CYANIDE

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; Total Plant Costs; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Cyanide is a carbon-nitrogen radical, which may be found in a wide variety of organic and inorganic compounds. A common form, hydrogen cyanide is a colorless gas or liquid with a faint, bitter, almond-like odor. Cyanide may exist as an ion with a valence of -1, and when combined carries a positive or negative charge. Cyanide, in some forms, is a very powerful and fast acting toxin. When combined with metals and organic compounds forms simple and complex salts and compounds, the most commonly used forms being hydrogen cyanide, sodium cyanide, and potassium cyanide. Hydrogen cyanide is a very dangerous fire hazard when exposed to heat, flame, or oxidizers.

B. Source in Nature: Cyanides are produced by certain bacteria, fungi, and algae, and may be found in plants and some foods, such as lima beans and almonds. Cyanide occurs naturally in cassava roots, potato-like tubers grown in tropical countries. Cyanide can enter surface water through releases from metal finishing industries, iron and steel mills, runoff from disposal of cyanide wastes in landfills, pesticides, and the use of cyanide-containing road salts. Most cyanide in surface water will form hydrogen cyanide and evaporate. It is not found commonly in drinking water at any significant concentration.

C. SDWA Limits: MCL/MCLG for cyanide is 0.2 mg/L.

D. Health Effects of Contamination: All forms of cyanide can be toxic at high levels, but hydrogen cyanide is the deadliest form of the toxins. At short-term exposure levels above the MCL, cyanide causes rapid breathing, tremors, and other neurological effects. Long-term exposure at levels above the MCL, cyanide can cause weight loss, thyroid effects, nerve damage and death. Skin contact with liquids containing cyanide may produce irritation and sores.

2. REMOVAL TECHNIQUES

A. USEPA BAT: Ion exchange, reverse osmosis, or chlorine treatment

! IX for cyanide uses a charged anion resin to exchange acceptable ions from the resin for the undesirable cyanide in the water. Benefits: acid addition, degasification, and repressurization is not required; effective; well developed. Limitations: pretreatment lime softening may be required; restocking of regenerate supply; regular regeneration; concentrate disposal.

! RO for soluble cyanide uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or dissolved solids (soluble cyanide), to pass through the membrane. Benefits: produces high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.

! For community surface and groundwater (under the direct influence of surface water) systems, treatment technique is applied. In this case, the accepted TT is the use of chlorine (Cl_2). Inorganic materials, such as cyanide, are oxidized by Cl_2 and converted to more manageable insoluable forms. Cl_2 reacts with organic matter breaking it down to simpler substances. Benefits: proven; reliable. Limitations: product water has objectionable taste; can react to organic compounds to form THMs.

B. Alternative Methods of Treatment: Distillation (for home drinking water only) heats water until it turns to steam. The steam travels through a condenser coil where it is cooled and returned to liquid. The cyanide remains in the boiler section. Alternately, solid block or precoated absorption filters made with carbon or activated alumina certified to reduce cyanide are available.

C. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for March 2001. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

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3A. Ion Exchange:

Process - In solution, salts separate into positively-charged cations and negatively-charged anions. Deionization can reduce the amounts of these ions. Anion IX is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in water. The process relies on the fact that water solutions must be electrically neutral, therefore ions in the resin bed are exchanged with ions of similar charge in the water. As a result of the exchange process, no reduction in ions is obtained. In the case of cyanide reduction, operation begins with a fully recharged anion resin bed, having enough negatively charged ions to carry out the anion exchange. Usually a polymer resin bed is composed of millions of medium sand grain size, spherical beads. As water passes through the resin bed, the negatively charged ions are released into the water, being substituted or replaced with the cyanide anions in the water (ion exchange). When the resin becomes exhausted of negatively charged ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the cyanide ions with Cl^- ions. Many different types of anion resins can be used to reduce dissolved cyanide concentrations. The use of IX to reduce concentrations of cyanide will be dependant on the specific chemical characteristics of the raw water.

Cation IX, commonly termed water softening, can be used with low flows (up to 200 GPM) and when the ratio of hardness-to-cyanide is greater than 1.

Pretreatment - Guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of TSS which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance - The IX resin requires regular regeneration, the frequency of which depends on raw water characteristics and the cyanide concentration. Preparation of the NaCl solution is required. If utilized, filter replacement and backwashing will be required.

Waste Disposal - Approval from local authorities is usually required for the disposal of concentrate from the regeneration cycle (highly concentrated alkaline solution); occasional solid wastes (in the form of broken resin beads) which are backwashed during regeneration; and if utilized, spent filters and backwash waste water.

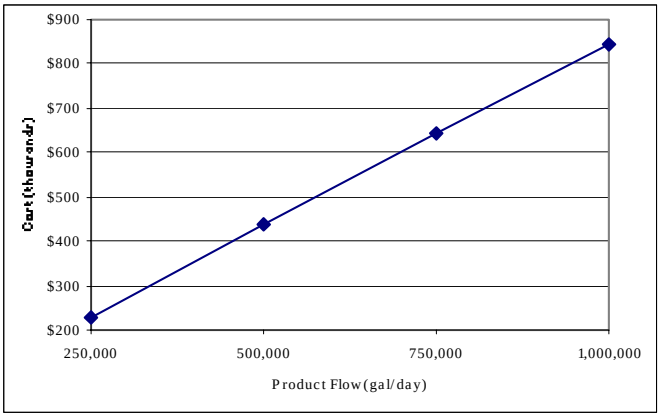
Advantages -

- Acid addition, degasification, and repressurization is not required.
- Ease of operation; highly reliable.
- Lower initial cost; resins will not wear out with regular regeneration.
- Effective; widely used.
- Suitable for small and large installations.
- Variety of specific resins are available for removing specific contaminants.

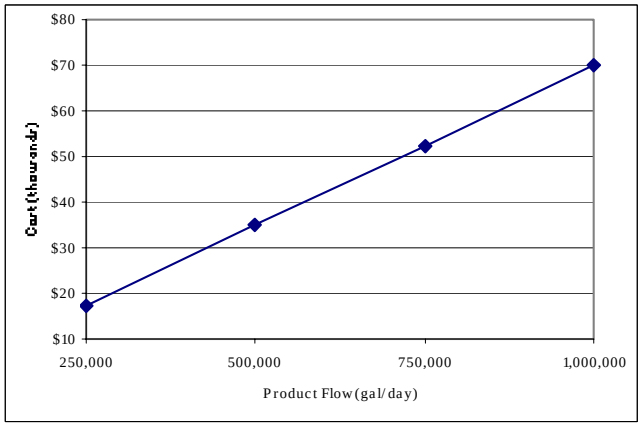
Disadvantages -

- Pretreatment lime softening may be required.
- Requires salt storage; regular regeneration.
- Strongly basic anion resins are susceptible to organic fouling; reduced life; thermodynamically unstable.
- Concentrate disposal.
- Usually not feasible with high levels of TDS.
- Resins are sensitive to the presence of competing ions.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3B. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. All materials and construction methods require regular maintenance. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

Maintenance - Monitor rejection percentage to ensure cyanide removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

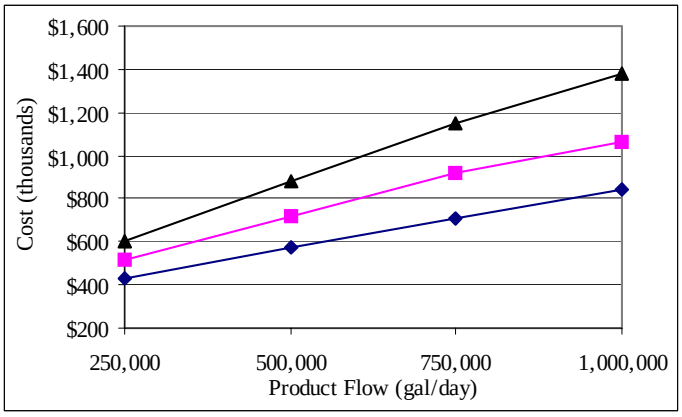
Advantages -

- Produces highest water quality.
- Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
- Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

Disadvantages -

- Relatively expensive to install and operate.
- Frequent membrane monitoring and maintenance; monitoring of rejection percentage for cyanide removal.
- Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Equipment Cost*



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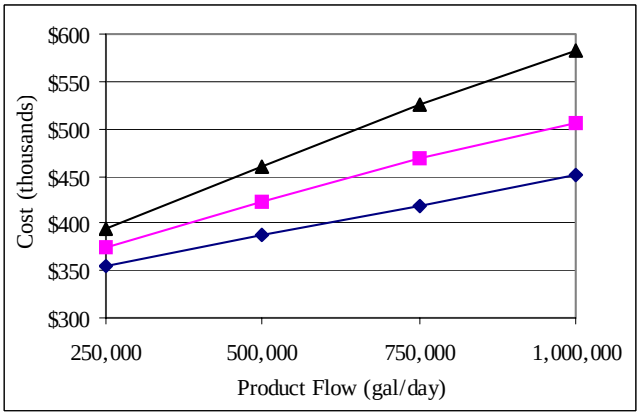

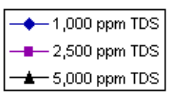

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3C. Chlorine Treatment:

Process - Depending on raw water quality and characteristics, Cl_2 can effectively treat cyanide. In chlorination treatment, Cl_2 is typically injected into the flow stream and reacts with any inorganic materials such as hydrogen sulfide, iron, or manganese, that may exist in the water. Any residual chlorine remaining, that is not reacted, will react with any organic matter present. The feed rate of Cl_2 is adjusted so that enough Cl_2 is available to react fully with the organics present in the water. Upon completion of mineral and organic reactions, any residual Cl_2 remains in the drinking water. Chlorination can be accomplished by using either liquid, tablet, or gaseous Cl_2.

Maintenance - Proper monitoring, operation, and maintenance procedures are essential to ensure the reliability of the treatment processes. Periodic cleaning of metering pump, tubing, injector, and mix tank is recommended.

Waste Disposal - None

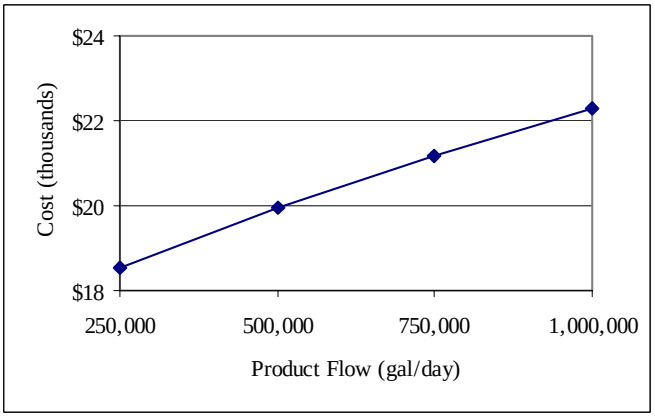
Advantages -

- Well established, conventional treatment process; readily available.
- Reliable, if properly operated and maintained; provides residual disinfectant.
- Suitable for community or on-site systems.

Disadvantages -

- Requires proper Cl_2 contact times; can give a chlorine after-taste and smell.
- Requires careful handling and proper storage of chlorine.
- Cl_2 may combine with organic precursors, natural organic material, to form THMs.

BAT Equipment Cost*



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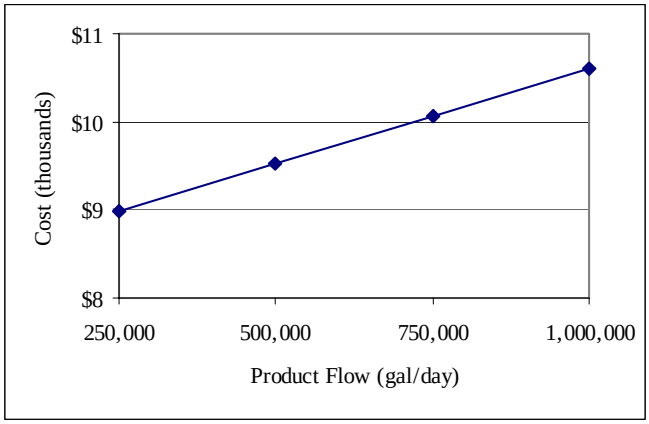

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