Factors Affecting the Formation of NDMA in Water and Occurrence [Project #2678]

ORDER NUMBER: 91063


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OBJECTIVES:
The objectives of this project were to
1. elucidate fundamental reaction mechanisms responsible for N-nitrosodimethylamine (NDMA) formation in drinking water, with a focus on the role of chlorination and chloramination;
2. determine the levels of NDMA in selected drinking water, recycled water, and wastewater through an occurrence survey of potentially vulnerable supplies; and
3. examine the impact of various drinking water and wastewater treatment technologies and process options on NDMA formation.

BACKGROUND:
NDMA has been found in highly purified wastewaters intended for recycle as well as some treated drinking waters at levels much higher than anticipated. Concentrations of NDMA leaving wastewater and drinking water treatment plants have been observed at levels higher than entering the plants, suggesting that NDMA occurrence is related to treatment practices.

HIGHLIGHTS:
Monochloramine can react with certain forms of organic nitrogen that contains precursors to produce NDMA. NDMA was detected in 18 of 21 drinking water utilities surveyed. Only two showed NDMA concentrations in excess of 9 ng/L. This indicates that excessive NDMA formation is not a widespread problem in drinking water. However, high concentrations were found in many chlorinated wastewaters. Treatment studies showed that polymers that contain DMA used in drinking water treatment can lead to excessive NDMA formation.

APPROACH:
Mechanistic studies were conducted primarily in laboratory-prepared waters to provide control of the reaction conditions. The primary focus of the research was to elucidate the role of monochloramine in systems containing DMA as a model precursor. Other studies investigated the importance of nitrite and bromide, and NDMA formation from a variety of other organic precursors.

An occurrence survey was conducted at drinking water, wastewater, and recycled water plants. The general approach was to sample enough facilities to give a preliminary indication of the potential extent of NDMA occurrence in North America. The 21 drinking water facilities selected for the survey represented various vulnerability factors, and comparisons were made to facilities without the vulnerability factors.

A significant portion of the treatment plant influence studies focused on NDMA formation from amine-based polyelectrolytes during bench-scale simulations of the coagulation/flocculation/sedimentation process followed by disinfection. Another part of the research focused on two waste treatment methods: secondary biological treatment and tertiary disinfection with chlorine.

RESULTS/FINDINGS:
Monochloramine can react with DMA to produce NDMA. However, DMA is a potentially important precursor if it is present at high enough levels. Reactions involving uncharacterized NOM may actually dominate in producing NDMA from reactions involving monochloramine. The presence of bromide can also accelerate the formation of NDMA presumably through the formation of bromamines produced as a consequence of its oxidation by either free chlorine or monochloramine. However, this is not expected to be an important process unless bromide concentrations are exceptionally high.

In the occurrence survey, the relatively high NDMA concentrations detected at one utility appear to be related to the use of ion exchange resins that contain DMA. The other had a chloraminated source water that was impacted by agricultural runoff. This suggests a relationship to particularly high organic nitrogen precursor concentrations. While excessive NDMA formation does not
appear to be a widespread problem in drinking water, it can be formed in very high concentrations in chlorinated wastewaters. Treatment studies show that polymers containing DMA can lead to excessive NDMA formation.

**IMPACT:**
- Both chlorination and chloramination have been implicated in reaction mechanisms that result in NDMA formation from natural precursors. The relative contribution of each must be considered, as well as the contribution from natural processes.
- While laboratory studies indicate that monochloramine may play a major role in NDMA formation, field observations do not indicate one method of disinfection leads to lower NDMA formation (ng/L levels in drinking water).
- Disinfectants produce relatively high NDMA levels in some treated wastewaters.
- Minimizing chloramine dosages should reduce NDMA formation in drinking water. This must be balanced with other water quality concerns.
- DMA-based polymers lead to formation of NDMA upon chlorination. Dosage rates of DMA-based polymers should be minimized to be consistent with turbidity and other water quality objectives.
- Treatment studies have focused on minimizing disinfection by removal of dissolved organic carbon. It is not known if this includes potentially important NDMA precursors.
- Treatability studies developed to evaluate strategies to minimize the formation of DBPs (e.g., trihalomethanes) should be conducted to evaluate the potential for minimizing NDMA formation.
- Compounds such as carbamates that occur in wastewater will react with nitrite to provide DMA. Disposal of known precursors into waste streams should be avoided, particularly if nitrification of waste will occur.

**RESEARCH PARTNER:**
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**PARTICIPANTS:**
Metropolitan Water District of Southern California and Orange County Water District participated in this project, as well as numerous other utilities that provided water samples.