



## Project Summary

# Organic Contaminant Removal in Lower Mississippi River Drinking Water by Granular Activated Carbon Adsorption

Wayne E. Koffsky, Noel V. Brodtmann, and Ben W. Lykins, Jr.

Concern over the detection of known and suspected carcinogens in the New Orleans, Louisiana, area water supplies resulted in a research effort to provide data for removal of these compounds. The primary objective was to examine the efficiency of using granular activated carbon (GAC) for the removal of organic contaminants in drinking water. Two full-scale systems were compared and evaluated--a post filtration adsorption GAC filter in series with a sand filter and a combined filtration adsorption GAC filter. Also examined were the ability of pilot GAC columns to predict the organics removal efficiency of full-scale GAC filters, the effects of varying empty-bed contact times, and variations in the organic contents of drinking water resulting from different types of water treatment processes. Correlations between certain nonspecific parameters (such as total organic carbon) and specific individual parameters were examined in the hope that one or more nonspecific parameters could be used as a surrogate monitoring parameter.

Both GAC systems effectively removed organic contaminants with the same relative adsorption efficiencies. Efficiencies were not reduced because of pore blockage by turbidity. A few organic substances (phthalates, n-alkanes, and substituted benzene derivatives) had little or no adsorptive affinity for GAC, however, at the ng/L level.

*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

The Mississippi River, in its 3,862-kilometer (2,400-mile) course to the Gulf of Mexico, ultimately drains nearly two-thirds of the continental United States. Water from the Mississippi and its major tributaries support many cities and industries and serves as the receiver for vast quantities of municipal and industrial wastes on a continuous basis. Moreover, some of the Nation's largest petrochemical manufacturing complexes are located along both banks of the river from Baton Rouge to below New Orleans. These large industrial complexes continuously cycle vast quantities of cooling and process water back to the river, in many cases adding dissolved organic contaminants to the river's total burden. It is this water that is the source of drinking water for the New Orleans metropolitan area, including Jefferson Parish.

This project, which was one of the first of its kind in the country on a full size plant scale, is of major importance particularly in light of the growing public and official concern about contaminants in the Nation's drinking water supplies. Furthermore, new and impending Federal legislation and regulations have required an expansion of the collective knowledge and abilities in the area of removing microcontaminants from drinking water during the treatment process.

## Procedures

### Study Design

To meet the study objectives, a four-phase study was designed. Four non-specific organic parameters, 18 volatile organic species, 66 nonvolatile organic species, and general chemical and microbiological water quality parameters were monitored for each step in the full-scale treatment process. This process included the post-filtration adsorption and the combined filtration adsorption GAC filters. During the latter two phases, parallel effluent quality data were collected from two 7.6-cm. diameter (3-in.-diameter) glass columns simulating both types of full-scale GAC filtration systems. Similar data were collected for four 10.2-cm.-diameter (4-in.-diameter) glass columns in series, each with an empty bed contact time (EBCT) of 10 min. The cumulative EBCT of each consecutive column in series was thus 10, 20, 30, and 40 min.

Flow rates, hydraulic loadings, and EBCT for all of the GAC systems, both full- and pilot-scale, were evaluated and used in comparative interpretations of the analytical data. GAC losses for the adsorber and filter adsorber were also closely monitored.

### Treatment Schemes

During each of four sequential phases of the project (I, IIA, IIB, and III), two different GAC filter configurations were evaluated simultaneously to determine the effect of influent turbidity on GAC adsorption and the suitability of 12x40 mesh GAC as a filtration media. The first filter (the filter adsorber) received clarified chloraminated water and served the dual purpose of removing filterable turbidity and adsorbing dissolved organic compounds. The second GAC filter (the adsorber) received sand filter effluent and functioned as a post-adsorption treatment step.

During Phases I and IIA, the filter adsorber consisted of a 15.2-cm. (6-in.) layer of sand covered by about 61-cm. (24-in.) of GAC (Westvaco WVG 12x40).<sup>\*</sup> For these two phases (I and IIA), the adsorber consisted of 76.2-cm. (30-in.) of the same type of carbon that was used in the filter adsorber. During Phases IIB and III, the sand layer was removed and the filter adsorber contained approximately 76.2-cm. (30-in.) of GAC (Westvaco WVG 12x40 for Phase IIB, and Calgon Filtrasorb 400 for Phase III). The adsorber for these two phases (IIB and III) also contained

76.2-cm. (30-in.) of the same type of GAC used in the filter adsorber.

All of the treatment variations along with the dosages used during each phase of the project are shown in Table 1.

To determine how well pilot columns could predict the performance of a similar full-scale system, two GAC pilot columns were operated under the same conditions and in parallel with the full-scale adsorber and filter adsorber units during Phases IIB and III. Both of these Pyrex glass columns were 7.6 cm. (3-in.) in diameter and 1.5-m. (5-ft.) high, and contained 76 cm. (30-in.) of GAC supported by 15.2-cm. (6-in.) of gravel. These pilot columns were designated as the adsorber simulator and the filter adsorber simulator. Each received influent water from the same sources and at the same relative hydraulic loadings as their full-scale counterparts.

To observe the effect of EBCT upon carbon adsorption, four other GAC pilot columns (contactor Nos. 1, 2, 3, and 4) were operated in series during Phases IIB and III at a flow rate of 74.1 mL/min. to simulate the effects of 10, 20, 30, and 40 min. of EBCT on a system operating as an adsorber. These Pyrex glass columns were 10.2 cm. (4-in.) in diameter and 1.8-m. (6-ft.) high. Each column contained 91-cm. (36-in.) of GAC supported by 15.2-

cm. (6-in.) of gravel. The influent water for these series contactors was the same as that for the adsorber filter and the adsorber simulator column.

### Results and Conclusions

1. The conventional treatment process effectively removed some organic contaminants, notably the surrogate parameters: total organic carbon (TOC) (3% to 25%) and trihalomethane formation potential (THMFP) (22% to 40%) across the precipitator; and ultraviolet (UV) (50% to 55%), rapid fluorescence measurement (RFM) (14% to 28%), and emission fluorescence scan (EMF) (10% to 31%) upon the addition of 0.5 to 1.0 mg/L potassium permanganate. These results indicate that conventional water treatment is significantly, but not totally, effective in removing general types of organic contaminants from drinking water. No significant difference with respect to organics removal was observed between lime softening and polyelectrolyte polymer treatment. Because of the nonreactive nature of monochloramine with the THM precursor substances, the formation of trihalomethanes (THM) was not affected by the difference in pH of these treatment processes.

2. The GAC systems were effective in removing organic contaminants studied.

**Table 1.** Treatment Schemes of All Phases During the Research Project

Treatment Step	Phase I 2/77 to 8/77	Phase IIA 11/77 to 4/78	Phase IIB 7/78 to 1/79	Phase III 4/79 to 10/79
Potassium permanganate (mg/L)	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0
DADM*-type polymer (mg/L)	0.5-4	4-8	2-8	1-8
DMA†-type polymer (mg/L)	-	0-1	0-3	0-3
Ferric chloride (mg/L)	-	-	-	0-25
Lime (mg/L)	50-115	7-10	8-10	-
Ferrous sulfate (mg/L)	3.5-34	-	-	-
Sodium hexameta-phosphate (mg/L)	1.0	1.0	1.0	-
Monochloramine residual (mg/L)	1.0-2.1	0.9-2.0	0.8-2.2	0.6-2.4
GAC type	WVG 12x40	WVG 12x40	WVG 12x40	Filtrasorb 400
GAC-adsorber (depth in cm.:m <sup>3</sup> )	76.2:27	76.2:27	76.2:27	76.2:27
(depth in in.:ft <sup>3</sup> )	30:954	30:954	30:954	30:954
GAC-filter adsorber (depth in cm.:m <sup>3</sup> )	61:21.6	61:21.6	76.2:27	76.2:27
(depth in in.:ft <sup>3</sup> )	24:763	24:763	30:954	30:954

<sup>\*</sup> Mention of trade names or commercial products does not constitute endorsement or recommendation for use

<sup>\*</sup> - diallyldimethylammonium chloride  
† - dimethylamine

Those GAC systems operating in the adsorber mode exhibited the same relative adsorption efficiencies as those operating in the filter adsorber mode; this indicated the applicability of either type of system for organics removal. No observable reduction in the adsorption efficiency of the filter adsorber existed because of pore blockage by turbidity.

3. The GAC pilot column simulators were generally quite effective in predicting the adsorption efficiencies of their respective full-scale counterparts after taking into account the variations caused by GAC losses during backwashing in the full-scale systems. Thus the pilot column system can be an effective and economical tool in the design of full-scale GAC facilities.

4. The breakthrough profiles of the surrogate parameters through the various GAC systems did not correlate reliability with those of the individual parameters under study when simple linear correlations were used. Multiple, nonlinear-type correlations were indicated; but none were found that correlated well with the data.

5. Evidence indicates that a critical GAC bed depth (which varies for different substances) is required to remove a particular organic contaminant. This critical bed depth is generally deeper for the THMs than it is for the higher-molecular-weight substances such as the chlorinated hydrocarbon insecticides because these THM substances break through the GAC beds at different rates. For example, the GAC beds with a 20-min. EBCT were saturated with THMs within 100 days, but contactor No. 1 with a 10-min. EBCT continued to remove more than 90% of the chlorinated hydrocarbon insecticides at the end of each phase.

The increase in EBCT across the series contactors resulted in increased adsorption efficiency for most of the parameters under study. But the increment of the increase in efficiency across each consecutive contactor decreased as EBCT increased.

6. A steady-state condition was reached for the surrogate parameters of TOC, UV, RFM, EMF, and THMFP after approximately 100 days where a relatively constant removal of these constituents was observed. The relative removal levels for each constituent increased with EBCT up to 30 min.; after that, no further significant removal was observed.

7. The use of chloramination (specifically monochloramine) as the sole means of disinfection without the use of GAC filtration was effective in maintaining the THM

level below 10 ppb in the distribution system. A mean coliform distribution of zero and total bacteria level of less than 50 counts/mL were observed during this time.

8. A concentration gradient effect was observed for both types of GAC systems. Even after saturation, large surges in influent concentration were effectively adsorbed with relatively no apparent adverse effects in the effluent of the GAC systems. This phenomenon greatly improved the effectiveness of GAC filtration in combating chemical spills in the surface water source.

9. The following organic substances had little or no adsorptive affinity for GAC at the ng/L level and did not exhibit the typical s-shaped breakthrough curve: phthalates, n-alkanes, and substituted benzene derivatives. Some of these substances exhibited a low degree of constant removal. Also, the surrogate parameters

(TOC, UV, RFM, EMF, and THMFP) showed less than 100% removal after 40 min. of EBCT during the series contactor studies.

10. Variations in the effectiveness of the different types of GAC used during this project were observed for the removal of the lower molecular-weight volatile substances. The WVG 12x40 mesh carbon used during the first three phases appeared to have had a higher adsorptive efficiency for these substances than did the Filtrasorb 400 used during Phase III.

11. The 12x40 mesh GAC medium in the filter adsorber appeared to remove turbidity as well, if not better, than the sand medium when equal depths of the media were compared. Thus since the adsorption efficiency of the two GAC systems (adsorber and filter adsorber) are similar, conversion from sand filtration to GAC filtration (sand replacement) would appear to be advantageous for those seeking organic removal and turbidity reduction.

*Wayne E. Koffskey is with the Jefferson Parish Department of Public Utilities, Jefferson, LA 70121; Noel V. Brodtmann is presently with Environmental Professionals Ltd., Metairie, LA 70001; the EPA author Ben W. Lykins, Jr. (also the present EPA Project Officer see below) is with the Municipal Environmental Research Laboratory, Cincinnati, OH 45268.*

*Jack DeMarco was the EPA Project Officer.*

*The complete report, entitled "Organic Contaminant Removal in Lower Mississippi River Drinking Water by Granular Activated Carbon Adsorption," (Order No. PB 83-194 506; Cost: \$47.00, subject to change) will be available only from:*

*National Technical Information Service  
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*The present EPA Project Officer can be contacted at:  
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