Controlling Nitrification in a Water Distribution System Using Sodium Chlorite

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Background

A study aimed at distinguishing between the comparative activity of the nitrifying organisms, *Nitrosomonas europea* and *Nitrobacter winogradskyi* (Hynes and Knowles, 1983), indicated that chlorite ion interfered with the activity of *N. europea* which mediates the oxidation of ammonium ion to nitrite ion. While seemingly only of academic interest, this research formed the scientific rationale for the application of chlorite ion to suppress nitrification in water distribution systems.

Subsequently, the results of water system studies have suggested that chlorite formed as a byproduct of the application of chlorine dioxide may serve to inhibit nitrification during distribution (McGuire et al., 1999). Calling for field verification, the authors suggested the direct addition of sodium chlorite might be an effective alternative nitrification control process.

Control of Nitrification

Since 1996, Willmar (MN) Municipal Utilities has employed breakpoint ammonium reduction treatment (BART) to control nitrification in their water distribution system (Murphy et al, 1998). Although effective, BART requires the use of large amounts of chlorine for the oxidation of ammonium ion, which is naturally present in the groundwater. source

This study was undertaken to assess an alternative procedure for control of nitrification: the addition of sodium chlorite, a chemical used both in water treatment and the food processing industry.

Initial trials involved the addition of low concentrations of sodium chlorite to the finished water of Willmar's Southwest water treatment plant. Prior to and following addition, extensive monitoring was conducted throughout the distribution system.

Results

Three weeks after the initiation of chlorite feed, a significant beneficial response was observed. Nitrification in the distribution system markedly decreased. Both oxygen and chloramine residuals increased at distribution sampling sites where they were formerly depleted. The implication of these results is that the activity of nitrifying bacteria in the distribution system was curtailed by the initial addition of sodium chlorite.

This procedure was replicated at each of Willmar's two water treatment plants serving the Southwest and Northeast portions of the distribution system. Comparable results were obtained at each plant and in each portion of the system.

In September 2000, distribution system monitoring results indicated an increase in nitrification. This was attributed to the increased amount of ammonium ion available in conjunction with relatively high water temperatures and seasonally-decreased demand. The chlorite feed was increased, and the importance of continuously modifying the feed based on monitoring was reinforced.

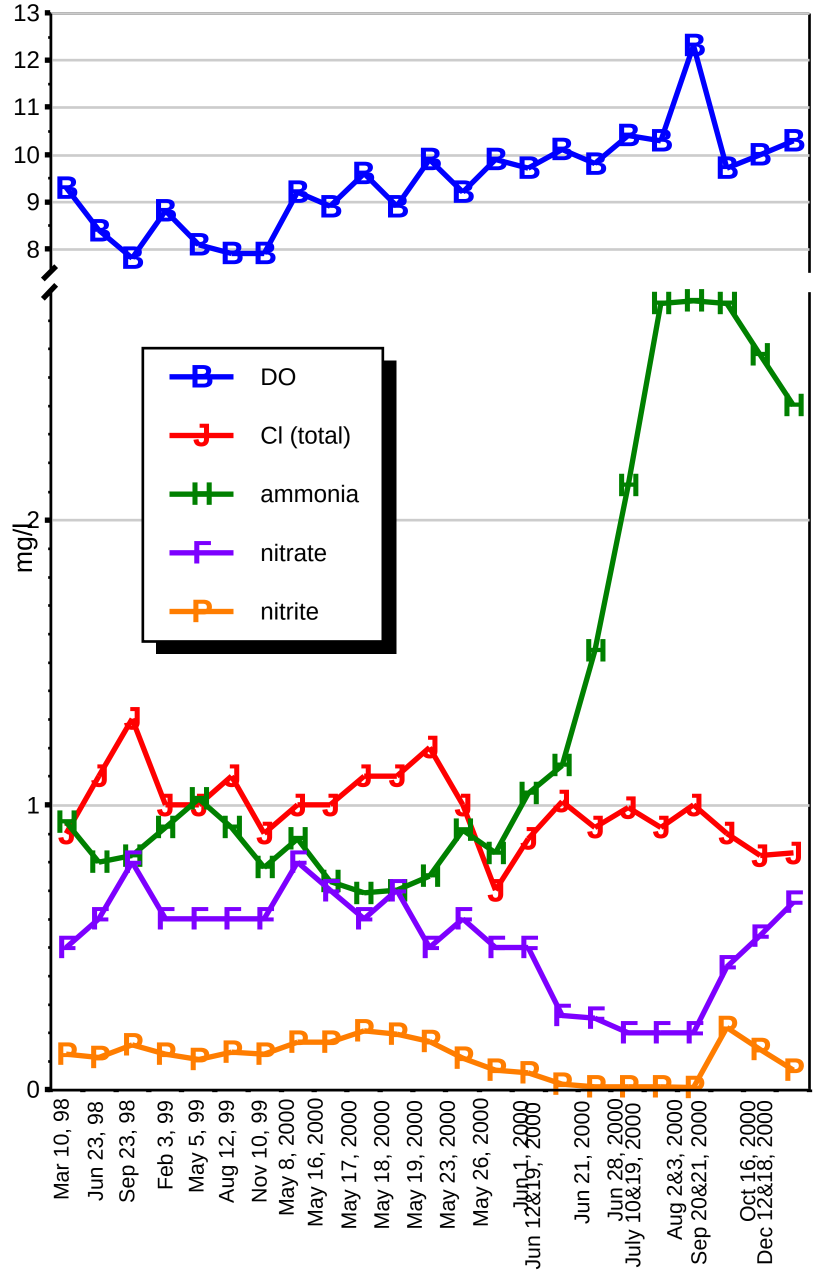
Dissolved Oxygen

Dissolved oxygen is one of the most sensitive and readily-monitored indicators of nitrification in the distribution system. At Willmar, highly-efficient tower aeration routinely results in saturation of dissolved oxygen while also increasing pH to over 8.0 by stripping carbon dioxide. At distribution sampling locations where nitrification was evident, dissolved oxygen concentrations declined to 6 mg O/l. Within weeks of the start of chlorite addition, DO concentrations exhibited a steady increase, converging on the saturation values observed in the treatment plant finished water.

Chloramine Residuals

Disinfectant residuals may also serve as a sensitive index of the progress of nitrification. However, at Willmar, applied chloramine residuals are regularly modified based on distribution system data so that chloramine levels can be maintained throughout the distribution system using the minimum chlorine addition possible. Willmar's treatment goal is to attain conditions in the distribution system which will allow chloramine residuals to remain relatively constant throughout the entire system. Under these circumstances, lower chlorine applications will be possible, and the chloramine monitoring data will converge.

An increase in chloramine persistence occurred following the addition of chlorite ion, allowing the chlorine feed at the Southwest plant to be reduced. Alternately, chloramine levels increased at the sampling sites which previously exhibited the strongest evidence of nitrification.



Ammonium Ion

The addition of sodium chlorite was expected to inhibit the first stage of nitrification. If inhibition was effective, levels of ammonium ion in the distribution system would increase to match the levels in the plant effluent. This effect was evident after three weeks, when distribution system samples matched up with finished water at approximately 1 mg N/l. Further increases in ammonium ion concentrations were expected when BART was discontinued at both plants.

Reduction of Nitrite and Nitrate Formation

Inhibition of nitrification would be expected to be accompanied by further reductions in the already low concentrations of nitrite and nitrate. Such reductions are evident in the distribution system where nitrite ion declined to an average of less than 0.1 mg N/l, and average nitrate ion concentrations bottomed out at 0.2 mg N/l.

Discontinuing BART

The second phase of the study was undertaken to observe the effect of discontinuing the BART procedure. This immediately resulted in a doubling of the ammonium ion concentration in the water entering the distribution system.

The BART process was discontinued first at the Southwest plant and, after several weeks, at the Northeast plant. The accelerated monitoring program was continued as ammonium ion levels increased throughout the distribution system. The increased concentration of ammonium ion is likely a contributor to the observed increase in nitrification.

Reduction of Chlorite Feed

The initial dosage of sodium chlorite was progressively reduced to determine the minimum effective chlorite dose required to control the activity of nitrifying bacteria. Chlorite concentrations in the distribution system declined in accordance with reductions in feed rate at the treatment plant, indicating that, even at lower applied concentrations, chlorite persisted in the distribution system.

Interferences

Many variables affected the authors’ ability to clearly observe the effect of the chlorite addition. In Willmar, two treatment plants with significant differences in source water quality provide water from opposite sides of town. Operationally, rates of chemical feed and distribution system blowoffs were modified throughout the study. Seasonally, factors such as reduced demand (increased water age), lower temperatures, and the behavior of major industrial water users, all had effects on distributed water quality.

Conclusions

Despite the complexities involved in a real distribution system, it was clear that the addition of sodium chlorite resulted in a reduction of nitrification. It was recommended that Willmar discontinue the BART and utilize sodium chlorite for the control of nitrification. Significant cost savings and safety benefits are expected to accompany the sharply reduced use of chlorine.

It was also determined that the use of sodium chlorite to control nitrification is not a set-it-and-forget-it type of chemical feed. Ongoing distribution system monitoring is required to continuously fine-tune the dosage in order to maintain an effective feed rate.

References

Hynes, R. K., and R. Knowles. 1983. Inhibition of chemoautotrophic nitrification by sodium chlorate and sodium chlorite: A reexamination. Appl. Environ. Microbiol. **45**: 1178-1182.

McGuire, M. J., N. Lieu and M. Pearthree. 1999. Using chlorite ion to control nitrification. Jour. AWWA **91**:10:52-61.

Murphy, B., O'Connor, J.T., and O'Connor, T.L., Willmar, Minnesota Controls Nitrification in the Distribution System, Part 1: Ozonation; Part 2: Breakpoint Ammonium Reduction Treatment, *Public Works*, Vol. 129, Nos. 10, 11, September, October, 1998.