



Project Summary

Effectiveness of Activated Carbon for Removal of Toxic and/or Carcinogenic Compounds from Water Supplies

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This research investigated the dynamic performance of fixed-bed granular activated carbon processes for treating public water supplies. The adsorption of representative toxic and/or carcinogenic trace compounds of man-related origin was evaluated.

Adsorption of humic substances—the predominant class of natural organic matter and the trihalomethane (THM) precursor—was also studied.

Adsorption efficiency tests and cost effectiveness evaluations were performed initially for a number of commercial activated carbons. A bituminous-base carbon was then selected for further use throughout the research.

Equilibrium, rate and continuous long-term adsorption studies were conducted for humic acids at raw water background concentrations and for carbon tetrachloride, benzene, two commercial mixtures of PCB's, dieldrin, and *p*-dichlorobenzene at representative trace concentration levels.

Experimental breakthrough profiles were developed for each of the trace compounds alone and in the presence of background humic acid solutions to investigate competitive and/or chromatographic effects. The results indicate that trace compound adsorption is generally affected adversely by background organic matter.

The adsorption capacity of activated carbon for humic substances was found to be markedly enhanced by the presence and concentration of several common constituents of water supplies, including Mg^{2+} and Ca^{2+} ions. There was evidence from the work that enhanced removal of humic substances might also provide for more effective removal of associated organic molecules—such as PCB's and dieldrin—in water treatment operations.

The Michigan Adsorption Design and Applications Model (MADAM) was generally able to simulate and predict the performance of fixed-bed adsorbers to remove the compounds investigated in the absence of the humic acids. With the strictly adsorption version of MADAM, reliable predictions were difficult because of the prolific biological growth in the adsorbers that received the humic acids. For such cases, biological degradation dynamics must be incorporated in the model. The single-solute version of MADAM was able, however, to simulate/predict independent pilot data provided by the EPA about the adsorption of 1,2-dichloroethane in the presence of naturally occurring background organics in Ohio River water.

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 widespread occurrence of undesirable trace organic compounds in public water sources is a matter of record. Urban and suburban developments along major water courses have affected both implicit and explicit multiple reuse of water. In many areas of the country, the need for successive reuse of water—either planned or covert—has led to accumulation of persistent organic compounds of industrial and/or agricultural origin in raw water sources and supplies, frequently to concentration levels that pose threats to human health and well being. Further, a variety of natural organic substances can be transformed to potentially harmful THM's in the course of water treatment with chlorine.

Treatment with granular activated carbon has evolved as a technically and economically viable technology for removing many of the compounds of concern from public water supplies. The efficiency and cost effectiveness of the design and operation of this process, however, depend markedly on optimum use of the adsorption capacity of the carbon, consistent with treatment objectives.

To accomplish efficiency and cost effectiveness, appropriate data regarding system dynamics, preferably from relatively simple laboratory experiments must be developed, and the body of these data must be synthesized in such a manner that they can be incorporated in actual plant design and operation. Mathematical modeling and simulation of the dynamics of granular carbon systems can be a particularly effective means for synthesis of data regarding adsorption dynamics, and resultant models can be employed to good advantage in predicting system performance under a variety of conditions. Models of this type can thus function as vehicles for design, control, and operation of adsorption systems.

The research described here focused on developing rate and equilibrium data on activated carbon adsorption of several representative compounds of natural, industrial, and agricultural origin from water: specifically, humic acids, carbon

tetrachloride, benzene, polychlorinated biphenyls, dieldrin, and *p*-dichlorobenzene. The Michigan Adsorption Design and Applications Model (MADAM), which has demonstrated potential for use in the design and operation of granular carbon systems for wastewater treatment, was used for simulation and prediction of the dynamic performance of carbon beds to remove trace quantities of these compounds under conditions approximating those encountered in water treatment practice. The MADAM algorithms incorporate coupled mass transfer resistances (external film and internal surface diffusion) and accommodate nonlinear isotherm expressions. Model predictions were predicated for the most part on bench-scale equilibrium and rate studies. Column experiments were then conducted to experimentally verify the model predictions and simulations.

Experimental Approach

Adsorption Equilibria

Experimental Methodology

Adsorption equilibrium experiments were conducted for each compound using conventional static bottle-point techniques, i.e., placing different amounts of activated carbon in each of a series of air-tight glass reactors. The reactors were then filled with background solutions spiked with the compound of interest. Depending on the compound's characteristics and the objective of a specific experiment, the background solution consisted of organic-free water (OFW), deionized-distilled water (DDW), tap water, or a solution of a 5 mg/l of humic acid prepared in one of the preceding background waters. The reactors were then agitated at room temperature to achieve equilibrium. The residual concentrations were determined using appropriate analytical techniques.

Isotherm Parameter Evaluations

Several theoretical and empirical equations, including the Freundlich, Langmuir, and three-parameter isotherms, were investigated for mathematical description and quantification of the adsorption equilibrium data. The data were best described by the Freundlich and the three-parameter isotherms, and the former was chosen for subsequent use because of its simpler form, which facilitated parameter estimation.

Adsorption Rates

Experimental Methodology

Completely-mixed batch (CMB) reactor adsorption rate experiments with the trace compounds were performed in carefully sealed 2.6-L glass reactors; 3.5-L capacity open-top glass reactors were used for the humic acid tests. Weighed and prewetted quantities of granular activated carbon were added to appropriate experimental solutions in the vapor-phase-free reactors. The carbon was dispersed by a motor-driven glass stirrer, and 5-ml samples were withdrawn at fixed time intervals. A displacement plunger built into the reactors eliminated introduction of headspace by sample volume displacement.

Rate Parameter Evaluations

The MADAM model was used to estimate mass transfer coefficients simultaneously from the CMB rate data. A two-parameter search routine was used to determine values for the external film transfer coefficient, k_f , and the intraparticle surface diffusion coefficient, D_s . A CMB rate experiment that employed a large amount of carbon to nearly deplete the solute within the first few minutes of the experiment was used to estimate a close control value for k_f . These coefficients were then used in the fixed-bed version of MADAM to predict breakthrough profiles. Sensitivity analyses were also performed to characterize the rate controlling mechanism.

Fixed-Bed Adsorbers

Experimental Methodology

Experimental fixed-bed column studies were designed and executed to investigate dynamic adsorption behavior and to obtain data about adsorption breakthrough characteristics for prediction/simulation modeling of each compound. The studies used mini-column, or large column experiments, or both. For mini-column, 1-ft. glass adsorbers with an internal diameter (ID) of 1 cm were employed; for large columns, 6-ft. glass columns with a 3-cm ID. Feed tanks were constructed of glass, or stainless steel, or both. All transfer tubing was stainless steel, or Teflon, or both. Influent and effluent samples were collected manually. Extreme care was taken during sample transfer to minimize losses by volatilization. When neces-

sary, the feed solution was dosed with 2 mg/L silver to inhibit biological growth.

Humic Acids

To provide a reasonably reproducible reference point and to ensure experimental consistency, Aldrich Chemical technical grade dried humic acid was used. Different techniques for analysis were investigated, and ultraviolet spectrophotometry at a wavelength of 250 nm was selected for routine use.

Equilibria

The data indicated (1) capacity was enhanced with decreased carbon particle size; (2) the extent of adsorption of the "humic acids" fraction was larger than that of "fulvic acid" fraction; (3) the amount of humic acid adsorbed generally increased with decreasing pH; (4) initial concentration has a significant effect on the position of the adsorption isotherm; (5) carbon of a given particle size simply sieved from a commercial lot demonstrated a larger capacity for humic acids than carbon of the same particle size prepared by crushing larger particles and sieving to the given size; and, (6) several ionic species—including Ca^{2+} , Mg^{2+} , and OCl^- —substantially enhance the adsorption capacity of humic acids (Figure 1).

Rates

Model simulation analyses performed on the CMB rate data for adsorption of humic acids from DDW to estimate values for the external film transfer and internal surface diffusion coefficients yielded $k_f = 1.44 \times 10^{-4}$ cm/sec and $D_s = 1.64 \times 10^{-10}$ cm²/sec, respectively.

A similar procedure used to analyze data for adsorption from tap water yielded $k_f = 7.04 \times 10^{-4}$ cm/sec and $D_s = 1.36 \times 10^{-10}$ cm²/sec. As noted, the background solution has a substantial effect on the adsorption rate of humic acid on carbon.

Fixed-Bed Adsorbers

The influence of carbon particle size, hydraulic loading, and background solution on the dynamic adsorption behavior of humic acids was systematically characterized in these studies. Typical breakthrough profiles for adsorption of humic acids from tap water and DDW indicate differences in the dynamic adsorption characteristics in the two different background solutions are pronounced (Figure 2).

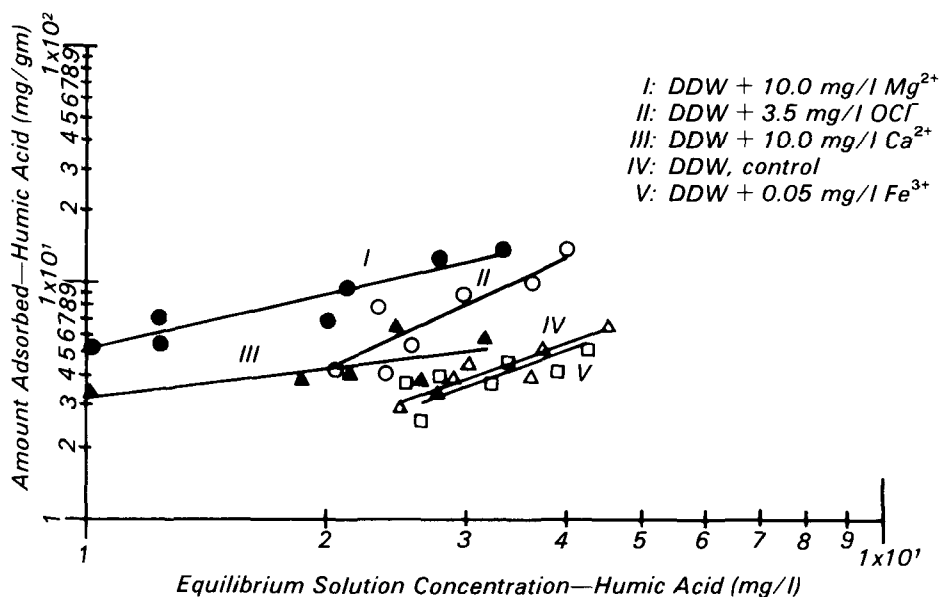


Figure 1. Adsorption isotherms for humic acids; effect of selected inorganic species on adsorption capacity. $C_0 = 4.9$ mg/l.

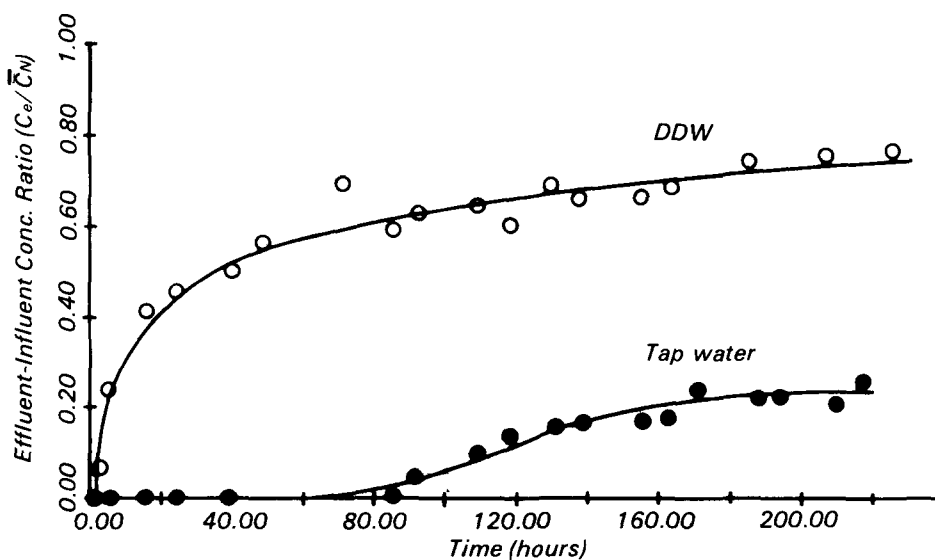


Figure 2. Column breakthrough profiles for humic acids in different background solution. $C_0 = 5$ ppm; flow = 1.94 gpm/ft²; 250 grams of 16.20 US sieve size carbon.

Simulation-prediction analyses were conducted for humic acids in DDW and tap water for different bed lengths. Extensive biological growth was noted, and it was concluded that the strictly physicochemical version of MADAM could not be used as a truly predictive model under these circumstances. Rather, MADAM was used in simulation mode with the values for the film transfer coefficient, k_f , and the intraparticle

diffusion coefficient, D_s , being determined from the column data. Figure 3 depicts experimental data and the simulated MADAM breakthrough profile for adsorption of humic acid from DDW.

Mechanism of Removal

A notable characteristic of the column data for humic acids was a relatively rapid approach of the breakthrough profile to an apparent plateau. The

precise level of the plateau, however, varied with system particulars and operating conditions. This was true for all adsorption column experiments conducted with humic acids for this investigation and has likewise been observed in other studies. Various mechanisms have been proposed for the near steady-state removal observed at the breakthrough plateaus; the two most prominent suggestions being catalytic oxidation and biological degradation, although secondary micropore diffusion is another possibility. Static adsorption equilibrium measurements were designed to gain some insight to the magnitude of bio-oxidation and/or catalytic oxidation effects. It was concluded that a combination of biological degradation and hindered diffusion of the large macromolecules within the carbon micropores was responsible for the observed plateau development.

Carbon Tetrachloride

Several different sample collection and concentration techniques—dynamic headspace, static headspace, liquid-liquid extraction, and aqueous injection—were evaluated. All demonstrated some degree of compatibility with the methodologies used to evaluate the adsorption properties and characteristics of CCl_4 . The liquid-liquid extraction technique followed by electron capture gas chromatographic analysis was selected as most appropriate for this work.

Equilibria

These data indicated that: 1) pH has no significant effect on the equilibrium adsorption characteristics of CCl_4 ; 2) there is no dependency of CCl_4 equilibrium capacity on carbon particle size; 3) initial concentration has no significant effect on the position of the isotherm for CCl_4 ; and, 5) background organic substances such as humic acids adversely affect the capacity of activated carbon for adsorption of CCl_4 .

Rates

A simulation-modeling analysis was performed on the CMB data for adsorption of CCl_4 from OFW to evaluate external and internal mass transfer coefficient values of $k_f = 4.07 \times 10^{-3}$ cm/sec and $D_s = 3.02 \times 10^{-10}$ cm²/sec, respectively. Values in the presence of 5 mg/L of humic acid were $k_f = 3.78 \times 10^{-3}$ cm/sec and $D_s = 1.86 \times 10^{-10}$ cm²/sec. The intraparticle diffusion coefficient

for the system containing humic acids was significantly lower than that for the organic-free system, suggesting that humic acid molecules retard the diffusion of CCl_4 molecules within the carbon pore structure.

Fixed-Bed Adsorbers

These studies were designed and executed in two phases. Phase I consisted of mini-column tests to obtain preliminary data for predictive model (MADAM) calibration. Phase II consisted

of breakthrough runs with large fixed bed adsorbers to develop data for model verification. Examples of mini-column and large column data and predicted breakthrough profiles are illustrated in Figures 4 and 5, respectively.

Desorption and Competitive Adsorption

Equilibrium adsorption-desorption experiments for CCl_4 using the bottle point technique indicated no significant equilibrium hysteresis. Rates of desorp

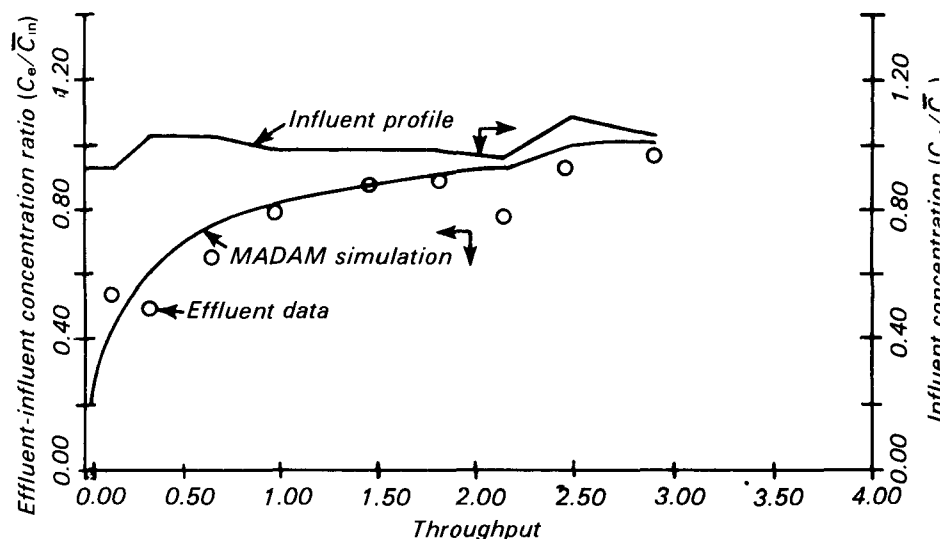


Figure 3. Effluent and influent concentration profiles for humic acids in DDW $C_0 = 5$ ppm; empty bed contact time (EBCT) = 15.6 min.

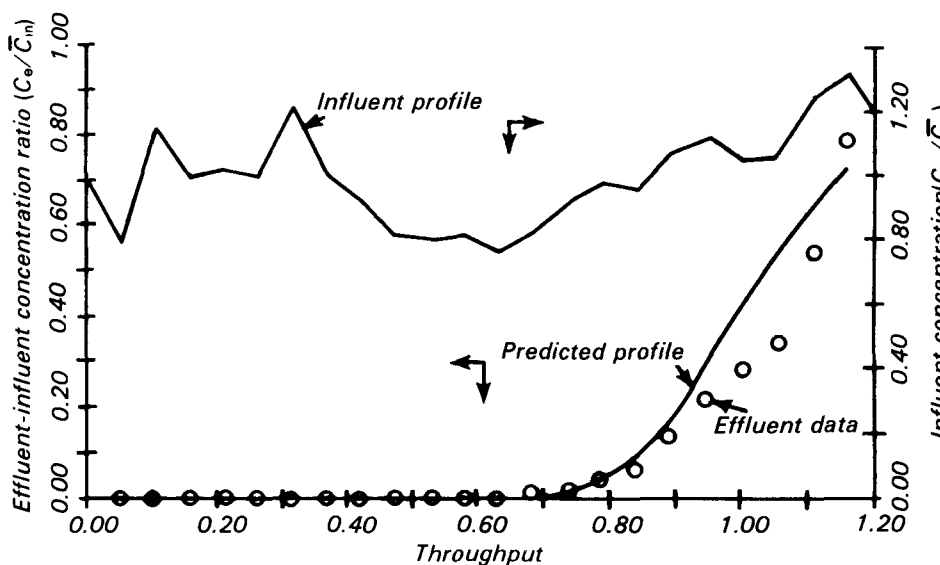


Figure 4. Influent and effluent concentration-history profiles for CCl_4 in fixed-bed mini-columns. 2 Grams of 50/60 US sieve size carbon; $C_{in} = 177$ $\mu\text{g}/\text{l}$; EBCT = 1.1 min.

tion of CCl_4 from carbon were also examined. The rate of approach to equilibrium in the desorption experiments was faster than that in the adsorption tests. Desorption studies with fixed-bed adsorber columns demonstrated that a significant amount of CCl_4 was desorbed.

Fixed-bed adsorption studies with CCl_4 in the presence of 5 mg/L humic acid were hampered by extensive biological growth, and it was impossible to reach any quantitative conclusions regarding the dynamic adsorption behavior of CCl_4 in the presence of humic acids. There was a suggestion, however, that competitive adsorption plays a significant role in the dynamics of removal of CCl_4 in typical adsorber applications.

Benzene

As with CCl_4 , several different sample collection and concentration techniques were evaluated for analysis of benzene in the $\mu\text{g/L}$ range, and a dynamic headspace/gas chromatographic analysis technique was selected.

Equilibria

Studies of adsorption equilibria for benzene in OFW and in a 5 mg/L humic acid background solution demonstrated no significant differences in extent of adsorption between the two systems.

Rates

A simulation-modeling analysis of CMB rate data for benzene in OFW background solution gave values of k_f 7.48×10^{-3} cm/sec and D_s 1.3×10^{-9} cm^2/sec for the mass transfer coefficients. A similar analysis of CMB rate data for benzene in the presence of 5 mg/L humic acid yielded values of k_f 6.38×10^{-3} cm/sec and D_s 1.37×10^{-9} cm^2/sec . The humic acid system demonstrated a slightly lower film transfer coefficient, k_f , than the OFW system, although no significant change in surface diffusion coefficient, D_s , was observed.

Fixed-Bed Adsorbers

As with CCl_4 , mini and large fixed-bed adsorber studies were conducted for benzene. Good agreement was demonstrated between the experimental data and MADAM's predicted profiles.

Fixed-bed adsorber experiments in the presence of 5 mg/L humic acid were hampered by biological growth, rendering

quantitative characterization of the dynamic behavior of benzene impossible in this situation.

Desorption and Chromatographic Effects

Equilibrium adsorption-desorption tests employing the bottle-point technique demonstrated no equilibrium hysteresis. In fixed-bed desorption studies using 3-cm ID adsorber columns, a

substantial quantity of benzene was desorbed.

To substantiate competitive adsorption, virgin and "humic acid pre-saturated" carbon columns were fed with benzene in OFW background solution. Figure 6 demonstrates the corresponding influent and effluent profiles, indicating a substantial reduction in the capacity of presaturated carbon for adsorption of benzene.

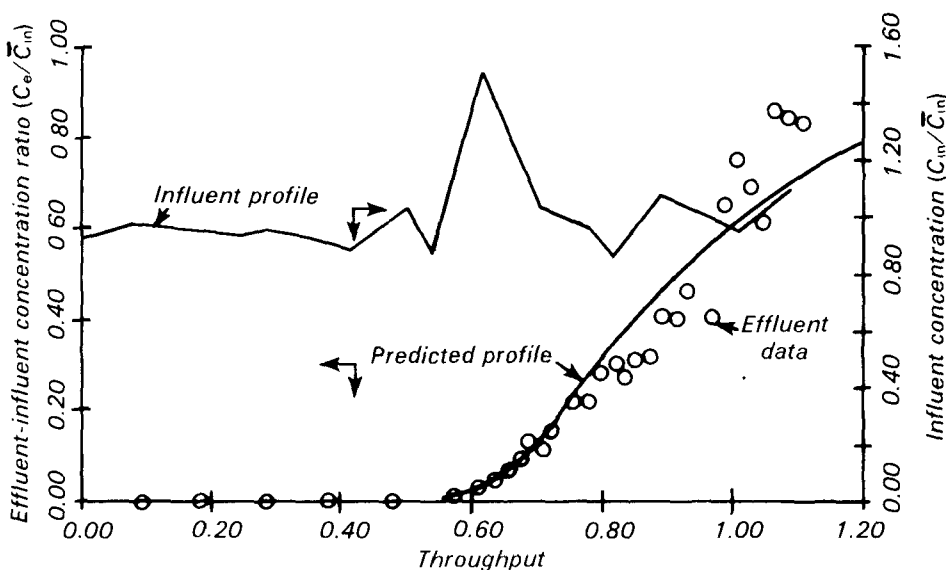


Figure 5. Influent and effluent concentration profiles for CCl_4 in large fixed-bed adsorbers. 250 Grams of 16/20 US sieve size carbon; $C_{in} = 570 \mu\text{g/l}$; EBCT = 6.0 min

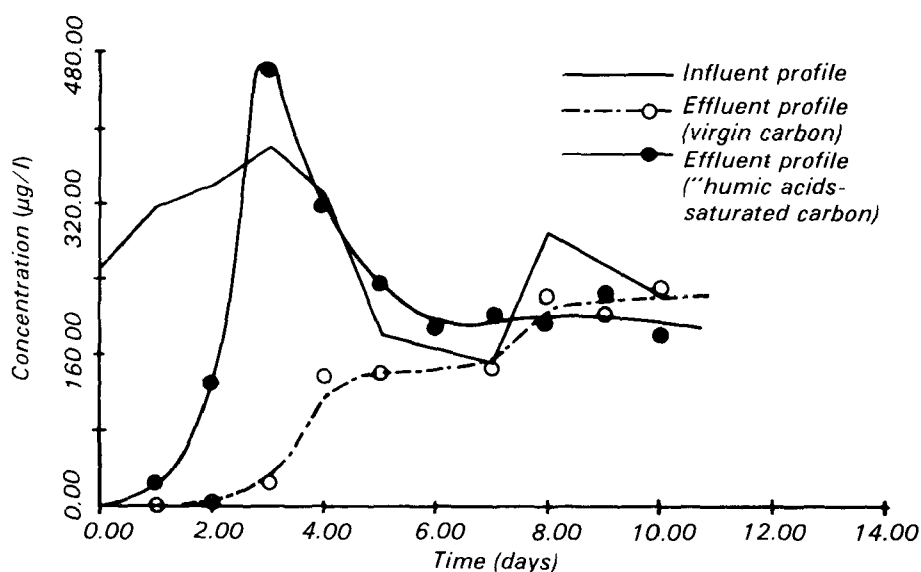


Figure 6. Effluent and influent profiles for adsorption of benzene on virgin carbon and presaturated carbon. 1 Gram of 50/60 carbon; flow rate = 10 ml/min; column diameter = 1.2 cm.

Polychlorinated Biphenyls

Two commercial polychlorinated biphenyl (PCB) mixtures were selected; namely, Aroclor 1254 (A-1254)* and Aroclor 1016 (A-1016). Analysis was by liquid-liquid extraction and gas chromatography. Depending on the quantity of PCB's in a given sample, either a vial extraction technique or a multiple extraction technique was employed. Because of the extremely low levels of PCB's found in water supplies, adsorption methodologies for these substances required recognition of a number of factors that markedly influence quantification of their adsorption parameters: sorption on reactor walls, volatilization, biological growth, interferences, and potential adsorption of carrier solvents.

Equilibria

A comparison of equilibrium data for adsorption of A-1254 and A-1016 from OFW indicated that A-1016 is adsorbed to a greater extent than A-1254, contrary to the general observation that adsorption is inversely related to aqueous solubility. The results of equilibrium studies for adsorption from OFW and humic acid background solutions demonstrated that PCB's are adsorbed to a lesser extent in the presence of humic acids. In the case of PCB's, possibly both the carbon and the humic acid molecules compete for adsorption of these substances. This phenomenon advances the possibility of enhanced PCB removal via mechanisms that enhance the adsorption of humic acids.

Rates

A simulation-modeling analysis was performed for adsorption of A-1016 and A-1254 from OFW and humic acid solution to evaluate the mass transfer coefficients, k_f and D_s . Because the form of the MADAM model used was the single-solution form, the results, as anticipated, demonstrated significant disparity between experimental data and fitted rate profiles. Because each PCB mixture is composed of a large number of different isomers, deviations from single-solute behavior are expected.

To investigate differential adsorption of PCB isomers, CMB reactor rate studies were performed for A-1254 in

OFW. The results indicated that lower isomers are adsorbed more extensively. Similar CMB studies with A-1254 in humic acid solution also exhibited differential adsorption of isomers. It was further observed that the background solution has a marked effect on the adsorption of isomers.

Fixed-Bed Adsorbers

For the mini fixed-bed adsorbers, no breakthrough of A-1016 was observed within 244 days of operation, a duration well beyond the theoretical carbon capacity. Several plausible explanations may be advanced, including biodegradation of PCB's and filtration of PCB aggregates by the column. Figure 7 depicts the influent and effluent concentration profiles for A-1016. Figure 7 also illustrates the results of dynamic desorption studies, indicating that no PCB was eluted or desorbed from the column.

Competitive Adsorption

Two mini-adsorber columns, one containing carbon saturated with humic acids and the other virgin carbon, were fed with a solution of A-1254 in OFW. The effluent concentration (Figure 8) indicated no significant reduction in the capacity of the presaturated carbon. This may be highly significant with respect to the ability of carbon, which is saturated with background organics, to continue to remove trace quantities of

materials with strong adsorption potential, such as PCB's.

Dieldrin

Determination of residual concentration of dieldrin in aqueous solution was accomplished in a manner similar to that discussed for PCB's.

Equilibria

Equilibrium experiments were carried out in OFW and 5 mg/L humic acid solutions. The results indicated lower dieldrin adsorption capacities in the presence of humic acids. The difference may be due to a preferential association of dieldrin and humic species in solution resulting in less dieldrin uptake by the carbon.

Rates

Values of $k_f = 1.75 \times 10^{-3}$ and $D_s = 4.43 \times 10^{-9}$ cm²/sec were obtained for adsorption from OFW solutions; the corresponding values measured for adsorption from 5 mg/L humic acid background solutions were $k_f = 1.29 \times 10^{-3}$ cm/sec and $D_s = 1.33 \times 10^{-10}$ cm²/sec. For systems containing humic acid, both the external film transfer coefficient, k_f , and the intraparticle diffusion coefficient, D_s , are significantly lower than those for OFW systems. Both mass transport steps associated with the adsorption of dieldrin are apparently retarded by humic acids.

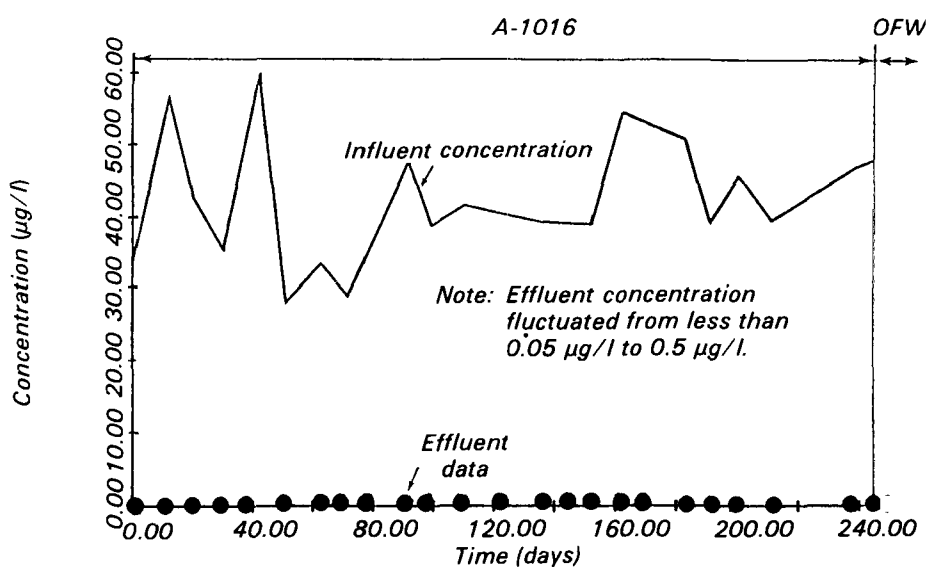


Figure 7. Influent and effluent concentration data for A-1016 in fixed-bed adsorbers. Flow = 20 ml/min; 5 grams of 50/60 US sieve size carbon; EBCT = 0.52 min.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

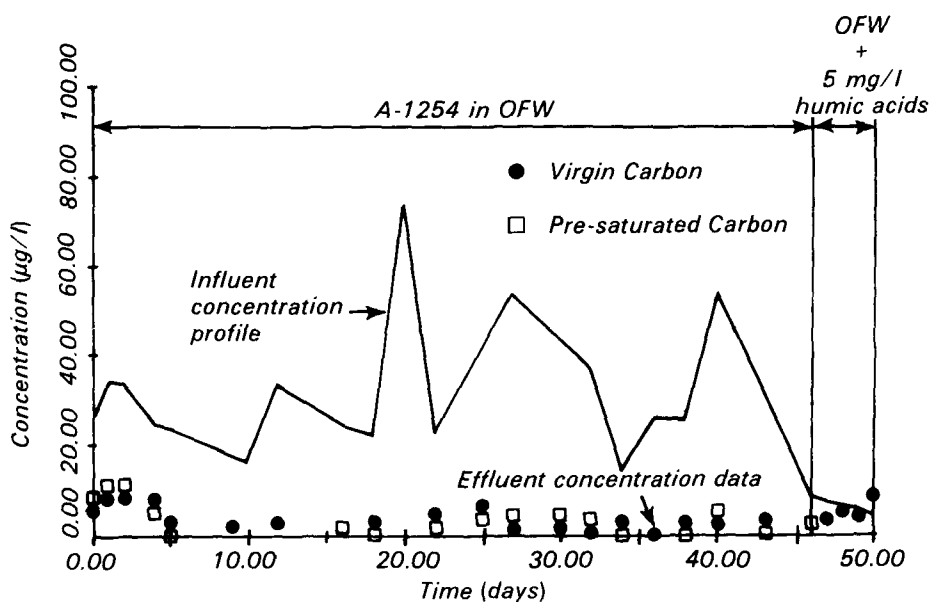


Figure 8. Influent and effluent concentration data for A-1254 in fixed-bed adsorbers. Flow = 10 ml/min; 1 gram of 50/60 US sieve size carbon.

Fixed-Bed Adsorbers

Large fixed-bed adsorber experiments were designed and executed to evaluate the effectiveness of carbon to remove dieldrin in a "close-to-real" situation. After 2 to 3 weeks of operation, profuse biological growth within the column became evident. Influent and effluent concentration data indicate the carbon bed was able to reduce influent levels of dieldrin as great as 30 µg/L to effluent levels lower than the detection limit (~ 0.01 µg/L) (Figure 9). As evident, no breakthrough was reached after 220 days of operation.

Mini-column adsorber experiments for dieldrin were designed and run to obtain data about adsorption breakthrough characteristics for prediction/simulation modeling investigations. No breakthrough was observed after 206 days of operation, a duration well beyond the isotherm capacity. Explanations similar to those discussed for PCB's may be advanced.

Desorption and Competitive Adsorption

Dynamic desorption studies were conducted in both the large and mini fixed-bed adsorbers, and dieldrin was observed to be eluted or desorbed from the column.

p-Dichlorobenzene

Determination of *p*-dichlorobenzene (PDB) in solution phase was by a vial

extraction technique and gas chromatographic analysis. Extraction efficiency was estimated to be 98%.

Equilibria

No significant differences in the extent of adsorption of PDB from OFW and 5 mg/L humic acid background solutions were observed.

Rates

Mass transfer coefficients for adsorption of PDB from OFW were determined to be k_f , 4.3×10^{-3} cm/sec and $D_s = 8.0 \times 10^{-8}$ cm²/sec. Values for adsorption from 5 mg/L humic acid solution were $k_f = 5.3 \times 10^{-3}$ cm/sec and $D_s = 8.0 \times 10^{-8}$ cm²/sec. It is reasonable to conclude that humic acids have essentially no effect on rates of adsorption of PDB.

Fixed-Bed Adsorbers

Relatively good agreement was demonstrated between experimental adsorber data and model predictions for PDB (Figure 10).

As with dieldrin, mini expanded-bed systems were employed to examine the dynamic characteristics of PDB in the presence of humic acids. The results once more confirmed little if any adverse effect of the humic acids on PDB adsorption mass transfer rates.

Case Study: Pilot-Plant Investigations of the Adsorption of 1,2-Dichloroethane

To test the MADAM model for generality, simulation-prediction analyses were performed on independent pilot-plant results obtained when 1,2-dichloroethane (DCE) was removed from settled Ohio River water (SRW). The Municipal Environmental Research Laboratory (MERL), USEPA, Cincinnati, Ohio, conducted the pilot-plant studies

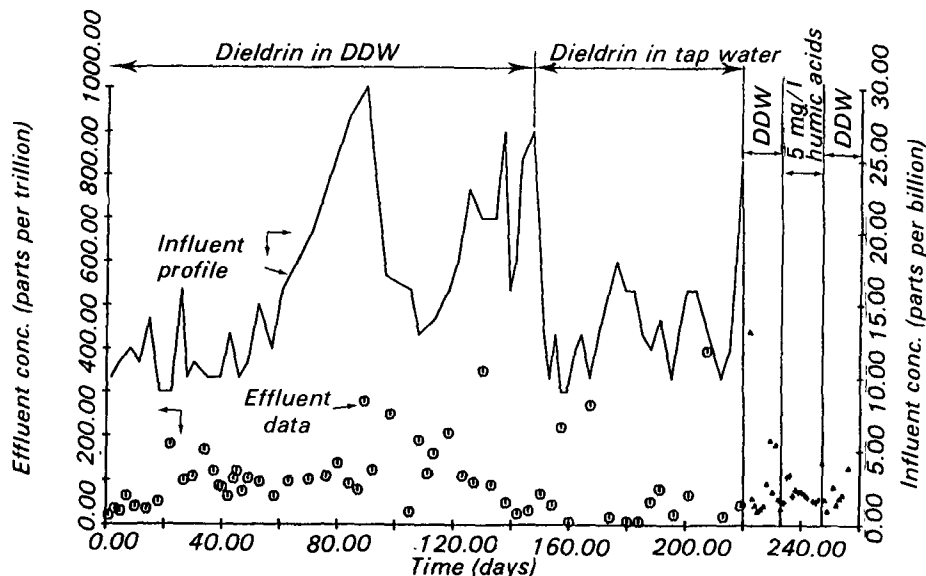


Figure 9. Influent and effluent concentration data for dieldrin in large fixed-bed adsorbers. Flow = 40 ml/min; 250 grams of 16/20 carbon; EBCT = min.

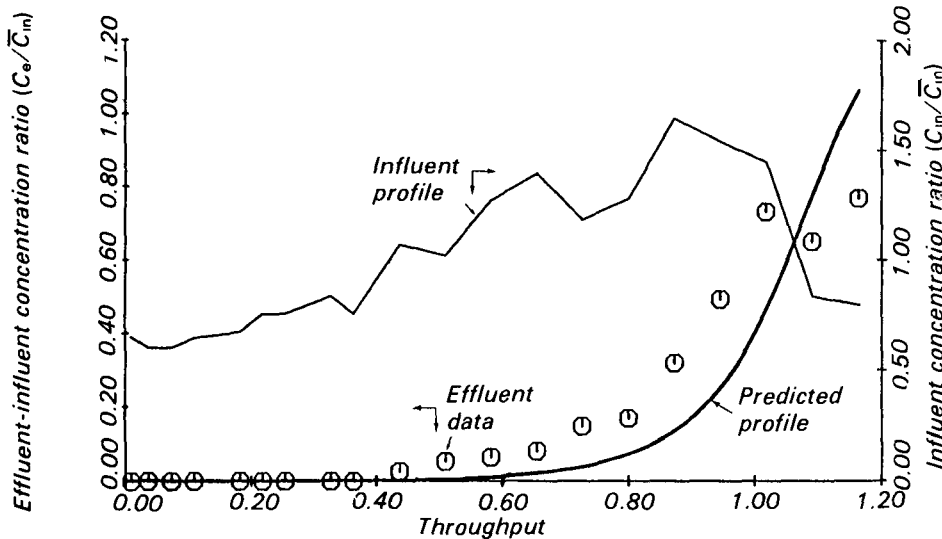


Figure 10. Effluent and influent concentration profiles for PDB in OFW-mini fixed-bed adsorbers. $C_{in} = 185 \mu\text{g/l}$; 1 gram of 50/60 carbon; flow rate = 15 ml/min; EBCT = 0.17 min.

and provided the experimental batch and column data used in these analyses.

The single-solute version of the MADAM model was used for three different sets of experimental conditions to simulate and predict the adsorption dynamics of DCE in fixed-bed adsorbers in the presence of naturally occurring background organics. The agreement between MADAM's predicted breakthrough profiles and the EPA pilot-plant verification data was generally very good and was only slightly affected by apparent biodegradation of DCE over the course of the pilot studies. Figure 11 presents experimental data and predicted breakthrough profiles for a typical fixed-bed pilot-plant adsorber.

Conclusions

- Adsorption capacities of activated carbon for background humic acids are markedly enhanced by the presence of several common ionic constituents of water, including Ca^{2+} , Mg^{2+} , and OCl^- .
- The effectiveness of activated carbon to remove PCB's and dieldrin from water is adversely affected by the association of these compounds with background humic substances. Introducing certain inorganic species such as Mg^{2+} and Ca^{2+} to remove humic substances more effectively might also remove associated organic molecules--such as PCB's and dieldrin--more effectively.
- The Michigan Adsorption Design

and Applications Model (MADAM) was generally able to simulate and predict the performance of fixed-bed adsorbers to remove carbon tetrachloride, benzene, and *p*-dichlorobenzene in organic-free-water background solutions. Because it was not possible to obtain experimental breakthrough profiles for PCB's and dieldrin (no breakthrough occurred in 7 to 8 months

of operation), no attempt was made to model the behavior of these substances in fixed-bed adsorber systems.

- Fixed-bed adsorber studies in water containing background humic acids were hindered by extensive biological growth and resulting headloss. Because of these operational problems, the strictly adsorption version of MADAM could not be adequately tested to forecast the dynamic performance of adsorber beds. When adsorbers that exhibit a tendency toward prolific biological growth are modeled using a version of MADAM that incorporates biological degradation terms would appear to be desirable. The single-solute, strictly adsorption version of the MADAM model was, however, used successfully to simulate-predict independent USEPA pilot-plant data on the adsorption of DCE in the presence of naturally occurring background organics in Ohio River water.
- The results of the long-term color studies with PCB's and dieldrin suggest the possibility of developing specific microorganisms that may be capable of biodegrading these relatively resistant compounds in activated carbon adsorbers.

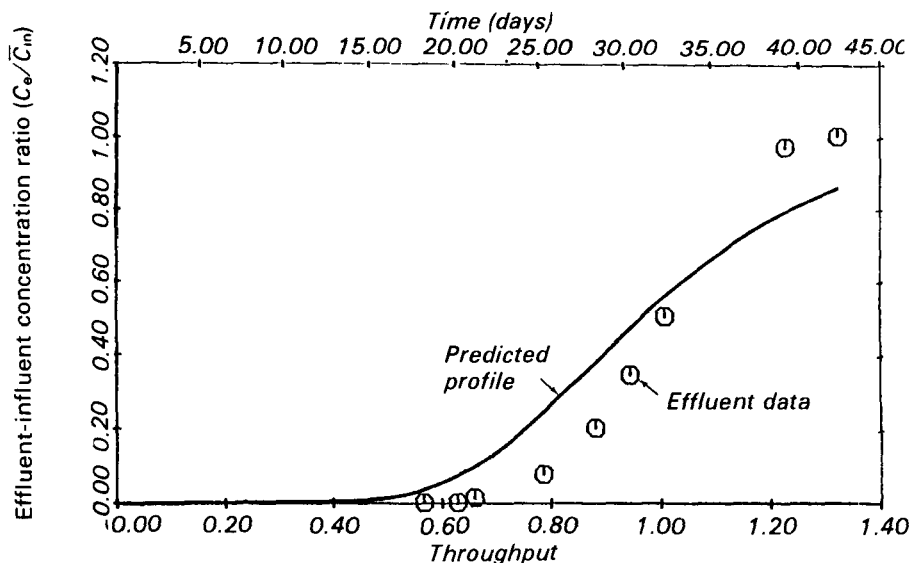


Figure 11. Effluent concentration profiles for DCE in SRW (fixed-bed adsorber Run I). $C_{in} = 112 \mu\text{g/l}$; hydraulic loading = 2 gpm/ft²; EBCT = 10 min; carbon: 400 grams of 12/40 mesh size; col. diam = 4 cm ID. (Data provided by MERL, USEPA).

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Alan A. Stevens is the EPA Project Officer (see below).

The complete report, entitled "Effectiveness of Activated Carbon for Removal of Toxic and/or Carcinogenic Compounds from Water Supplies," (Order No. PB 81-187 197; Cost: \$27.50, subject to change) will be available only from:

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The EPA Project Officer can be contacted at:

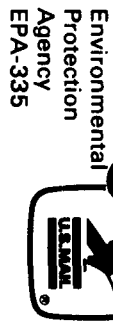
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