Migration of Polychlorinated Biphenyls in Soil Induced by Percolating Water

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The thermal and chemical stability of the polychlorinated biphenyls (PCBs) are clearly responsible for their widespread use in the electrical industry. Unfortunately, many of the environmental concerns about PCBs are attributable to the same properties. Where fire resistance and efficient transmission of electrical energy are important, PCBs are the preferred dielectrical fluid. In fact, the U.S. Government's Interdepartmental Task Force on PCBs, PCBs IN THE ENVIRONMENT (1972), concluded that for closed systems such as transformers and capacitors there are no suitable replacement products for PCBs. Consistent with these conclusions, Monsanto introduced a new PCB product, Aroclor* 1016, containing substantially less of the degradation resistant higher chlorinated isomers, restricted the sales to use in closed systems, and set up a high temperature incinerator for disposal of used fluids. While incineration is an acceptable solution to the disposal of used fluids, it is not feasible for many reasons at this point in time for disposal of PCB impregnated material from transformers and capacitors.

The objective of this study was to produce data which would help evaluate the suitability of landfill disposal of Aroclor 1016 impregnated capacitors. Of prime concern was the rate at which percolating ground water might leach Aroclor 1016 from various types of soils.

Experimental

The experimental procedure employed consisted of percolating water through a column packed with soil coated with Aroclor 1016 and then monitoring the effluent water for PCBs. The set up used is shown schematically in Figure 1. The soil columns employed are approximately 3" in diameter by 12" in height and were dry packed in layers. Each soil layer being 3"

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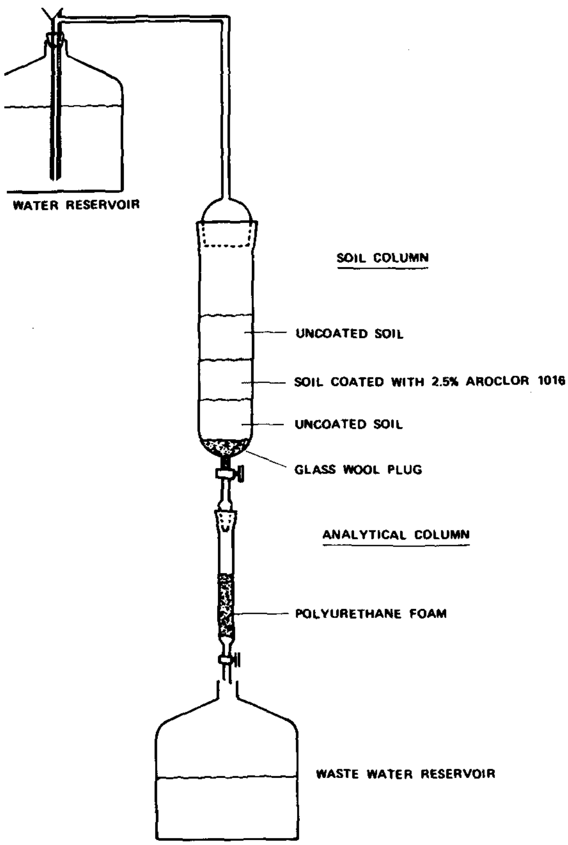

FIGURE 1. SOIL PERCOLATION SETUP

thick - first uncoated soil, followed by soil coated with 2.5% (w/w) of Aroclor 1016, and finally another layer of uncoated soil. An acetone solution of Aroclor 1016 was used to coat the air dried soil, followed by removal of the acetone in a rotary evaporator.

Three different types of soils were used in this study. The characteristics of each are shown in Table I.

TABLE I

COMPOSITION OF SOILS USED IN STUDY

Soil	Norfolk Sandy Loam	Ray Silty Loam	Drummer Silty Clay Loam
% Sand	82.5	6.2	2.8
% Silt	11.0	83.2	55.4
% Clay	5.5	9.6	35.8
% Organic Carbon	1.0	1.0	6.0

The intent was to simulate the various soil types which could be encountered at different landfill sites. The soils and the procedure employed have been used to evaluate the soil mobility of agricultural chemicals.

Distilled water was fed from the reservoir at a constant pressure to each soil column. The flow rates were observed to increase the first few days, and then decrease and level out. Apparently, after the wetting phase some channeling occurs until the soil becomes compressed in the column. This effect was most pronounced with the silty soils. The average flow rates in liters/day for Norfolk Sandy Loam, Ray Silty Loam and Drummer Silty Clay were 0.26, 0.53 and 0.32, respectively.

The effluent water from the soil column was in turn passed through a polyurethane foam column which quantitatively absorbs PCBs, GESSER (1971). Sampling was carried out on a periodic basis by interchanging a new polyurethane foam column for the old column. In this manner, the effluent could be continuously monitored. The PCBs were recovered from the polyurethane by elution with 20 ml of acetone followed by 100 ml of nanograde hexane and collected in a 250 ml separatory funnel. The aqueous phase was discarded and the hexane layer was filtered through anhydrous sodium sulfate into a Kunderna-Danish evaporative concentrator. The hexane concentrate was transferred to an alumina† column and eluted with 125 ml of hexane. The hexane eluent was concentrated in a Kunderna-Danish evaporative concentrator and analyzed using a gas chromatograph equipped with an electron capture detector. The conditions for the gas chromatographic analysis were as follows:

Instrument:	Hewlett-Packard Model 5753A Gas Chromatograph (Ni-63 Electron Capture Detector)
Column:	2M x 4 mm 4% XE-60 silicone on 80/100 Mesh Chromosorb W High Performance - Glass
Injection Port Temperature:	220°C
Column Temperature:	170°C isothermal
Detector Temperature:	300°C
Carrier Gas:	Helium, 60 ml/min.
Purge Gas:	10% Methane/Argon, 120 ml/min.
Pulse Internal:	50 μsec

Results and Discussion

The polyurethane foam columns were changed and analyzed on days 5, 10, 17, 24, 31, 39, 52, 98 and 185. Table II summarizes the levels of PCBs found in the column effluents.

Breakthrough of the PCBs in the effluent water was related to the clay content of the soil. The soils containing higher levels of clay retained the PCBs. The order in which breakthrough occurred as a function of effluent volume was Norfolk Sandy Loam followed by Ray Silty Loam and finally Drummer Silty Clay Loam

† Alumina, chromatographic grade, 80/200 mesh, heated at 400°C for 4 hours and deactivated with 5% (w/w) distilled water. 30g of alumina packed into a glass chromatographic column 25 cm x 20 mm O.D. topped with 2 cm of anhydrous sodium sulfate and washed with 75 ml of nanograde hexane before addition of sample.

TABLE II

PCBs FOUND IN PERCOLATING WATER

Norfolk Sandy Loam		Ray Silty Loam		Drummer Silty Clay Loam	
Total Effluent Volume (ℓ)	ppb PCBs	Total Effluent Volume (ℓ)	ppb PCBs	Total Effluent Volume (ℓ)	ppb PCBs
1.3-8.1	ND	2.7-16.4	ND	1.6-9.9	ND
10.1	ND	20.7	65	12.5	ND
13.5	23	27.6	92	16.6	ND
25.5	63	51.9	153	31.4	ND
48.1	63	98.1	136	59.2	ND

ND = None detected, <1 ppb

(none observed). This is in agreement with recent work, HAQUE (1974), demonstrating that clay has a high affinity for PCBs.

Experimentally, the water solubility of Aroclor 1016 has not been determined; however, it is estimated to be in the range of 225-250 ppb. This estimate is based on the fact that Aroclor 1016 contains more of the less chlorinated, more water soluble isomers than does Aroclor 1242 which has a water solubility of 200 ppb. In all cases, the concentration of PCBs in the effluent water was less than the estimated solubility of Aroclor 1016 in water.

The electron capture chromatograms shown in Figure 2 detail the isomer distribution of the PCBs observed in the effluent water. Aroclor 1242, the product formerly sold for use in capacitors, is shown at the top. The Aroclor 1016 which was coated on the soil is shown next, followed by the PCBs leached from the soils, and finally a less chlorinated member of the Aroclor series, Aroclor 1221, which was used as a standard for quantitation. The number above each peak indicates the dominant chlorobiphenyl in that peak. A comparison of the Aroclor 1242 and Aroclor 1016 chromatograms illustrates the reduction of the penta and higher chlorobiphenyls achieved in the manufacture of Aroclor 1016.

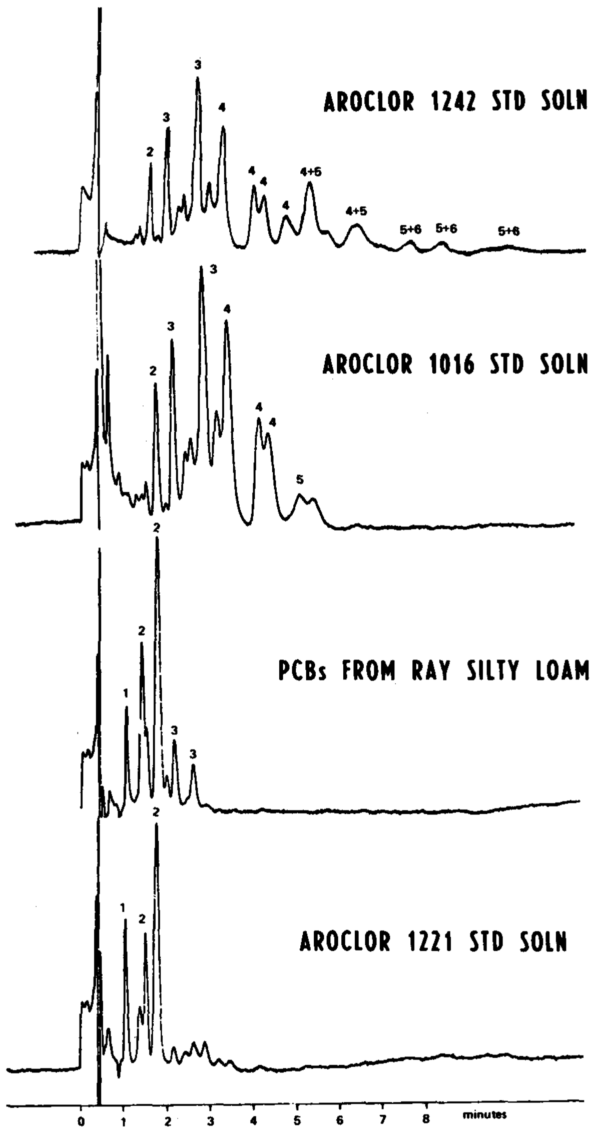

FIGURE 2. PCB ELECTRON CAPTURE GAS CHROMATOGRAMS

The isomer distribution of the PCBs in the effluent water is the result of differences in the water solubility and adsorption characteristics of the isomers in Aroclor 1016. It is evident that only the less chlorinated, more biodegradable PCBs, AHMED and FOCHT (1973a,b), TUCKER (1972), similar to Aroclor 1221, were leached from the soil. A degradation rate for Aroclor 1221 of 73 ± 21% has been observed in semi-continuous activated sludge tests at feed levels of 1 and 5 mgs/24 hours, TUCKER (1972).

Conclusions

The results of this study clearly demonstrate that PCBs are not readily leached from soil by percolating water. In the worst case, less than 0.05% of the total Aroclor 1016 available (25,000 ppm) was leached from the soil during the entire four-month duration of these experiments. During this period of time approximately 50-100 liters of water were passed through the three soil columns, an amount of water roughly equivalent to 50-100 ft. of rainfall, assuming no run off.

The ease of leaching Aroclor 1016 from the different types of soils was in the following order: Norfolk Sandy Loam>Ray Silty Loam>Drummer Silty Clay Loam.

Additionally, it was observed that only the less chlorinated, more degradable homologs were leached from the soils.

The results of this study support the conclusion drawn by the Michigan Water Resources Commission that landfills are only a minor source of PCB environmental contamination, HESSE (1971).

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