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# Illinois State Water Survey

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Subject: Technical Letter 20  
Removal of Water Supply Contaminants -- Chromium

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This is the sixth in a series of Technical Letters dealing with state of the art methods for removal of contaminants from water supplies so that the supply will be in compliance with state and federal drinking water standards.

## Contaminant

This Technical Letter is concerned with chromium (Cr) as a contaminant of drinking water. In 1976 there were no water supplies in use in the state of Illinois which exceeded the drinking water standard of 0.05 milligram per liter (mg/l).

## Prevalence and Uses

Chromium is found in groundwater supplies as a result of leaching of underlying geological deposits or from contamination by industrial usage.

Chromium is found widely throughout the earth's crust in very small amounts. Some localized high level deposits also exist in nature. Because of its industrial importance, chromium ores have been mined with a resultant redistribution in the environment due to man's activities.

Chromium is used in the electroplating industry to form protective or decorative coatings, as a corrosion inhibitor in cooling waters, in the tanning industry, as a pigment in paints and dyes, as a catalyst in the production of plastics and petrochemicals, and as an important constituent of steel alloys.

## Health Effects

Chromium is considered by some to be a necessary trace element required for good health. Chromium can exist in two oxidation states which differ in their toxicity. Chromium VI is far more toxic than chromium III. Chromium VI is considered to be a carcinogen when inhaled into the lungs; however, no data are available on its effects by ingestion. The concern about chromium VI as a carcinogen is based on health records from workers in the production of lead chromate and zinc chromate salts.

At the present time there are no data on the effects of long-term exposure to low levels of chromium either as chromium III or chromium VI.

#### Maximum Levels

The maximum level of chromium for drinking water is 0.05 mg/l.

#### Removal

Since chromium can exist as both a cation (chromium III) or an anion (chromium VI), different methods of removal might be necessary depending on the form, or else pretreatment will be required to convert all the chromium to chromium III. Chemicals used for dechlorination such as sulfur dioxide ( $\text{SO}_2$ ) or bisulfite ( $\text{HSO}_3$ ) are effective in reducing any chromium VI to chromium III. Available methods are described in the following sections.

#### *A. Ion Exchange*

Ion exchange techniques used for water softening are applicable to the removal of chromium III from water. The chromium is exchanged for sodium ions from the ion exchange media. The resin is regenerated and the chromium removed by treatment with brine. The efficiency of this process for chromium removal is influenced by the hardness of the water and the total dissolved solids. Generally, removal efficiencies of 90 percent or more are reported for chromium up to concentrations of about 1 mg/l according to the Federal Environmental Protection Agency. Careful control of regeneration is necessary so that breakthrough of the chromium does not occur. This process will not remove chromium VI unless it is first reduced to chromium III.

Chromium VI can be removed using an anion exchange resin. The chromium will be exchanged for the chloride from the resin. The resin can be regenerated with brine or hydrochloric acid. Because any sulfate and carbonate in the water will also be removed, control of the resin regeneration is necessary to prevent breakthrough of the chromium VI. The process will not remove any chromium III from the water. Normal chemicals or processes used in a water treatment plant cannot effectively oxidize chromium III to chromium VI.

Both forms of chromium can be removed by complete demineralization using a dual-bed ion exchange system. The chromium III is replaced with hydrogen ion from a cation exchanger in the hydrogen form and the chromium VI is replaced with hydroxide ion from an anion exchanger in the hydroxide form. The hydrogen and hydroxide ions combine to form water. This will completely demineralize the water by removing all cations and anions. It will be necessary to add alkalinity and hardness

to the finished water to protect the distribution system. It might be possible to blend treated water with untreated water. This will decrease the cost of treatment by reducing the amount of water which needs to be treated. The amount of untreated water which can be blended will be determined by the amount of chromium in the raw water. The chromium level in the final water must not exceed 0.05 mg/l.

### *B. Lime Soda Softening*

Lime soda softening is used to remove calcium and magnesium by precipitation of calcium carbonate and magnesium hydroxide after addition of lime and sodium carbonate. This process should be efficient for removal of chromium III from solution by precipitation as chromium hydroxide. Exact data are not available on efficiency, but based on the solubility of the hydrated oxide, efficiencies of 90 percent or more are expected. Chromium VI will not be removed to any great extent under the conditions existing in lime soda softening. Reduction of chromium VI to chromium III is necessary for removal of chromium. Since complete hardness removal does not occur, it is not necessary to adjust the finished water hardness for protection of the distribution system. Blending of the treated and untreated water can be used to reduce treatment costs. The blended water should have a chromium level of less than 0.05 mg/l.

### *C. Reverse Osmosis*

Reverse osmosis involves the removal of soluble minerals by passage of water through a semipermeable membrane. To get water to pass through the membrane it is necessary to apply pressure to the water containing the minerals to overcome the natural direction of flow which would be for pure water to diffuse into the mineral-containing water. The amount of pressure necessary depends on the mineral content of the raw water.

Although reverse osmosis can be used to reduce the chromium level, its application is impractical and costly unless it is already in use for the treatment of brackish water. The most significant cost is plant construction. For a 1000 m<sup>3</sup>/day plant (183 gpm), construction costs will be about \$250,000 based on 1976 costs. This cost does not include costs for any interest during construction, site and site improvement, discharge facilities, storage and delivery facilities, or special treatment. Operating costs are about \$18,000 for a plant of that capacity.

### *D. Electrodialysis*

Electrodialysis involves the removal of salts by means of ion selective membranes and a d.c. current to assist transport of the

ions across the membrane. There is depletion of ions on one side of the membrane if current is passed for any length of time, while there is concentration on the other side of the membrane. Any level of desalting can be achieved by increasing the residence time or increasing the current density.

For efficient operation good water pretreatment is required. This should include coagulation of colloidal particles, oxidation of iron and soluble organics, carbon filtration, and finally acidification.

Although this process can be used for the reduction of chromium levels, its application is impractical and costly even if other contaminants are to be removed unless the equipment is already in use or planned for use to reduce brackish water to an acceptable salt level. The cost for electrodialysis is dependent on the level of contaminant to be reduced. In general it will be more costly than reverse osmosis. The pH of the effluent may require adjustment to protect the distribution system.

#### *E. Distillation*

Distillation involves the volatilization of water to separate it from all dissolved or suspended materials which are not volatilized. Normally the water is heated under pressure to improve the thermal efficiency of the method by recovering some of the heat. This process produces water of very low dissolved solids. Since the water is corrosive to the distribution system, it is necessary to increase the hardness. This can normally be accomplished by appropriate blending of the finished water and the raw water.

Some pretreatment of the feedwater may be necessary to remove suspended solids and calcium and magnesium to prevent scaling.

Distillation is a relatively expensive and impractical solution for the removal of specific contaminants from water. The process involves the removal of a large volume of water from a small amount of dissolved material. This results in an unfavorable energy requirement since it is essentially independent of the contaminant level and only dependent on the amount of water to be treated. The major cost is plant construction which will be about \$1.2 million for a 1000 m<sup>3</sup>/day plant (183 gpm). The operating costs for energy are also high, since there is only partial heat recovery in this process.

#### General Comments

All of the removal techniques discussed above require pilot-scale testing for a specific application to determine their efficiency. Pilot-scale

studies are also needed to determine what, if any, pretreatment is necessary to insure good operating efficiency. All of the processes which effectively demineralize the water require some adjustment of pH and/or hardness and alkalinity to prevent corrosion of the distribution system.

Technical Letters are issued as part of the Water Survey's continuing service to citizens of Illinois. Should you need further clarification, please let us know.

Very truly yours,

A handwritten signature in cursive script that reads "Francis Amore". The signature is written in dark ink and is positioned below the typed name.

Dr. Francis Amore  
Associate Professional Scientist

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