

Adsorption of Insecticides on Pond Sediments and Watershed Soils¹

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Abstract

Adsorption of malathion, phorate, and carbaryl was studied on pond sediments and watershed soils. Mineralogical characterization showed the clay fractions of both the sediment and soil to contain kaolinite, micaeous minerals and vermiculite. Adsorption studies with the soils revealed malathion was adsorbed to the greatest extent followed by carbaryl and then phorate. Since adsorption tends to retain pesticides in soil, the probability of contamination of pond water following application of these insecticides is slight.

Introduction

The pollution of water resources by pesticides and other organo-toxicants has received much attention since contamination of the Tennessee River by toxaphene in 1951 as reported by Young and Nicholson (7). Entrance of a pollutant into water from use on agricultural land is regulated by the factors controlling the fate of pesticides in the soil. Removal of the pesticide from the soil might occur through leaching, volatilization, or runoff while adsorption of pesticides tends to retard or prevent removal. In addition, pesticides may undergo alterations in the soil as the result of chemical, biological, or photochemical processes. The ultimate fate of a pesticide depends on a combination of these parameters. However, adsorption on colloidal surfaces of the soil appears to determine to a greater extent than any other single factor the ultimate fate of pesticides. The nature and extent of adsorption has been discussed by Bailey and White (2) and Meyers (4).

This study deals with the adsorption of three insecticides on watershed soils and their corresponding pond sediments. Generally, adsorption of a pesticide to a significant degree will greatly reduce, if not eliminate, movement into surface waters. To facilitate the study, three small farm ponds were selected on the Purdue University Southern Indiana Forage Farm in Dubois County. The watershed soil types were Zanesville (6-18% slope) and Welston (12-18% slope) silt loams which have developed from sandstone and shale. The soils are similar except for the fragipan formation in the Zanesville soil. Each of the watersheds was devoted to alfalfa production. Prior to the application of insecticides, soil samples were collected from the watersheds and sediment samples were collected from the pond bottoms. The mineralogical characterizations and the adsorption studies described below were conducted using these materials. Since the mineralogical and physical properties of the three ponds were similar, only results from one of the ponds are reported.

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Results

Mineralogical Characterization

The mineralogical composition of the clay fraction of pond sediment in relation to its watershed soil has not previously been reported in Indiana. Therefore, the mineralogical composition of both soil and sediment was determined to provide information on this relationship

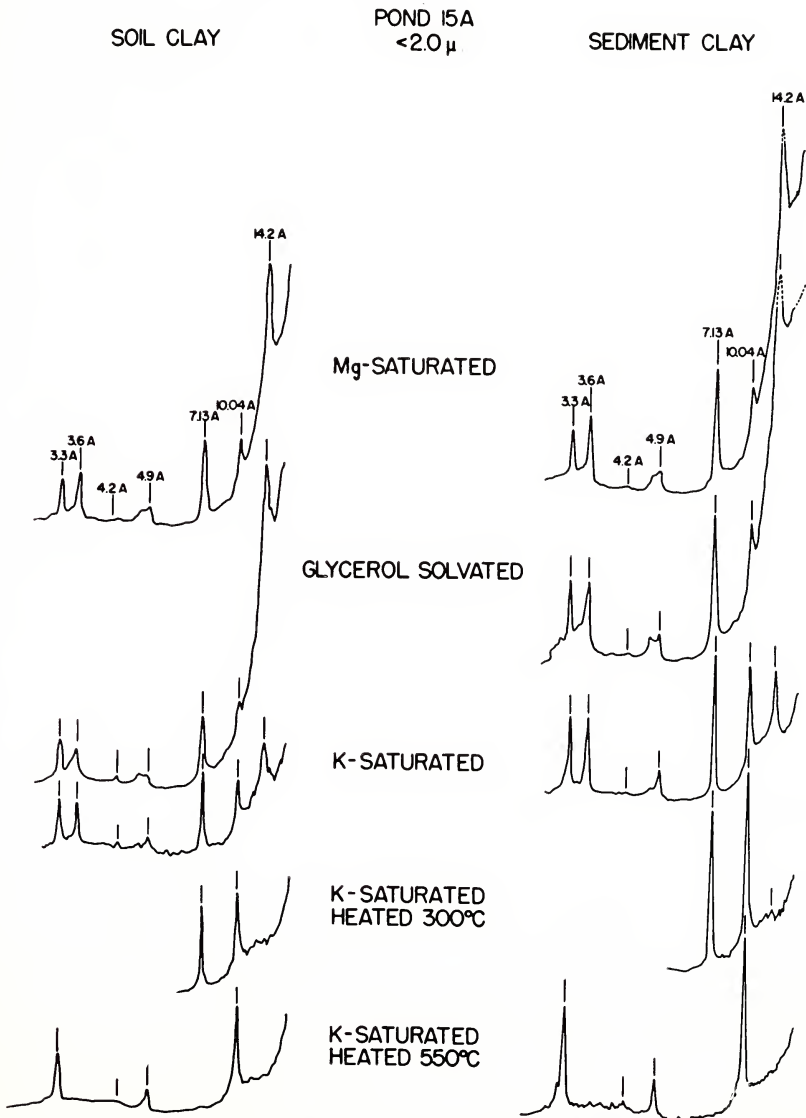


FIGURE 1. X-ray diffractogram of the soil and sediment clay.

as well as to provide a basis for meaningful interpretation of the adsorption studies. The mineralogical composition was determined by x-ray diffraction and infrared techniques. The x-ray diffractograms of the soil and sediment clay fraction ($<2.0\mu$) from the pond are shown in Figure 1. The positions of intensities of the peaks show the mineralogical composition of the soil and sediment to be essentially identical. The 14 Å peak present on Mg saturation, glycerol solvation, and mild heating was interpreted to indicate the presence of vermiculite. The 10 Å peak is characteristic of micaeous minerals and is greatly enhanced by collapse of the 14 Å material on strong heating (550°C). The presence of kaolinite is confirmed by the 7 Å peak remaining on K saturation and mild heating and by the disappearance of the 7 Å

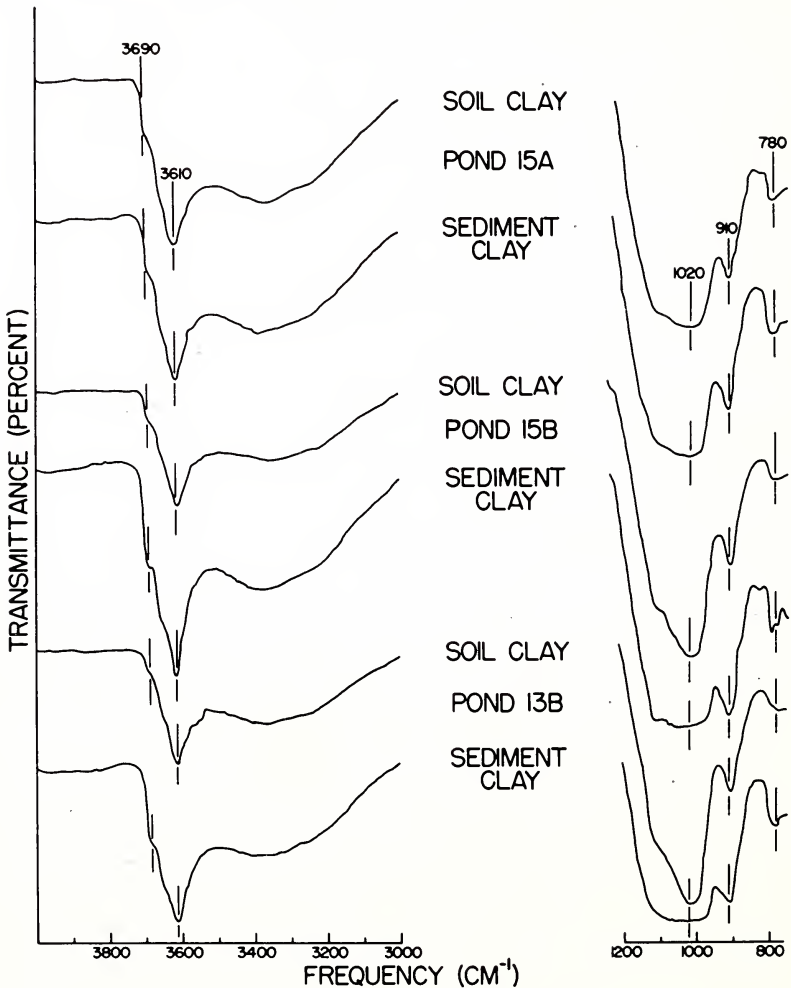


FIGURE 2. Infrared absorption spectra for soil and sediment clays.

peak on heating to 550° C which destroys the kaolinite structure. Detailed procedures for the identification of clay minerals are given by Whittig (6).

The infrared patterns of the clay fractions are shown in Figure 2. The presence of kaolinite is confirmed by the weak band at 3690 cm^{-1} and a strong band at 3620 cm^{-1} . Montmorillonite or vermiculite would also exhibit a strong band at 3620 cm^{-1} in addition to a broad band in the 3400 cm^{-1} region. Details concerning the application of infrared spectroscopy to clay mineral systems has been given by Ahlrichs *et al.* (1).

Although the mineralogical composition of the clays appears to be identical, the quantity of clay is much higher in the sediment than in the soil (Table 1). This is in agreement with the work of Kohnke (3) and is in the order expected. Thus, clay and silt are preferentially eroded into the pond at the expense of sand but no differential erosion of clay types occurs.

TABLE 1. *Texture of the watershed soil and pond sediment.*

| | % Sand | % Silt | % Clay | Coarse clay % of total | Fine clay % of total |
|----------|--------|--------|--------|---------------------------|-------------------------|
| Soil | 15.6 | 68.4 | 16.0 | 63.1 | 36.9 |
| Sediment | 4.6 | 70.4 | 25.0 | 58.7 | 41.3 |

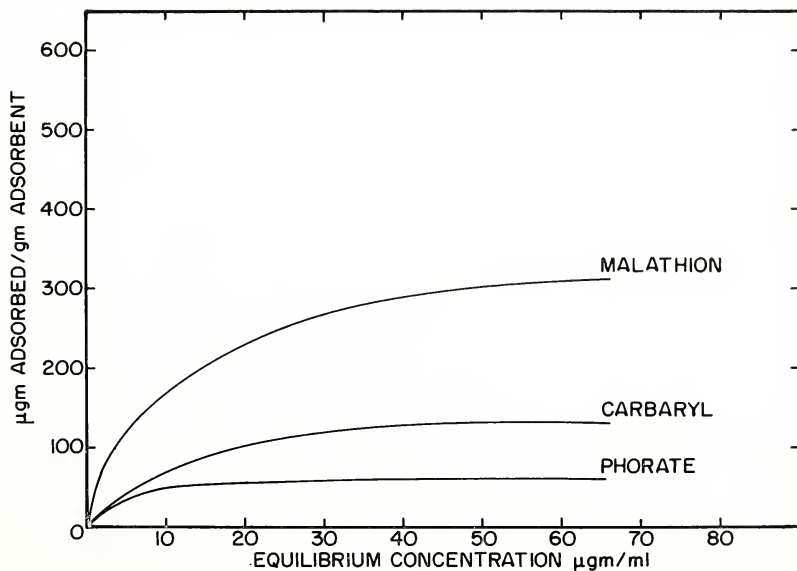


FIGURE 3. *Adsorption isotherms for the three insecticides.*

Adsorption Studies

Adsorption of malathion, phorate, and carbaryl was studied using watershed soils and the pond sediments as adsorbents. Selection of these materials was based largely on their current use on alfalfa for weevil and spittlebug control. Adsorption of the insecticides is represented as Freundlich isotherms in Figure 3. It can be noted that malathion is strongly adsorbed followed by carbaryl, with phorate showing limited adsorption.

Comparison of adsorption on soil with adsorption on sediment showed little difference for malathion and phorate while carbaryl adsorption was greater on the sediment. Examination of Table 1 would lead one to expect greater adsorption on the sediment due to the increased clay content. However, the expected increase occurred only with carbaryl.

Absolute interpretation of adsorption data is of limited value but comparison of the relative extent of adsorption is worthwhile. If a pesticide is adsorbed it would be less likely to enter a pond as compared to a non-adsorbed counterpart. We might expect then that the degree of pollution for these insecticides following application to the soil would be in the order phorate > carbaryl >> malathion. In addition, adsorption in the soil under field conditions should be more complete since concentrations used in laboratory studies represent an application of 10-300 times the normal rates of application.

Conclusions

Little difference was found between the clay mineralogy of a pond sediment and the soil from which it is derived. The soils and sediments used in this study contain kaolinite, micaeous minerals, and vermiculite.

Adsorption studies showed that malathion is adsorbed to the largest extent followed by carbaryl and then phorate with significant adsorption by the soil of all three. If a pesticide is adsorbed, it should not be subject to movement into a pond by leaching or runoff; thus, we would conclude that contamination of a farm pond probably would not occur following application of malathion, carbaryl or phorate to the watershed, and that phorate would probably be the first to reach the pond if contamination did occur. These conclusions are based on the assumption that pesticide applications are made according to the manufacturers suggestion and applied at the recommended rate.

Further support of these observations is given by the work of other cooperators on the project (5). Continuous monitoring of the pond water for 8 months following application of phorate and carbaryl at levels 4 times their recommended dosage showed no trace of carbaryl at anytime in the water and only a slight temporary trace of phorate. When recommended rates were applied, no trace of either insecticide was found in the pond.

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