

MEMORANDUM

SUBJECT: Drinking Water Assessment of HCB and PCB

FROM: James K. Wolf, Soil Scientist
Environmental Risk Branch 3
Environmental Fate and Effects Division (7507C)

TO: Luis Suguiyama, Branch Chief
Fungicide Branch
Registration Division (7505C)

THRU: Michael R. Barrett, Chemist
Environmental Risk Branch 3
Environmental Fate and Effects Division (7507C)

Daniel Rieder, Branch Chief
Environmental Risk Branch 3
Environmental Fate and Effects Division (7507C)

DATE: April 24, 1998

CHEMICALS: Atrazine, clopyrilid, chlorothalonil, chlorpyrifos-methyl, dacthal, endosulfan, pentachloronitrobenzene (PCNB), pentachlorophenol, picloram, simazine

PC CODE #s: 80803, 117401, 81901, 59102, 78701, 79401, 56502, 63001(2,3), 5101, 80807

INTRODUCTION

The Environmental Fate and Effects Division (EFED) has been requested to provide the Health Effects Division (HED) with a drinking water assessment for Hexachlorobenzene (HCB) and Pentachlorobenzene (PCB). A toxicological profile has been recently (1996) prepared by the Agency of Toxic Substances and Disease Registry (ATSDR) for Hexachlorobenzene (USDHHS, 1996). This profile was prepared in accordance with guidelines developed by the ATSDR and USEPA. Included within this profile is an exposure assessment for drinking water contaminated with HCB. The Division proposes to use the assessment presented in the Toxicological Profile for HCB. The EPA has previously addressed hexachlorobenzene in drinking water (USEPA, 1985) and exposure to HCB (USEPA, 1986). A recent search of the EPA STORET Database was also conducted for HCB and PCB and considered in this assessment.

SUMMARY

Hexachlorobenzene (HCB) and pentachlorobenzene (PCB) are both persistent (years) and relatively immobile in the environment. The major route of dissipation is through sorption to soil in the terrestrial environment and to sediment and suspended particulates (organic and inorganic) in water. It appears that HCB and PCB contamination of ground water resources is relatively unlikely due to the high binding potential of both these chlorobenzene compounds. Based upon monitoring data and fate properties it seems unlikely that long term HCB and PCB concentrations in surface water would exceed 10 ppt (0.01 µg/L). These chemicals although persistent will not remain in solution very long at high concentrations, as they become sorbed to suspended materials and bottom sediment. Higher concentrations have been reported in surface and ground water, but tend to be related to hazardous waste, and landfill sites, and suspended sediment. It should also be noted that while water concentrations tend to be very low, HCB and PCB will accumulate to bottom sediment and bioaccumulate in fish. Due to desorption kinetics or through the disturbance of sediments, it is possible that some of the time HCB and PCB will go back into the solution phase if equilibrium is disrupted.

BACKGROUND

Hexachlorobenzene (HCB) is a chlorinated hydrocarbon that does not occur naturally. Pentachlorobenzene (PCB) is also a chlorinated hydrocarbon. The production of HCB (as an end-product) for industrial uses have decreased since the 1970's. HCB and PCB are also formed as by-products, or contaminants, during the manufacture of chemicals (solvents), other chlorine-containing compounds and pesticides. HCB produced as a by-product during the production of chlorinated chemicals was estimated to be between 2.47 to 4.91 million pounds in 1972 (USDHHS, 1996; after IARC, 1979). More recent estimates of amounts of HCB stored on site as a by-product or impurity range from 0.15 to 1.52 million pounds per year (USDHHS, 1996; after TRI93, 1995). Hexachlorobenzene was a widely used pesticide until 1984. It appears several other registered products containing HCB were registered until 1989 with stocks available until 1990. PCB is also a degradation product of the pesticide PCNB.

The major releases of HCB are by discharges into air and water from its production as a by-product of chemical manufacture or from pesticide applications. It is also released by some waste incineration processes (USEPA, 1998a). According to the EPA's Toxic Chemical Release Inventory, during 1987 to 1993, HCB releases to water totaled 1,287 pounds (USEPA, 1998a). The application of contaminated pesticides is also important means of releasing HCB and PCB into the environment.

Sources of hexachlorobenzene and pentachlorobenzene from a "draft" of the Emissions Inventory of Section 112(c)(6) pollutants (from 1990) are listed in Table 1. Information concerning how inclusive these data are not yet available. Thus it is not entirely clear whether these are national estimates are only a subset of all sources. Based upon estimates given in

Table 1, pesticide application only contributes, at a maximum, about 6 percent of the HCB in the environment. Based upon this information, the anticipated PCB contributions would be much less.

Table 1. Summary of "Draft" Emissions Inventory Data for Pentachlorobenzene (PCB) and Hexachlorobenzene (HCB).				
EMISSIONS SOURCE CATEGORY¹	PCB (tons/yr)	PCB (~percent)	HCB (tons/yr)	HCB (~percent)
Chlorinated Solvents Production	- ²	-	5.81e-01	25.26
Hazardous Waste Incineration	2.78e-02	17.38	-	-
Industrial Oil Combustion	4.97e-05	0.03	-	-
Medical Waste Incineration	4.03e-02	25.19	-	-
Municipal Waste Combustion	8.01e-02	50.06	-	-
Other Biological Incineration	2.49e-03	1.56	-	-
Pesticides Application	-	- ³	1.46e-01	~6.35
Pesticides Manufacture	-	-	4.58e-01	19.91
Scrap or Waste Tire Combustion	1.04e-03	0.65	-	-
Sewage Sludge Incineration	5.12e-03	3.20	-	-
Tire Manufacturing	-	-	4.35e-01	18.91
Utility Coal Combustion	-	-	6.80e-01	29.57
Utility Oil Combustion	1.49e-04	0.09	-	-
Total Emissions (tons/yr)	0.16	98.16	2.30	100.00

¹ Summary of draft 1990 Emission Inventory Data for Section 112(C)(6) Pollutants (sources currently not available).

² - No value provided.

³ Contaminant and degradation product of some pesticides, amount not specified.

⁴ Difference from 100 is due rounding..

Table 2 lists the current (1998) maximum contaminant levels (in percent) of HCB and PCB and the (available) product usage amounts for ten pesticides that have HCB and/or PCB contaminants resulting from manufacturing. The estimated annual mass of HCB released to the environment based upon the amount of pesticides used and maximum percent contaminants per pound of pesticide is 6.5 tons/year compared to 0.146 tons/year estimated in Table 1. The amount PCB attributed to pesticide application is not stated in Table 1; PCB is a degradation product of the pesticide pentachloronitrobenzene (PCNB). The difference between Tables 1 and

2 may reflect the fact that the estimates in Table 2 assume that all of these pesticides contain the maximum percent of contaminants which may not to be the case. The potential for the total mass of HCB and PCB contaminants from pesticides is also not complete, since product usage information was not available for five of the pesticide. These additional pesticides are not expected to increase the mass significantly (since % contaminants are relatively low) unless usage is as great as atrazine, chlorothalonil, or simazine.

Table 2. Summary of Selected Pesticides with maximum percentage of hexachlorobenzene (HCB) and/or pentachlorobenzene (PCB) manufacturing contamination.			
Active Ingredient	Maximum Contaminant (%) ¹		Product Usage ²
	HCB	PCB	(lbs ai for 1995)
Atrazine	1.70e-03 (1275 lbs)	2.50e-05	75,000,000
Clopyralid	8.00e-04	1.90e-04	not available
Chlorothanil	5.00e-02 (7500 lbs)	--	15,000,000
Chlorpyrifos-methyl ³	-- ⁴	3.00e-05	not available
Dacthal (DCPA)	3.00e-01 (4020 lbs)	--	1,340,000
Endosulfan	7.50e-05	6.00e-04	not available
PCNB	5.00e-02	1.00e-02	not available
Pentachlorophenol	7.50e-03	--	not available
Picloram	1.00e-02 (100 lbs)	--	1,000,000
Simazine	2.00e-03 (80 lbs)	--	4,000,000
Total	11,827.5 lbs (6.5 tons/year)		96,340,000 lbs (48,170 tons/year)

¹ Obtained from HED, 2/10/98 and is assumed to be % relative to the mass of active ingredient..

² Letter to L.Driver, EPA, from T. Gilding, ACPA, 11/27/96 concerning Emissions Inventory.

³ Indoor use.

⁴ Data not available.

PHYSICAL PROPERTIES, CHEMISTRY, AND ENVIRONMENTAL FATE

Chemical properties and environmental fate properties are summarized in Tables 3 and 4 for HCB and PCB, respectively. More information was available for HCB as compared to PCB. The fate

data for both contaminants indicated that both are persistent in the environment with a high potential to sorb to soil particles and organic carbon. Representative fate values are presented below by compound.

HCB: Under most conditions, HCB is highly resistant to degradation in soil, water, and air. When released to the atmosphere, HCB exists primarily in the vapor phase and degradation is extremely slow. Estimated atmospheric degradation half-lives range from 0.6 years to more than 6 years (USDHHS, 1996). HCB may be removed from the atmosphere via washout by precipitation, or by dry deposition. Atmospheric transport of HCB may be an important transport mechanism (Kelly et al., 1991). HCB concentrations in the vapor phase represented 92 to 100 % of the total HCB concentration in air samples collected at a monitoring site in Ontario, Canada (Lane et al., 1992).

In water, HCB will partition from the water column into sediment and suspended particulates. It is not readily degraded by either abiotic or biotic process in water. Half-lives are estimated to range from 2.7 to 5.7 years in surface water and 5.3 to 11.4 years in ground water (USDHHS, 1996). Volatilization from water is moderately rapid. However, due to strong sorption to particulates and the organic fraction, HCB is extremely persistent in sediment. Solubility in water ranges from 3.5 to 20 $\mu\text{g/L}$ (Laseter et al. 1976, after USEPA, 1998b; USEPA, 1998a, USDHHS, 1996). Photodegradation of HCB also appears to be quite slow (USEPA, 1998a; USEPA, 1998b, USDHHS, 1996).

HCB volatilizes relatively rapidly from the soil surface. Because it is strongly sorbed to organic carbon (K_{oc} range from 3,890 to 1,202,264), HCB is generally considered to be relatively immobile with respect to leaching. Information was not available to explain the wide range of K_{oc} values. Half-lives in soils have been estimated to range between 3 to 6 years (USEPA, 1998a; USEPA, 1998b, USDHHS, 1996).

In summary, HCB is a very persistent compound. HCB has a high affinity for lipophilic materials. It appears that photolysis, oxidation, hydrolysis, and biodegradation have little effect on the fate HCB in the aquatic environment.

Table 3. Physical, chemical, and environmental fate properties of Hexachlorobenzene (Source of Information from USDHHS, 1996) .

Property	Value	References cited from USDHHS, 1996
Molecular Formula	C ₆ Cl ₆	
Molecular Weight	284.78	Lide 1994
Melting Point	230 °C	Verschuieren 1983
Boiling Point	322 °C	Verschuieren 1983
Density @ 23.6 °C @ 23 °C	1.5691 2.044	Lide 1994 Merck 1989
Solubility in Water @ 20 °C @ ?	6.0 µg/L 3.5 µg/L	Verschuieren 1983 EPA OGWDW 1998
logK _{oc}	5.22; 6.08; 3.59 (Strongly adsorbed to organic matter, considered immobile with respect to leaching.)	Kenega and Goring, 1978; EPA, 1981 Kenega and Goring, 1978
Log O/W partition coef.	6.18	Verschuieren 1983
Henry's Law constant	6.84E-04 atm-m ³ /mol 1.30E-03 atm-m ³ /mol	EPA, 1981 Atlas et al., 1982
Vapor Pressure@ 20 °C	1.089E-05 mm Hg	Verschuieren 1983
Persistence:		
T _{1/2} in atmosphere	0.63 yrs (tropics/subtropics) 1.94 yrs (temperate/boreal) 6.28 yrs (polar)	
T _{1/2} in surface water (~Rate: hrs ⁻¹)	2.7 to 5.7 yrs (2.931E-05/hr to 1.388E-05/hr)	
T _{1/2} in ground water (~Rate: days ⁻¹)	5.3 to 11.4 yrs (3.58E-04/d to 5.97E-08/d)	
T _{1/2} in soil (~Rate: days ⁻¹)	3 to 6 years (6.33E-04/d to 3.17E-04/d)	

CHARACTERIZATION SUMMARY FOR HCB	
Volatilization:	
From water column	HCB is volatilized moderately rapid, however, the strong adsorption can lead to lengthy persistence in sediment.
From soil	HCB can volatilize from the soil surface relatively quickly
Media	Fate
In water	<p>HCB is persistent and not significantly degraded by either abiotic or biodegradation processes in water. It is resistant to the hydrolysis reactions, and not subject to photolytic decay.</p> <p>HCB released to water will volatilize, adsorb to sediments or bioaccumulate in fish and other aquatic organisms.</p>
In soil and sediment	<p>HCB is persistent and is not significantly degraded in soils by either abiotic or biodegradation processes.</p> <p>If released to soil, some HCB partitions to the atmosphere from soil surfaces through volatilization. The remainder is adsorbed strongly to soil where it persists for extended periods (months to years) due to resistance to biodegradation. Leaching is not anticipated due to the high adsorption characteristics.</p> <p>HCB can volatilize from the soil surface relatively quickly.</p>

PCB: Less chemistry data and environmental fate data were readily available for PCB (Table 4) as compared to HCB (Table 3). These data, however, suggest that PCB like HCB is persistent and not very mobile in the environment. It also appears less volatile than HCB, but based upon Henry's low constant volatilization from water can still be important. The solubility of PCB, 1330.0 µg/L, is 38 to 222 times more soluble than HCB. The major source of dissipation appears to be sorption to soil particles and organic carbon and volatilization. As with HCB, PCB will bioaccumulate.

Table 4. Physical, chemical, and environmental fate properties of Pentachlorobenzene.

Property	Value	References from USDAHHA, 1996 and OPTTS database search 1998
Mole Formula	C ₆ HCL ₅	
Mole Weight	250.32	
Melting Point	86 °C	SRC Recommended (Weast et al., 1985)
Boiling Point	277 °C	(SRC Recommended (Weast et al., 1985)
LogP O/W	5.17	Hansch and Leo, 1985
Water Solubility	1,330 µg/L	SRC Recommended (Banerjee et al., 1980).
Vapor Pressure	2.19E-03 mmHG@25 °C Extrapolated from a liquid state from a T-range of 98.6 to 276.0 °C with fugacity correction.	SRC Recommended (MacKay and Shiu, 1981).
Henry's Law	4.89E-5 atm-cu/mol @ 22 °C 7.0E-04 atm-cu/mol @ 25 °C	Hellmann, 1987 SRC Recommended (Oliver, 1985)
K _{oc}	5450 3162 (K _{oc} represents best or average value, as appropriate, back-calculated from log K _{oc}). 40000	Sabljić (1984) Koch et al (1983) SRC Recommended (Karickhoff and Morris, 1985)
Persistence:	Evidence suggests that it is persistent	

Table 4. Physical, chemical, and environmental fate properties of Pentachlorobenzene.

Bioconcentration:	Log Bioc Fact: Species: 4.22 Rainbow T. 3.55 Bluegill sunfish	Oliver and Niimi (1983) Barrows et al (1980)
Hydrolysis	Rate: 0.9 Half-life: 3208day @pH9	Ellington et al.(1988A)

MONITORING DATA

Monitoring Data From Toxicological Profile for HCB (USDHHS, 1996)

Monitoring data for HCB in atmosphere, soils, sediment, and water are reported for a considerable time period (1971 - 1995) (USDHHS, 1996). It is my understanding from discussions here at the Agency that pesticide manufacturers have reduced HCB and PCB contaminant levels in some pesticides over this time. However, due the persistence of HCB (and PCB) in soil, sediments, and the atmosphere, the potential from exposure continues from previous HCB and PCB releases.

Atmosphere: Monitoring has focused in the Great Lakes region where the historical production of chlorobenzenes was high. HCB was also detected in precipitation up to 0.174 ng/L in the Great Lakes region (Oliver and Nichol, 1982). Recent air monitoring detected mean concentrations greater or equal to 0.054 ng/m³ in Ontario, Canada (Hoff et al. 1992).

Sediments and Soil: HCB has been detected in soil and sediment in both agricultural areas where it was used as a fungicide on seed grains and in urban soils near production and waste disposal sites (Carey et al., 1985). HCB residues were detected in soils from 11 of 1,485 agricultural sites (0.7%) in 37 states with concentrations ranging from 10 to 440 ng/g), in 1972. In 1973, one of 1,470 sites (0.1%) contained HCB residues at 10 ng/g. Whether or not HCB was, use was not specified. A study in 1976 in 11 states, two of 391 sites (0.5%) had soil HCB at concentrations ranging from 10 to 20 ng/g (Carey et al., 1985). The author's concluded that occurrence of HCB in the agricultural soils was associated with registered pesticide uses of HCB rather than environmental or industrial contamination (USDHHS, 1996, after Carey et al., 1985). Detectable levels of HCB (10 to 590 ng/g) were found in soils sampled in seven of 40 urban areas, during the 1970's (USDHHS, 1996, after Carey et al., 1985). They concluded that HCB in the urban areas were attributed to releases from manufacturing, the use, or the disposal of HCB or HCB-containing waste rather than the use of hexachlorobenzene as a pesticide.

Mean concentrations of HCB in Great Lakes sediments have ranged between 0.2 and 97 ng/g (USDHHS, 1996; after Oliver and Nicol, 1982). HCB levels ranging from 0.5 to 460 ng/g were detected in 8-cm long sediment cores sampled in 1-cm segments. Deeper sediment core segments (1-2 cm) had higher concentrations (460 ng/g) than the surface (0-1 cm) segment (270 ng/g). The highest concentrations were attributed to sediment deposited during 1971 to 1976 (Oliver and Nichol, 1982). They further reported that the concentration of HCB in Lake Ontario sediment is 1 million times greater than HCB concentrations in Lake Ontario water.

HCB is expected to be immobile in soil, due to high sorption, and therefore unlikely to leach (USDHHS, 1996; after Swann et al., 1983). It is suggested in the Toxicological Profile (USDHHS, 1996) that there is a potential for augmenting the leaching properties of HCB and other organochlorines. The lipid materials in bacterial cell membranes may lead to a repartitioning of hexachlorobenzene sorbed to colloids. This could lead to a process called facilitated transport where the mobility of hydrophobic compounds such as HCB adsorbed to soils may be enhanced by biosorption on bacteria and move to aquifers along with the bioremediation bacterial cultures (Lindqvist and Enfield, 1992). Human exposure may also occur via dermal contact with contaminated soil or sediment or via ingestion of contaminated soil by children (USDHHS, 1996).

Water: Monitoring for HCB residues in surface and ground water are generally conducted in areas thought to have a potential for hexachlorobenzene contamination (e.g., industrial site or waste disposal site nearby). Limited monitoring appears to have been conducted to assess pesticides as the source of HCB or PCB contamination. The Pesticides in Ground Water Data Base reports the collection of 1328 water samples for HCB (pesticide) in five states (CA, HI, MS, MT, and OR) (USEPA, 1992). HCB was detected in ground water in Mississippi. Four samples out of 263 samples collected in MS had HCB detections; concentrations ranged from 0.0039 to 0.0056 µg/L. The contamination was attributed to normal field use.

Much of the surface water monitoring for HCB have occurred in regions of the country where HCBs are more prevalent. Therefore, monitoring values would tend to provide "high" exposure concentrations. The mean concentration of HCB in drinking water for three cities on Lake Erie was 0.00001 µg/L (range 0.00006 to 0.0002 µg/L) (USDHHS, 1996; after Oliver and Nichol, 1982).

HCB was detected in two of the Great Lakes and their tributary rivers. Mean concentrations in Lake Ontario, Lake Huron, and the Grand River were 0.00006 µg/L (range, 0.00002-0.0001 µg/L), 0.00004 µg/L (range, 0.00002-0.0001 µg/L), and 0.00006 µg/L (range, 0.00002-0.0001 µg/L), respectively. In the Niagara River, concentrations ranging from 0.00002 to 0.017 µg/L were detected; the highest value was downstream from a waste disposal site (Oliver and Nichol, 1982). It was noted, by the study authors, that the widely variable concentrations in the Niagara River may have been attributed to the fact that the measurements were near the analytical detection limits. In more recent data, HCB was detected in 42% of

whole water samples (dissolved plus particulate phases) collected during 1991 in the St. Lawrence River basin. The concentrations ranged from non-detect to 0.00009 µg/L (mean 0.00001 µg/L) (Quemerais et al., 1994).

Water samples collected (in 1974-1975) from the Mississippi River, from areas of known hexachlorobenzene contamination in Louisiana, ranged from 2 to 90 µg/L (USEPA, 1976; Laska et al., 1976). Industrial waste water samples have reported HCB levels as high as 300 µg/L (USEPA, 1976; Schmitt, 1990). Some of these high values exceed the solubility of HCB (3.5 to 20 µg/L) in water; and therefore probably reflect the analysis of unfiltered water (includes soil and organic colloids), filtered water that still has some colloidal material, or the reported units are incorrect. Most likely the higher numbers reflect HCB in the water column and HCB sorbed to particulates or colloidal material in the water, rather than water alone.

Other Monitoring Data- STORET

Monitoring data obtained from STORET are briefly discussed and presented below. STORET is a computerized database utility maintained by the Office of Water, EPA for the STOrage and RETrieval of chemical, physical, and biological data pertaining to the quality of waterways within and contiguous to the United States. Geographical, political, and descriptive information concerning sites where data have been collected, known as "stations" are the base to which data is attached. The data contained in STORET are collected, stored, and used by a variety of Federal, State, Interstate, and local government agencies. These data are generally made freely available to every citizen under the Freedom of Information Act (FOIA) or by direct access through a number of mechanisms.

The STORET data generally confirm that HCB and PCB concentrations in surface and ground water will be quite low, generally less than 0.01 µg/L. However, these monitoring data generally appear to represent sample that have not been filtered, and therefore may have sorbed contaminants in the bulk water samples. This may also explain why some of the higher concentrations were reported. Monitoring results from some sites, such as the hazardous waste site in Alabama, represent sites with potentially higher exposure possibilities than those resulting from pesticide use (label rates).

Discussion

All data in STORET are owned by the user-agencies (data owners). Incoming data to the system are edited for errors and inconsistencies, however, the owners of the data have the primary responsibility for its content. Additionally, the STORET system imposes a structure and some minimum content requirements on incoming data, e.g., station identifier data, sample data temporal and spatial information, parametric data. Each agency which submits data to STORET

manages its own data for its own purposes, and because their needs vary widely, the STORET data they maintain varies widely from one agency to the next. Therefore, it is often recommended that prior to use of STORET data for regulatory purposes the circumstances under which it was collected be ascertained.

The STORET database includes a method category code (analysis description), water body type, sample medium, number of samples, reporting units, maximum and minimum values, and remark codes. Three major remark codes are K, U, and "blank" used provide information concerning the quality of the data. These codes instructs you how to interpret the STORET data. The K indicates that the value is "off-scale low", the actual value is not known, but is known to be less than the value shown. The U indicates that the value was analyzed for, but not detected. The value reported is the limit of detection for the process used. The "blank" indicates that the value should be interpreted exactly as reported. Other remark codes are W which indicates that the value observed is less than the lowest value reportable value under remark T. Remark T indicates the value is less than the "criteria" of detection. M indicates that the material was verified, but not quantified, and Q means sample was held beyond specified holding the time. **Therefore, only the data with a "blank" remark code are considered in this assessment.** The remaining data are, however, included in the attached Appendix.

Hexachlorobenzene monitoring data obtained from STORET are briefly discussed and summarized in Tables 5 (water) and 6 (sediments), respectively. Four method categories were indicated in STORET for the determination of HCB in water (39039, 39700, 82621, 34401). HCB residues were detected, under category 39700, in 73 samples with concentrations ranging between 0.00002 and 0.10 µg/L in lake water samples. For category 34401, HCB was detected in one stream sample, at 0.026 µg/L. Method category 39700 indicates whole water and not filtered water was analyzed, thus the measured HCB may include that which is sorbed to suspended particulates or colloids in water, in addition to that which is dissolved. The remaining information for water samples is summarized in Appendix Table A1. The significance of these data could not be evaluated, but are less than the value reported, with most of the listed values being much less than the maximum values being reported.

Several other limitations for interpreting monitoring data should be noted. Monitoring data is often limited by the lack of correlation between sampling date and the use patterns of the pesticide within the study's drainage basin. Additionally, the sample locations were not associated with actual drinking water intakes for surface water nor were the monitored wells associated with known ground water drinking water sources. Also, due to many different analytical detection limits, no specified detection limits, or extremely high detection limits, a detailed interpretation of the monitoring data is not always possible. A lack of data concerning the hydrogeology of the study sites also influences the interpretation of the monitoring data.

The maximum values reported for the HCB residues in sediments, bottom, etc. (Table 6) are much greater than those reported in water (Table 5). This agrees with the high potential for binding as indicated by the high sorption potential (high K_{oc} s). Four category codes were also

given to the samples used to determine HCB levels in sediments (39701, 49343, 75042, 78312). HCB residues were detected in 132 samples (Table 6), with concentrations ranging from 0.001 to 750 µg/kg (39701 and 78312), in lake sediments.

Method Category	Sample	Data Quality Remark ¹	Number of Samples	Maximum (µg/L)	Minimum (µg/L)	Water Type
39700 ²	Total		73	0.10	0.00002	Lake
34401 ³	Dissolved		1	0.026	0.026	Stream

¹ Data Quality Remark: The remark code is used to interpret the STORET data. A “blank” indicates that the value should be interpreted exactly as reported.

² 39700 - Hexachlorobenzene in whole water.

³ 34401 - Hexachlorobenzene in water, dissolved.

Method Category	Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/kg)	Minimum (µg/kg)	Water Type
39701 ²	Sed dry weight bottom		131	750.00	0.001	Lake
78312 ³	Sed wet Weight core		2	2.00	0.90	Lake

¹ Data Quality Remark: A “blank” in the remark code column indicates that the value should be interpreted exactly as reported.

² 39701 - Hexachlorobenzene in bottom deposits, dry solids.

³ 78312 - Hexachlorobenzene in sediment, wet weight.

Of the four method categories described in STORET for analysis of PCB, only method 77793 (Table 7) measured PCB levels in water, the remaining methods address sediment. For the samples designated with the “blank” remark, the surface water values are low, ranging between 0.00002 to 0.0001 µg/L. However, for well water samples, PCB concentrations ranged from 0.001 to 62.1 µg/L. These high values are associated with a “hazardous” waste site in Alabama. These values also appeared to have been measured with “whole” water, not filtered water. Thus,

sorption of PCB to suspended particulates or colloidal material in the water is possible (also probable given that the maximum values exceed the solubility in water). The other three methods determine PCB levels in sediments (Table 8). The highest values, which far exceed the solubility, were found in stream sediment samples.

Method Category	Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/L)	Minimum (µg/L)	Water type
77793 ²	Total water		24	0.0001	0.00002	Stream
77793	Total water		51	0.0003	0.00001	Lake
77793	Total water		19	62.10	0.001	Well

¹ Data quality remark: A “blank” in the remark code column indicates that the value should be interpreted exactly as reported.

² 77793 - Pentachlorobenzene in whole water.

Method Category	Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/L)	Minimum (µg/L)	Water type
39118 ²	sediment		8	540000.0	40.00	Stream
79772 ³	wet weight, core		41	0.47	0.02	Stream
79790 ⁴	dry weight, bottom		1	5.9	5.9	Stream
79772	wet weight, core		2	0.00062	0.00029	Lake

¹ Data quality remark: A “blank” in the remark code column indicates that the value should be interpreted exactly as reported.

² 39118 - Pentachlorobenzene in sediment.

³ 79772 - Pentachlorobenzene in sediment, wet weight.

⁴ 79790 - Pentachlorobenzene in sediment, dry weight.

Fish and Game: HCB residues in commercial fish from the Great Lakes have been as high as 17 mg/kg (Newsome and Andrews, 1993; Zabik et al., 1995). Concentrations have been reported as high as 700 mg/kg in fish samples collected in contaminated areas (Schmitt et al., 1990).

HEALTH ADVISORIES

The USEPA's Office of Water has proposed several Health Advisories (HAs) for HCB. The proposed lifetime HA for children is 50 µg/L and for adults 200 µg/L (USEPA, 1997). The Cancer risk is defined as 2.00 µg/L at 10^{-6} (USEPA, 1997). The EPA's Office of Water has set the MCL for HCB at 1.00 µg/L (USEPA, 1997).

EXPOSURE ASSESSMENT

HCB and PCB contaminant levels in pesticides have generally declined since the 1970's, concomitant with declines in HCB releases into the environment. However, due to the persistence of HCB (and PCB) in soil, sediments, and the atmosphere, the potential for exposure from contaminated drinking water continues for previous HCB and PCB releases in addition to continuing releases. It appears that HCB and PCB contamination of ground-water resources is relatively unlikely due to the high binding potential of both these chlorobenzene compounds. Detections of HCB in ground water generally have ranged between 0.00002 to 0.100 µg/L. Surface water detections show much more variability and have been measured at up to 750 µg/L. These high values appear to include sorbed HCB. The HCB concentrations which actually appear to be dissolved in the water tend to be generally less than 0.001 µg/L. Great Lakes region concentrations generally ranged from 0.00002 to 0.0001 µg/L, when concentrations exceeded this range, they appeared to be related to industrial areas or contaminated areas more than 20 years ago.

Monitoring data is less prevalent for PCB than HCB. It is anticipated that the likelihood of exposure to PCB would be less than that of HCB because of fewer sources. Concentrations of PCB in surface water have ranged between 0.00002 and 0.0001 µg/L. PCB levels in ground water at a hazardous waste site ranged from 0.001 to 62.1 µg/L. PCB concentrations also tend to be very low, 0.00002 to 0.001 µg/L, in unfiltered water samples.

Based upon these monitoring data and fate properties it seems unlikely that long term HCB and PCB concentrations in surface and ground water would exceed 0.01 µg/L. Both of these chemicals although persistent will not remain in solution very long, as they become sorbed to suspended materials and bottom sediment.

The USDHHS (1996) estimates that the average exposure in the United States from drinking HCB contaminated water is 0.00085 µg/kg/year (~ 0.000082 µg/L).

Drinking water systems are required to analyze water for HCB. The monitoring requirements are given in Table 9.

Table 9. HCB MONITORING REQUIREMENTS FOR GROUND WATER AND SURFACE WATER SOURCES (USEPA/OGWDW, 1998).	
Sampling Frequency	Number of samples
Initial Frequency	4 quarterly samples every 3 years
Repeat Frequency	If no detection during initial round: 2 quarterly samples per yr if serving >3300 persons; 1 sample per 3 years for smaller systems
	Triggers - Return to Initial frequency if detection at > 0.1 µg/L

The best available technology for treatment is activated granular charcoal. The high sorption indicated by the high K_{oc} supports that this kind of treatment would greatly reduce HCB and PCB in water.

SELECTED REFERENCES

- Carey, A.E., T.E. Dixon, H.S.C Yang. 1985. Environmental exposure to hexachlorobenzene in the United States. OPTS USEPA. Washington, DC.
- Hoff, R.M. D.C.G. Muir, N.P. Grift. 1992. Annual cycle of polychlorinated biphenyls and organohalogen pesticides. Environ. Sci. Technol. 26:276-283.
- Kelly, T.J., J.M. Czuczwa, P.R. Sticksel. 1991. Atmospheric and tributary inputs of toxic substances to Lake Erie. J. Great Lakes Res. 17:504-516.
- Lane, D.A., N.D. Johnson, M.J. Hanely. 1992. Gas- and particle-phase concentrations of alpha-hexachlorocyclohexane, gamma-hexachlorocyclohexane, and hexachlorobenzene in Ontario air. Environ. Sci. Technol. 26:126-133.
- Lindqvist, R. and C.G. Enfield. 1992. Biosorption of dichlor-diphenyltrichlorethane and hexachlorobenzene in groundwater and its implications for facilitated transport. Applied and Environmental Microbiology 58:2211-2218.

- Newsome, W.H., D. Davies, and J. Doucet. 1995. Organochlorine pesticides and polychlorinated biphenyl congener in commercial fish from the Great Lakes. *J. of AOAC International*. 76:707-710.
- Oliver, B.G. and K.D. Nicol. 1982. Chlorobenzenes in sediments, water, and selected fish from Lakes Superior, Huron, Erie, and Ontario. *Environ. Sci. Technol.* 16:532-536.
- Quemerais, B., C. Lemieux, K.R. Lum. 1994. Concentrations and sources of PCBs and organochlorine pesticides in the St. Lawrence River (Canada) and its tributaries. *Chemosphere* 29:591-610.
- Schmitt, C.J., J.L. Zajicek, and P.H. Peterman. 1990. National contaminant biomonitoring program: Residues of organochlorine chemicals in U.S. fresh water fish, 1976-1984, *Arch Environ Contam. Toxicol.* 19:748-781.
- Swann, R.L., D.A. Laskowski, P.J. McCall. 1983. A rapid method for the estimation of the environmental parameters octanol/water partition coefficient, soil sorption constant, water to air ratio, and water solubility. *Residue Rev.* 85:17-28.
- TRI93. 1993. National Toxicology Information Program, Toxic Chemical Release Inventory. National Library of Medicine. Bethesda, MD.
- USDHHS. 1996. Toxicological Profile for Hexachlorobenzene (Update). U.S. Dept. of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Division of Toxicological/Toxicology Information Branch. Atlanta, GA.
- USEPA. 1985. Drinking Water Criteria document for hexachlorobenzene. USEPA. ODW, EPA/600/x-84/1790-1. Washington, DC
- USEPA. 1986. Exposure assessment for hexachlorobenzene. USEPA. OPPTS. EPA 560/5-86-019. Washington, DC
- USEPA. 1992. Pesticides in Ground Water Database. A compilation of monitoring studies: 1971- 1991 National Summary. EPA 734-12-92-001. U. S. Environmental Protection Agency: Arlington, VA.
- USEPA. 1997. Drinking Water Standards and Health Advisories. USEPA Office of Water. Washington, DC
- USEPA. 1998a. Technical Factsheet on Hexachlorobenzene (HCB). 1/27/98. USEPA OGWDW (<http://www.epa.gov/OGWDW/dwh/t-soc/hcb.html>) Office of Water, Washington, DC.

USEPA. 1998b. Database search by OPPTS. USEPA. OPTS. Washington, DC.

Zabik, M.E. and RI Schemmel. 1980. Influence of diet on hexachlorobenzene accumulation in Osborne Mendel rats. *J. Environ. Pathol. Toxicol.* 4:97-103.

APPENDIX. Remaining Hexachlorobenzene and pentachlorobenzene monitoring data reported in STORET.

Table A1. Summary of remaining hexachlorobenzene (HCB) monitoring data in water from STORET.						
Method Category	Sample	Data Quality Remark ¹	Number of Samples	Maximum (µg/L)	Minimum (µg/L)	Water Type
39039 ²	Water	K	2	0.10	0.10	Lake
39700 ³	Total	K	11	0.80	0.010	Lake
39700	"	U	6	0.010	0.010	Lake
39700	"	K	502	100.00	0.000003	Lake
39700	"	T	1	10.00	10.00	Lake
39700	"	U	63	25.0	0.000	Lake
39700	"	W	15	10.00	10.00	Lake
82621 ⁴	Total Recoverable	K	1	0.02	0.02	Lake
39700	Total	U	42	8.70	0.00	Ocean
34401 ⁵	Dissolved	K	16	5.00	0.006	Stream
34401	Dissolved	M	25	0.018	0.007	Stream
34401	Dissolved	Q	3	0.014	0.008	Stream

¹ Remark: The remark codes K and U are used to interpret the STORET data. The K indicates that the value is "off-scale low", the actual value is not known, but is known to be less than the value shown. The U indicates that the value was analyzed for, but not detected. The value reported is the limit of detection for the process used. Other remark codes are W which indicates that the value observed is less than the lowest value reportable under remark T. Remark T indicates the value is less than the criteria of detection. M indicates that the material was verified, but not quantified and Q means sample was held beyond specified holding time.

² 39039 - Hexachlorobenzene in water, electron capture.

³ 39700 - Hexachlorobenzene in whole water.

⁴ 82621 - Hexachlorobenzene in water, total recoverable.

⁵ 34401 - Hexachlorobenzene in water, dissolved.

Table A2. Summary of hexachlorobenzene (HCB) monitoring data in sediment from STORET.

Method Category	Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/kg; ng/g)	Minimum (µg/kg; ng/g)	Water Type
39701 ²	Sed dry weight bottom	U	26	3.00	1.50	Lake
	Sed dry weight bottom	K	1231	2232.0	0.01	Lake
	Sed dry weight bottom	T	22	1.0	0.00	Lake
	Sed dry weight bottom	U	58	5000.0	0.00	Lake
49343 ³	Sieved	K	34	2220.00	1.00	Lake
75042 ⁴	Sed dry Weight bottom	U	1	47.5	47.5	Lake
78312 ⁵	Sed wet Weight core	K	11	350.0	0.70	Lake
39701	Sed dry weight	K	1	5.00	5.00	Ocean
	Sed dry weight	U	63	1700.00	0.00	Ocean

¹ Data Quality Remark: The several remark codes are K, U, and T are used to interpret the STORET data. The K indicates that the value is “off-scale low”, the actual value is not known, but is know to be less than the value shown. The U indicates that the value was analyzed for, but not detected. The value reported is the limit of detection for the process used. Remark T indicates the value is less than the criteria of detection.

² 39701 - Hexachlorobenzene in bottom deposits, dry solids.

³ 49343 - Hexachlorobenzene in sediment, sieved, dry weight.

⁴ 75042 - Hexachlorobenzene in sediment, dry weight.

⁵ 78312 - Hexachlorobenzene in sediment, wet weight.

Table A3. Summary of pentachlorobenzene (PCB) monitoring data in water from STORET.

Method Category		Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/L)	Minimum (µg/L)	Water type
77793 ²	“	water	K	85	20.00	0.000	Stream
	“	water	U	7	6.000	0.020	Stream
77793	“	“	K	1	0.000003	0.000003	Lake
77793	“	“	K	186	10.00	0.007	Well
	“	“	U	20	50.00	0.001	Well

¹ Data Quality Remark: Two remark codes are K and U are used to interpret the STORET data. The K indicates that the value is “off-scale low”, the actual value is not known, but is know to be less than the value shown. The U indicates that the value was analyzed for, but not detected. The value reported is the limit of detection for the process used.

² 77793 - Pentachlorobenzene in whole water.

Table A4. Summary of pentachlorobenzene (PCB) monitoring data in sediment from STORET.						
Method Category	Medium	Data Quality Remark ¹	Number of Samples	Maximum (µg/kg; ng/g)	Minimum (µg/kg; ng/g)	Water type
39118 ²	sediment	K	138	13000.0	0.00	Stream
79790 ³	dry weight, bottom	U	1	250.0	250.0	Stream
	dry weight, bottom	U	49	6.9	2.2	Stream
79772 ⁴	dry weight, bottom	U	1	250.0	250.0	Lake
39118		K	64	2247.2	0.000	Estuary
		K	32	40.00	0.020	Estuary
39118		K	13	2183.0	0.000	Reservoir
		K	1	0.020	0.020	Reservoir

¹ Data Quality Remark: The three major remark codes are K and U are used to interpret the STORET data. The K indicates that the value is “off-scale low”, the actual value is not known, but is known to be less than the value shown. The U indicates that the value was analyzed for, but not detected. The value reported is the limit of detection for the process used.

² 39118 - Pentachlorobenzene in sediment.

³ 79772 - Pentachlorobenzene in sediment, wet weight.

⁴ 79790 - Pentachlorobenzene in sediment, dry weight.