

Case Study

Bennington, Vermont Revisits Its Sodium Bicarbonate Water Treatment Method



Overview

In the late 1970s when Bennington, Vermont first began to investigate how to treat its lead contaminated drinking water, a common method of corrosion control used in several European cities was the adjustment of pH in combination with the addition of sodium bicarbonate to reduce metal contaminants. This CEM Message discusses Bennington's 1977 test of this process, the town's ten year experience with sodium bicarbonate/hydroxide treatment of its drinking water, and the potential of this treatment method to meet new Federal safe drinking water requirements.

Background

EPA guidelines governing drinking water quality have been published as "interim standards" for many years, however, it was not until the last decade that mandatory compliance became tied to numerical values. The Safe Drinking Water Act (SDWA) approved by Congress in 1974 and amended in 1986, called for the EPA to establish maximum contaminant levels (MCLs) for 88 specific chemicals and establish a timetable for action on toxic contaminants.

Final SDWA standards, expected early next year, will bring to 61 the number of contaminants affected. It will be no surprise to municipal water suppliers when the proposed ten-fold MCL reduction of lead - from .05 to .005 mg/L at the plant - becomes law. While there are some "non-action" contingencies in EPA's proposal, the new regulations are bound to trouble distributors in regions of the U.S. where excessive lead levels at the tap are largely a result of geological conditions at the source.

One of the affected regions is in New England, where acid rain and the lack of carbonate as natural limestone produce very soft water with low pH and alkalinity - a condition which favors corrosion of the distribution lines and consequent leaching

of lead into drinking water. A 1977 study of 16 New England water distribution systems reported twelve of them exceeding the current lead standard of .05 mg/L, and the EPA itself found excess lead in over 90 percent of the samples collected in Vermont.

That same year, an OSHA team checking blood-levels of workers at a Bennington battery factory became alarmed when not only the workers, a control group made up of other townspeople in this Vermont community, exhibited high lead content. The problem was traced to the town's corrosive water supply, and to the fact that one-third of the dwellings in Bennington had lead service lines connecting the water main to the houses. Lead levels as high as .86 mg/L were measured at the tap - over 17 times the .05 mg/L maximum contaminant levels.

The Vermont Department of Health and EPA's Region I office in Boston were alerted and immediately organized a survey of the Bennington area to evaluate possible quantitative effects of any future treatment scheme.

Beginning in April of 1977, three morning samples were collected at each of ten residential locations on a monthly basis. All the homes on the survey had lead service lines; most had interior copper plumbing.

While the pretreatment survey was in process, Bennington's Water Department heard a variety of proposals for solving the problem. The one that appeared most feasible, from the viewpoint of economy and implementation, was developed by Dr. James W. Patterson, Professor of Environmental Engineering at Illinois Institute of Technology.

Patterson's technology was currently undergoing tests by two separate study groups working independently at the Institute and at the Lawrence Experiment Station in Massachusetts, both reporting favorable results.

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These groups were investigating the European corrosion control method of adjustment of pH in combination with the addition of sodium bicarbonate to reduce metal contaminants, a technique which although common in Europe, had never been applied specifically to limiting lead levels.

City officials agreed to test the bicarbonate method for raising the alkalinity to 20 mg/L. But, owing to the extremely acidic condition of the untreated surface water (pH 4.9), it was necessary to also add small amounts of caustic to achieve a final pH of 8.0- to 8.6. Treatment was begun in June of 1977, allowing two months of pretreatment data to be evaluated.

When rainwater that has been acidified by dissolved CO₂ percolates through limestone subsoil it picks up calcium salts, primarily in the form of carbonate. Water "hardness" relates to the concentration of the dissolved calcium ions and is commonly reported in terms of their calcium carbonate equivalent. (It is not alkalinity per se but, rather, calcium carbonate in solution that determines hardness. With proper pH adjustment CaCO₃ will form a protective barrier against corrosion in water mains and pipes; however, this coating is extremely difficult to control.)

Corrosive waters, on the other hand, tend to be acidic and relatively free of mineral content. They are generally associated with low carbonate alkalinity levels, low pH, low dissolved solids, and (sometimes) high dissolved oxygen.

In natural waters, the carbonate system - comprised of carbon dioxide (CO₂), carbonic acid (H₂CO₃), bicarbonate (HCO₃⁻) and carbonate (CO₃⁻⁻) ions - regulates pH, as, incidentally, are many of the processes used to treat public water supplies, including coagulation and chlorination. By maintaining pH and carbonate alkalinity at the proper levels, plant equipment and piping in the distribution systems can be provided with protective metal oxide or hydroxy-carbonate lining which prevents corrosion and the release of metal ions such as copper, lead, zinc and cadmium. The greatest reduction of lead corrosion occurs when carbonate levels are adjusted

along with the pH. Optimum pH appears to be between 8.0 and 8.6 with a minimum alkalinity level of about 25 mg/L (as CaCO₃). Hence the decision to add both caustic (NaOH) and bicarbonate (NaHCO₃) to Bennington's water.

The primary consideration in this strategy was based on the low theoretical solubility of metal carbonate salts - particularly lead hydroxy-carbonate. At the proper water pH and carbonate alkalinity levels, this salt will deposit itself uniformly on the pipe surface, providing a thin impervious anti-corrosive coating. The coating once formed is very tenacious and its protective character will prevail through minor system upsets. However, if either pH or carbonate alkalinity level should go outside the control limits for a significant period of time, then the piping system will revert to its former corrosive condition.

From a public health viewpoint, pH adjustment in the absence of sufficient carbonate alkalinity may be worse than no treatment at all. Under these conditions it is possible for large slugs of toxic lead hydroxides to slough off periodically from the piping and be ingested by the consumer. Because this unloading effect tends to be intermittent, it may escape detection by monitoring surveys.

The salutary aspects of moderate carbonate alkalinity have been recognized for many years. Carbonates were claimed to inhibit iron corrosion as early as 1926, and similar protection has since been reported for cadmium, lead and zinc. With respect to removing lead contaminants from water in contact with lead pipe or fixtures, the use of bicarbonate provides three key requisites: a source of carbonate alkalinity, a protective lining on the water vessels, and stabilization of pH ion the distribution system.