SORPTION OF CARBON TETRACHLORIDE, ETHYLENE DIBROMIDE, AND TRICHLOROETHYLENE ON SOIL AND CLAY

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Abstract. The sorption of carbon tetrachloride, ethylene dibromide, and trichloroethylene in two silty clay loam soils and aluminium (Al\textsuperscript{3+}) or calcium (Ca\textsuperscript{2+}) saturated montmorillonite clay was studied. When the adsorbents were exposed to environmental levels of these chemicals (10 to 1000 ppb in water) the amounts of each of the chemicals sorbed were 6% or less of that available except for a 17% sorption of trichloroethylene by Al-saturated clay. In the case of the Ca-saturated clay, there was no apparent sorption of carbon tetrachloride or trichloroethylene. When soil sorption was normalized based on the soil organic carbon content (K\textsubscript{ooc}), a correlation was found between the K\textsubscript{ooc}, water solubility, and octanol/water partitioning coefficients of the chemicals. However, carbon tetrachloride did not behave according to with the predicted relationships.

1. Introduction

As interest in the fate of organic pollutants in the environment increases, special concern is justified for chemicals which are known to be, or are suspected of being, carcinogenic. For our initial studies we selected benzene, carbon tetrachloride, ethylene dibromide, and trichloroethylene. These chemicals were picked because they ranked high on the list of carcinogens in terms of activity and quantities produced and released [1]. Their elevated volatility and low water solubility make them difficult to work with and may have precluded them from other environmental studies. Our interest was not the fate of chemicals resulting from a large spill onto the soil, but rather the behavior of those quantities which could be dissolved in surface water or scrubbed from the atmosphere by precipitation.

In a previous study with benzene, experimental and interpretational procedures were developed which allowed for a more rapid evaluation of the sorption characteristics of chemicals [2]. The object of this report is to present the sorption-partition constants for carbon tetrachloride, ethylene dibromide, and trichloroethylene in soils and clay, as well as the relationships between the soil sorption constants and some physical properties of the chemicals which were investigated. These data add to an understanding of the relationships between physical and chemical properties upon which predictions of the fate of organic chemicals in soil will be based.

2. Materials and Methods

The adsorbents used for the study included two soils (Overton series from southeastern Nevada and Hastings series from Nebraska), and montmorillonite clay (montmorillonite

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Before use, the clay was saturated with either $\text{Al}^{3+}$ or $\text{Ca}^{2+}$. The methods used to prepare the soils and clay were reported previously [2]. Chemical and physical properties of these adsorbents are found in Table 1.

**TABLE I**  
Physical and chemical properties of adsorbents

<table>
<thead>
<tr>
<th>Adsorbent</th>
<th>% Sand</th>
<th>% Clay</th>
<th>% Organic carbon</th>
<th>Cation exchange capacity, mequiv/100 g</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hastings silty clay loam</td>
<td>1</td>
<td>31$^a$</td>
<td>2.6</td>
<td>17</td>
<td>5.6$^c$</td>
</tr>
<tr>
<td>Overton silty clay loam</td>
<td>15</td>
<td>34$^a$</td>
<td>1.8</td>
<td>29</td>
<td>7.8$^c$</td>
</tr>
<tr>
<td>Al-saturated montmorillonite</td>
<td>0</td>
<td>100</td>
<td>0$^b$</td>
<td>80$^b$</td>
<td>4.2$^d$</td>
</tr>
<tr>
<td>Ca-saturated montmorillonite</td>
<td>0</td>
<td>100</td>
<td>0$^b$</td>
<td>80$^b$</td>
<td>6.6$^d$</td>
</tr>
</tbody>
</table>

$^a$ Montmorillonitic in character.  
$^b$ Assumed value.  
$^c$ 1:5 soil-water solution.  
$^d$ 1:50 clay-water solution.

Carbon tetrachloride, ethylene dibromide and trichloroethylene were obtained from New England Nuclear premixed in distilled $\text{H}_2\text{O}$. Each chemical was uniformly labeled with 0.10 mCi of $^{14}\text{C}$, mixed with 20 ml distilled $\text{H}_2\text{O}$ and sealed in glass ampules. Specific activity of the chemicals were: carbon tetrachloride, 4.7 mCi/mmol; ethylene dibromide, 20.0 mCi/mmol; trichloroethylene, 2.1 mCi/mmol. Upon arrival, the solutions were frozen at $-5 \, ^\circ\text{C}$ until needed. Three solution concentrations of each chemical were used; 10, 100, and 1000 ppb (W/W) in the case of carbon tetrachloride and ethylene dibromide and 100, 500, and 1000 ppb (W/W) for trichloroethylene.

Sorption of the chemicals to the adsorbents was determined by triplicate batch equilibration. Time periods for equilibration were 16, 42, and 144 h for all the chemicals. The amount of chemical associated with an adsorbent was determined by oxidation followed by liquid-scintillation. The techniques used for this study together with the methods used to generate Freundlich sorption constants ($K_f$ and $1/n$) were carefully detailed in a previous report [2].

3. Results and Discussion

An investigation of $K_f$ values versus adsorbent-chemical equilibration times was made so that time dependent sorption could be determined for each of the chemicals. In general, there were no significant changes (greater than 2X) of $K_f$ values with time. For convenience, 16 h was chosen for the equilibrium time period.