Movement of PCB from a Contaminated Reservoir Into a Drinking Water Supply

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Since the initial report of polychlorinated biphenyls (PCB) in the environment by JENSEN (1966), there has been a steady flow of data regarding these pollutants. The widespread distribution of PCB and subsequent ramifications on the global fauna have been notably reviewed by FISHBEIN (1972), NISBET and SAROFIM (1972), PEAKALL (1972), and HUTZINGER et al. (1974). The early reports of PCB effects on humans came as a result of industrial exposure and the occurrence of chloracne (SCHWARTZ (1936); MEIGS et al. (1954). KURATSUNE et al. (1972) reported the effects of Yusho disease in Japan as a result of the consumption of PCB-contaminated rice oil. YOBS (1972), FINKLEA et al. (1972), PRICE and WELCH (1972), and KUTZ and STRASSMAN (1975) have also reported the occurrence of PCB in humans.

Presently, PCB are mainly used as the dielectric base for the manufacture of transformers and capacitors. Current trends indicate that PCB will be phased out in the near future in favor of less environmentally-stable substitutes. However, PCB input into freshwater by industries has been high in the past, and PCB have accumulated in sediments (CRUMP-WIESNER et al. 1974). Even if PCB use were stopped today, these sediments could continue to release PCB into freshwater systems for years to come. The following report concerns the movement of PCB from a contaminated reservoir through a water treatment plant into a drinking water supply.

SITE DESCRIPTION

Samples were collected from Twelve Mile Creek and the facilities of the Easley-Central Water District, which are located in Pickens County, South Carolina (Fig. 1). Twelve Mile Creek is fed by several smaller streams, among them is Town Creek which receives wastewater discharges from a company which uses PCB in the manufacture of capacitors. Information supplied by the Environmental Protection Agency indicated that the firm used more than 1480 tons of Aroclor 1016 from 1972 through mid-1975 (Aroclor 1242 was used prior to the introduction of Aroclor 1016 in 1972), and 85 tons of Aroclor 1254 from 1971-74 with no use of 1254 indicated for 1975. Information regarding the amounts of PCB entering Town Creek via the manufacturer's wastewater treatment facilities is unavailable, but this discharge is believed to be the major source of contamination. A single sediment sample taken about 100 m downstream from the discharge point

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contained 25 ppm (10^{-6} g/g sediment) Aroclor 1016 and 8.1 ppm Aroclor 1254.

Approximately 16 km below the capacitor plant, water is taken from Twelve Mile Creek and is pumped into an open storage pond. This pond has an estimated capacity of 19 million liters and is less than 3 m deep. The water treatment facility processes about 900 million liters annually from this pond for distribution by the Easley-Central Water District or other water districts.

SAMPLING

Shallow sediment samples (under less than 0.5 m water) were collected using an 8-cm i.d. x 70 cm aluminum corer. Deep sediment grab samples were collected with an Ekman dredge and were sub-cored with a glass cylinder. The collection equipment was thoroughly cleaned and rinsed with solvent before use. Sediment cores were sectioned into 2-cm thick layers and were placed in clean glass jars with foil-lined lids.

Water was collected in empty 3.8-liter Nanograde solvent bottles. Before collecting drinking water, the faucets were flushed for two minutes or more. All potable water samples came from the Easley-Central Water District distribution lines.

ANALYTICAL METHODS

Reagents and Apparatus

Mallinckrodt Nanograde brand solvents were used for sample extraction and cleanup. Distilled water was extracted before use with dichloromethane and petroleum ether to remove possible contaminants. Woelm activity grade III alumina, prepared by adding 6% water to the activity I product, was used for sample cleanup. Sodium sulfate was baked at 400°C to remove organic contaminants. Sulfuric acid and mercury were reagent grade.

Sample extracts were analyzed using a Tracor Microtek 222 dual-column gas chromatograph equipped with ^{63}Ni electron capture detectors. Column A was packed with 1.5% OV-17/1.95% OV-210 and Column B was packed with 4% SE-30/6% OV-210, both on 100/120 mesh Supelcoport. Operating conditions were: column temperature: 200°C; inlet temperature: 225°C; detector temperature: 320°C; nitrogen carrier gas flow rates: Column A: 45 ml/min, Column B: 60 ml/min.

Procedure

Sediment samples were processed using a modified GOERLITZ and LAW technique (1974). Homogenized sediment samples (20 g wet wt) were placed in pre-extracted cellulose thimbles and soxhlet extracted with 120 ml acetone for 3 hours. Hexane was added to make a 60:40 acetone:hexane mixture and extraction was resumed for an additional 10 hours. The acetone-hexane mixture was shaken with 360 ml distilled water; the hexane layer was removed, and the aqueous phase was re-extracted with 100 ml petroleum ether. The organic extracts were combined and concentrated in a Kuderna-Danish apparatus.

Water samples were extracted in their original collection bottles by rolling on a jar mill with 300 ml dichloromethane for 10 hours or longer. The solvent was removed and concentrated as above. The last traces of dichloromethane were removed by refluxing with hexane.

The remainder of the procedure was the same for sediment and water samples. Alumina (4 g) was slurried with petroleum ether, packed into a 1-cm diameter column, topped with 1 cm sodium-sulfate, and washed with 20 ml petroleum ether. The sample was added and the PCB were eluted with 20 ml petroleum ether. The eluate was further cleaned up by shaking with sulfuric acid (MURPHY, 1972) and mercury (GOERLITZ and LAW, 1974) to remove oxygen- and sulfur-containing compounds.

PCB were identified by comparing sample chromatograms with those of Aroclor 1016 and 1254 standards (Figs. 2 and 3). The PCB levels reported in Tables 1 and 2 were based on the sum of the peak heights in sample and standard chromatograms. Blanks were carried through the entire procedure, and duplicate analyses agreed within 10%. Recoveries of PCB from fortified water samples averaged 99% for Aroclor 1016 and 94% for Aroclor 1254.

RESULTS AND DISCUSSION

PCB are well mixed in Twelve Mile Creek sediments to at least 20 cm depth (Table 1). The sediment samples were taken above a dam which was formerly used by a hydroelectric generating station. The dam is approximately 36 m wide and 5 m high with water flowing over it at an estimated rate of 6000 liters/sec. The main body of impounded water ranges from depths of about 1 m over a coarse sand base to 4 m over fine silty sediments. Because of the high flow rate and shallowness of the impounded area, thorough mixing probably occurs, resulting in minimal stratification in the sediments.

Table 2 shows the changes in PCB content as raw water was passed from Twelve Mile Creek to the storage pond, through the treatment facility, and delivered as potable water. The decline in PCB levels is probably due to adsorption onto suspended particles which settle out during the transport and treatment process.

All PCB levels were well within the solubility ranges reported in the literature. TUCKER *et al.* (1975) estimated the solubility of Aroclor 1016 to be in the 225-250 μg/liter range. The water solubility of Aroclor 1254 is 50-56 μg/liter (NISBET and SAROFIM, 1972; HAQUE *et al.*, 1974).

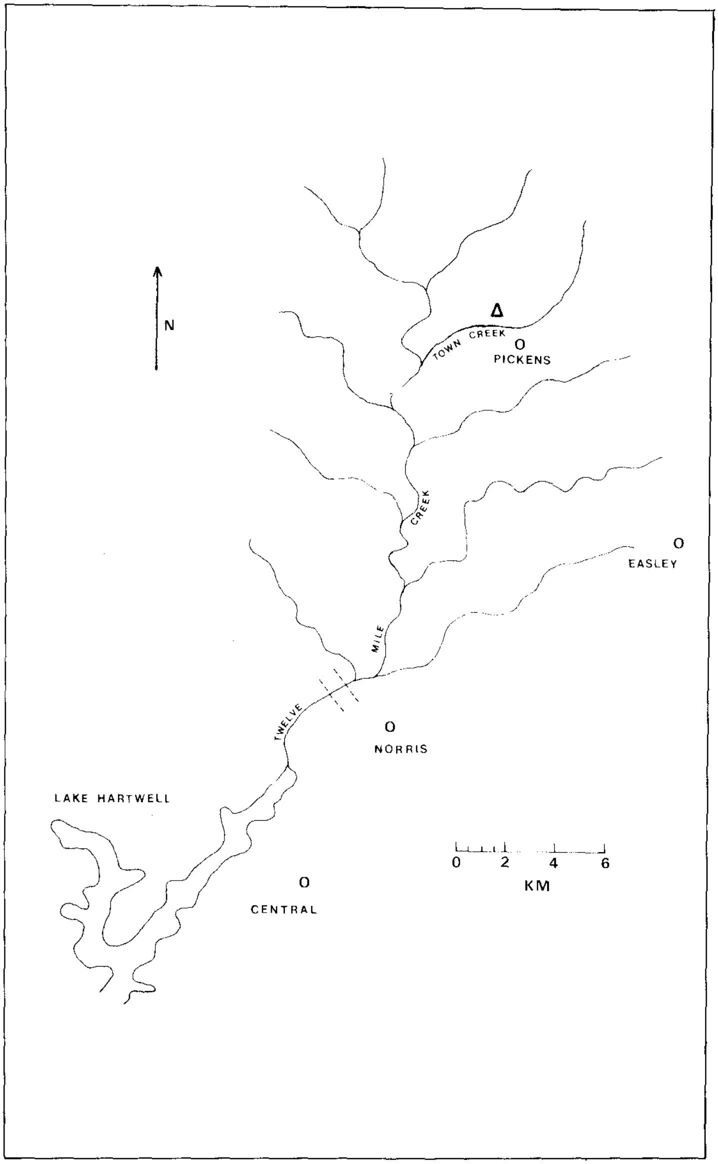
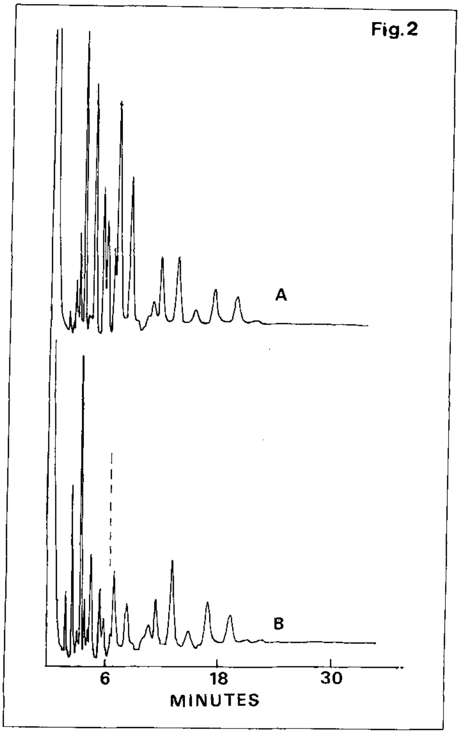


Figure 1

Twelve Mile Creek Watershed

Δ Location of the capacitor manufacturing plant

----- Location of the reservoir and water treatment facility for the Easley-Central Water District



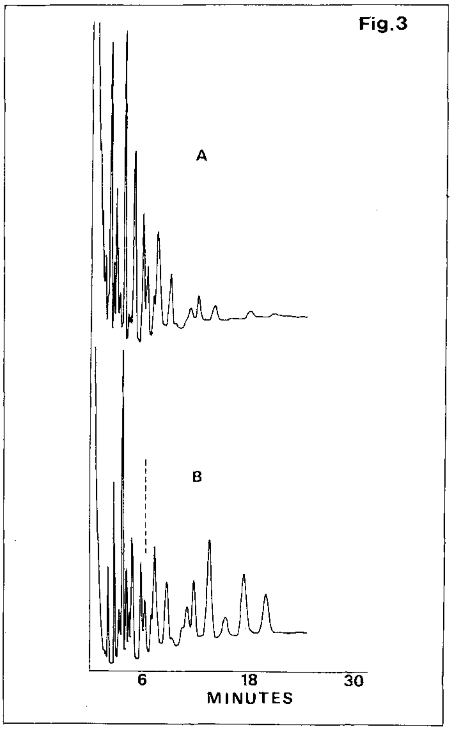


Figure 2

Gas chromatograms (OV-17/ OV-210)

A. PCB extracted from Twelve Mile Creek raw water, 3.4 μℓ injection, 9.5 ml extract volume

B. 0.6 ng Aroclor 1016 + 0.3 ng Aroclor 1254 (- - - - indicates 1016-1254 division)

Figure 3

Gas chromatograms (OV-17/ OV-210)

A. PCB extracted from potable water collected at the treatment plant; 4.8 μℓ injection, 2.5 ml extract volume.

B. 0.6 ng Aroclor 1016 + 0.3 ng Aroclor 1254 (- - - - indicates 1016-1254 division)

Table 1

Levels of PCB in Sediments of Twelve Mile Creek and the Storage Pond

	Aroclor, 10^{-6} g/g sediment, dry wt[1,2]					
	Twelve Mile Creek				Storage Pond	
	Shallow[3]		Deep[3]			
Sediment layer cm	1016	1254	1016	1254	1016	1254
0-2	11.1	4.8	13.9	5.1	2.5	2.4
4-6	7.3	3.4	5.1	2.2	0.23	0.25
8-10	3.3	0.92				
12-14	1.7	0.77				
16-18	10.2	3.5				
20-22	6.2	2.8				

[1] Moisture content of the sediments ranged from 56.5% in the top layer of the creek sediments to 34.7% in the lower soils under the storage pond.

[2] Blank values were <2 x 10^{-9} g/g sediment, based on a 10-g (dry) sample.

[3] Shallow = under less than 0.5 m water; deep = under 3 m water.

Drinking water samples collected on the same day from several points within the Easley-Central Water District all showed that PCB contamination increased 2-3 fold with distance from the treatment plant (Table 2). The combined level of Aroclors 1016 and 1254 in the potable water supply nearest the treatment plant was 180 times the maximum permissible level of 10^{-9} g/liter (1 part-per-trillion) that has been proposed by the Environmental Protection Agency for ambient fresh water (FEDERAL REGISTER, 1976), while the total PCB in drinking water taken 10 km from the treatment plant was 800 times the proposed limit. One possible explanation for this increase is the desorption of PCB from scale accumulations in the distribution lines that may have occurred during years of greater pollution of Twelve Mile Creek. Another possibility is the reaction of aromatic compounds with residual chlorine in the distribution lines after chlorination at the treatment plant. Increased levels of PCB following chlorination of water containing aromatics has been reported by CARLSON, *et al*. (1975) and JOHNSEN (1975).

In conclusion, we note that the partition coefficient of PCB between sediments and water (P = g PCB/g sediment ÷ g PCB/g water) is on the order of 10^5 (HARVEY and STEINHAUER, 1976). Thus, even if PCB discharges were ceased tomorrow, water in equilibrium with Twelve Mile Creek sediments could contain PCB at the 100 part-per-trillion level. Because of the contamination in the sediments of these freshwater systems, it seems likely that the people living in these areas will be exposed to PCB long after direct PCB pollution of the streams has been controlled.

Table 2

PCB Levels in Raw and Finished Drinking Water

Water Sample	Location	Distance from Treatment Plant,Km	Date	10^{-9} g/liter[1] Aroclor		Total PCB[2]
				1016	1254	
Raw	Twelve Mile Creek	0.2	5/21	782;465[3]	187;215[3]	793
			6/18	618;607[4]	156;145[4]	
Raw	Storage Pond	0	5/21	332	94	426
Potable	Treatment Plant	0	6/18	160	43	184
			8/29	130;135[4]	43;39[4]	
Potable	Easley-Central Water Supply Lines	1.1	8/29	163	55	218
Potable	"	2.7	8/29	251	105	356
Potable	"	5.4	8/29	321	105	426
Potable	"	10.0	8/29	709	109	818

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[1] Blank values were 1 x 10^{-9} g/liter each of Aroclors 1016 and 1254.

[2] Arithmetic mean, in the case of more than one sample.

[3] Collected in different areas of the impounded area.

[4] Duplicate samples.

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