Significance of Trihalomethanes in Preventing Distribution System Nitrification in Chloraminated Waters [Project #3173]

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OBJECTIVES:
The research addressed the following questions:
1. What combinations of trihalomethane (THM) concentration and speciation will halt existing nitrification?
2. What combination of THM concentration and speciation must be present in the system to prevent the initial onset of nitrification?
3. What is the combined role of monochloramine and THMs in preventing the onset of nitrification?

BACKGROUND:
Nitrification in drinking water distribution systems is a widespread issue when chloramination is employed as a residual disinfection process. In addition to metabolizing ammonia to nitrite, ammonia-oxidizing bacteria (AOB) can biodegrade THMs through an enzymatic process known as cometabolism. The by-products produced during the biodegradation of THMs can be toxic to the AOB. These observations lead to a working hypothesis that under certain conditions and THM concentrations, THMs play a significant role in preventing distribution system nitrification.

APPROACH:
Experiments were conducted in four annular reactors operated to simulate water distribution system conditions. Ammonia concentrations, pH, monochloramine concentration, and THM concentration and speciation were studied to determine the concentrations of THMs needed to halt nitrification within an existing biofilm and prevent nitrifying biofilms from developing. Experiments were initially performed in the absence of monochloramine to study the interaction between THMs and nitrifying bacteria. Later experiments introduced monochloramine to provide a more realistic simulation of drinking water distribution system conditions.

RESULTS/CONCLUSIONS:
The likelihood of distribution system nitrification is determined by the interacting factors of monochloramine concentration, ammonia concentration, pH, and THM concentrations and speciation. Temperature may also play a significant role. The complexity of the system is such that the likelihood of nitrification episodes cannot be predicted from examining water quality data alone; nevertheless, the availability of accurate water quality data is a prerequisite to predicting the potential for a nitrification episode. For example, small changes in pH can impact the potential for nitrification through changes in unionized ammonia concentration and monochloramine disinfection efficiency, so accurate pH measurements are needed to predict the potential for nitrification reliably. The Nitrification Index (NI) developed in this research provides a theoretically sound basis for characterizing the relative contributions of the many variables in a way that permits predictions of the likelihood of nitrification. The research also clearly demonstrated that THMs can play a significant role in preventing the onset of nitrification especially in situations where the monochloramine concentration is low.
APPLICATIONS/RECOMMENDATIONS:
The Nitrification Index can be used as a guide to suggest the nitrification risk in a distribution system, or more practically, specific sections of a distribution system, within which the water quality is similar. It is unlikely that nitrification episodes will directly correspond to the theoretical dividing line of NI = 1. Therefore, an empirical correlation between NI and nitrification episodes will likely be needed for each distribution system. Presumably, the correlation will approach 1 more closely if kinetic constants specific to the distribution system are measured. If NI is tracked on a regular basis, corrective action to head off a nitrification episode can be taken when NI rises. This research suggested that, as long as NI is no larger than 2, nitrification takes some time to develop. Therefore, NI may be an effective early warning system that would permit timely adjustments to lower the NI value before nitrification commences. Possible adjustments include increasing the monochloramine concentration, decreasing the ammonia concentration (usually achieved by increasing the Cl2:N ratio), and decreasing the pH (lower values decrease free ammonia availability for AOB growth and improve monochloramine disinfection of AOB). In a similar way, if a utility is considering treatment process changes that will affect distribution system water quality, NI can be used to assess the impact of the changes on the nitrification risk in the distribution system.