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Carbon Filtration of EDB-Contaminated Well Water: A One-Year Study

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Chemical contaminants in U.S. aquifers pose potentially adverse human health effects since about half of all Americans obtain their drinking water from groundwater (USEPA 1984). Among the several known kinds of groundwater contaminants are pesticides, gasoline and diesel oil, industrial solvents, degreasing agents, and dry cleaning fluids (Mackay 1985).

Recently a number of wells in three Washington State counties (Whatcom, Franklin, and Yakima) were shown to be contaminated with pesticides - principally 1,2-dichloropropane, dacthal, prometon, and 1,2-dibromoethane (ethylene dibromide or EDB) (Washington State Department of Ecology 1989).

Many agricultural-region aquifers in the U.S. have been contaminated with EDB owing to its use as a soil fumigant to control nematodes (root worms) which attack raspberry, strawberry and other row crops (Brown, Jr. 1984). This chemical was used intensively for decades until banned through an emergency suspension by USEPA in 1983. It was banned in Canada in 1984.

EDB is of particular concern since it is a potent human mutagen and carcinogen (USEPA 1981). It has been estimated that at a concentration of 0.02 μg/L (ppb) in drinking water, EDB creates a lifetime risk of 3 x 10^{-5} excess cancers (3 per 100,000) of exposed population (Simpson 1984). Given these data, the USEPA has established a health advisory and a proposed MCL (maximum contaminant level) of 0.02 μg EDB/L in drinking water.

Considerable attention is being given to the treatment of both surface and subsurface water supplies contaminated by organic chemicals (Higgins 1987). Because these are organic chemicals, one of the more important water remediation strategies under investigation is based on the use of activated carbon filters since organics are generally adsorbed strongly by activated carbon. The adsorption efficiency of trace levels of organics on carbon depends on the nature of the organic chemical and the characteristics of the filter device.

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The use of activated carbon is perhaps the simplest and most cost effective way to treat water supplies contaminated by organic chemicals; this includes synthetic organics, such as pesticides, as well as the trihalomethanes (THM's), such as chloroform, that are formed when raw water supplies are chlorinated.

Recently, we reported that agricultural soils can serve both as a sink and a source for EDB. In Whatcom County Washington, soils that were treated with EDB (until banned in 1983) now serve as a source of EDB to underlying groundwaters. Residual EDB in soils is added to local unconfined aquifers following precipitation events (Mayer et al. 1991).

The purpose of this study was to monitor the performance of a typical commercial activated carbon filter used to remove EDB from a domestic EDB-contaminated well water source over a 1-year time period. In addition, the bacteriological quality of the well water was monitored both before and after carbon filtration by determining both total coliform and total heterotrophic plate counts (HPC).

MATERIALS AND METHODS

All of the work in this study focused on a 36-ft private domestic well in northern Whatcom County, Washington known to be contaminated with EDB since 1974. The well, which serves a family of four, draws its water from an unconfined aquifer adjacent to and down-gradient from a commercial raspberry farm where EDB was used for many years.

A 9-in diameter Culligan "P.E." granular activated carbon filtration unit, containing 1 ft^3 of carbon and designed to supply water to a residence, was installed in the well's pump house. The filtration unit was plumbed so that well water influent to ("before") and effluent from ("after") the filter could be sampled. Duplicate influent and effluent water samples were collected monthly using 100 mL Class "A" volumetric flasks shown by GC analysis to be free of traces of EDB. Samples were refrigerated until analyzed; analyses were carried out within 1 wk of sample collection.

A Hersey/Amitrol American Water Meter was installed to measure monthly water flow through the carbon filter; water flow was limited to a maximum of 5 gal min^{-1} as specified by the filter vendor. The vendor recommended that this filter be replaced after 6 mon of continual use; however we did not replace the filter in this study.

Well-water temperature (corrected mercury thermometer) and EDB concentrations (see below) influent to and effluent from the carbon filter were determined monthly. In addition, pH (Orion Model SA 720 pH Meter), conductivity (Yellow Springs Instrument Co. Conductivity Meter), and turbidity data (Hach Model 2100A Turbidimeter) were also collected.

Total coliform and total heterotrophic plate count (HPC) were determined both before and after the filter by the Whatcom County Health Department, Whatcom County, Washington (Standard Methods for the Examination of Water and Wastewater 1989).

Analyses for EDB (USEPA Method 504, modified, U.S. Department of Commerce, 1988) utilized an HP 5890A gas chromatograph (Hewlett Packard, North Hollywood, California) fitted with a ^{63}Ni electron capture detector; 0.53 mm id, 30 m SPB-5 GC column (Supelco Inc., Bellefonte PA) and on-column injector. 2.0 μL hexane extracts were chromatographed isothermally at 50°C and 30 kPa nitrogen head pressure.

Confirmation chromatography (10% of samples) was conducted isothermally using a 0.53 mm id, 30 m Supelcowax-10 GC column (Supelco Inc.) at 70°C and 30 kPa nitrogen head pressure. The EDB standard was obtained from Supelco Inc. EDB results are expressed as μg EDB/L (s.d. $\pm$ 0.05 μg/L).

RESULTS AND DISCUSSION

The experimental results of our one-year study are reported in Table 1. No significant changes ($P = 0.05$) were observed in water temperature, pH, conductivity, turbidity, or total coliform bacteria before or after the filter.

EDB levels before the filter in samples collected from the domestic well varied between a high of 2.29 and a low of 1.45 μg EDB/L (parts per billion); the mean level was 1.89 μg EDB/L which exceeded the EPA health advisory of 0.02 μg EDB/L by a factor of 94. The granular activated carbon filter removed EDB from the well water to below our instrumental detection limit (0.010 μg EDB/L) for 11 mon; however at the end of month 12, the EDB level after the filter had increased to 0.026 μg EDB/L, which exceeded the health advisory.

HPC levels before the filter were consistently below 500 colony forming units per milliliter (cfu/mL). While there is no U.S. public health standard defining an MCL for heterotrophic bacteria, an informal guideline of 500 cfu/mL is often regarded as an acceptable maximum. The 500 cfu/mL threshold was exceeded in water after the filter four times: in months 4, 6, 8, and 12. The largest heterotrophic bacterial population was observed in month 12: 2320 cfu/mL.

Bell (1984) studied several "point-of-use" water purifying devices designed to remove organic chemicals from drinking water. The organic contaminants he investigated included trihalomethanes (THM's), 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, p-dichlorobenzene, hexachlorobenzene, and chlordane. The removal of THM's varied from 4 to 99% while the removal of the other organics varied between 20 and 99%; the wide range of

Table 1. Month of study (4/88 - 3/89), total volume of water filtered (gallons), EDB level (µg/L), temperature (°C), pH, µmhos/cm (conductivity), turbidity (NTU's), total coliform (cfu/100 mL), HPC (heterotrophic plate count, cfu/mL); parameters measured before (BF) and after (AF) carbon filtration.

Month of Study	Filtered Water Volume	[EDB]		Temp		pH		µmhos/cm		Turbidity		Coliform		HPC	
		BF	AF	BF	AF	BF	AF	BF	AF	BF	AF	BF	AF	BF	AF
1	4,000	1.99	<0.010	10.0	10.5	6.0	6.2	174	205	0.24	0.22	0	0	10	46
2	13,518	1.45	<0.010	10.5	11.0							0	0	2	50
3	25,790	1.83	<0.010	10.0	10.5							0	0	3	30
4	42,020	2.16	<0.010	10.5	11.0	6.1	6.1	185	191	0.18	0.18	0	0	10	646
5	66,390	1.92	<0.010	10.5	11.0							0	0	2	426
6	91,687	1.92	<0.010	10.5	11.0							0	0	1	998
7	104,155	1.59	<0.010	10.5	11.0	6.1	6.1	172	176	0.25	0.14	0	1	9	36
8	112,904	1.72	<0.010	10.0	10.0							0	0	7	824
9	121,797	1.64	<0.010	10.5	10.5							2	0	3	216
10	131,932	2.29	<0.010	10.5	10.0	6.1	6.1	184	183	0.22	0.20	0	0	1	270
11	140,056	2.02	<0.010	10.0	9.0							0	0	2	200
12	147,845	2.13	0.026	10.0	10.0	6.0	5.9	150	180	0.14	0.14	0	0	131	2320

removal efficiencies depended on the filter type, activated carbon loading, and length of time the filter was in service. In no case did a filter process more than 4,000 gal of water.

Bell (1984) also showed that "point-of-use" carbon filters contribute moderate and variable heterotrophic bacterial populations to filtered water as compared to influent water supplies; the average increase was about one order of magnitude. Taylor (1979) working with four different types of activated carbon filters found that while influent waters reflected heterotrophic plate counts generally less that 10 cfu/mL, effluent waters generally exceeding 100 cfu/mL.

We found that after 11 mon of use by a family of four, the carbon filter employed in this study allowed breakthrough by EDB. At the same time the filter released heterotrophic bacterial populations four times greater than that generally regarded as an acceptable maximum (500 cfu/mL).

These findings support the vendor's current recommendation that the filter be replaced after 6 mon of use. Since the demand for water will vary from user to user, it may be important to base a recommended time of filter use on a case by case study of water use patterns.

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REFERENCES

Bell Jr FA, Perry DL, Smith JK, Lynch SC (1984) Studies on home water treatment systems. J Am Water Works Assoc 76:126-130

Brown Jr AF (1984) Ethylene dibromide: its use, hazards, recent regulatory action. J Environ Health 46:220-225

Higgins TE, Romanow S (1987) Treatment processes for contaminated groundwater - three case studies. Hazard Waste Hazard Mater 4:307-323

Mackay DM, Roberts PV, Cherry JA (1985) Transport of organic contaminants in groundwater. Environ Sci Technol 19:384-392

Mayer JR, Lacher Jr TE, Elkins NR, Thorn CJ (1991) Temporal variation of ethylene dibromide (EDB) in an unconfined aquifer, Whatcom County, Washington USA: a twenty-seven month study. Bull Environ Contam Toxicol 47:368-373

Simpson MM (1984) Ethylene dibromide. Science Policy Research Division, Congressional Research Service Report IP280, Feb 15. Library of Congress. Washington, DC

Standard Methods for the Examination of Water and Wastewater (1989) 17th ed., American Public Health Association, Washington, DC

Taylor RH, Allen MJ, Geldreich EE (1979) Testing of home use carbon filters. J Am Water Works Assoc 71:577-579

United States Department of Commerce (1988) Methods for the determination of organic compounds in drinking water. National Technical Information Service: EPA-600/4-88/039

United States Environmental Protection Agency (1981) Ethylene dibromide: position document 2/3. Office of Pesticide Programs

United States Environmental Protection Agency (1984) National primary drinking water regulations: volatile synthetic organic chemicals. 40 CFR Part 141 [OW-FRL-2514-3]

Washington State Department of Ecology (1989) Agricultural chemicals pilot study interim report

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