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Project Summary

Pilot Plant Project for Removing Organic Substances from Drinking Water

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A study was conducted to evaluate the European practice of ozonating water to modify naturally occurring organics and then using biological activated carbon (BAC) adsorption to remove trihalomethane (THM) precursors. A 22.7-m^3/hr (100-gpm) pilot plant was designed, constructed, and operated to evaluate this process on groundwater in Miami, Florida. The main objective was to extend the bed life of the carbon adsorbers.

Two pilot-plant studies were conducted. The first evaluated removal of THM precursors from ozonated and nonozonated influent treated with anaerobic BAC. Later in the study, both BAC adsorbers were oxygenated for aerobic operation to determine whether bed life could be extended by this means. In the second pilot study, BAC adsorbers with ozonated and nonozonated influents were oxygenated at initial startup to compare aerobic and anaerobic systems. Throughout all ozone studies, a complete bacterial profile was made for comparison with that of conventional breakpoint chlorination.

Results indicated that ozone applied at about 12 mg/L may be a desirable primary disinfectant for future use in the local south Florida area, but it does not extend bed life enough to make BAC a practical method for removing THM precursors from local groundwater. A cost analysis of the BAC process was not conducted as a part of this project.

In addition to the two pilot studies, bench-scale studies were also conducted to (1) select the best of four commercially available granular activated carbons (GAC's) for use in the pilot plant, (2) determine the ability of GAC to remove agricultural and industrial organic chemicals from water high in total organic carbon (TOC), and (3) determine the source of volatile chlorinated ethene compounds in raw groundwater in the Miami area and other parts of Florida. Results of the bench studies are presented in the appendices to the main report.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This project addresses the problem of removing organic substances from drinking water by a European method of ozonating water to modify naturally occurring organics and then using biological activated carbon (BAC) adsorption to remove trihalomethane (THM) precursors. The project resulted from an earlier 3-year study of carbon adsorption showing that at a flowrate of 7.35 m/hr (3 gpm/ft^2), 3.05 m (10 ft) of GAC and an empty-bed contact time (EBCT) of 24.8 min were required to achieve a bed life of 81 days. (P. R. Wood, J. A. Gervers, D. H.

Waddell, and L. Kaplan. 1980. *Removing Potential Organic Carcinogens and Precursors from Drinking Water.* Vol. I. EPA-600/2-80-130a, U.S. Environmental Protection Agency, Cincinnati, Ohio). This bed life was based on the number of days required to reach a certain breakthrough of trihalomethane formation potential (THMFP). The breakthrough was the point at which the total trihalomethanes (TTHM's) reached 100 μg/L when the effluent was rechlorinated to a free chlorine residual of 2.5 mg/L and held for 2 days.

The purpose of the present study was to extend this bed life by using the European method of ozonation and carbon adsorption. This treatment technique took advantage of aerobic biological oxidation on granular activated carbon (GAC). Bed life was said to extend well beyond the period of pure adsorption, and the mechanism appeared to be one by which biodegradable organics were metabolized by bacteria growing on the GAC. Further extension of bed life could reportedly be obtained by ozonation of the water feeding the GAC adsorbers. This ozonation was believed to modify the naturally occurring organics and render them more readily degradable by the bacteria.

Consequently, a 22.7-m^3/hr (100-gpm) pilot plant was designed, constructed, and operated to evaluate this process on groundwater in Miami, Florida. The pilot plant was located at the Preston Water Treatment Plant in Hialeah, Florida. The raw groundwater feed was from wells 27.4 m (90 ft) deep on the plant site and contained substantial amounts of naturally occurring organics--8 to 10 mg/L total organic carbon (TOC) and 600 to 800 μg/L THMFP.

The pilot lant was designed to study parallel systems of GAC adsorbers that were 3.05 m (10 ft) deep, had an EBCT of 24.8 min, and received ozonated and nonozonated, lime-softened water that was recarbonated to pH 8.5 and sand filtered. The GAC adsorbers were operated under anaerobic conditions in the first study and aerobic conditions in the second study. The absorbed ozone dosages in these studies were 11.3 and 14.5 mg/L, respectively. The bed life for each of the two parallel systems was determined.

In addition to the pilot studies to extend GAC bed life, bench-scale studies were conducted to determine:

1) The best of four commercially available GAC's for removing THM precursors from the local groundwater.
2) The bacteria profile of the Preston Water Treatment Plant, including the distribution system.
3) The bacteria profile of the bench-scale GAC work.
4) The ability of GAC to remove agricultural and industrial organic chemicals from waters high in TOC.
5) The source of chloroethene compounds present in raw groundwater in the Miami area and in other locations in Florida.
6) Removal of volatile halogenated organics from water by aeration techniques.

These studies are detailed in the appendices to the main report.

Plant Conditions

Conclusions in this report are based on the particular groundwater feed and water treatment practices existing at the Preston Water Treatment Plant during the study period. Groundwater containing high concentrations of TOC and THM precursors was lime-softened, breakpoint-chlorinated, and sand-filtered. Finished water leaving the plant had a free chlorine residual of 2.5 to 3.0 mg/L for continued disinfection in the distribution system. The average TTHM concentration in the finished water was 150 μg/L. This concentration increased to 300 μg/L in the distribution system because of the continued reaction of free chlorine residual with precursor substances remaining in the finished water.

Both the original research project and the present study were based on the possibility of removing enough THMFP at the water treatment plant to limit further growth of TTHM in the distribution system to 100 μg/L (assuming that the finished water left the plant with a free chlorine residual of 2.5 to 3.0 mg/L).

Under the given plant conditions, a GAC adsorber effluent breakthrough of approximately 3 mg/L of TOC or 200 μg/L of THMFP was found to produce the 100 μg/L TTHM concentration. In this report, bed life based on these conditions is referred to as "Criterion 1" bed life.

Procedures

Pilot Studies

The first of the two pilot-plant studies evaluated the effects of ozonated and nonozonated influent on the removal of THMFP with GAC adsorbers operated under anaerobic conditions. After the psuedo-steady-state region of the THMFP breakthrough curve was reached on the GAC adsorber effluents, both GAC adsorbers were oxygenated for aerobic operation to determine whether the effective GAC bed life could be extended by a change to aerobic operation.

In the second pilot-plant study, both ozonated and nonozonated GAC systems were oxygenated on initial startup to compare aerobic operation with the anaerobic operation of the first study. Other studies were conducted in the pilot plant to determine how TOC and THMFP were affected by absorbed ozone dosages at various pH ranges.

Throughout all ozone studies, a complete bacterial profile was made to be compared with that of conventional breakpoint chlorination.

Bench-Scale Studies

Both bench- and pilot-scale studies were conducted at the same time. The first bench-scale project was designed to select the best of four commercially available GAC's for use in the pilot plant. Selection was based on the greatest adsorptive capacity (longest bed life) for removing THM precursors from the Preston plant finished water. The best GAC selected was then evaluated for bed-life performance on lime-softened Preston plant water that was first adjusted to pH 8.5 by recarbonation and then sand-filtered. This type of water feed was used to supply both the ozonated systems and the nonozonated controls.

During the bench-scale studies, a complete bacteria profile was made for the Preston plant. This profile included the distribution system and all bench-scale systems.

Methods were developed during the bench-scale studies for continuous spiking of plant effluents with agricultural and industrial pollutants. Studies were then made on the removal of these compounds by the GAC adsorbers. Such information will be useful if the local groundwater supply ever becomes contaminated, since little is known about the ability of GAC to remove such pollutants from high-TOC waters.

Bench-scale studies were also conducted to determine the source of volatile, chlorinated ethene compounds in raw groundwater in the Miami area and in other locations in Florida.

Results

Chemical Parameters

1. Of the four commercially available GAC's tested for THMFP removal on finished water, Calgon Filtrasorb 400* gave the longest bed life and was selected for the pilot plant study.

2. When a 2.13-m (7-ft) deep bed of Filtrasorb 400 was tested for THMFP removal on lime-softened, sand-filtered water adjusted to a pH of 8.5, the Criterion 1 bed life was 21 days.

3. In the first pilot plant study, the ozone- and nonozone-GAC systems were operated anaerobically for the first 98 days of the 160-day test. Based on Criterion 1, the bed life was 44 days for the ozone-GAC system and 19 days for the nonozone control system.

4. In the first pilot plant study, changing from anaerobic to aerobic operation did not appear to alter the shape of the psuedo-steady-state portion of the TOC or THMFP breakthrough curves.

5. In the second pilot plant study, the ozone- and nonozone-GAC systems were operated aerobically throughout the full 172-day test period. Based on Criterion 1, the bed life was 25 days for the ozone-GAC system and 9 days for the nonozone control system.

6. Because the TOC and THMFP loadings were different for the two pilot studies (anaerobic and aerobic), direct comparisons were impractical.

7. Ozone in the ozone contractors greatly reduces the concentration of double bond chlorinated compounds. At an absorbed ozone dose of 14.5 mg/L, the initial concentration of cis 1,2-dichloroethene, vinyl chloride and chlorobenzene was reduced 90, 91 and 94 percent, respectively. At an absorbed dose of 4.25 mg/L, these compounds were reduced 73, 88, and 78 percent, respectively.

8. In a 335-day test of the removal of spiked organics from finished water, several polyaromatic hydrocarbons (PAH's), several halogenated pesticides, and one polychlorinated biphenyl (PCB) were fed to a 0.76-m (2.5-ft) deep bed of Filtrasorb 400. During the test period, this GAC removed essentially 100 percent of all the PAH's, 98.6 percent of all the halogenated pesticides, and 97.5 percent of the PCB.

9. In an aeration system (i.e.,stirred beaker, aeration tower, spray head), the decrease in contaminant levels in water with time is linear if the log of the effluent concentration is plotted versus time and if all compounds present are in the soluble range.

10. When aeration decreases contaminant levels in water with time, the decrease is independent of other organic compounds when all compounds are present in the soluble state. The decreased concentration with time is also independent of initial concentration in the range of solubility.

11. The source of volatile chloroethene compounds (vinyl chloride, vinylidene chloride, cis and trans 1,2-dichloroethylene, etc.) in the local groundwater is the result of the biodegradation of parent, volatile chlorinated degreasing solvents accidentally spilled on the ground above the aquifer. The solvents were trichloroethylene and/or tetrachloroethylene. Chloromethane and ethane compounds are the result of the biodegradation of 1,1,1-trichloroethene.

12. Field data from an actual contaminant spill in the environment confirmed the results of the laboratory biodegradation studies.

Biological Parameters

1. In the GAC beds used to filter raw, lime-softened, or chlorinated finished drinking water, large numbers of bacteria grew and sloughed off into the water flow.

2. Bacteria isolated from the GAC adsorbers were common to the raw water supply and were normal inhabitants of soil and fresh-water sediments.

3. Often, many of the bacteria that made up the total plate counts (and those most frequently encountered) were unidentifiable by taxonomic keys, did not survive subculturing, or were inert in standard biochemical tests.

4. Common heterotrophic organisms recovered from raw and treated water from the bench-scale tests, the pilot plant, and the full-scale treatment plant were species of *Alcaligenes, Psuedomonas, Moraxella, Acinetobacter, Micrococcus, Flavobacterium,* and Gram-positive rods.

5. The composition of the GAC effluent flora was generally the same as that of the flora on the GAC surface, but the species existed in different proportions. Perhaps these results reflect different resistances of the species to dislodgement by the water flow.

6. No real difference existed in the numbers or kinds of bacteria recovered from the GAC adsorber effluents that received aerated, oxygenated , ozonated, or untreated influents. Many of the heterotrophic bacteria cultured from samples of the GAC or their effluents were able to grow well without atmospheric oxygen.

7. Bacterial populations in the GAC adsorbers were dynamic. Periodic sampling and analyses indicated that the sizes and compositions of these populations changed constantly. Probable causes were succession of species within the adsorber and introduction of new species from the raw groundwater supply.

8. Gram-negative rods, which had no especially resistant forms, survived in GAC effluents that were chlorinated to breakpoint and had up to 10 mg/L free residual chlorine at the time of plating.

Conclusions

Ozone applied in the 12-mg/L-range may be a desirable in-plant primary disinfectant for future use in the local south Florida area. At this concentration ozone appears to be as effective as current breakpoint chlorination at 18 mg/L for pathogen and microorganism control,

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use

and it may provide even better color reduction. At this dosage, ozone also effectively oxidizes double-bond chlorinated compounds that are present in the raw groundwater. For residual control in the distribution system, ozone could be followed by a secondary disinfectant that would not form additional THM's.

If the local groundwater source ever becomes contaminated with organic compounds that are not readily removed by other means, the use of GAC adsorption in this high-TOC water would be very effective.

The full report was submitted in fulfillment of Cooperative Agreement CR806890 by Florida International University, Miami-Dade Water and Sewer Authority, and Dade County Department of Public Health under the sponsorship of the U.S. Environmental Protection Agency.

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***Jack DeMarco** is the EPA Project Officer (see below).*
The complete report, entitled "Pilot Plant Project for Removing Organic Substances from Drinking Water," (Order No. PB 84-128 685; Cost: $29.50, subject to change) will be available only from:
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