted. CL is heavier than air and can accumulate in lower levels or utility corridors inside the buildings.</p>																																
Health Effects	Onset	Onset of symptoms is dose and route dependent. Symptoms may occur within seconds after exposure to gas (eyes and respiratory) or liquid (instant frostbite).																															
	Signs/Symptoms	<p>Symptoms will vary depending on exposure route; however, the following is a general list of all possible symptoms. The severity of effects depends upon the dosage.</p> <p>Mild to Moderate: <i>Inhalation:</i> Immediate coughing spasms and a choking sensation; retching and vomiting of stomach contents that may smell like CL. Hoarseness or complete loss of voice. Symptoms generally resolve within 6 hours after mild exposures but may continue for several days after severe exposures. High-pitched sounds caused by narrowing of the upper airway and severe chest discomfort. An early and prominent effect of exposure is narrowing of the lower airways. The patient or victim may describe the sensation of feeling smothered (suffocated). Symptoms and signs of accumulation of fluid in the lungs (pulmonary edema) may appear within 2 to 4 hours after exposure. <i>Eye:</i> Immediate burning, spasmodic blinking or involuntary closing of the eyelids, redness, inflammation of eye's membranes, and tear production. <i>Skin:</i> Irritation, burning pain, inflammation, and blisters.</p> <p>Severe: <i>Inhalation:</i> Sudden death can occur from critical narrowing of the upper airway. Severe difficulty breathing or shortness of breath may be so prominent that the patient or victim refuses to move. Another symptom includes copious secretions (up to 1 liter per hour) from the nose and mouth and airways. Pulmonary edema may occur within 30 to 60 minutes after exposure. <i>Eye:</i> Corneal burns leading to cell death and eye ulcers. <i>Skin:</i> Severe chemical burns leading to cell death and skin ulcers. Exposure to liquefied (compressed) CL can result in frostbite injury and/or chemical burns.</p>																															
	Exposure Routes	<p>Inhalation: The primary route of CL exposure is in gaseous form. Respiratory symptoms may be immediate or delayed for several hours or days after exposure to CL. Respiratory deterioration may continue for several hours.</p> <p>Skin: Contact with CL in gaseous form can cause chemical burns to skin. Contact with compressed liquid CL can cause frostbite. Significant skin absorption is unlikely.</p> <p>Eyes: Contact with CL in gaseous form can cause chemical burns to the eyes. Contact with compressed liquid CL can cause frostbite.</p> <p>Ingestion: CL is a gas at room temperature, making ingestion an unlikely exposure route.</p>																															
Effect Levels	<p>Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for CL (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Toxic Industrial Chemicals):</p> <table border="1"> <thead> <tr> <th>AEGL Level in mg/m³, at various exposure durations</th> <th>10 min.</th> <th>30 min.</th> <th>1 hr.</th> <th>4 hr.</th> <th>8 hr.</th> </tr> </thead> <tbody> <tr> <td>AEGL 1: Threshold mild effects</td> <td>1.5</td> <td>1.5</td> <td>1.5</td> <td>1.5</td> <td>1.5</td> </tr> <tr> <td>AEGL 2: Potentially irreversible effects or impaired ability to escape</td> <td>8.1</td> <td>8.1</td> <td>5.8</td> <td>2.9</td> <td>2.0</td> </tr> <tr> <td>AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality</td> <td>145</td> <td>81</td> <td>58</td> <td>29</td> <td>21</td> </tr> </tbody> </table> <p>Exposure Guidelines: IDLH = 30 mg/m³; OSHA PEL = 3 mg/m³ [ceiling]; ACGIH TLV-TWA = 1.5 mg/m³ [an 8-hr time-weighted average occupational value]; NIOSH REL = 1.45 mg/m³ [15-minute ceiling]. Regional Screening Level (RSL) for Residential Soil = 7.5 x 10³ mg/kg; RSL for Industrial Soil = 1.0 x 10⁶ mg/kg. Drinking Water RSL = 2.0 mg/L. Soil and Water: Should be monitored for acceptable pH values.</p>									AEGL Level in mg/m ³ , at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.	AEGL 1: Threshold mild effects	1.5	1.5	1.5	1.5	1.5	AEGL 2: Potentially irreversible effects or impaired ability to escape	8.1	8.1	5.8	2.9	2.0	AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	145	81	58	29	21
	AEGL Level in mg/m ³ , at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.																											
AEGL 1: Threshold mild effects	1.5	1.5	1.5	1.5	1.5																												
AEGL 2: Potentially irreversible effects or impaired ability to escape	8.1	8.1	5.8	2.9	2.0																												
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	145	81	58	29	21																												
Personnel Safety	Note	<p>Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decontamination may vary depending upon the amount and purity of agent, site conditions and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb. We also recommend that responders check their own internal procedures (i.e., SOPs), if they have them.</p>																															
	Medical	<p>Pre-incident: Annual physical and respiratory function exam. During Incident: Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per Health Effects section above and treat accordingly as per First Aid section below.</p>																															
	First Aid	<p>Immediately remove person from affected area and remove contaminated clothing and articles. Compressed liquid: Observe and treat for frostbite and chemical burns. Wash bare skin immediately with water, or warm, soapy water if available, at normal household pressures (~50-60 psi) for three minutes, ensure thorough soaking. Rinse eyes exposed to liquid agent with potable water for 15 minutes. Gas: Observe and treat for respiratory distress and maintain clear airway, <i>effects may be delayed up to 4 hours.</i> Administer humidified oxygen if respiratory distress develops. Antidote: THERE IS NO ANTIDOTE. Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.</p>																															
	PPE	<p>GENERAL INFORMATION: NIOSH-approved Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, and protective clothing should be used. Pre-incident training and exercises on the proper use of PPE are recommended. Per NIOSH guidance - LEVEL A: Recommended for the initial response to a CL incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the CL concentration is unknown or above the IDLH or AEGL-2, and when there is a potential of ocular or dermal exposure. LEVEL B: Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the CL concentration is unknown or above the IDLH or AEGL-2 and dermal exposure is less of a risk. Level B differs from Level A in that it typically incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not vapor tight. LEVEL C: Select Level C when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e., < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. LEVEL D: Select Level D when the contaminant is known and the concentration is below the appropriate occupational exposure limit or less than AEGL-1 for the stated duration times. Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring. CL will react rapidly with air to form acidic atmospheric conditions that will present a contact hazard to exposed skin as well as inhalation hazards; monitoring for HCL or pH may be required.</p>																															
Field Detection	<p>Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment. The following is a summary of minimum screening concentration ranges or levels for equipment procured by many EPA and HAZMAT response teams. Other screening tools may be used by these teams and other agencies and responders, some with similar capabilities and limitations. CAUTION: CL reacts with water and moisture in air to form HCl; monitoring for HCl and changes in pH as well as CL is therefore recommended.</p>																																

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of CL at levels as listed below.								
Minimum Screening Ranges/Levels for Air	Dräger – Miniwarn / Pac III / X-am 7000	Honeywell - SPM	Dräger - CL tube / CDS Kit	MultiRAE	Minimum Screening Levels for Water	pH meter	Colorimetric field test kits (e.g., Hach, Lamotte, etc.)	
ppm	0.05	0.05-1.5	0.2-0.3	0.1		(acidic degradates)	0.01 (mg/L in water)	
mg/m ³	0.03	0.15-4.4	0.6-0.9	0.3		+/- 0.1 pH units		
Sampling	<p>Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)</p> <p>Sampling Concerns: Detection, sampling equipment and procedures, and analytical techniques will be site-specific and depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. non-porous); 3) the purpose of sampling (e.g., characterization, decontamination efficacy and clearance); and 4) specific laboratory requirements. Because CL is reactive and volatile, field detection instead of laboratory analysis of samples may suffice and sometimes be necessary to achieve many goals of sampling. The U.S. Environmental Protection Agency (EPA) has set up mobile and fixed labs and analytical assets for chemical agent analysis of environmental samples under their Environmental Response Laboratory Network (ERLN), see ANALYSIS section below (www2.epa.gov/emergency-response/environmental-response-laboratory-network). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.</p> <p>Sample Locations and Planning: Initially consider air monitoring to ensure worker safety and to determine if there is a CL cloud that could impact other areas. Characterization sampling is initiated by targeted or judgmental sampling to identify "hot spots," potential agent flow paths, and media or objects potentially acting as sinks. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify the efficacy of decontamination. More thorough probabilistic sampling (e.g., grid, statistical approach) may be required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because CL is generally not persistent, sampling for CL and HCl (air), and pH (surfaces, water, and soil) determination to help to "clear areas" should be included in the sampling plan.</p> <p>Note: CL is highly reactive, so reaction by-products, mainly HCl and HOCl, may be detected in the field and used as markers to determine the extent of contamination of the parent CL. Laboratory analysis will be necessary for organochlorine reaction by-products. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes.</p> <p>Types of Samples:</p> <p>Air (CL in gaseous form is heavier than air): On-site CL monitors may provide sufficiently accurate real-time results. For lab analysis, samples are collected using appropriate solid phase absorbent media (with silver membrane filter) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces.</p> <p>Water: Dissolved CL is accurately analyzed in the field; delays in transport to lab may result in inaccurate determination. Measuring the pH of the water may be sufficient.</p> <p>Soil: For localized hot spot areas where soil deposition may occur, surface soil samples may be analyzed for pH and organochlorine reaction by-products and should be taken from a non-vegetated area to a depth of less than one inch. Measuring the pH of the soils may be sufficient. Concurrent air monitoring is recommended. Sub-surface soil samples (e.g., for organochlorines) may not be necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered.</p> <p>Surface Wipes: Wipe samples are often desired to indicate CL breakdown products, mainly HCl and chlorinated organics, on non-porous surfaces. Measuring the pH of collected wipes may be sufficient. Concurrent air monitoring is recommended.</p> <p>Bulk: For hot spot areas where liquid CL deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring or drills) for subsequent laboratory extraction analysis for organochlorines. Damage to some surfaces may be visually obvious. Bulk samples of suspected sink materials may be recommended to rule out absorption of organochlorines into these materials.</p> <p>Other Sample Matrices: Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.</p>							
	<p>Sample Packaging and Shipping: The packaging and shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA and IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.</p>							
	<p>CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil). The ERLN will use uniform, compatible sample prep and analytical methods. (See www2.epa.gov/emergency-response/environmental-response-laboratory-network). Reactive compounds such as CL, HCl, HOCl, and other chlorites/chlorates may be accurately determined in the field using available meters and field kits. For access to the nearest ERLN laboratory specially trained and equipped for analysis of CL and its organochlorine reaction by-products, contact the EPA/HQ-EOC at 202-564-3850.</p>							
	<p>CAUTION: USE WATER SPRAY ONLY TO REDUCE CL CLOUD OR DIVERT CL CLOUD DRIFT; DO NOT PUT WATER IN DIRECT CONTACT WITH LIQUID CL. AVOID ALLOWING WATER RUNOFF TO CONTACT REMAINING CL LIQUID. CL is so volatile and reactive that it will either dissipate, be consumed by reaction with surfaces/materials it encounters, and/or be readily neutralized. Hence, most decontamination will not necessarily be for CL itself, but for reaction by-products, mostly acids and organochlorine compounds. Separate, long-term decontamination strategies will need to be developed if those by-products are of concern in a particular situation. This decontamination section refers to CL itself.</p> <p>Decontamination/Cleanup Planning: Once site controls are in place, develop a site-specific decontamination/cleanup plan. Decontamination may require a "tiered approach" using a variety of techniques and products. Call the EPA/HQ-EOC at 202-564-3850 for more information.</p> <p>General Considerations: A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service and any socio-economic, psychological, and/or security impacts that may result. Large volumes of decontamination wastes may be generated that will need to be collected, treated and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see Waste Management section below).</p> <p>Disposal Option: The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decontamination formulations, or may be cheaper to discard and replace than to decontaminate and restore.</p> <p>Monitored Natural Attenuation: CL degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation may require institutional controls (e.g., access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options and will allow CL to react with materials for a longer period of time.</p> <p>Fix-in-Place Option: The contaminated area may be unable or impractical to be treated. Physical barriers can be used to separate and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution.</p> <p>Decontamination Strategy: A decontamination strategy can be developed by designating contaminated areas based on presence of: 1) liquid CL, 2) gaseous CL, or 3) aqueous solutions of CL.</p> <p>Strategy for Liquid CL: CL is easier to remove when in gaseous form; actions that promote safe volatilization may be useful. Volatilization may be a slow process.</p> <p>Strategy for Gaseous CL: Aerate spaces where gaseous CL may be present. CL has corrosive properties and attacks plastic, rubber, and coatings. Impact on materials should be assessed for mitigation efforts. Mechanical, electrolytic, or chemical cleaning of corroded products may be needed. Forced or Hot Air ventilation methods are recommended for CL cloud contamination or low concentration of CL in large volumetric spaces or open areas.</p> <p>Strategy for Aqueous Solutions of CL: If CL is present in solution, contain liquid or transfer liquid to appropriate containers. Neutralize CL liquid with thiosulfate, sulfite, ascorbic acid (Vitamin C), or reducing agents. Adjust acidic solutions with caustic soda, soda ash, or lime solutions.</p> <p>CAUTION: Decontamination/neutralization products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use.</p> <p>Verification of Decontamination: Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.</p>							
Waste Management	<p>CAUTION: Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmqreqs.htm#hmp. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org/. Current resources on packaging, labeling and shipping are available at www.phmsa.dot.gov/hazmat.</p>							
	<p>Waste Management: Under the Resource Conservation and Recovery Act (RCRA), waste generally is classified as hazardous waste (subtitle C) or solid waste (subtitle D). Under RCRA's statutory authority, a waste is considered hazardous if it: (A) causes or significantly contributes to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness or (B) poses a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. The RCRA regulations generally define a waste as hazardous if it is: (1) a listed waste (40 CFR §261.31, §261.32), (2) exhibits specific characteristics (40 CFR §261.21-261.24) or (3) is a discarded commercial chemical product, off-speciation species, container residue, or spill residue thereof (40 CFR §261.33). The States (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements than the Federal program, so it is critical to open a dialogue with regulators as early as possible. Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. The EPA has developed I-WASTE, a web-based tool that contains links to waste transportation guidance, treatment and disposal facilities, state regulatory offices, packaging guidance, and guidance to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (www2.ergweb.com/bdrtool/login.asp).</p>							