Evaluation of Alternative Drinking Water Treatment Processes at Pilot Scale by Means of Mutagenicity Testing [Project #210]

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BACKGROUND
The use of ozone and chlorine dioxide in drinking water treatment has become common in Europe, and utilization of these disinfectants and chloramines is increasing in North America. Much effort has been expended to identify the reaction products of these disinfectants with synthetic and naturally occurring organic compounds present in raw water supplies. However, only a small percentage of these reaction products have been identified, and biological testing is required in addition to chemical characterization to better define the possible health risk from these compounds. Biological testing has the potential to assess all compounds in a sample which are isolable by the concentration procedure used regardless of their concentration and whether or not they have been identified. Mutagenicity testing is commonly used as the first level of biological screening. The premise is that a compound’s ability to cause mutation is often correlated with its ability to cause cancer in animals. The most commonly used mutagenicity test is the Ames Salmonella assay.

APPROACH
Mutagenicity produced by chlorine, chloramines, chlorine dioxide and ozone was examined in a pilot scale study conducted at Edmonton, Canada. Both the Ames Salmonella mutagenicity assay (strains TA98 and TA100), and a yeast assay using Saccharomyces cerevisiae (strain D7144-2) were employed. Samples were concentrated on XAD-2 macroreticular resin, and only the neutral fraction was examined. In an attempt to correlate mutagenic activity with other parameters, total organic carbon (TOC), trihalomethanes (THMs) and ultraviolet (UV) absorbance were also monitored. Compound identification was accomplished by gas chromatograph-mass spectrometer (GC/MS). In addition, adsorption isotherms were performed for the recently identified strong acid fraction mutagen "MX" (3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone).

RESULTS
In the Ames test, chlorination produced mutagenicity the most frequently while occasional weak mutagenicity was observed in chloramine and chlorine dioxide samples; samples obtained following ozonation were never mutagenic. The rat liver preparation S9 always eliminated any mutagenicity observed. In the yeast assay, mutagenicity was seen infrequently, but some of this activity was pro-mutagenic in nature. Granular activated carbon effectively removed mutagenicity for eight months (18,000 whole bed volumes) although some breakthrough occurred in upper portions of the bed at the time of a spring run-off TOC peak. Chlorine stream mutagenicity was correlated to TOC, THM, and UV absorbance levels for this particular water source. In a brief experiment, pre-ozonation itself did not produce mutagenicity. Although mutagenicity was seen following post-chlorination in a treatment train with pre-ozonation but without GAC, this result must be viewed as inconclusive. MX and its isomers were not isolable by the procedures used. Laboratory experiments indicated that MX was well removed by activated carbon.
The results can be seen as a "warning flag" for chlorine and suggest that there should be some reservations concerning the use of chloramines or chlorine dioxide. The elimination of mutagenicity by GAC is encouraging as is the absence of mutagenicity following post-GAC disinfection. The following recommendations can be made on the basis of this study: (1) mutagenicity testing could be considered in the choice of drinking water treatment processes, especially in the selection of a disinfectant and its conditions of use; (2) if chlorination is used as a disinfectant in a treatment process without GAC, the level of organic carbon (and perhaps ammonia and organic nitrogen) should be reduced to the maximum extent possible before the application of the disinfectant; and (3) if GAC is included in a treatment process with chlorination, the breakthrough of mutagenicity or mutagenic precursors could be used as one of the design and operating criteria.