DISCUSSION

Many investigations into the factors contributing to pesticide leaching have been completed (Carsel et al., 1985) which have illustrated that the migration of pesticides within the root zone is a dynamic process with many interacting factors. Factors such as the chemical solubility in water, sorptive properties, pesticide formulation, soil persistence, soil properties, climatic conditions, crop type and cropping practices all effect chemical movement. Since the objective of this study was to establish a base comparison of various pesticides on various soil type, as many of these factors were eliminated as possible. Observation of the effects of the remaining factors on pesticide leaching are discussed within this section.

Leachate Volumes

The weekly leachate volumes collected and percent recoveries listed in Table 6 indicate that water loss by evaporation had occurred during the column study. The percent recoveries listed are probably higher than what had actually occurred due to the apparent excess water collected during different weeks of the study. The more permeable soils, Sparta and Plainfield had excess water over that applied collected in weeks 2, and 4. Percent recoveries during those weeks were higher than the recoveries observed during other weeks. The excess water from week 2 can be attributed to water held in the columns beyond its FMC levels at the beginning of the study probably form the initial saturation of the columns.
The less permeable soils, Burkart and Antigo, were more consistent, with the exceptions of the anomalies detected in week 4 and 6 for Burkart Column 2. It is suspected that since the more permeable soils (Sparta and Plainfield) were above FMC at the start of the study that the less permeable (Antigo and Burkart) were also be above FMC, but due to their lower permeability and higher water holding capacity they would be expected to release the excess water at a slower rate and would therefore, take longer to reach FMC. The higher FMC of these soils would also tend to buffer differences between columns.

The water loss from the columns is believed to be due to evaporation, either through the top of the column or through the vacuum. The column system is otherwise closed (i.e. sample containers or stoppered). It is suspected that the majority of the evaporation occurred from the top of the column since the vacuum was only run periodically.

The cumulative leachate volumes related to FMC listed in Table 7 showed good correlation between the soil types, with the exception of Antigo column 14 which was approximately 20% less than the other three antigo columns.

The total leachate collected from the Burkart soil sets represents about two-thirds of the calculated FMC. This is a factor of the pore size of this soil type and its ability to hold water. The same is true for the Antigo soil which also showed about two-thirds the calculated FMC being collected as leachate. These low volumes should result in minimal leaching of chemicals
from these columns since most pesticide movement is associated with water movement (Bailey and White, 1970).

The more permeable, larger pored soils, showed that approximately two times the calculated FMC was leached through the soil columns. Therefore, for the Sparta and Plainfield soils, the columns were actually flushed with the added water. An increase in the movement of water through the soil column will increase the extent of leaching (Friesen, 1965).

If the Antigo and Burkart columns were leached with a proportional volume of water relative to FMC, the leaching results between these and the sandy soils may have shown more similarities. If you use the inorganic nitrate and chloride data as an indicator, remembering that they are not subject to the degradation or volitization that organics are, evidence that leaching similarities between the soil types receiving equivalent FMC pore volumes can be seen in Figures 21 and 22. As stated previously, the inorganics from these two columns were subject to additional leaching that amounted to approximately one and one-half times the FMC. Comparison of this data to the leaching results of the Sparta (Figure 11, 12, 13, and 14) and Plainfield (Figures 27 and 29) shows more similar results than what was observed between the different soil types receiving equal volumes of water. It is believed that results under these conditions would still show significant difference between the soil types due to other factors influencing chemical movement. Compounds with lower adsorptive capacities would likely been detected more often than chemicals.
with strong adsorptive characteristics.

**Chemical Properties**

In past studies of the effects of chemical properties on leaching results it was determined that solubility is the most important factor (Felsot, 1984; Gray and Weierich, 1968)

This conclusion is supported by the data collected in this study based on the similarities of the oxamyl, total aldicarb and total carbofuran results from the Sparta and Plainfield soils. Based on chromatographic separation of these compounds during reverse phase column HPLC analysis, it would be expected that oxamyl, aldicarb sulfoxide, and aldicarb sulfone would leach much faster than carbofuran. It would also indicate that carbaryl, a much less soluble compound (Table 3), would also leach based on its weak adsorptive capacity. Carbaryl has similar adsorptive capacities to carbofuran based on HPLC column retention times but is more than an order of magnitude less soluble. Carbofuran was detected in leachate from all four Sparta and Plainfield columns and in one Antigo and one Burkart column, but no carbaryl was detected in any leachate samples (Table 8).

Atrazine, however, has a water solubility similar to carbaryl and was detected at levels greater than detection limits in all Sparta and Plainfield columns (Table 8). The levels detected were however, noticeably less than the more soluble compounds.

Alachlor has a solubility approximately 5-times that of atrazine (Table 3), but was detected at lower levels. It appears that other processes, absorption, degradation and/or
volatilization, are limiting the detections for this compound.

Table 17 summarizes the average pesticide recoveries for both leachate samples and soil samples.

Table 17. Pesticide leaching summary. Percent pesticide recovered in leachate or remaining in soil columns for four soil types and six pesticides over a seven week leaching study.

<table>
<thead>
<tr>
<th></th>
<th>Antigo</th>
<th></th>
<th></th>
<th>Plainfield</th>
<th></th>
<th></th>
<th>Sparta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leachate</td>
<td>Soil</td>
<td>Leachate</td>
<td>Soil</td>
<td>Leachate</td>
<td>Soil</td>
<td>Leachate</td>
</tr>
<tr>
<td>Aldicarb</td>
<td>0.1</td>
<td>43</td>
<td>0.1</td>
<td>19</td>
<td>33.3</td>
<td>0.8</td>
<td>37</td>
</tr>
<tr>
<td>Oxamyl</td>
<td>0.2</td>
<td>17</td>
<td>ND</td>
<td>0.3</td>
<td>40</td>
<td>0.4</td>
<td>48</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>0.2</td>
<td>31</td>
<td>0.1</td>
<td>25</td>
<td>38.6</td>
<td>2</td>
<td>36</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>ND</td>
<td>5</td>
<td>ND</td>
<td>5.7</td>
<td>ND</td>
<td>0.4</td>
<td>ND</td>
</tr>
<tr>
<td>Atrazine</td>
<td>&lt;0.1</td>
<td>17</td>
<td>&lt;0.1</td>
<td>14</td>
<td>3.0</td>
<td>12</td>
<td>1.7</td>
</tr>
<tr>
<td>Alachlor</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>15</td>
<td>&lt;0.1</td>
<td>0.9</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

N/A = not analyzed
ND = not detected

The difference in the carbaryl and atrazine data may be related to adsorption/desorption processes. These processes are also believed to be important in determining chemical leachability (Jury, 1986) The $K_w$ (measure of adsorptive capacity) for atrazine is higher (less absorptive) than carbaryl (Table 3). The $K_w$ for alachlor indicates it is more suspectable to adsorptive processes than carbaryl.

The effects of chemical absorptive properties is obvious in the leaching data collected for this study. The timing and amount of leaching observed for the readily leachable pesticides oxamyl and aldicarb sulfoxide compared to the more adsorptive pesticides carbofuran, aldicarb, atrazine, and alachlor. This shows the effect of chemical adsorption properties on leaching.
In each Sparta and Plainfield column, oxamyl and aldicarb sulfoxide (sulfoxide) were first detected in the same week and the maximum concentrations detected also occurred during the same week. It can therefore be assumed that within the sandy soil types these two compounds are similar leachers. Aldicarb sulfone (sulfone) generally followed the same leaching pattern with the exceptions of Columns 4, 11 and 12. It is suspected that these differences are due more to the degradation process of aldicarb to its metabolites than the adsorptive process. Since the breakthrough of these chemical occurs rapidly with the sandy soils (3 or 4 weeks), the degradation from sulfoxide to sulfone may not have occurred yet. The degradation of aldicarb to sulfoxide occurs readily because the sulfoxide has a lower partition coefficient allowing for the dissolved concentration to increase until most of the conversion is complete. The degradation of sulfoxide to sulfone follows a first-order decay curve and is slower (Mullins, 1993).

In Columns 4, 8, 12, and 15 carbofuran (Tables 12 and 15) was first detected during the same week as oxamyl and sulfoxide, but the maximum concentrations were observed in a later sample (1-week later). In Column 7 carbofuran was detected one week later than oxamyl and sulfoxide. This initial detection for this column also represented the maximum concentration detected, indicating a form of slug movement through this column. This slightly delayed movement of carbofuran is believed to be related to the effects of absorption.

Both aldicarb initial detection and its maximum detection
followed that of oxamyl and sulfoxide by one week for Columns 3, 4, 7, and 8 (Sparta soil) The data from the Plainfield columns showed that only column 15 followed this trend.

Atrazine was first detected during the same week as oxamyl and sulfoxide in Sparta Columns 3 and 4, and Plainfield Column 16, but the maximum detections were a week or more later. Atrazine was detected after oxamyl and aldicarb sulfoxide in Columns 8 and 15.

In columns with detections of alachlor, it was detected after oxamyl and sulfoxide.

These data indicate that if solubility were the only factor effecting leachability, all pesticides would have been detected at the same time and would of followed similar distributions and only concentrations would have varied. In other words leachate results would be the same as water movement and no retardation would occur.

**Soil Effects**

Soil properties and conditions affecting pesticide leaching include: Texture (%sand, silt, and clay), structure, bulk density, moisture content, organic matter content, pH, cation-exchange capacity, and microorganism population and types. These properties act in combination to influence water movement, pesticide absorption and desorption and degredation.

The effects of soil properties on the pesticide leachate data collected were not that distinguishable, with the exception of texture. Texture in directly related to the previous discussion of leachate volumes.
It is assumed that if this study were to have been extended the effects of other soil properties would have had a more noticeable effect on pesticide leaching results. The less permeable soils would have leached at a slower rate which would have allowed for the greater separation of the pesticides applied due to adsorption/desorptive processes. Degredation rate differences between soils may also have showed up. Antigo soil from Columns 10 and 14 actually show a more distinct separation of chloride from nitrate than the current column study. This illustrates that soil properties also effect leaching, but it appears that the properties of the chemical is the more dominant force for the conditions present within this soil column study.

Leaching differences were observed for the sandy soils compared to the Antigo and Burkart, with apparently larger total degredation occurring in the heavier soils where total chemical residues were lower at the end of the study.

Application Amounts

Both a "High Concentration" and a "Low Concentration" amount of pesticides were applied to soil columns for each soil type. The "High Concentration" amounts represent the upper end of the recommended application rates by the manufacturer. This value was selected without consideration of the soil type referred to in the instructions. The "Low Concentration" is the lower end of the application rates. A table is included in Attachment 1 with the manufacturers instructions, which show the pounds per acre used.

No consistent trends differentiating the "low" from the "high"
applications were noted. Inconsistencies were noted in percent recoveries of columns of similar soil types, are assume to be related to other processes (i.e. column packing procedures, etc...). Although, based on this study the application rate, within the range of the instructions, does not increase leaching percentages, it does increase concentrations. The mass of compounds detected in the leachate samples and within soil residue were consistently higher for the higher application rates.

Residual Soil

Burkart soil data (Table 11) indicates that for Columns 1, 5, and 6 the majority of total aldicarb applied had migrated through the upper 45 cm of soil. For these columns, the total percentage found between 45 and 75 cm ranged between 13 and 21 percent. Based on the soil characteristics of the lower horizon of the Burkart soil, it could be assumed that the continuation of the water application would have caused breakthrough for that compound (Table 4). It also appears that carbofuran would be a continued leaching threat.

Oxamyl was not detected in any significant quantities and carbaryl, atrazine, and alachlor residues were limited to the upper horizons and would be of minimal threat to further migration.

The Antigo pesticide residual data Table 14 shows the potential for breakthrough of fatal aldicarb, oxamyl, and carbofuran. A 7.33 percent detection in the 45-60 cm horizon is the result of the longer/8 week leaching. These values at this depth is a threat for breakthrough.
The reason for the much higher recoveries of oxamyl compared to the Burkart soil is not known, however, there are significant pH differences between these soils that could export chemical or biological breakdown.

The results from the soil indicates that under the environmental conditions used, and pesticides compound determine to be leachable would also migrate through the heavier soils used for this project.