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Project Summary

Feasibility Study of Granular Activated Carbon Adsorption and On-Site Regeneration

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A cooperative study was undertaken by the Cincinnati Water Works (CWW) and the U.S. Environmental Protection Agency (EPA) to investigate the feasibility of municipal water treatment using granular activated carbon (GAC) adsorption and on-site regeneration. The project was to determine whether the use of GAC in either deep-bed contactors or conventional-depth gravity filters with on-site carbon regeneration (reactivation) would be a feasible means of removing trace organics from Ohio River water at a reasonable cost and without adverse effects on the level of treatment provided by the existing plant.

GAC removed a broad spectrum of organics from Ohio River water, and it functioned as well if not better than sand in removing turbidity. Reactivation restored the GAC to its virgin adsorptive capacity. Because GAC removes all free chlorine and all but a trace of combined chlorine, a post chlorination facility and additional clearwell capacity would be needed for adequate disinfection. Costs for implementing GAC treatment at the CWW facility were estimated to be $12.5 million per year for the filter option and $8.5 million per year for the contactor option.

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

In August 1977, the CWW entered into a cooperative agreement with the EPA to pursue a feasibility study of municipal water treatment using GAC adsorption and on-site regeneration. This project is one of only a few in the country to use full-scale filters, post-filtration contactors, and a granular carbon regeneration (reactivation) furnace, all on site.

The water treatment plant has a design capacity of 10.2 m^3/sec (235 mgd), and is a typical alum coagulation, rapid sand filter plant with two large presettling basins having a combined capacity of approximately 1.4 million m^3 (372 million gallons) and a retention time of 2 to 3 days. The resulting finished water from the treatment plant is low in turbidity and meets all maximum contaminant levels (MCL's) as established under the Safe Drinking Water Act. Average daily pumping rates are currently 6.1 m^3/sec (140 mgd). As such, this system is the largest community water system on the Ohio River.

The main objective of the project was to determine whether the use of GAC in either post-filtration deep-bed contactors or conventional-depth, sand-replacement gravity filters with on-site carbon reactivation would be a feasible means of removing trace organics from Ohio River water at a reasonable cost and without adverse effects on the quality of treatment provided by the existing plant.

A secondary objective was the development of plant design and operating parameters for full-scale plant conversion to GAC treatment. Additional aspects of the project included the study of various filter-adsorber configurations and types of activated carbon in pilot and full-scale applications.

The project was divided into three phases conducted over a period of 3.5 years. In the first phase of the project, three existing rapid sand filters (1.7 L/sec · m^2 or 5 mgd) were converted to GAC filter adsorbers. Various GAC types and bed depths were studied to compare organic removal efficiencies, bed lives, general water quality characteristics, the need for a sand underlayer, and operational problems.

The second phase involved the use of pilot-scale components to investigate the effects of reactivation on the activated carbon's adsorptive ability and to determine the reliability of pilot columns as indicators of the performance of full-scale components. The relative performance of lignite and bituminous-based GAC was also studied.

In the last phase of this project, the relative performances of carbon filters and 0.3 L/sec·m^2 (1 mgd) post-filtration carbon contactors were studied, the most advantageous empty-bed contact time for the GAC was determined, and the effectiveness of on-site reactivation was evaluated. Pilot columns were also operated in parallel with the full-sized units to assess again their usefulness as predictors of full-scale operation. Finally, a significant aspect of this project was the development of preliminary cost estimates for full-plant conversion to the GAC adsorption process.

The first three GAC filter adsorbers went on line in February 1978. While data and experience were being gained on GAC filters and pilot-scale filters and contactors, contracts were negotiated for the construction of plant-sized contactors and a carbon reactivation furnace. Contactor operations started in October 1979, and furnace shakedown operations commenced in March 1980. All operations were carefully monitored and recorded to permit a rational evaluation of the costs, effectiveness, and problems to be expected in full-plant utilization of GAC with on-site reactivation.

Significant Findings

1. GAC is effective in removing a board spectrum of organics from Ohio River water. Though many specific organics were investigated, they were generally present in such low concentrations (ng/L or parts per trillion) that evaluation of the effects of GAC was possible only with rather elaborate and newly developed analytical techniques GAC proved to be effective on all but a few of the organics investigated.
2. Since it is nearly impossible to monitor daily for all of the compounds present in the raw water (many of which are naturally occurring), more general criteria were needed with which to determine the life cycle (or exhaustion) of a GAC adsorber bed. The criteria selected included the existing MCL of 0.10 mg/L trihalomethanes (THM's) and 1.0 mg/L total organic carbon (TOC), which was developed in accordance with design criteria in the proposed EPA GAC regulation (now rescinded), *Control of Organic Chemical Contaminants in Drinking Water,* Federal Register, February 9, 1978.
3. GAC functioned as well as or better than sand in removing turbidity. Filter beds that contained part sand and part GAC did not function as well as either a full sand or a full GAC bed. In all cases, the filter medium was supported by a coarse sand underlayer, and it was virtually impossible to prevent removing some of this sand with the carbon for reactivation. A sand separator was included in the reactivation equipment, but it was not efficient enough for this application. Sand carryover caused frequent shut-downs of the furnace by plugging the fluidizing gas ports. This problem was not associated with contactor operations. Data indicated that floc removal by GAC filters had little effect on the carbon's adsorptive capacity when compared with a similar contact time in a contactor.
4. Longer contact times resulted in more than a proportionately longer service life, thus affording more efficient use of the GAC. Overall, the data indicated that the optimum empty-bed contact time was 7 to 15 minutes under average conditions and greater than 15 minutes during critical summer conditions. These results tend to support the use of contactors that can be constructed with the optimum contact time.
5. Reactivation restored the GAC to its virgin adsorptive capacity with respect to both the various organic parameters and carbon characteristics studied.
6. The cost of buying carbon to make up for that lost in the process of removing it from the bed (filter or contactor), reactivating it, and returning it to the bed would be a significant factor in the overall costs of implementing carbon treatment. The average bed-to-bed GAC loss for nine reactivation cycles for contactors was 15.3% compared with 18.5% for six reactivation cycles for filters. By contrast, earlier estimates by furnace manufacturers and the EPA were about 5%.
7. The National Institute of Occupational Safety and Health (NIOSH) conducted a survey for working conditions. GAC is not considered hazardous, and the level of dust present was well below the acceptable level for nuisance dusts. Though noise levels outside the control room exceeded the standards for continuous exposure, noise was not deemed a hazard because the operators spend only brief periods outside the control room.

   An independent laboratory under contract sampled and analyzed the furnace off-gases. The Southwest Ohio Air Pollution Authority reviewed the laboratory's report and determined that the emissions were well within the limits established for a process plant. In-house analysis of samples from various waste effluents contained no contaminants at levels significant enough to require special treatment before disposal.
8. As expected, GAC removes all free chlorine and all but a trace of combined chlorine. These removals permit the growth of bacteria within the carbon bed with potential for carryover into the distribution system. Thus, though it may not be necessary to increase the

amount of chlorine used throughout the entire treatment process, it would be necessary to construct a post-chlorination facility and additional clearwell capacity to provide sufficient chlorine contact time for disinfection with full-scale GAC conversion.

9. GAC implementation costs were projected for the CWW facility as it exists today. The annual cost of GAC treatment will depend on which treatment alternative is selected — the application of GAC in existing but modified filters or in newly constructed contactors following normal sand filtration.

Under the sand-replacement option, about $37 million would be needed for capital costs and about $8 million for operating expenses (in 1981 dollars). The annual amortization of the capital expenditures would bring the total annual cost to about $12.5 million, adding about 18¢ per hundred cubic feet to the cost of water to both city and suburban customers.

Under the post-filtration contactor option, about $38 million would be needed for capital costs, but only about $4 million for operating expenses (in 1981 dollars). The annual amortization of the capital expenditures would bring the total annual cost to about $8.5 million, adding about 13¢ per hundred cubic feet to the cost of water.

The full report was submitted in fulfillment of Cooperative Agreement No. CR805443 by the City of Cincinnati Water Works under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report consists of two volumes, entitled "Feasibility Study of Granular Activated Carbon Adsorption and On-Site Regeneration:"

"Volume 1. Detailed Report," (Order No. PB 83-121 731; Cost: $25.00, subject to change)

"Volume 2. Supplemental Figures and Data," (Order No. PB 83-121 749; Cost: $43.50, subject to change)

The above reports will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officers can be contacted at:

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