LEAD

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: Lead (Pb), atomic number: 82, atomic weight: 207.2, most stable oxidation state is +2, is a soft, malleable heavy metal resistant to physical deterioration

B. Source in Nature: Pb is generally not present in source water, but is usually introduced into the water by corrosive water leaching Pb from household plumbing (lead pipe, lead solder, or galvanized pipes). Corrosive (acidic or low pH) and higher temperature waters can dissolve Pb materials within the distribution, plumbing, and wastewater conveyance systems. Pb in the environment is a result of chemical and physical weathering of igneous and metamorphic rocks and soils. Domestic wastewater and industrial effluents can contribute to Pb concentrations in surface (more common) and groundwater.

C. SDWA Limits: TT action level for Pb is 0.015 mg/L.

D. Health Effects of Contamination: Pb has no beneficial effect on humans. Chronic exposure over long periods to even low concentrations of Pb can have severe health effects, especially on infants, children, and pregnant women. Pb is accumulated and stored in the bone. When Pb exposure is so high that the bone become saturated, Pb displaces calcium in the blood effecting the central nervous system. Excessive levels on Pb in the blood contribute to reduced metal and skeletal development, interference with kidney and neurological functions, and hearing loss, especially in children under the age of 6.

2. REMOVAL TECHNIQUES

A. USEPA BAT: Ion exchange, reverse osmosis, lime softening, or coagulation and filtration.

! IX for soluble Pb uses charged cation resin to exchange acceptable ions from the resin for undesirable forms of Pb in the water. Benefits: effective; well developed. Limitations: restocking of salt supply; regular regeneration; concentrate disposal.

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

! Lime softening for soluble Pb uses $Ca(OH)_2$ in sufficient quantity to raise the pH to about 10, keeping the levels of alkalinity relatively low, to precipitate carbonate hardness and heavy metals, like Pb. Benefits: lower capital costs; proven and reliable. Limitations: operator care required with chemical usage; sludge disposal; insoluble Pb compounds may be formed at low carbonate levels requiring coagulation and flocculation.

! Coagulation and filtration for insoluble Pb uses the conventional treatments processes of chemical addition, coagulation, and dual media filtration. Benefits: low capital costs for proven, reliable process. Limitations: operator care required with chemical usage; sludge disposal.

B. Alternative Methods of Treatment: Distillation heats water until it turns to steam. The steam travels through a condenser coil where it is cooled and returned to liquid. The Pb remains in the boiler section.

Allow tap water to run 3-5 minutes before drawing water for drinking or cooking. Do not use hot tap water for drinking or cooking. Boiling water concentrates Pb. Use bottled water.

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.

Bureau of Reclamation, Technical Service Center
Water Treatment Engineering and Research Group, D-8230
PO Box 25007, Denver CO 80225 (303) 445-2260

Revision Date: 9/21/01

3A. Ion Exchange:

Process - In solution, salts separate into positively-charged cations and negatively-charged anions. Deionization can reduce the amounts of these ions. Cation 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 Pb, operation begins with a fully recharged resin bed, having enough positively charged ions to carry out the cation 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 positively charged ions are released into the water, being substituted or replaced with the soluble Pb in the water (ion exchange). When the resin becomes exhausted of positively charged ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the Pb^{+2} ions with $2Na^{+}$ ions. Typically, Pb ion exchange utilizes a strong acid cation resin bed.

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.

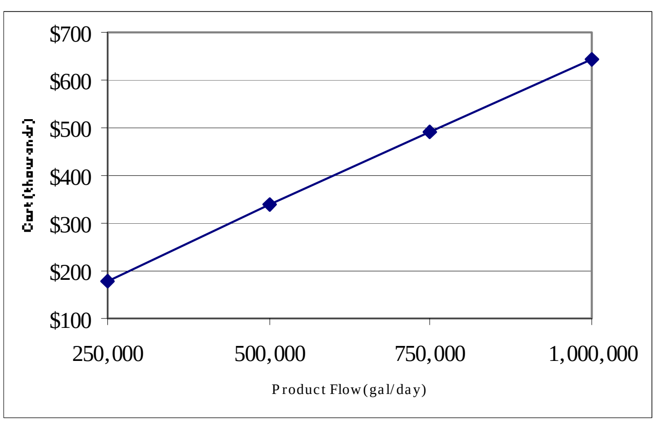
Maintenance - The IX resin requires regular regeneration, the frequency of which depends on raw water characteristics and the Pb concentration. Preparation of the NaCl solution is required. If utilized, filter replacement and backwashing will be required.

Waste Disposal - Approval from local authorities is usually required for the disposal of concentrate from the regeneration cycle (highly concentrated Pb 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.

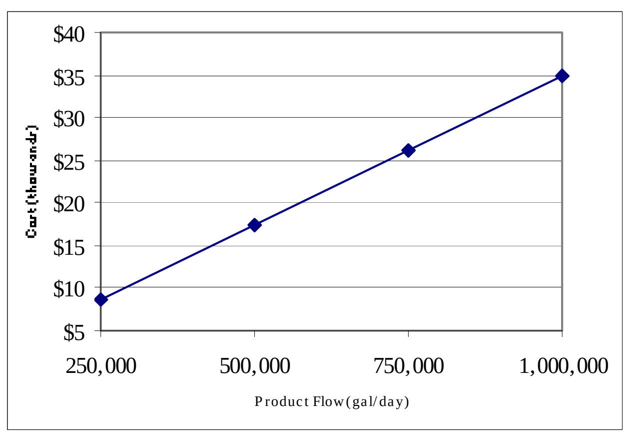
Advantages -
- Ease of operation; highly reliable.
- Lower initial cost; resins will not wear out with regular regeneration.
- Effective; widely used.
- Suitable for small and large installations.
- Variety of specific resins are available for removing specific contaminants.

Disadvantages -
- Requires salt storage.
- 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.

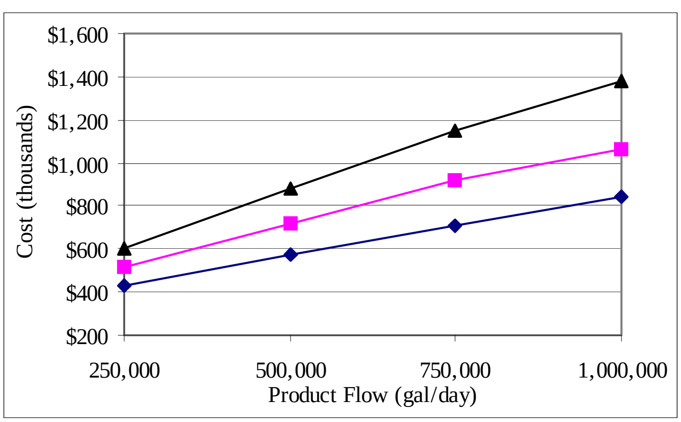
Maintenance - Monitor rejection percentage to ensure Pb removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly 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.

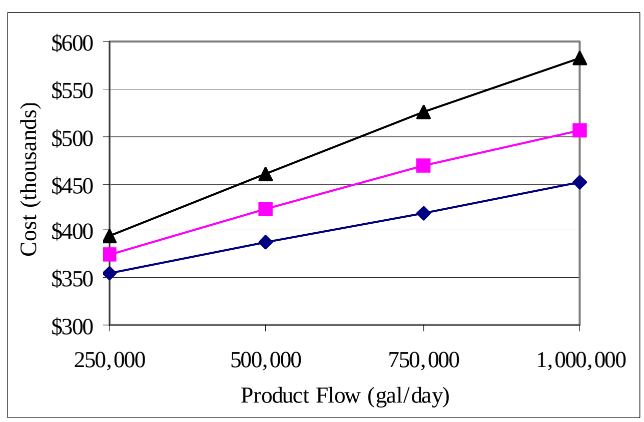
Advantages -
- ! Produces highest water quality.
- ! Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
- ! Low pressure (<100 psi), compact,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

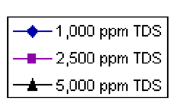
Disadvantages -
- ! Relatively expensive to install and operate.
- ! Frequent membrane monitoring and maintenance; monitoring of rejection percentage for Pb removal.
- ! Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

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.

3C. Lime Softening:

Process - Lime softening uses a chemical addition followed by an upflow SCC to accomplish coagulation, flocculation, and clarification. Chemical addition includes adding $Ca(OH)_2$ in sufficient quantity to raise the pH while keeping the levels of alkalinity relatively low, to precipitate carbonate hardness. Heavy metals, like Pb, precipitate as $Pb(OH)_2$. In the upflow SCC, coagulation and flocculation (agglomeration of the suspended material, including Pb, into larger particles), and final clarification occur. In the upflow SCC, the clarified water flows up and over the weirs, while the settled particles are removed by pumping or other collection mechanisms (i.e. filtration).

Pretreatment - Jar tests to determine optimum pH and alkalinity for coagulation, and resulting pH and alkalinity adjustment, may be required. Optimum pH is about 10.

Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Similar procedures also apply to the sludge disposal return system, which takes the settled sludge from the bottom of the clarifier and conveys it to the dewatering and disposal processes.

Waste Disposal - There are three disposal options for Pb sludges: incineration, landfill, and ocean disposal. Isolation and recovery of the Pb and other economically important materials is also a viable option, however, costs of the isolation and recovery must be compared to the value of the recovered materials.

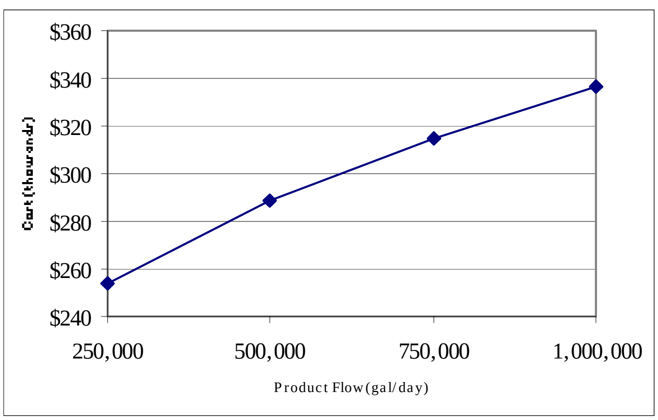
Advantages -

! Other heavy metals are also precipitated; reduces corrosion of pipes.
! Proven and reliable.
! Low pretreatment requirements.

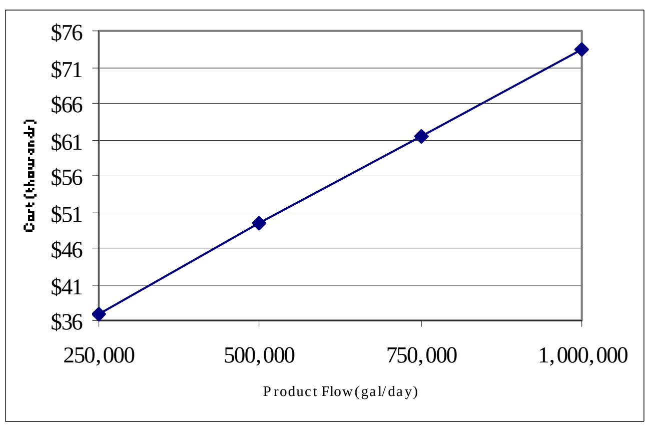
Disadvantages -

! Excessive insoluble Pb may be formed requiring coagulation and filtration.
! Operator care required with chemical handling.
! Produces high sludge volume.

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.

3D. **Coagulation and Filtration:**

Process - Coagulation and filtration for insoluble Pb uses the conventional chemical and physical treatment processes of chemical addition, rapid mix, coagulation with dry alum, flocculation, and dual media filtration. Chemical coagulation and flocculation consists of adding a chemical coagulant combined with mechanical flocculation to allow fine suspended and some dissolved solids to clump together (floc). $Al_2(SO_4)_3$ has been proven to be the most effective coagulant for insoluble Pb removal. Filtration consists of final removal by dual media filtering of all floc and suspended solids.

Pretreatment - Jar tests to determine optimum pH for coagulation, and resulting pH adjustment, may be required.

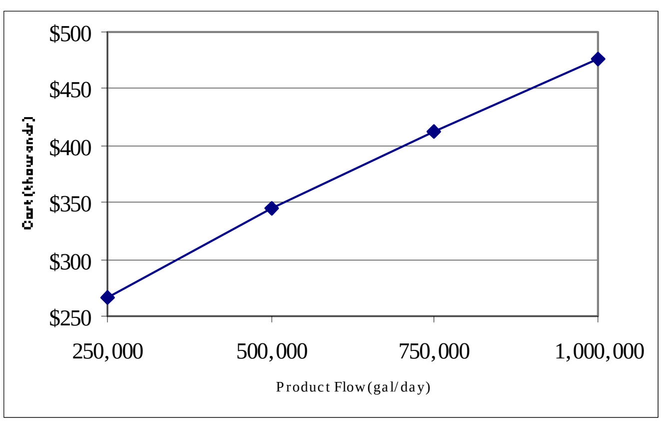
Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Routine checks of contaminant buildup in the filter is required, as well as filter backwash. Recharging or clean installation of media is periodically required.

Waste Disposal - Filter backwash and spent material require approved disposal.

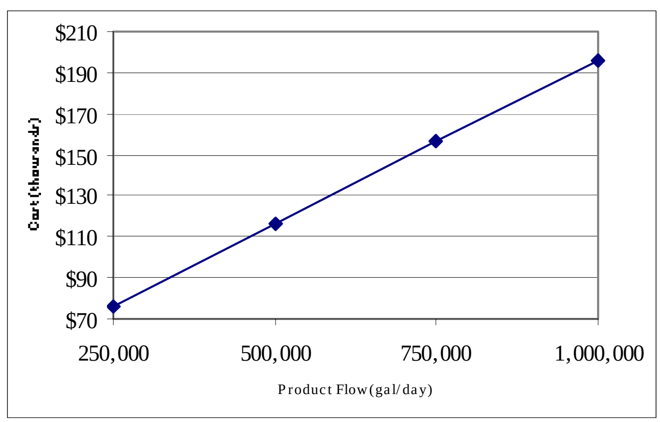
Advantages -
! Lowest capital costs.
! Lowest overall operating costs.
! Proven and reliable.
! Low pretreatment requirements.

Disadvantages -
! Operator care required with chemical handling.
! Suitable only for insoluble Pb.
! Produces high sludge volume.
! Waters high in sulfate may cause significant interference with removal efficiencies.

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. Costs are presented for direct filtration (coagulation and flocculation plus filtration). Costs for coagulation and filtration would be less since flocculation is omitted.