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Research and Development

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Project Summary

Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y.: Phase II

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Phase II continues pilot plant research to examine treatment alternatives for the removal of organic contaminants from ground water. The specific processes of resin adsorption and aeration were evaluated for their ability to remove trichloroethylene, tetrachloroethylene, cis-1, 2-dichloroethylene, and 1, 1, 1-trichloroethane from the City of Glen Cove's drinking water supply.

The resin used was Rohm and Haas' Ambersorb XE-340®*. Major additions and modifications were made to the resin testing system investigated during Phase I to facilitate the study of cocurrent and countercurrent flow applications as well as countercurrent steam regeneration techniques and also to ensure the presence of pure steam throughout the regeneration process. In addition, Phase II included an evaluation of the feasibility of regenerating granular activated carbon (GAC) with steam.

Aeration studies consisted of the determination of organic contaminant removal capabilities by different aeration designs. The relative efficiencies of three aeration methods were compared: diffused aeration vs. packed aeration vs. induced draft cooling. Air-to-water ratios (A/W) were varied with each pilot system.

Flows of 1, 2, and 5 mgd (3785, 7575, and 18,925 m^3/d) were chosen to obtain a range of costs for a full-scale installation that wishes to consider diffused aeration, packed column aeration, or a resin system for treatment of its ground water.

Project results are being used to conduct a third phase in which the technical and economic feasibility of an aeration-adsorption approach will be assessed.

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).

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

Introduction

Background

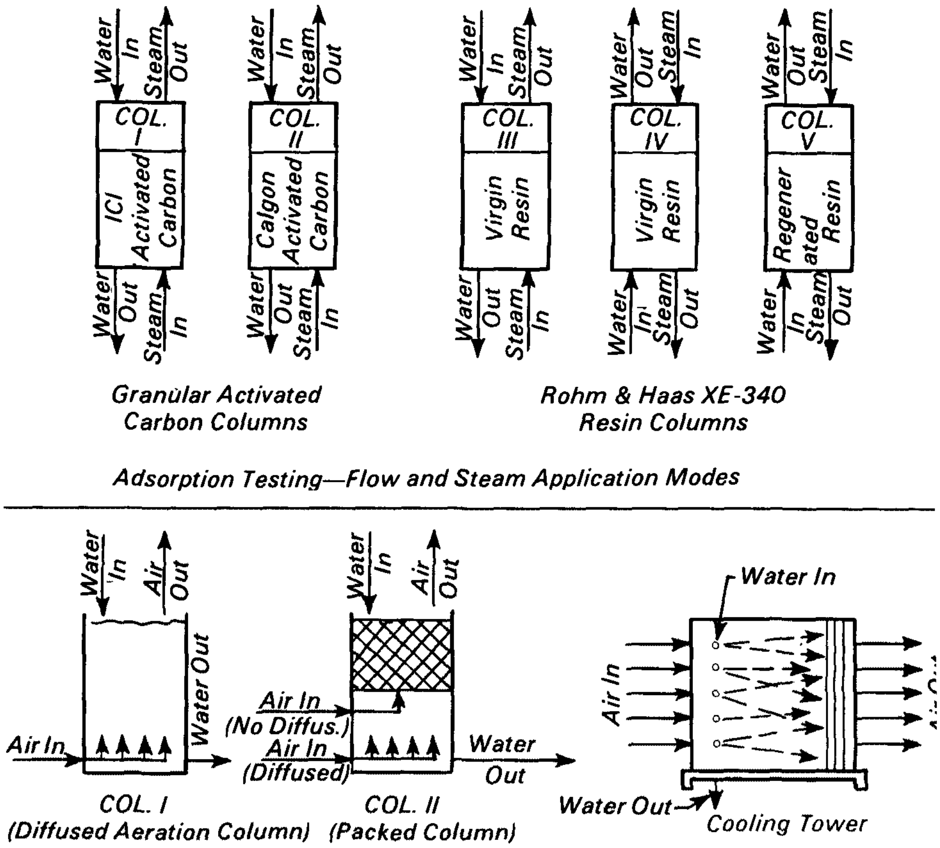
In 1977, the City of Glen Cove, NY, experienced a water shortage resulting from the closing of several wells polluted by the presence of organic contamination. Realizing that the contamination could migrate throughout the aquifer, the city was interested in finding methods for treating its contaminated water. A research project was funded with the EPA in 1978 to study two treatment techniques; adsorption of the contaminants by synthetic resin and stripping of the contaminants by diffused aeration. Pilot plant operation took place for 9 months. The results indicated that (1) the resin was capable of lowering the contaminants to below 1 microgram per liter (μg/L), producing an acceptable water quality for several months and (2) the aeration system, with the proper A/W, could reduce contaminant levels below present New York State guidelines. These promising results warranted the continuation of this project with the overall objectives for obtaining relevant design parameters and capital and operating costs for both removal techniques.

Pilot Plant Facilities

The pilot plant consisted of two separate operations (Figure 1) corresponding to the two methods being evaluated, adsorption and aeration. Several changes were made to the pilot plant equipment used during Phase I before Phase II testing began. These modifications and additions included a change in the size of columns used for the resin testing, the installation of activated carbon columns, a larger steam supply, and the installation of a packed aeration column and a cooling tower for air stripping. The same influent well water flowed to the resin, carbon, and aeration systems.

Changes to the resin system were made to facilitate the testing of upflow and downflow applications, countercurrent steam regeneration, and to ensure that pure steam was present for the regeneration of the resin. Three new columns (III, IV, and V), shown in Figure 1, were installed, each 4 in. (0.1 m) in diameter and 2.2 ft (0.67 m) high. This height allowed for 2 ft (0.61 m) of resin depth and 10% freeboard. Water flow through the resin was in a downward mode for Column III and upward mode for Columns IV and V. An electric steam generator, capable of producing 100 lb/hr (45 kg/hr), was used to regenerate the resin.

Phase II included the evaluation of regenerating GAC with steam. To facilitate this evaluation, two 6-ft (1.8-m) high columns, which were used during the Phase I resin testing period, were left in place and connected to the new steam system. These columns (Nos. I and II in Figure 1) were each filled with a 4-ft depth of activated carbon and operated in a downward mode. Regeneration of these columns was then attempted in an upward mode.



Air Stripping Tests—Flow Application Modes

Figure 1. Pilot plant testing modes of operation.

To continue the evaluation of aeration designs, a second column identical to that used in Phase I aeration testing was installed. Six feet of packing material purchased from Munters Corporation was placed in the column. This packing rested on a ledge 2 ft above the bottom of the column and air was applied below the packing. The packing was supplied in 1-ft sections and was installed so that the orientation of the channels in the packing was altered from layer to layer. The space between the packing and the inside of the column was sealed at each 1-ft interval to prevent air from circumventing the packing. Air was supplied to both the column used in Phase I and the new column from the same blower utilized during Phase I.

To evaluate the stripping efficiency of the cooling tower, a small demonstration model of an induced draft cooling tower, provided by Baltimore Air Coil, was installed. This model is based on a self-sustaining aerating system requiring no outside source of energy other than the water pressure itself.

Relative efficiencies of the three methods of aeration were determined. In addition, the packed aeration column evaluation consisted of determining the effect of introducing air into the column below the packing media by two methods, stone diffusers and a hole in the air pipe at the center of the media. The packed column was operated with the media flooded, partially flooded, and unflooded. Variables in the testing program were the air-to-water ratios (15:1, 10:1, and 5:1), the water depth in the packed aeration columns, and the water flow to the induced draft cooling tower. The water flow to both aeration columns was maintained at 28 gpm (6.4 m^3/hr).

Required analyses were performed onsite with the gas chromatograph system purchased for Phase I and the addition of a new recorder purchased from Varian Corporation.

Results

Adsorption Studies — XE-340® Resin

A summary curve of the performance of the three resin columns appears in Figure 2 for the major contaminants present. A water application rate of 4 gpm/ft^3 of adsorbent (0.42 Lpm/m^3) was used, which resulted in an empty bed contact time of approximately 1.9 min. Column III (virgin resin operating in a downward mode) showed longer service times than Columns IV and V (virgin and regenerated resins operating in the upward mode). In addition, tetrachloroethylene was more effectively removed than cis-1, 2-dichloroethylene. For example, the performance of Column III observed from Figure 2 shows the following service times to reach an effluent level of 5µg/L: 43 days for cis-1, 2-dichloroethylene, 110 days for trichloroethylene, and 142 days for tetrachloroethylene. The data indicate the importance of establishing an effluent target level so that proper design, operating procedures, and costs can be determined.

Several steam regenerations took place and the results showed that, in most cases, steam stripping removed the majority of the organics from the resins. Mass balances indicated about 90% of total organics by weight were removed. To achieve this stripping efficiency, approximately 20 to 30 bed volumes of steam were required. Methods of condensate disposal were researched and the results are described in the complete report. "Superloading," a process whereby the aqueous phase of the condensate collected from one regeneration cycle was returned to the resin column next in need of regeneration, appeared successful as observed by the concentration of organics percent in the organic layer of the newly regenerated resin's condensate. A further positive indication of success was that the resin's performance returned to about virgin conditions.

Granular Activated Carbon Regeneration Studies

The purpose of adsorption testing using activated carbon was to determine the feasibility of regenerating spent activated carbon with steam rather than the adsorptive ability of the carbon. Because a hydraulic loading twice the manufacturer's recommendation was used to load the carbon in as short a time as possible, no attempt was made to evaluate the adsorption results of the activated carbon or compare them to the resin.

Regeneration of activated carbon with steam took place twice for each of two GAC's using the equipment sized for the regeneration of resin in Phase II and no special considerations were given to the carbon. The carbons were regenerated using the maximum steam flow available over a 24-hr period. No attempt was made, however, to achieve zero contaminants in the steam condensate.

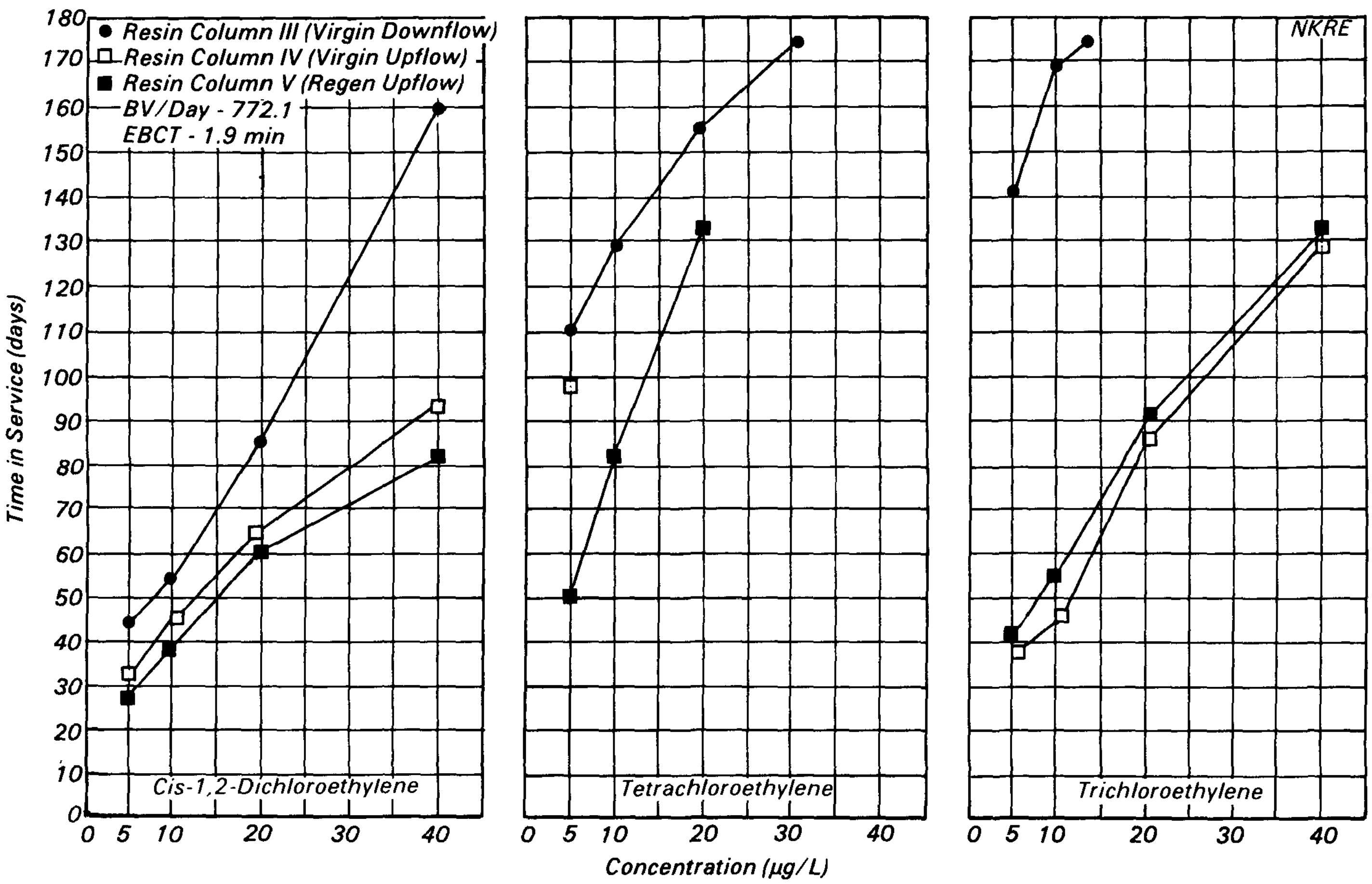


Figure 2. *Variance of service time with respect to contaminant breakthrough levels.*

Several steam regenerations were conducted, and the results showed low regeneration efficiency when compared to the resin. Mass balances indicated that only 25% to 35% of the organics were stripped from the carbons. In addition, the effluent from the regenerated carbon columns exhibited breakthrough contaminant concentrations in approximately half the service time of virgin resin or the previous carbon run.

Aeration Studies

Results from the diffused aeration and packed column studies represent percent removals for each organic contaminant at the three A/W evaluated (Figure 3). In general, increased A/W resulted in increased contaminant removals for the designs tested — the lowest average removals occurred at an A/W = 5:1 and the highest occurred at A/W = 15:1. The packed column, operated in the unflooded mode with air introduced through spargers, removed a greater percentage of each contaminant at a given A/W than the other systems evaluated. In addition, removal efficiencies for both systems tested were greatest for tetrachloroethylene (overall average 84%) and least for cis-1, 2-dichloroethylene (overall average 67%). Both designs, however, resulted in effluent contaminant levels below the present New York State guideline level (50 µg/L per contaminant) 98% of the time for all contaminants. The induced draft cooling tower was the least effective removal method evaluated and, in fact, was never able to reduce trichloroethylene levels below the guideline level.

Estimated Costs for Full-Scale Installations

Figures 4 and 5 summarize the estimated capital and operating costs for full-scale design for the major systems evaluated during Phase II. The estimates indicate that the resin system has the greatest capital cost and the diffused aeration system the least. Approximately 40% to 65% of the capital cost for the resin system is for the required piping and valves, particularly those associated with steam regeneration. Operating costs, however are greatest for the diffused aeration system and least for the resin system. The greater costs for the aeration systems are a result of the electrical power required to provide the air. These costs could be reduced if environmentally acceptable alternative methods of

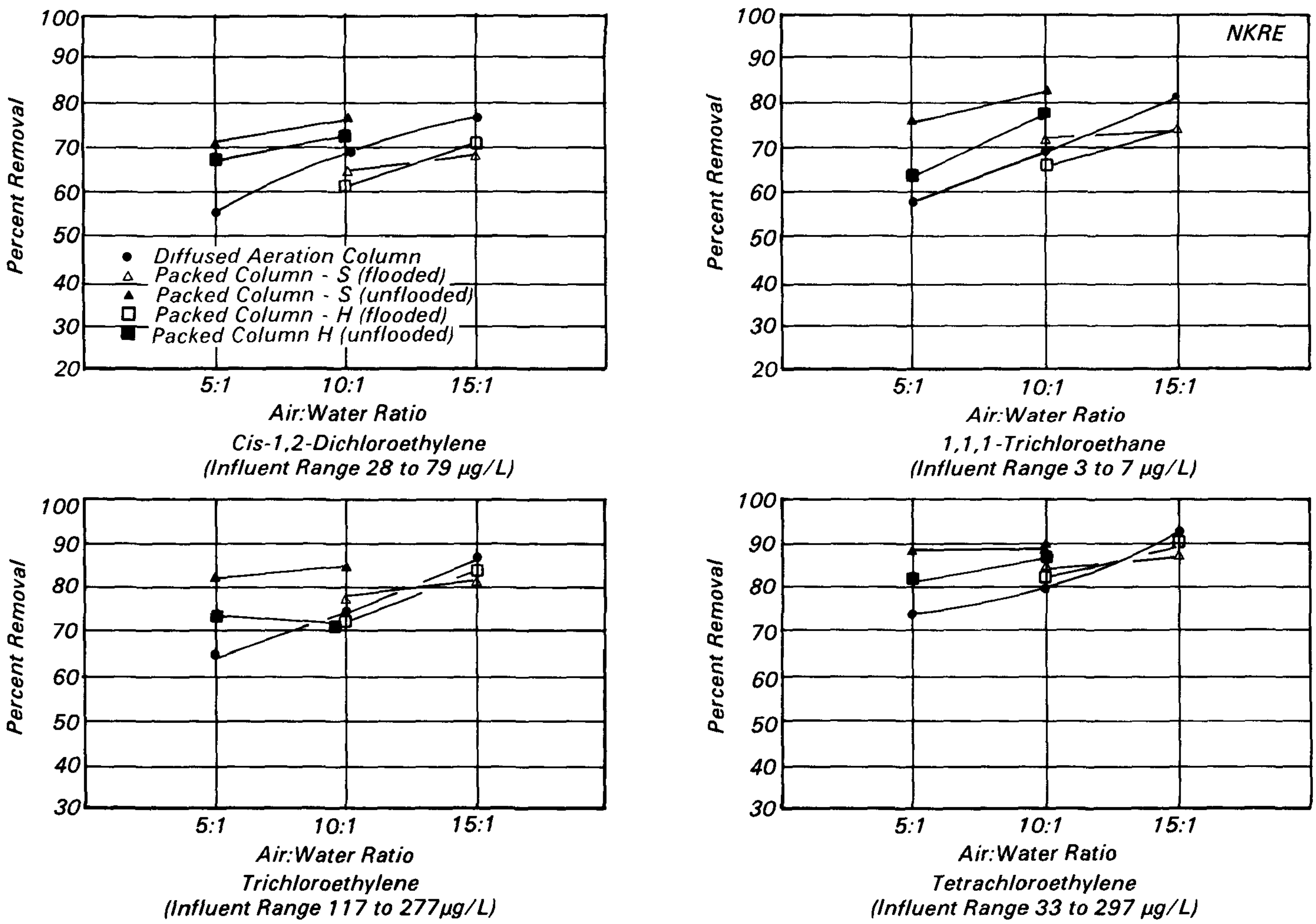


Figure 3. *Average percent removals at selected air : water ratios.*

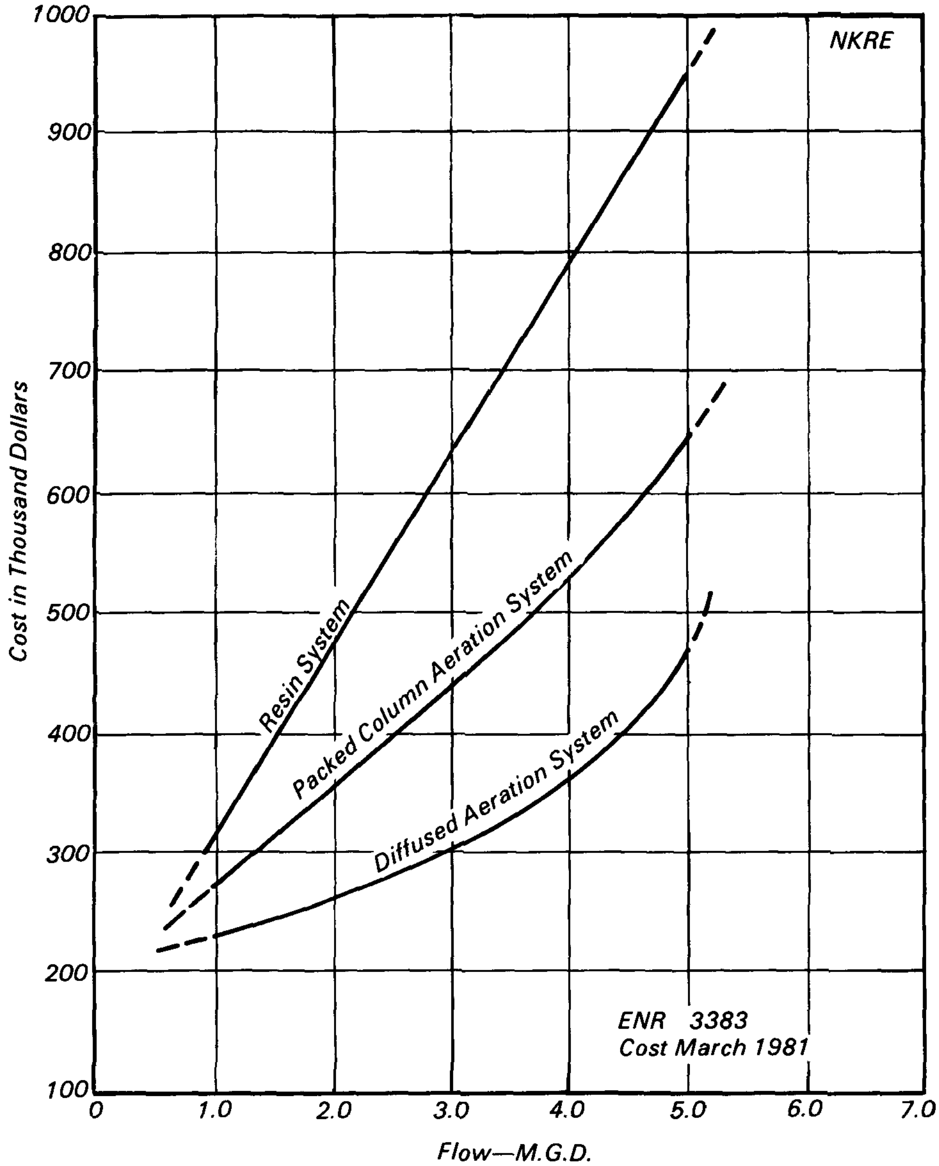


Figure 4. *Capital cost comparison.*

air introduction can be demonstrated and used.

Conclusions

Resin Adsorption Studies

1. The test results using Rohm and Haas' Ambersorb XE-340® indicated that this resin was capable of reducing the levels of contaminants to very low concentrations, and, in most cases, virgin or freshly regenerated resins achieved reductions of each contaminant to less than 1 μg/L. These results were achieved for the following influent ranges: cis-1, 2-dichloroethylene, 38 to 79 μg/L; 1, 1, 1-trichloroethane, 3 to 7 μg/L; trichloroethylene, 117 to 277 μg/L; and tetrachloroethylene, 33 to 207 μg/L.
2. The best mode of operation was downward flow application and upward steam regeneration.
3. The ability of the resin to be regenerated with steam, achieving better than 90% of virgin adsorbent capacity, was conclusively demonstrated. Steam regeneration techniques, however, require further development. Approximately 20 bed volumes of steam at an application rate of 1 bed volume /hr were required to regenerate the resin. The collecting of the condensate, separation of the organic phase for disposal, and recycling the condensate to the resin column next to be regenerated for treatment was determined feasible during this phase of testing.

Granular Activated Carbon Regeneration Studies

1. The results of the three 24-hr regeneration attempts (two on the ICI carbon and one of the Calgon carbon) showed that the regeneration of activated carbon with steam, utilizing the steam equipment and conditions designed to regenerate resin, was not successful.

Diffused Aeration Studies

1. Diffused aeration appears to be a viable treatment option for the removal of volatile organic contaminants from groundwater, and this approach could be used as a pretreatment to additional treatment if more stringent water quality is required than that achievable by diffused aeration.
2. Aeration can reduce the contaminants present in the well water at Glen Cove to levels below present New York State guidelines, and to levels that might be acceptable throughout the nation. This was true greater than 98% of the time for all A/W tested (5:1, 10:1, and 15:1) and for all contaminants involved.

Packed Column Aeration Studies

1. Both conclusions made above for the diffused aeration studies also apply to the packed column aeration studies.
2. The use of packing material in the unflooded mode produced the best results with a slight improvement over those for diffused aeration at A/W of 5:1 and 10:1; however, at increased estimated capital and operating costs.

Recommendations

1. Evaluate the combination of aeration and adsorption as a possible method of organic contaminant removal from groundwater. This

approach would reduce the major portion of the contamination by aeration and polish the water by adsorption.

2. Determine the maximum hydraulic loading for the resin system. To date, only one application rate (4 gpm/ft³) has been used. Several rates should be tested using both raw and aerated well waters.
3. Continue the development of a practical and economically feasible stead regeneration technique. The proper handling and disposal of the steam condensate need to be optimized and the economics established.
4. Evaluate the process of multi-stage aeration as an approach to achieving organic contaminant removal.

The full report was submitted in fulfillment of Cooperative Agreement No. 806355-01 by Nebolsine Kohlmann Ruggiero Engineers, P.C., for the City of Glen Cove, NY, under the partial sponsorship of the U.S. Environmental Protection Agency.

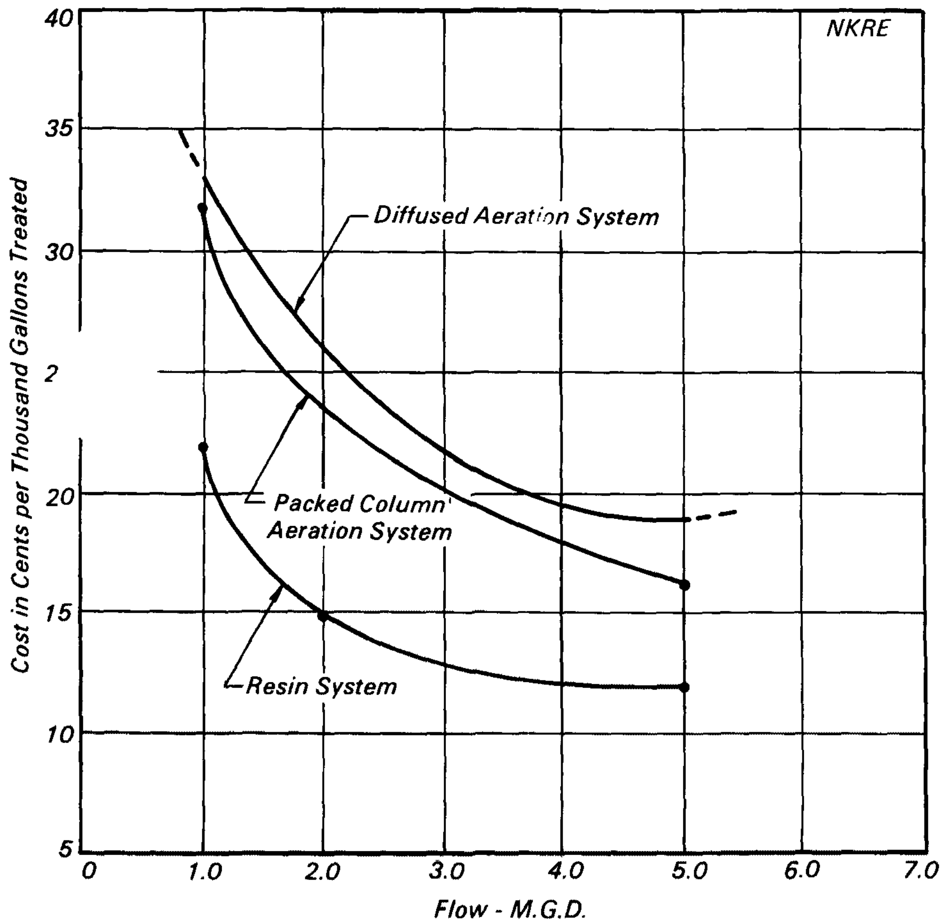


Figure 5. *Comparison of annual operating cost per thousand gallons treated (energy cost at 9¢/kw-hr).*

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The complete report, entitled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y.—Phase II," (Order No. PB 82-258 963; Cost: $12.00, subject to change) will be available only from:

National Technical Information Service
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