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Project Summary

Fate and Persistence in Soil of Selected Toxic Organic Chemicals

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The environmental fate and behavior of several toxic organic materials are reviewed in the final report on which this summary is based. This effort has sought to summarize the chemical and physical properties of these materials, and discusses how these properties affect persistence and behavior of toxic chemicals in the soil/water/air systems.

In general, the organic carbon content of a soil has the greatest effect on the behavior of hydrophobic toxic organic compounds. The organic compounds sorb strongly to the organic matter in the soil. Several equations have been derived that define water solubility relationships. These are partition coefficients between octanol/water and organic matter/water.

Persistence of the toxic organic compounds depends on several environmental factors, including soil organic matter, total precipitation and intensity, temperature, sunlight intensity, and soil texture. Organic chemicals are subject to one or more of seven possible fates: (1) sorption, (2) volatilization, (3) microbial degradation, (4) photodecomposition on the soil surface, (5) translocation to plants, (6) chemical degradation, and (7) leaching to ground water. Some of these fates are directly related to the degree of sorption; i.e., very little of a material that is strongly sorbed will be in solution and available for degradation or movement by the other processes.

Some generalities are presented regarding the environmental conditions and chemical/physical properties that affect persistence and mobility; however, the reader should bear in mind that there are always exceptions to the rule.

Disregarding any interactions between environmental conditions, the following effects might be expected:

1. ***Temperature*—The warmer the temperature is, the greater the volatility, the lower the organic matter content of the soil, the more active the microbial population, and the higher the rate of evapotranspiration. The result is a decrease in pesticide persistence.**
2. ***Moisture*—There is an optimum level of soil moisture for microbial activity. If a soil is too wet or too dry, activity slows down. Volatility is also affected by moisture content; the nature of the effect depends on the solubility of the chemical. The total amount, the intensity, and the frequency of rainfall or irrigation water received affect the movement of chemicals in soil.**
3. ***Light*—Photochemical reactions are directly proportional to the number of photons absorbed by a chemical. Nearness to the equator or an increase in altitude will accelerate photochemical reactions.**
4. ***Soil texture*—Soil texture is an important factor. Soil organic matter is directly influenced by**

the soil texture. Coarse (i.e., sandy) soils will normally be low in organic matter; therefore, water percolation will be rapid and the leaching potential of chemical compounds will be high regardless of K_{ow} or K_{oc} values. The opposite is true for heavy (i.e., clayey) soils.

The property that affects persistence and mobility most directly is water solubility. Within a class of compounds (e.g., dioxins or PCBs), the higher the degree of chlorination or bromination is, the lower the water solubility and, therefore, the greater the persistence.

Low-molecular-weight compounds with low chlorine content (e.g., chlorobenzene, dichlorobenzene, napthalene) will be subject to a greater degree of biodegradation, photodecomposition, volatilization, and leaching than will high-molecular-weight compounds with higher chlorine or bromine content (e.g., hexachlorobenzene, dibenzodioxins and dibenzofurans, PCBs, PBBs, and DDT and its related compounds).

The literature search revealed a sparsity of information on many of the compounds discussed in this document, and gaps were numerous. No information was found on biphenylenes and azoxybenzenes.

Half-life estimates between compounds were difficult to compare because of the differences in experimental and/or environmental conditions. If a standard set of conditions were adopted, and half-life estimates were developed for a well-studied compound (e.g., DDT) under each set of conditions, other compounds could be studied under these same standard conditions and half-life estimates could then be calculated relative to the standard materials. These relative half-lives could then be compared and used to predict behavior based on similarities and differences among other compounds of interest.

This Project Summary was developed by EPA's Office of Health and Environmental Assessment, Washington, DC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Discussion

The implementation of environmental programs to clean up organic chemicals that have been released onto and contaminated soils requires an understanding of the long-term risk associated with leaving the soil in place or transporting it to an ultimate disposal site. Currently available information on the persistence of highly toxic organic chemicals is too sparse to allow development of exposure assessments with the degree of confidence needed by the regulator or by the public. The U.S. Environmental Protection Agency (EPA) recognizes the need for guidance materials to assist in the determination of long-term human health risks posed by persistent toxic compounds.

The objective of the guidance material in this document is to provide information needed to support procedures for estimating the environmental half-life of compounds having a high affinity for soils. Specific compounds discussed herein were selected from the following groups:

- Chlorinated benzenes
- Halogenated biphenyls
- Chlorinated azobenzenes
- Halogenated biphenylenes
- Chlorinated azoxybenzenes
- Chlorinated naphthalenes
- Chlorinated cyclohexanes
- Halogenated dibenzofurans
- Halogenated dibenzodioxins

Also identified for investigation were toxaphene, DDT, and hexachlorobutadiene.

Selection of representative compounds or mixtures (e.g., toxaphene, polychlorinated biphenyls) was based on their potential for human toxicity and the availability of information on their behavior in soil (Table 1). Some compounds (e.g., DDT and γ-hexachlorocyclohexane) have been studied by many investigators; therefore, much information is available. Other compounds, however, including the entire groups of biphenylenes and azoxybenzenes, have not been studied. Because information is sparse on these latter compounds, they are not addressed here.

Before the primary objective of this guidance material could be achieved, several lesser objectives had to be identified and addressed. For example, this study addresses how soil characteristics, physical/chemical processes, biological processes, chemical structure, microorganisms, and interactions influence the persistence of compounds in soils. It also evaluates the influences of various environmental factors (including solar radiation, temperature, moisture, pH, Eh, and the presence of other chemicals) on persistence in and affinity for soils.

Wherever possible, the final report includes information on the behavior of toxic organic compounds under varying soil and climatic conditions throughout the United States. Factors responsible for half-life variability under various conditions are also identified.

Table 1. *Representative Organic Compounds Selected for Review Based on Potential Toxicity in the Environment*

Group	*Compound*
Chlorinated benzenes	*Hexachlorobenzene* *1,2-Dichlorobenzene*
Chlorinated azobenzenes	*3,3',4,4'-Tetrachloroazobenzene (TCAB)*
Chlorinated cyclohexanes	*γ-Hexachlorocyclohexane (HCH)*
Halogenated dibenzofurans	*2,3,7,8-Tetrachlorodibenzofuran (TCDF)*
Halogenated dibenzodioxins	*2,3,7,8-Tetrachlorodibenzodioxin (TCDD)*
Halogenated biphenyls	*Polychlorinated biphenyls (PCBs)* *Polybrominated biphenyls (PBBs)*
Chlorinated naphthalenes	*Polychlorinated naphthalenes*
Related Compounds	*Toxaphene* *Hexachlorobutadiene* *DDT*

A method for estimating the half-life of compounds for which no such data are available is discussed. This method uses the K_{oc} partition coefficient to place compounds with unknown half-lives in a position relative to those whose half-lives are predicted with some degree of certainty. Finally, the relative soil adsorptive characteristics, persistence, and toxicity of the selected organic compounds are presented.

Section 2 of the final report provides a review of soil and its physical/chemical properties, including composition and texture, water content, pH, organic matter, cation exchange capacity, and temperature. Section 3 describes each of the major pathways of chemical loss from the soil. Section 4 presents an explanation of partitioning in the environment and includes information on determining the likelihood of each chemical's fate. Section 5 provides information on the persistence, toxicity, and half-life of the specific organic compounds selected for investigation.

The materials used for the final report were drawn from an existing literature data base. The sources are cited in the text of that report.

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The complete report, entitled "Fate and Persistence in Soil of Selected Toxic Organic Chemicals," (Order No. PB 87-186 433; Cost: $18.95, subject to change) will be available only from:
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