NRT Quick Reference Guide:
Hydrogen Cyanide (AC)
[February 2017 Update]

For references, please see Key References Cited/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Toxic Industrial Chemicals. QRGs are intended for Federal OSC/RPMs.

Agent Characteristics

Agent Classification: Toxic Industrial Chemical, Schedule 3 Chemical Warfare Agent; CAS: 74-90-8; Formula: HCN; Molecular Weight: 27.03 g/mol.
Description: Hydrogen cyanide (AC) is a colorless gas above boiling point (78°F/25.6°C) and a pale blue or colorless liquid below boiling point. Only 60-70% of the population can detect a bitter, almond odor from AC, and olfactory fatigue onsets rapidly, diminishing this safeguard. AC is typically transported as a compressed gas or liquid, but may be produced by the reaction of cyanide salts (see Cyanide Salts QRG) with acids. AC interferes with the body's use of oxygen, causing asphyxiation. AC reacts with environmental moisture to form hydrocyanic acid, which in turn may form other cyanide compounds, depending on pH. AC may combine with chlorine to form cyanogen chloride. None of these reactions significantly lower the toxicity but they alter the exposure pathways. AC is flammable with a flash point of 0°F/-18°C; explosive potential is severe in the presence of heat, flame, and oxidizing, acidic, or alkaline compounds. AC has a lower explosive limit (LEL) of 5.6% v/v and an upper explosive limit (UEL) of 40% v/v.
Persistence: AC 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. In the presence of water at environmental pHs, significant AC persistence may occur via conversion to cyanide ion (CN^-), unless conditions allow for volatilization.

Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m^3 x 0.9064; mg/m^3 = ppm x 1.103

Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point / Explosive Range	Liquid Density	Aqueous Solubility	Non-aqueous Solubility
0.941 (air = 1)	630 mm Hg (68°F/20°C)	1,080,000 mg/m^3 (77°F/25°C)	78°F/25.6°C	7°F/-13°C	0°F/-18°C Flammable gas 5.6% LEL - 40% UEL	0.684 g/mL (75°F/24°C) gas above 78°F/25.6°C	miscible	Ethers, benzene, chloroform, glycerin. Miscible with alcohol.

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.
Open Areas: Due to its volatility, AC is easy to disperse as a gas, and the primary release/attack scenario is an airborne release. AC is expected to disperse or to degrade by reaction with encountered surfaces/materials. AC is reactive, extremely flammable and may ignite combustible materials.
Water/Water Systems: AC released into or over natural waters or water systems can dissolve and form hydrocyanic acid and other cyanide compounds, depending on the pH. If a large cloud of AC is released, not all AC may dissolve before the AC cloud leaves the vicinity of the water.
Indoor Facility: Due to its volatility, AC could potentially be dispersed as a gas inside a building or facility; HVAC systems could be impacted. Explosive vapors can be formed with oxidants, amines, and caustic and combustible materials. AC is slightly lighter than air and will follow prevailing air flows inside the buildings.

Health Effects

Onset	Onset of symptoms is dose and route dependent. Effects occur rapidly following exposure to AC. Inhalation exposure to AC gas produces symptoms within seconds to minutes; death may occur within minutes. After skin exposure, symptoms may be immediate or delayed 30-60 minutes.
Signs/ Symptoms	Appearance and severity of symptoms will vary depending upon exposure route, concentration and duration. However, the following is a general list of possible symptoms. AC interferes rapidly with the body's use of oxygen, particularly affecting the brain, cardiovascular system, and pulmonary system. Mild to Moderate: Headache, confusion, anxiety, dizziness, weakness, and loss of consciousness; heart palpitations; respiratory tract irritation, difficulty breathing; nausea, vomiting. Severe: Coma, seizures, dilated pupils, shock, abnormal heart rhythms, very low blood pressure, cardiac arrest. Abnormally rapid breathing followed by slow respirations, pulmonary edema and respiratory arrest. Blue discoloration of skin may be a late finding.
Exposure Routes	Inhalation: The primary route of AC exposure is in gaseous form. Inhalation of very small concentrations can produce health effects. Skin: Irritation, tissue ulceration, burning and pain. Absorption through skin is rapid and can contribute to whole-body (systemic) toxicity (see Signs/Symptoms above). Eyes: Redness, pain, and severe deep burns. Ingestion: Nausea, vomiting, abdominal pain, and irritation and corrosion of lining of esophagus and stomach. Ingestion can contribute to whole-body (systemic) toxicity.

Exposure Levels

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for AC (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Toxic Industrial Chemicals):

AEGL Level in ppm, at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	2.5	2.5	2.0	1.3	1.0
AEGL 2: Potentially irreversible effects or impaired ability to escape	17	10	7.1	3.5	2.5
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	27	21	15	8.6	6.6

Exposure Guidelines: IDLH = 50 ppm; OSHA PEL (TWA) = 10 ppm (skin); NIOSH REL (STEL) = 4.7 ppm (skin); ACGIH TLV (ceiling) = 4.7 ppm (skin); Inhalation Provisional Advisory Level (PAL-1) for AC released for 24 hours = 0.025 ppm. Soil: Industrial Exposure Scenario = 610 mg/kg; Residential Exposure Scenario = 47 mg/kg. Drinking Water: 0.2 mg/L (maximum contaminant level as cyanide ion).

Personnel Safety

Note	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 applicable.
Medical	Pre-incident: Annual physical and respiratory function exams. 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.
First Aid	Immediately remove person from affected area into fresh air and remove contaminated clothing and articles. 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 AC with potable water for 15 minutes. Antidote: Amyl nitrite, I.V. sodium nitrite followed by sodium thiosulfate, and/or hydroxocobalamin for injection (e.g., Cyanokit®) can be administered by experienced medical staff. Provide cardiorespiratory supportive care, and administer 100% oxygen, for inhalation/oral exposures. Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly. For exposure to cyanide salts, see Cyanide Salts QRG.
PPE	GENERAL INFORMATION: NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), 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 an AC 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 AC 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 AC 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. If using APR for Level C, use a filter suitable for inorganic gases and vapors. Level C may be appropriate when decontaminating personnel or equipment. Note: AC gas is flammable and/or explosive at ambient temperatures in confined spaces. AC may have limited inhalation warning properties due to olfactory fatigue; use APR/PAPR with caution. 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.

Field Detection

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.

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of AC at levels as listed below.

Minimum Screening Ranges/Levels for Air	AP4C	Honeywell - SPM	Dräger - CDS Kit	Dräger XS/XXS (sensors)	MultiRAE	ToxiRAEII	M256/ M256A1
ppm	1.5	1	1	0.1–0.5	1	1	7
mg/m^3	1.7	1.1	1.1	0.11–0.55	1.1	1.1	8

Minimum Screening Levels for Water	CN^- Potentiometric	CN^- Colorimetric
	0.040 mg/L	0.02 mg/L

Sampling	*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)* 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 AC 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.
	Sample Locations and Planning: Initially consider air monitoring to ensure worker safety and to determine if there is an AC 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 AC is reactive and generally not persistent, sampling/monitoring for a variety of cyanide compound breakdown and reaction products along with AC to help to "clear areas" should be included in the sampling plan. Concurrent air monitoring for AC is recommended during all sampling activities.
	Note: AC is highly volatile and reactive, forming a variety of cyanide compound breakdown and reaction products. Laboratory analysis may need to include these additional products. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. Types of Samples: Air (AC in gaseous form is slightly lighter than air): On-site AC monitors may provide sufficiently accurate real-time results. For lab analysis, samples are collected using appropriate solid phase absorbent media (e.g., NIOSH 6010, 6017) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces. Water: AC escapes from aqueous solutions and/or decomposes quickly, but is relatively easy to analyze in the field by colorimetric, titrimetric or potentiometric methods. Water samples should either be analyzed as quickly as possible or immediately preserved for later analysis. Total, free, and other forms of cyanide in solution can be analyzed for the presence of AC contamination of water systems. Concurrent air monitoring is recommended. Soil: For localized hot spot areas where soil deposition may occur, surface soil samples may be analyzed for AC and cyanide compounds 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 may not be necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered. Surface Wipes: Although AC is very volatile, wipe samples are often desired to indicate the presence of AC and any cyanide compounds on non-porous surfaces. Bulk: Although AC is very volatile, for hot spot areas where liquid AC 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 AC and any cyanide compounds. Bulk samples of suspected sink materials may be recommended to rule out absorption of AC and cyanide compounds into these materials. Other Sample Matrices: Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.
	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.
Analysis	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). Cyanide testing methods include numerous forms, including: total, free, amenable, and other forms of cyanides, of which any or all may be appropriate for specific scenarios. Free cyanide ion (CN^-) 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 cyanide compounds other than free CN^- that may be present at a particular site, contact the EPA/HQ-EOC at 202-564-3850.
Decontamination/Cleanup	CAUTION: Use water spray only to reduce AC cloud or divert AC cloud drift. Avoid allowing water runoff to contact liquid AC. Use non-sparking tools. Confined liquid AC may violently polymerize in presence of heat, alkaline materials, or moisture. AC gas mixes well with air; flammable/explosive mixtures are easily formed. AC is so volatile that unless present in confined spaces or dissolved in confined liquids, it will dissipate quickly. Reaction of AC with environmental moisture can produce persistent, toxic cyanide compounds, which will need to be decontaminated. This decontamination section refers to AC itself, along with cyanide compounds found in aqueous solutions of AC. 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. 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). 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. Monitored Natural Attenuation: AC dissipates 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 but is non-destructive to materials. Fix-in-Place Option: AC dissipates rapidly via natural processes, as such a "Fix-in-Place Option" will not be required or feasible. Solid or liquid AC decomposition residues or wastes may require a separate decontamination evaluation process. Decontamination Strategy: A decon strategy can be developed by designating contaminated areas based on presence of: 1) liquid AC, 2) gaseous AC, or 3) aqueous solutions of AC. Strategy for Liquid AC: Do not allow direct contact with water. Actions that promote safe volatilization of liquid AC may be useful since AC in gaseous form is easier to decontaminate or can be allowed to dissipate; volatilization may be a slow process depending on site conditions. Strategy for Gaseous AC: Aerate spaces where gaseous AC may be present. Forced Air ventilation method is recommended for AC cloud contamination or low concentration of AC in large volumetric spaces or open areas. Hot Air ventilation is NOT recommended, based on explosive hazards of gaseous AC. Strategy for Aqueous Solutions of AC: AC is miscible with water and will quickly dissolve in water causing a reaction that creates heat. Due to the high volatility and solubility, AC, when present as dissolved gas, can volatilize from water, which can be enhanced by aeration or sparging, but will cause an inhalation danger. When AC is present in water as cyanides, aggressive chlorination at elevated pH should be sufficient to convert cyanide compounds to less toxic compounds. AC can react with metals present in water to form stable (e.g., iron cyanide or copper cyanide) complexes, which vary in toxicity depending on the metal. Recovered contaminated water can be treated by thermal, chemical, or wet-air oxidative processes. Alkaline chlorination and ozonation are effective in treating most metal-cyanide complexes. Sensitive Equipment and Items: For difficult-to-clean equipment thought to be contaminated with small amounts of AC, options for consideration include flushing with soap and water, although the residual aqueous solution may contain cyanide compounds or AC gas may be produced that may require decontamination strategies as described above. Verification of Decontamination: Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.
Waste Management	CAUTION: Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.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.
	Waste Management: Under the Resource Conservation and Recovery Act (RCRA), solid waste can be classified as hazardous (subtitle C) or non-hazardous (subtitle D). 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-specification species, container residue, or spill residue thereof (40 CFR §261.33). Hydrogen cyanide is listed under RCRA chemical code P063 for discarded commercial chemical products; soluble cyanide salts are listed as P030, and other specific cyanide salts are also listed (§261.33). Cyanide waste can also be reactive hazardous waste, chemical code D003, if it generates toxic gases when exposed to pH conditions between 2 and 12.5 (§261.23). Cyanide waste is approved for land disposal only if the concentration in the waste or treatment residual does not exceed 590 mg/kg for total cyanides or 30 mg/kg for amenable cyanides in non-wastewaters and 1.2 mg/L for total cyanides or 0.86 mg/L for amenable cyanides for wastewaters (§268.40). 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).