Agent Characteristics

Agent Classification: Toxic Industrial Chemical; CAS: 143-33-9 (sodium salt), 151-50-8 (potassium salt), 592-01-8 (calcium salt); Formula: NaCN (sodium salt), KCN (potassium salt), $Ca(CN)_2$ (calcium salt). Molecular Weight: 49.0 g/mol (sodium salt), 65.11 g/mol (potassium salt), 92.12 g/mol (calcium salt).

Description: This QRG is based on sodium, potassium, and calcium cyanide salts, which are widely commercially available as white powders, crystals, granules, flakes, lumps, or egg-shaped pellets. Many other cyanide salts and compounds exist, which generally may share similar properties, effects, and decontamination methods, although some salts can vary significantly. Application of this QRG to unidentified cyanide salts may represent a conservative approach until identification occurs. Cyanide compounds can interfere with the body's use of oxygen causing asphyxiation. They are most toxic when ingested, but also pose an inhalation hazard if they convert to toxic hydrogen cyanide gas (AC) following the addition of water or acid. The amount and rate of AC release is dependent on the acidity and moisture content, but **when salt is present, always consider that AC may be present. Refer to the AC QRG for additional information for dealing with AC appropriately.** Cyanide salts are not volatile and hence, odorless, but atmospheric moisture may cause salts to release AC. 60-70% of the population can detect a bitter, almond odor if AC is released; however, olfactory fatigue onsets rapidly, diminishing this limited safeguard. Solutions of cyanide salts, depending on concentration, are reported (e.g., by suicidal individuals) to have a bitter, burning taste; lower doses may be mostly tasteless. **Note: If AC is formed from cyanide salts, AC is flammable with a flash point of 0°F/-18°C (see AC QRG); explosive potential is severe in the presence of heat, flame or alkaline agents.**

Persistence: Isolated cyanide salts are stable and persistent. Cyanide salts will persist in water and on moist surfaces as cyanide ions. The cyanide ion (CN^-) may form cyanide compounds by reaction with other substances in the water or, depending on pH, may be converted to AC, which is considered "non-persistent" because it can readily volatize from surfaces and open water vessels. Persistence will depend upon amount and purity of the cyanide salt, method of release, environmental conditions, and the types of surfaces and materials impacted.

Physical properties are listed at/near STP unless otherwise indicated. Properties refer to cyanide salts, which have negligible vapor properties at ambient temperatures. NA = not available.

Salt	Boiling Point	Melting Point	Density	Aqueous Solubility	Non-aqueous Solubility
Sodium	2700°F/1500°C	1050°F/550°C	1.60 g/mL (70°F/20°C)	480 g/L (50°F/10°C)	Alcohols
Potassium	NA	1170°F/630°C	1.55 g/mL (70°F/20°C)	300 g/L ("cold water") 500 g/L (176°F/80°C)	Alcohols, glycerol, ammonia, formamides
Calcium	NA	decomposes (350°C)	1.85 g/mL (70°F/20°C)	decomposes to AC	Alcohols
Others	Usually NA	varies from ~300°F/150°C to decomposition	Varies; most 1.5 – 2.0 g/mL	Varies from insoluble to freely soluble	Varies

Release Scenarios

FOOD (INGESTION) OR WATER RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.

Introduction of solid cyanide salts into food supplies or water systems are viable release scenarios. The use of cyanide solid particulates or aqueous solutions released into the air as an aerosol are possible but are less probable release scenarios. In addition, cyanide salts can be easily transformed into hydrogen cyanide gas (AC) by acids, water, and humid air, which will yield an immediate inhalation hazard and air release scenario.

Open Areas: The use of solid cyanide salts in open areas is a possible but less probable release scenario.

Water/Water Systems: Cyanide salts released into natural water or water systems can dissolve in seconds to release cyanide ions (CN^-), which can subsequently be converted to cyanide compounds that may exert toxic effects if present in high concentration. In addition, at the pH of many natural and drinking waters, AC can be formed and may off-gas yielding an inhalation hazard. Some cyanide compounds formed by reaction with disinfectants or substances in the water systems may persist, so water systems, plumbing, surfaces and equipment that have contacted contaminated water must be evaluated for decontamination along with the bulk water.

Indoor Facility: The use of solid cyanide salts in indoor facilities is a possible but less probable release scenario.

Other Scenarios: Contamination of the food supply by solid cyanide salts or aqueous cyanide solutions are viable release scenarios that could result in ingestion, dermal and inhalation hazards.

Health Effects

Onset	Onset of symptoms is dose and route dependent. Effects occur rapidly following exposure to cyanide salts. Inhalation exposure to AC gas released from cyanide salts 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 values for hydrogen cyanide (AC) are used to obtain the conservative AEGL values for the cyanide salts. Hydrogen cyanide is used as a surrogate for data on the cyanide salts because the cyanide moiety is responsible for the acute toxicity of the cyanide salts. The AEGL values for the cyanide salts are the concentrations of those salts required to produce the equivalent AEGL concentration of hydrogen cyanide after complete hydrolysis.

Note: AEGLs and Exposure Guidelines are listed in this order -- NaCN (sodium salt), KCN (potassium salt), $Ca(CN)_2$ (calcium salt); NA = Not Available.

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	5.0, 6.6, 4.7	5.0, 6.6, 4.7	4.0, 5.3, 3.8	2.6, 3.5, 2.4	2.0, 2.7, 1.9
AEGL 2: Potentially irreversible effects or impaired ability to escape	34, 45, 32	20, 27, 19	14, 19, 13	7.0, 9.3, 6.6	5.0, 6.6, 4.7
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	54, 72, 51	42, 56, 39	30, 40, 28	17, 23, 16	13, 18, 12

Exposure Guidelines: IDLH (mg/m^3) = 25, 25, NA; OSHA PEL (mg/m^3) = 5, 5, NA; RfC (reference concentration for lifetime inhalation exposure) = NA; Inhalation Provisional Advisory Level (PAL-1) for AC released for 24 hours = 0.21 mg/m^3. Soil: Industrial Exposure Scenario (mg/kg) = 1000, 2000, 1000; Residential Exposure Scenario (mg/kg) = 78, 160, 78. Drinking Water (EPA MCL) = 0.2 mg/L (as CN^-).

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 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.
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 exposed skin and eyes exposed to cyanide salt particulates and liquid cyanide solutions 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 AC gas or vapors, see AC QRG.

Personnel Safety (continued)

CAUTION: Inhalation, ingestion, dermal and ocular exposure guidelines (IDLH, AEGLs, TLVs) have not been directly established for cyanide salts. Exposure guidelines (see EFFECT LEVELS section above) are primarily calculated using AC values. Inhalation hazards are primarily due to the evolution of AC, but the direct inhalation and dermal contact of cyanide salts aerosols and particulates is possible. Appropriate PPE and inhalation safeguards used for aerosols, dusts and particulates should be employed in addition to those used for vapors.

PPE

GENERAL INFORMATION (PPE levels based on AC gas inhalation risks): 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 solid particulates and 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. Caution: Cyanide salts can generate AC gas, which is flammable and/or explosive at ambient temperatures in confined spaces. AC may have limited inhalation warning properties due to olfactory fatigue; use of APR/PAPR in Level C must be done 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 contaminant identity, concentration and the risks of ingestion, inhalation and dermal exposures are known and must be accompanied by on-site monitoring (i.e., vapor and total aerosol and particulate 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 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 cyanide salt contaminant levels. Rather, they detect the presence of AC (air) or **CN^-** (water) at levels as listed below. Cyanide salt particulates/aerosols can be measured as total particulates in air.

Minimum Screening Levels for Air	AP4C	Honeywell SPM	Dräger CDS Kit (tubes)	Dräger XS/XXS (sensors)	MultiRAE	ToxiRAEII	M256/ M256A1		Screening Levels for Particulates or Aerosols in Air	DataRAM (range)		Minimum Screening Levels for Water	CN^- Potentiometric	CN^- Colorimetric
ppm	1.5	1	1	0.1–0.5	1	1	7			0.001-400 mg/m³			0.040 mg/L	0.02 mg/L
mg/m³	1.7	1.1	1.1	0.11–0.55	1.1	1.1	8							

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. Cyanide salts can easily form AC gas, which should be addressed in all sampling plans. Because AC is reactive and volatile, and **CN^-** is reactive and soluble, 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: Cyanide salts can easily form AC gas. 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 cyanide salts are reactive and can form CN^- and AC, which are reactive and generally not persistent, sampling/monitoring for CN^- and AC, along with total, free, amenable, and other forms of cyanides, to help to "clear areas" should be included in the sampling plan. Many field screening methods and real-time monitoring for CN^- in water and AC in air and may provide sufficiently accurate results for sample planning purposes. Concurrent air monitoring is recommended during all sampling activities.

Note: Cyanide salts are reactive, forming AC gas and a variety of cyanide compound breakdown and reaction products. Laboratory analysis may need to include these additional products (e.g., total, free, amenable, and other forms of cyanides). See ANALYSIS section below to ensure sampling procedures are compatible with all analytes.
Types of Samples:
Air: Cyanide salts can easily form AC gas under normal air moisture/humidity conditions. On-site AC gas monitors may provide sufficiently accurate real-time results. For lab analysis, samples are collected using appropriate media at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces. Cyanide compounds in the air as particulates and as AC can be determined using mixed media adsorbent and impingers (e.g., OSHA ID-120). AC in the air can sampled using appropriate adsorbent media (e.g., NIOSH 6010, 6017).
Water: Cyanide salts in aqueous solutions react and/or decompose quickly and can form CN^- in solution that is relatively easy to analyze in the field by using available field kits and meters. Water samples should either be analyzed as quickly as possible or immediately preserved for later analysis. Total, free, amenable, and other forms of cyanides can be analyzed for the presence of cyanide contamination in 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 total, free, amenable, and other forms of cyanides, and should be taken from a non-vegetated area to a depth of less than one inch. Some field screening methods may be sufficiently accurate. 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: Wipe samples are often desired to indicate the presence of cyanide salts. Dry filter paper wipes or smear tabs (Whatman) can be used to collect surface particles which are later extracted with deionized (DI) water. The level of CN^- in the extraction solution can be measured in the field to indicate the presence of cyanide salts. Alternatively, wipes can be sent to the lab for analysis of CN^-, as well as total, free, amenable, and other forms of cyanides.
Bulk: For hot spot areas where cyanide 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 total, free, amenable, and other forms of cyanides. 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 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: Avoid contact of salt with liquid or airborne acids as this creates highly toxic and flammable hydrogen cyanide (AC) gas. Avoid calcium cyanide from getting in contact with water or high humidity for same reason. Despite precautions, AC gas may be present during decontamination of cyanide salts. See AC QRG for decontamination of AC gas. 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: Not recommended: Solid cyanide salts do not evaporate appreciably over months to years, but may instead hydrolyze in presence of moisture to create highly toxic and flammable AC. 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. Decontamination Strategy: A decontamination strategy can be developed by designating contaminated areas based on presence of: 1) solid cyanide salts, or 2) aqueous solutions containing cyanide salts. Strategy for Solid Cyanide Salts: For decontamination of solid cyanide salts, solids may be transferred carefully into containers with care being taken that cyanide dust is not dispersed into the air. The residue after shoveling, or small spills, may be removed by dry vacuuming. All necessary precautions must be taken to prevent cyanide salts from coming into contact with liquid or airborne acids, water, or humid atmospheres; especially if it is unknown which salt is present. Strategy for Aqueous Solutions of Cyanide Salts: Warning: Highly toxic and flammable AC gas may be present near aqueous solutions. See AC QRG. Oxidation with excess chlorine at pH > 8.5 can convert cyanide ions to less toxic compounds, but insufficient reaction conditions may produce toxic cyanogen chloride gas. Sensitive Equipment and Items: For difficult-to-clean equipment thought to be contaminated with small amounts, additional options for consideration include flushing with soap and water, although the residual aqueous solution may contain cyanide ions or AC gas may be produced that may be decontaminated 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: (1) is a listed waste (40 CFR §261.31-261.33), or (2) exhibits specific characteristics (40 CFR §261.21-261.24). Numerous cyanide salts are listed under RCRA chemical codes for discarded commercial chemical products (40 CFR §261.33), including barium cyanide ($Ba(CN)_2$, code P013), calcium cyanide ($Ca(CN)_2$, code P021), copper cyanide (CuCN, code P029), nickel cyanide ($Ni(CN)_2$, code P074), potassium cyanide (KCN, code P098), potassium silver cyanide ($KAg(CN)_2$, code P099), silver cyanide (AgCN, code P104), sodium cyanide (NaCN, code P106), and zinc cyanide ($Zn(CN)_2$, code P121). Soluble cyanide salts not otherwise specified are listed under chemical code P030, and hydrogen cyanide is listed under RCRA chemical code P063. 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 (40 CFR §261.23(a)(5)). Listed or characteristic cyanide waste may be land disposed only if the waste meets applicable treatment standards (40 CFR part 268). For D003 waste in the reactive cyanides subcategory, the treatment standards are a) wastewaters: 0.86 mg/L for amenable cyanides, and b) nonwastewaters: 590 mg/kg for total cyanides and 30 mg/kg for amenable cyanides (40 CFR §268.40). For listed cyanide wastes, the treatment standards are a) wastewaters: 1.2 mg/L for total cyanides and 0.86 mg/L for amenable cyanides, and b) nonwastewaters: 590 mg/kg for total cyanides and 30 mg/kg for amenable cyanides (40 CFR §268.40). EPA Method 9010C or 9012B must be used to determine if the treatment standard for nonwastewaters has been met (40 CFR §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).