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Project Summary

Pilot Scale Evaluation of Biological Activated Carbon for the Removal of THM Precursors

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This project evaluates a method for the removal of trihalomethane (THM) precursors from surface water sources. The site of the project, Cross Lake in Shreveport, Louisiana, represents sources in the southern United States with high concentrations of THM precursors. In *one phase of the project, a pilot plant* was operated for 80 weeks to test the combination of ozone and granular activated carbon (GAC) for THM precursor removal. An important objective of the pilot study was to investigate the possibility of microbiological degradation of *precursors in the GAC columns and the* effect of preozonation on this process. The combination of ozone and GAC is sometimes referred to as biological activated carbon (BAC).

Analysis of the pilot plant data shows microbiological activity to be a significant *contributor to the removal process for* total organic carbon (TOC) and trihalomethane formation potential (THMFP) in GAC columns under the conditions tested. In the initial stages, the removal mechanism appears to be primarily adsorption. But, after 50 × 10^3 bed *volumes of water have been processed,* only microbiological removal remains. During the interim period, both adsorption and microbial processes appear to contribute to TOC and THMFP removal.

Comparison of costs associated with the addition of GAC and BAC to traditional *water treatment plants of 100-, 10-,* and 1-mgd capacities shows that, for the conditions of this study, the addition of ozone was not cost effective in extending the time between reactivations of the GAC.

In a second phase of the project, studies *were conducted at Shreveport's Amiss* treatment plant complex to define the extent of their THM problem. Results there showed high concentrations of THM's. Alternatives for lowering the concentrations to less than 0.10 mg/L include addition of GAC and conversion to chloramination. In either case, some type of oxidant will be required for manganese control.

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

Following the passage of the Safe Drinking Water Act by the U.S. Congress in 1974, the U.S. Environmental Protection Agency (EPA) proceeded to act under the authority of this legislation to promulgate National Interim Primary Drinking Water Standards. These standards set maximum contaminant limits for several inorganic elements and com-

pounds, organic pesticides, radioactivity levels, and microbiological parameters. Furthermore, they were applied to essentially all water supplies serving populations in the United States. Recently, these standards were amended to include the establishment of maximum contaminant levels for four organic substances known as the trihalomethanes (THM's). Trihalomethanes are known to be formed by the disinfection process that uses chlorine, the most disinfectant used in water treatment in the United States. The reaction of chlorine with naturally occurring organic compounds, called THM precursors, is well known to result in the formation of a variety of chlorinated organic compounds, including the THM's. Four THM's are now regulated by the requirements of the Safe Drinking Water Act—chloroform, bromodichloromethane, dibromochloromethane, and bromoform. As of November 29, 1981, the combined levels of these four THM's were not permitted to exceed 0.10 mg/L in water supplies serving populations greater than 75,000. This limit will apply to all water systems serving populations of 10,000 to 75,000 as of November 29, 1983. Trihalomethane limits are expected to be extended to cover essentially all U.S. water supplies in the future.

Methods for controlling THM levels include modification of the disinfection process (including substitution of an alternative disinfectant), removal of THM's once formed by advanced treatment processes including adsorption and aeration, and removal of THM precursors before the use of chlorine as a disinfectant.

Among the treatment methods available for the removal of THM precursors, GAC adsorption has emerged as the most promising alternative. Various studies have shown that GAC can remove natural organic compounds from groundwaters and surface waters with great efficiency. The principal disadvantage of the use of GAC is the need to replace or reactivate it periodically to renew its adsorption capabilities. The relatively high cost of this process has discouraged its wide application as a water treatment process. A recent discovery suggests the possibility of extending the lifetime of GAC columns for water treatment. This discovery involves the recognition that microbiological processes occur on GAC much as they do in trickling filters used for wastewater treatment. The fact that bacterial colonies proliferate on GAC has been known for some time, but only recently has it been appreciated that this presence may be used beneficially to remove organic substances from the influent water.

Naturally occurring organic compounds in water supplies (sometimes referred to as aquatic humus) are relatively refractory materials, and their biological degradation is usually a relatively slow process. Thus in the application of microbiological processes to GAC, various workers have proposed to increase the biodegradability of these substances by the application of an oxidation pretreatment process. Ozone has been the most favored oxidant for these purposes. The combination of ozone followed by GAC for the removal of organic substances in water has been termed the biological activated carbon (BAC) process. Proponents of this process contend that BAC can extend the life of granular activated carbon columns almost indefinitely, provided microbiological colonies can be maintained. Treatment efficiencies during such extended lifetimes ordinarily do not equal those of fresh carbon, but the proponents of the BAC process contend that longer empty bed contact times in the carbon can be used to obtain desirable treatment efficiencies. According to this view, the increased capital costs associated with longer GAC contact times and the addition of an oxidant are more than offset by the avoidance of GAC reactivation or replacement costs.

Most of the data on which these conclusions are based have evolved from the application of ozone and GAC adsorption in European waterworks. Few cases have been studied in which the performance criteria match those required by U.S. drinking water regulations; that is to say, the operational criteria used in Europe to evaluate the BAC process do not correspond to the minimization of the THM's. For this reason, EPA is sponsoring several pilotscale investigations to evaluate GAC adsorption for the direct removal of THM's or THM precursors.

This report describes the results of one such investigation. The study was conducted in the southern part of the United States in Shreveport, Louisiana. The test water is taken from Cross Lake, the principal water supply for the city of Shreveport. Cross Lake contains relatively high levels of THM precursors, but it is relatively uncontaminated by anthropogenic sources. A pilot study was carried out to evaluate GAC adsorption with and without preozonation as a means for removing these high levels of precursors. A variety of chemical and microbiological parameters were measured in the pilot plant and in associated laboratory experiments to obtain more information on the physical, chemical, and biological processes that occur in GAC filters. Parallel to this effort, studies were taking place in the Thomas L. Amiss treatment plant of the city of Shreveport to help municipal authorities develop approaches for minimizing trihalomethanes in the city water supply.

Conclusions

The pilot-scale portion of this study has shown that GAC columns may be operated for extended lifetimes by optimizing the physical and microbiological processes that occur in these columns. With the trihalomethane formation potential (THMFP) as the principal analytical criterion, water from a southern U.S. reservoir has been treated effectively for a period of 1 year using a combination of alum flocculation, multi-media filtration and 24 min of contact with Filtrasorb-400* GAC. During this period the THMFP of the product water was less than the 0.10 mg/L maximum contaminant level except on two occasions.

Engineering and cost analyses have been conducted for the addition of GAC adsorption with a 24 min contact time to an existing plant using the same reservoir as the water source. The analysis shows that costs of this additional treatment are not unreasonable. For 1-, 10-, and 100-mgd plants, additional costs per 1000 gal were computed to be $0.33, $0.20, and $0.13, respectively.

The addition of ozone before GAC adsorption may extend the lifetime of GAC columns, presumably by direct oxidative reduction of THMFP and by encouragement of microbiological removal mechanisms in the GAC columns. Under the conditions used in this study, the addition of ozone was not cost effective in extending the time between reactivations of the GAC.

An analysis of the chemical and microbiological data from the pilot study suggests that the following conclusions may be drawn regarding the pilot plant operation.

1. Traditional treatment consisting of alum flocculation, sedimentation and mixed-media filtration results

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

in the removal of 30% to 40% THMFP, with more efficient removal occurring in the summer periods. Except for occasional periods in the winter months, the product of this treatment has THMFP values well in excess of 0.10 mg/L.

2. Oxidation with ozone is not an effective method *per se* for the removal of THMFP. For the relatively low doses (applied ozone dose range = 2.0 to 6.3 mg/L) used in this work, 5% to 20% destruction of THMFP was observed. When combined with traditional treatment, ozonation produced water that met the 0.10 mg/L THMFP criterion only 20% of the time.
3. The addition of GAC columns to traditional treatment is an effective means for controlling THM precursor levels. Various data point to the following mechanisms as those responsible for the sustained removal of natural organics from the GAC columns:
   (a) *Physical Adsorption.* This process is prevalent during the early stages of operation and shows the expected decline in rate as macropore sites become saturated and the process is limited by pore diffusion. But as other workers have shown, the capacity of GAC for natural organics is very large if the micropore capacity is fully utilized.
   (b) *Microbiological Degradation.* This process is temperature dependent and accounted for the removal of approximately 0.21 moles of carbon/m^3 GAC-hr (or approximately 0.13 mg THMFP/m^3 GAC-hr) during its optimum period.

These two processes combine to yield a sustained period of THMFP removal. During the early stages, the removal is largely due to physical adsorption; but in the latter part of the study, microbiological processes appear to prevail. The intermediate period (referred to by some as a pseudo-steady-state period) is apparently due to a combination of the two processes.

4. Results of the parallel study at the T.L. Amiss plant are incomplete, but they suggest the following conclusions:
   (a) Instantaneous THM concentrations in the Amiss distribution system are extremely high by Federal standards, ranging approximately from 0.10 mg/L in the winter to 0.35 mg/L in the summer.
   (b) A substantial fraction of the THM's is produced upon prechlorination—a common practice at the Amiss plant. During summer months, concentrations above 0.10 mg/L often occur after a detention time of only 10 to 20 min beyond prechlorination.
   (c) Elimination of prechlorination results in more effective coagulation of precursors in the sedimentation basins. The result is not only lower THM concentrations leaving the Amiss plant, but lower ultimate values in the distribution system.
   (d) Control of pH levels after lime stabilization is an ineffective means of minimizing THM formation.
   (e) Control of chlorination practice alone cannot solve the THM problem in systems such as the Amiss plant. Other measures that may be used are GAC adsorption (as indicated by the pilot study) and substitution of an alternative disinfectant for chlorine.
   (f) If chloramination is to be used in place of chlorination, it must be substituted throughout the plant, at least during summer periods. The control of primary producers in the plant basins, taste and odor problems, and manganese levels in the product water then become management problems that will require renewed attention.

Recommendations

This project has shown that biologically enhanced removal of THM precursors is possible. Full-scale studies should be encouraged to optimize the process. Particular attention should be given to the development of regimes for partial reactivation of the GAC beds in some type of rotary fashion so that biological and physical adsorption can be coordinated and the entire process optimized.

The full report was submitted in fulfillment of Cooperative Agreement No. CR-806157 by The University of Texas at Dallas, Richardson, Texas, under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Pilot Scale Evaluation of Biological Activated Carbon for the Removal of THM Precursors," (Order No. PB 82-230 301; Cost: $16.50, subject to change) will be available only from:

National Technical Information Service
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