1. Project Title: Approaches to Reduce Taste and Odor Problems in Drinking Water

2. Principal Investigators: Milton R. Sommerfeld
Thomas A. Dempster
Department of Plant Biology
Arizona State University
Tempe, Arizona 85287-1601

3. Congressional District: First Congressional District (both Principal Investigators)

4. Description Information: Key words - 2-methylisoborneol (MIB), geosmin, taste and odor problems, earthy/musty odor, water treatment, blue-green algae, cyanobacteria, citral, powder activated carbon (PAC)

A. Problem and Research Objectives

Taste and odor problems associated with drinking water are a pervasive problem for many municipalities. Suffet et al.[1] reported that 22% of the water providers surveyed in a national study reported taste and odor problems in their source waters. Taste and odor problems have been traced to both planktonic and benthic algae in surface impoundments and in water supply and distribution networks, including canals (Izaguirre et al.[2]; Means and McGuire[3]; Izaguirre and Taylor[4]).

Municipalities in the Phoenix Metropolitan area have experienced taste and odor problems for many years, but the problems seem to be increasing, especially beginning during the late summer and extending well into the late winter.

Water treatment costs for taste and odor problems alone have become exorbitant and consumers are more outspoken about expectations of receiving water that tastes and smells good, as well as is safe to drink. Two compounds, 2-methylisoborneol (MIB) and geosmin, are most commonly cited as imparting unpleasant earthy/musty tastes and odors to water. The source of these and other compounds associated with taste and odor is primarily blue-green algae (cyanobacteria) and certain fungi (actinomycetes).

Research objectives were achieved through collaboration between operators of the City of Chandler Treatment Plant and researchers at Arizona State University, in cooperation with the Salt River Project. The on-going and focused effort was instrumental in an attempt to (1) identify the organisms causing the taste and odor problems, and (2) to explore the use of citral to mitigate taste and odor problems.

B. Methodology

Water samples were collected from two sites along the South Canal and five sites along the Consolidated Canal, including the intake into the Chandler Water Treatment Plant. Each sample was collected and stored on ice in 16-ounce plastic Whirl-Pak storage bags in the field and transferred to 125-ml plastic screw top bottles in the laboratory. Bottles were subsequently kept on storage racks at room temperature under light conditions similar to those in the natural environment. Aliquots of each sample were streaked on agar plates (1.5%) of Bold's Basic Medium (BBM; Carolina

Biological Supply Co.) with an inoculating loop. After approximately two weeks, isolated colonies were transferred to culture tubes with 10-ml of liquid BBM. Additional streaks were performed when multiple organisms appeared in the same colony. This procedure was performed repeatedly in an attempt to isolate the maximum number of organisms from each sample. Cultures grown on BBM agar plates and in liquid medium were repeatedly checked in an attempt to detect earthy/musty odors.

Solid phase microextraction (SPME) and Gas Chromatography/Mass Spectroscopy (GC/MS) were employed to determine the effect of citral on the compounds MIB and geosmin, as well as the determination of optimum PAC concentrations to mitigate tastes and odors from MIB and geosmin. During SPME, 25-ml of sample was added to a 40-ml septum-capped vial containing 9 grams of desiccated sodium chloride and a magnetic stir bar. An internal standard, 2,4,6-trichloroanisole (TCA), was then added to the sample at a concentration of 10 ng/l. The sample was heated to 50 +/- 1.5 ^{o}C in a water bath. An SPME fiber (Supelco # 57348 U) was injected through the septum into the gas-phase headspace (approx. 11.0 cm^3) above the sample. The sample was maintained at the elevated temperature and stirred for 30 minutes. The SPME fiber was removed from the vial and inserted into the gas chromatograph injector at 250 ^{o}C for 5 min. to desorb compounds from the fiber. Compounds were eluted from the column and analyzed using selective ion storage (m/z values: 95 for MIB; 112 for geosmin; 152 for citral; 165 for TCA). Spectrum peaks identified as citral, MIB, geosmin, and TCA were analyzed for area under the peak (a measure of total ion count). Compound concentrations were calculated from predetermined calibration curves generated from commercially available products (citral, Aldrich #C8300-7; MIB/geosmin mixture, Supelco #47525-U; TCA, Aldrich #23539-3).

Odor profile analysis (OPA) panels were assembled on two occasions at Arizona State University to determine odor threshold concentrations for MIB, geosmin and citral using the human sense of smell. The panel was also used to elucidate the citral and PAC concentrations necessary to mitigate or remove the odors associated with different concentrations of MIB and geosmin from the water. The OPA panel was subjected to a matrix of samples which contain either 0 or 50 ng/L of both MIB and geosmin, a concentration range of citral from 0-100 nl/L, and PAC concentrations from 0-600 mg/L.

The City of Chandler flavor profile analysis (FPA) panel was also used to test for the presence of taste and odor compounds using the human senses of taste and smell. The panel rated each sample on a scale of 0 to 1 based on the intensity (0=undetectable to 1=most intense) of a variety of tastes and odors, *e.g.*, earthy, musty, chlorine, septic, etc. The panel was conducted weekly from July to November 1999 and tested water samples from the canal intake, sedimentation basins, filtered water storage and finished water. The weekly results were used in a 15-week study that compared the efficiency of Chandler's FPA panel to the GC/MS results generated at Arizona State University on parallel water samples.

Chandler operators conducted weekly tannin/lignin tests (Method 5550-B; Standard Methods for the Examination of Water and Wastewater (18^{th} Edition/1992) on water samples from the canal intake, sedimentation basins, filtered water storage and finished water. The potential for using tannin/lignin concentrations to predict future taste and odor episodes was investigated by comparing the weekly tannin/lignin results to the GC/MS results generated at Arizona State University on parallel water samples during the 15-week comparative study.

C. Principal Findings and Significance

Sampling and subsequent isolations indicate that taste and odor compounds most likely originate in "hotspots" along the canals rather than being distributed uniformly throughout the supply system. Detectable earthy/musty odors occurred intermittently along the supply system, as opposed to similar intensities at each site. Approximately 40 organisms (algae) have been isolated. Three of these isolates, two *Oscillatoria* spp. and *Pseudanabaena* sp. appear to be MIB and/or geosmin producers. These results must be verified using GC/MS after individual organisms have been cultured in larger quantities. These results are significant because the cost of the current approach of applying chemical treatments to the entire system to eliminate taste and odor problems may be reduced substantially if treatment efforts can be concentrated at supply system "hotspots".

OPA panel results suggest that a citral concentration of 100 nl/L renders 50 ng/L of each MIB and geosmin undetectable and concentrations as low as 10 nl/L make 50 ng/L of each MIB and geosmin barely detectable to the human sense of smell. GC/MS results revealed that citral masks the tastes and odors associated with MIB and geosmin. At the concentration used, citral also imparted a "citrus" aroma to the water. MIB, geosmin and citral were all detected at their original concentrations (100 ng/L) when water was spiked with all three compounds. There was neither an indication that citral initiated a chemical change in MIB or geosmin, nor that citral increased the binding efficiency of PAC. Despite the initial promise of using citral as a cost efficient alternative or supplement to PAC, citral was found to be an oily compound that was not readily miscible in water. At the present time, additional research is required to determine whether citral may be mixed thoroughly enough with supply water during water treatment to make its use feasible and cost effective. The propensity for citral to float on the water surface currently renders its use a non-viable solution for treating taste and odor problems. Due to the oily characteristic of citral, we were unable to determine the optimum citral:PAC ratio for maximum reduction of taste and odor compounds. Therefore, pilot-scale studies were not conducted.

As a result of the difficulty associated with using citral for water treatment, we examined an additional question with a direct impact on water treatment efficiency and cost for the City of Chandler. A collaborative study examined weekly water samples for 15 weeks from Chandler's canal intake, sedimentation, filtered water storage and finished water. The study was designed to 1) correlate the effectiveness of the City of Chandler's FPA panel measurements for monitoring taste and odor compounds with GC/MS results at Arizona State University, and 2) determine whether the tannin/lignin concentration in the supply system is a reliable predictive indicator of future taste and odor episodes. Taste and odor results from Chandler's FPA panel were compared to actual MIB and geosmin concentrations determined by GC/MS analyses at Arizona State University. Chandler operators performed tannin/lignin tests on the same samples. Although results were variable, comparison of the Arizona State University GC/MS results with City of Chandler's FPA panel odor and taste results revealed that the FPA panel results were much more reliable at detecting the presence of taste and odor compounds (MIB and geosmin) in water samples than could be predicted by tannin/lignin concentrations. The results support the use of the City of Chandler's FPA panel as a fairly accurate and cost efficient way to quickly assess water quality before it reaches consumers. No relationship appeared to exist between the MIB and geosmin results from GC/MS and weekly tannin/lignin concentrations.

[1]Suffet. I.H., C. Anselme, and J. Mallevialle. 1993. AWWA Taste and Odor Survey, Proc. AWWA Water Quality and Technology Conference, Miami, FL, pp. 1785-1831.

[2]Izaguirre, G., C.J. Hwang, S.W. Krasner, and M.J. McGuire. 1982. Geosmin and 2-methylisoborneol from cyanobacteria in three water supply systems. *Appl. Environ. Microbiol. 43:708-714.*

[3]Means, E.G. III, and M.J. McGuire. 1986. An early warning system for taste and odor control. *Journal AWWA,* March, 1986: 77-83.

[4]Izaguirre, G., and W.D. Taylor. 1995. Geosmin and 2-methylisoborneol productionin a major aqueduct system. *Water Sci. Technol.* 31:41-48

5. Publication Information:

a. Articles in Refereed Scientific Journals
None yet

b. Book Chapters
None

c. Dissertations
None completed, but one in progress as follows:
Dempster, Thomas A.
"Taste and Odor Problems in Water Supplies in Phoenix Metropolitan Area"
Ph.D. Dissertation
Department of Plant Biology, Arizona State University, Tempe, AZ 85287-1601

d. Water Resources Research Institute Report
None

e. Conference Proceedings

None yet

f. Other Publications

None

6. Student Support:

Section 104 Base Grant

Undergraduate	0
Masters	0
Ph.D.	1
Post-Doc	0
Total	1

7. Notable Achievements and Awards:

A cooperative and collaborative effort between personnel from the City of Chandler, Arizona and researchers from Arizona State University demonstrated that the practical experience of plant operators and staff, and the scientific approach and technology available at the University can be successfully brought together to address water quality problems.