

117863

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

DmtCE #5
EPA 600/8-83-019
May 1983

Research and Development



Treatment of Volatile Organic Compounds in Drinking Water

Case No.	117
HS#	409810122
Specs	7
Order	cu 1
	5133

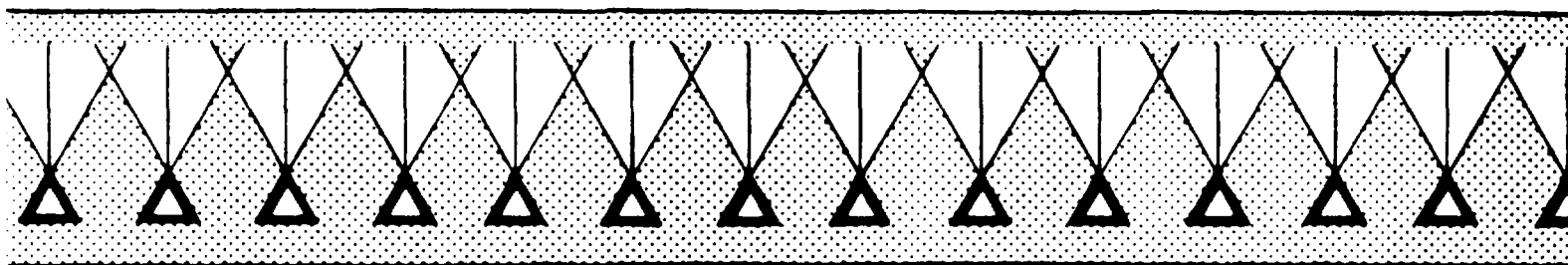


S00118330
SUPERFUND RECORDS

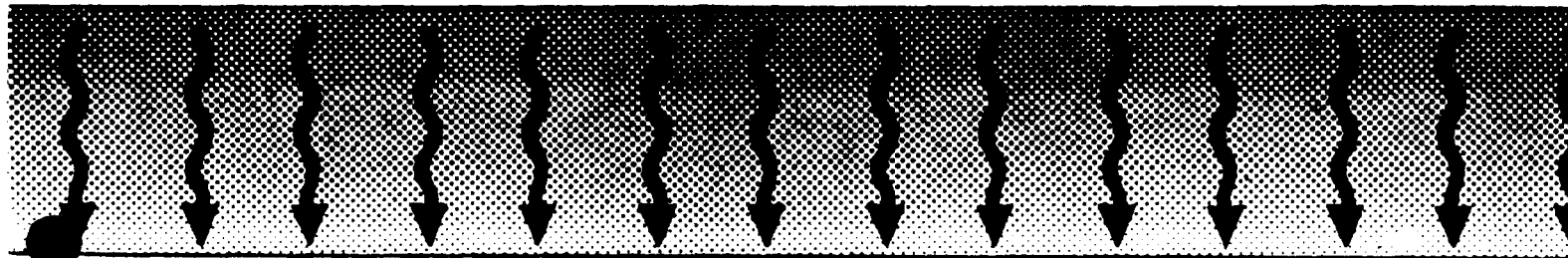
RECEIVED

MAY 1983

SUPERFUND SECTION

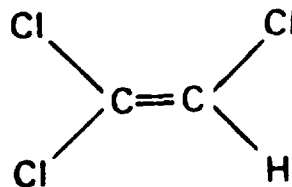


- Methylene chloride
- Cis-1,2-dichloroethylene
- 1,3-Dichlorobenzene
- Trans-1,2-dichloroethylene
- Vinyl chloride
- 1,2-Dichloroethane
- Carbon tetrachloride
- Trichloroethylene
- Tetrachloroethylene
- 1,2,4-Trichlorobenzene
- 1,1-Dichloroethylene
- Chlorobenzene
- 1,1,1-Trichloroethane
- Benzene
- 1,2-Dichlorobenzene
- 1,4-Dichlorobenzene



TRICHLOROETHYLENE*

Structure



Other Names (31-33)

TCE; 1,1,2-trichloroethylene; 1,2,2-trichloroethylene; trichloroethene; acetylene trichloride; ethynyl trichloride; ethylene trichloride; Triclene; Trielene; Trilene; Trichloran; Trichloren; Algylen; Trimar; Triline; Tri; Trethylene; Westrosol; Chlorilen; Gemalgene; Germalgene; Benzinol; 1,1-dichloro-2-chloroethylene; Blacsolv; Blancosolv; Cecolene; 1-chloro-2,2-dichloroethylene; Chlorylen; Circosolv; Crawhaspol; Dow-tri; Dukeron; Fleck-flip; Flock-flip; Lanadin; Lethurin; Nalco 4546; Nialk; Perm-a-clor; Petzinol; Philex; Triad; Trial; Trisol; Anamenth; Chlorylen; Densinfluat; Fluate; Narcogen; Narkosoid; Threthylene; Threthylene; Trilen

Trichloroethylene is commercially produced by chlorinating ethylene ($\text{CH}_2 = \text{CH}_2$) or acetylene ($\text{CH} \equiv \text{CH}$). Its use is declining because of stringent regulations; however, it has been a common ingredient in many household products (spot removers, rug cleaners, air fresheners), dry cleaning agents, industrial metal cleaners and polishers, refrigerants, and even anesthetics (17, 29, 34). Its ubiquitous use is perhaps why trichloroethylene is the organic contaminant most frequently encountered in ground water.

Conventional Treatment

Two studies were found in the literature in which trichloroethylene was identified and measured before and after conventional water treatment. In both studies, the trichloroethylene concentration in the source was lower than $1 \mu\text{g/L}$, but no significant removals were observed through the treatment plant (7, 35).

Aeration

Pilot scale laboratory and field aeration studies were conducted using a 4-cm (1.5-in) diameter glass column, approximately 1.2 m (4 ft) long, with a fritted glass diffuser in the bottom. Water was introduced at the top of the column to give a counter-current flow. In the laboratory, trichloroethylene was added to Cincinnati, Ohio, tap water to give concentrations of approximately 100 to 1000 $\mu\text{g/L}$. The water was aerated at varying temperatures. Trichloroethylene was stripped from the water at an efficiency of from 70 to 92 percent using an air-to-water ratio (volume-to-volume) of 4:1, and a contact time of 10 minutes (Table 2). An identical aerator consistently removed over 80 percent of the trichloroethylene from a contaminated

*See Table 1, page 6, for properties.

TABLE 2. REMOVAL OF TRICHLOROETHYLENE FROM DRINKING WATER BY DIFFUSED-AIR AERATION

Location of study	Average influent concentration, $\mu\text{g/L}$	Average effluent concentration, $\mu\text{g/L}$							Remarks
		Air-to-water ratios							
		1:1	2:1	3:1	4:1	8:1	16:1	20:1	
"Spiked" Cincinnati, Ohio tap water	1064	796	614	508	319	53			4-cm (1.5-in) diam. counter-current flow glass column with activated carbon filtered air; 10 min. contact time. Water temperature 6-16°C. Depth = 0.8m.
	397	223	273	102	82	22	<1	<1	
	241	136	110	61	53	8	2	3	
	110	40	28	18	9	3	<1	<1	
	73	22	14	8	6	1	<1	<1	
Contaminated well in New Jersey	3				<1				
		Air-to-water ratios							
		5:1	10:1	15:1	20:1				
Contaminated well on Long Island (36)	112	72 ^a	48 ^c						0.4 m ³ (16 ft ³) rectangular tank with 4 diffusers. Depth = 0.6m a. 10-min contact time b. 15-min contact time
	64		27 ^{a,d}						
	118				40 ^e				
					40 ^b				
	122						33 ^f	44 ^b	27-cm (10.5-in) diameter column. Depth = 0.6m c. 5-min contact time d. 10-min contact time e. 15-min contact time f. 20-min contact time
		Air-to-water ratios							
		5:1	15:1	20:1	30:1				
Contaminated well on Long Island (37)	180	56							76-cm (30-in) diameter 3-m (10-ft) deep glass column with 5 diffusers; 10-min contact time.
	218		45						
	210				35				
	225						22		

Note: Blank spaces indicate no tests conducted.

well in New Jersey with a mean influent concentration of 3.3 $\mu\text{g/L}$.

Nebolsine Kohlman Ruggiero Engineers (NKRE) (36) also evaluated diffused-air aeration on a pilot scale at a well site on Long Island, New York (see Table 2). They used a rectangular aeration tank [0.6m x 1.2m x 0.6m deep (16 ft³)] having four diffusers and a 27-cm (10.5-in) diameter Plexiglas column having a single diffuser and observed TCE removal efficiency. Retention times ranged from 5 to 20 minutes and air-to-water ratios from 5:1 to 20:1. The highest removal efficiency was 73 percent. In a follow-up study (37) that employed a 76-cm (30-in) diameter column, 3m (10 ft) in length and with five diffusers, the efficiency of removal ranged from 69 percent to 90 percent, with air-to-water ratios from 5:1 to 30:1. The trichloroethylene concentration in the unaerated water ranged from 132 to 313 $\mu\text{g/L}$.

Joyce (38) reported concentrations of trichloroethylene ranging from 4.5 to 22 $\mu\text{g/L}$ at Smyrna, Delaware, after water containing 20 to 70 $\mu\text{g/L}$ trichloroethylene was passed through an induced-draft, redwood slat aerator. Also, the advanced waste treatment research conducted in southern California at Water Factory 21, although not focused directly on drinking water, showed that trichloroethylene concentrations of approximately 1 to 2 $\mu\text{g/L}$ were removed with 98 percent effectiveness. This was accomplished through an ammonia-stripping tower with an air-to-water ratio of approximately 3000 to 1 (when the fan was operating). Similar removal efficiencies for volatile organic chemicals were observed on wastewater passed through a polyethylene-packed decarbonator operating with an air-to-water ratio of about 22 to 1 (24,39).

Adsorption

Dobbs and Cohen (40) developed an adsorption isotherm for trichloroethylene in distilled water by using pulverized Filtrasorb[®] 300* activated carbon. The Drinking Water Research Division, USEPA, followed the same procedure but used both Filtrasorb[®] 300 and Witcarb 950† pulverized carbons. These data are illustrated in Figure 2 as Freundlich isotherms. With a trichloroethylene concentration of 100 $\mu\text{g/L}$, the capacity predicted from these isotherms ranges from 7 to 10 mg trichloroethylene per gram of activated carbon (mg/g). Other than isotherm data, little information has been reported on the effects of powdered activated carbon for removing high concentrations of this contaminant. Singley's group (41) observed a 50 percent reduction in trichloroethylene concentrations (from 1.5 to 0.7 $\mu\text{g/L}$) at the Sunny Isles Water Treatment Plant, North Miami Beach, Florida. The reduction was accomplished with a powdered activated carbon dosage of 7 mg/L.

A great deal more adsorption data have been developed for granular adsorbents. In the summer and fall of 1977, the Drinking Water Research Division installed pilot scale adsorption columns of 4 cm (1.5 in) diameter

*Calgon Corporation, Pittsburgh, PA.

†Witco, Inc., New York, N.Y.

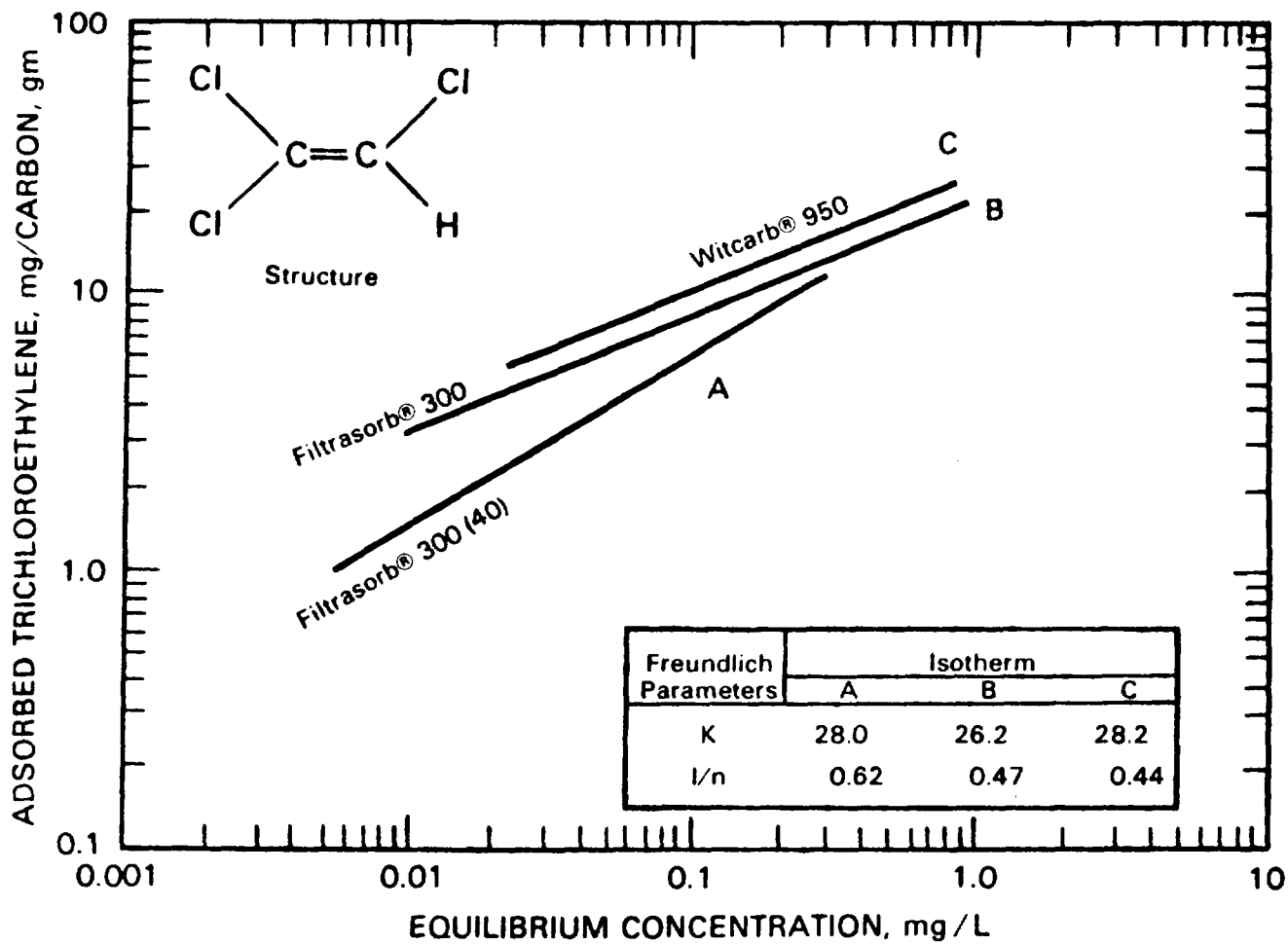


Figure 2. Isotherms for Trichloroethylene Adsorption on Activated Carbon.

and 80 cm (31 in) media depth near contaminated wells at water utilities in Connecticut and New Hampshire. At the Connecticut installation, an industrial waste lagoon was thought to have contaminated the well field. The affected waterworks had just completed two years of pumping the contaminated well to waste, yet volatile organics were still present. At both locations, granular activated carbon (Filtrisorb® 400) and a synthetic resin, (Ambersorb® XE-340*, were exposed to the contaminated water.

In the New Hampshire study, trichloroethylene was the predominant contaminant, and concentrations ranged from 120 to 276 µg/L. Unfortunately, after 18 weeks, the test column became clogged with what appeared to be precipitated iron. When cleaning was attempted, the contaminant wavefront was disrupted; the study was ended after 23 weeks (Figure 3). In the Connecticut study, trichloroethylene was one of the lesser contaminants, and its concentrations ranged from less than 1 µg/L to 10 µg/L. The test columns were sampled weekly for one year, were then allowed to run continuously for one year, and were finally resampled. While trichloroethylene was removed to below detection (0.1 µg/L) for the first year, the granular activated carbon was exhausted after two years. This means the adsorption capacity was between 61,570 and 123,340 bed volumes, or 0.7 to 1.4 mg/g. The resin, however, was still removing trichloroethylene to "below detection" at the time (Figure 3).

In laboratory studies with trichloroethylene concentrations at the 2 mg/L level, Neely and Isacoff (42) reported the equilibrium capacity on XE-340 was 84 mg/g (25,200 m³/m³). A pilot scale field study on Long Island (37) further evaluated the XE-340 resin. In this project, 10-cm (4-in) diameter columns with different depths of resin (to vary contact times) were examined. Trichloroethylene capacity to breakthrough† on the XE-340 resin was approximately 12 mg/g (29,500 m³/m³). The influent trichloroethylene concentrations ranged from 132 to 313 µg/L, and the resin depths varied from 0.3 to 1.2 m, giving contact times of 2 to 8 minutes.

In Montgomery County, Pennsylvania, some homes with private wells contaminated with trichloroethylene have used Culligan adsorption units. These home treatment devices contain approximately 40 kg (87 lbs) of granular activated carbon and reportedly maintain effluent trichloroethylene concentrations below 5 µg/L for several months (43). Information on the effectiveness of other home treatment units to remove trichloroethylene, particularly the small, low flow cartridges containing only a few grams of activated carbon, is not yet available.

Boiling

Boiling is sometimes suggested as a means of ridding drinking water of

*Rohm and Haas Co., Philadelphia, PA.

†Unless otherwise indicated, breakthrough is the length of service when at least 0.1 µg/L of the contaminant is consistently detected in the effluent from the adsorbent. Length of service is expressed in both time and bed volumes (m³ water/m³ adsorbent).

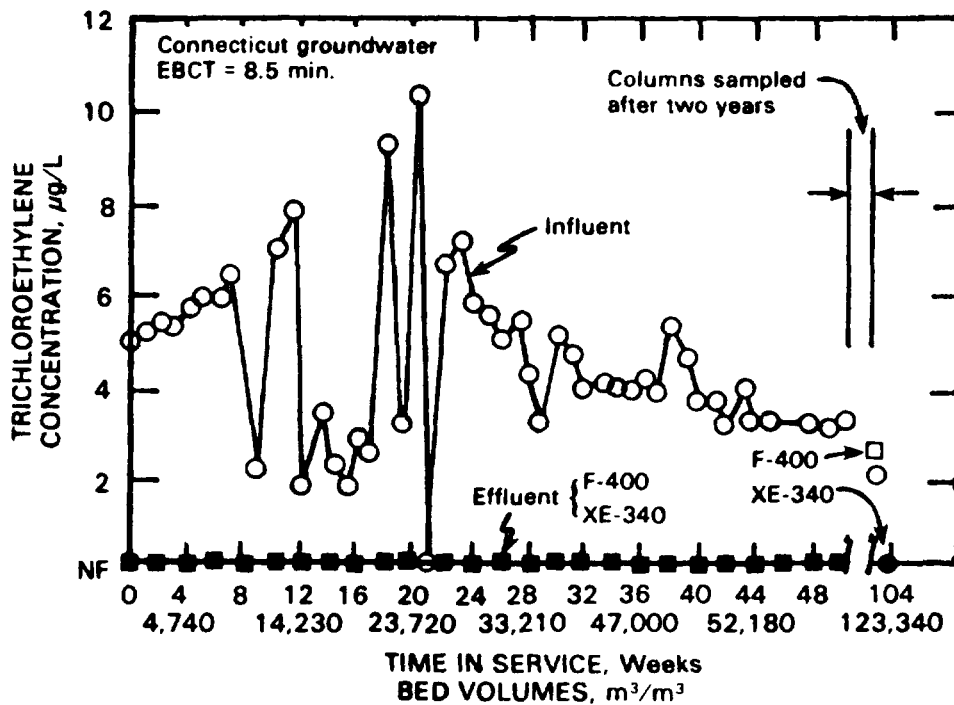
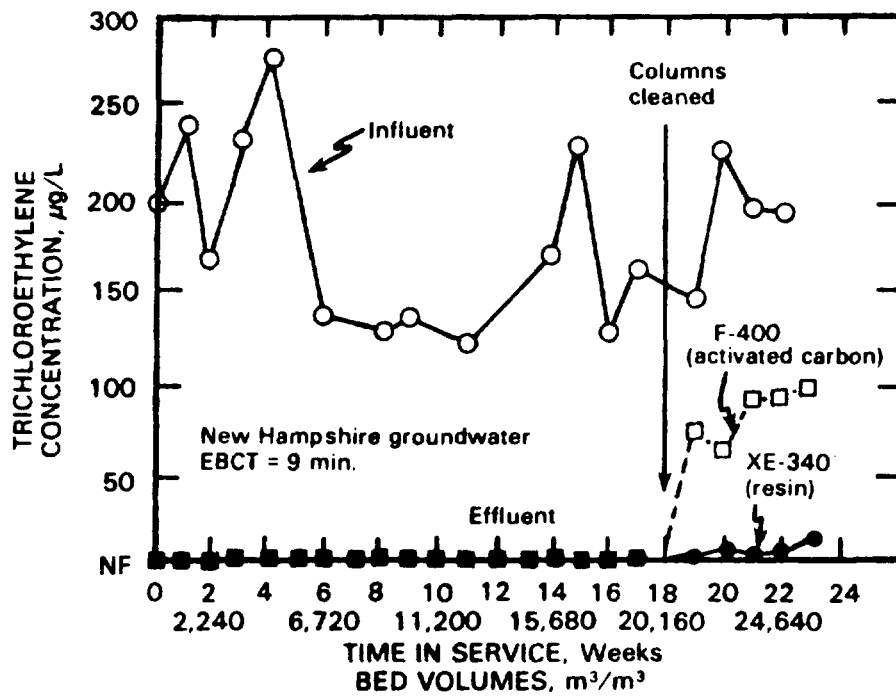


Figure 3. Removal of Trichloroethylene by Adsorption on Granular Activated Carbon and Polymeric Resin.

volatile organics. Table 3 shows the results from four studies conducted by the USEPA in which 12 water samples were boiled for varying times. Because boiling is not a standardized procedure, conditions are likely to vary between households. Lataille (44) for example, noted the importance of water depth to boiling efficiency. She found trichloroethylene was more efficiently removed by boiling from a vessel containing 2 to 5 cm (1 to 2 in) of water than from one having greater water depths (Table 3).

TABLE 3. REMOVAL OF TRICHLOROETHYLENE FROM DRINKING WATER BY BOILING

Time of boiling, minutes	Trichloroethylene concentration, $\mu\text{g/L}$										
	A		B		C		D				
0 (before heating)	142	1262	137	1107	176	1830	730	1460	2920	2000	
1	25	237	45	589	28	279					
2	17	186	44	389	20	110					
3	12	136	35	261	20	57					
5	5	65	23	118	11	20	12	17	194	6*	29†, 500‡

A - Spiked tap water from Cincinnati, Ohio

B - Spiked distilled water

C - Contaminated well water from Pennsylvania

D - Spiked tap water from Lexington, Massachusetts

* Water depth = 2 cm (1 in)

† Water depth = 5 cm (2 in)

‡ Water depth = 11 cm (5 in)

Studies A-C by Drinking Water Research Division, USEPA, Cincinnati, Ohio.
Water depth approximately 10 cm (4 in).

Study D by USEPA Region I, Surveillance and Analysis Laboratory, Lexington,
Massachusetts (44).

Note: Blank spaces indicate no tests conducted.