I. Introduction

As most pesticides are either insoluble or only slightly soluble in water and must be applied in relatively small amounts over large areas, they are formulated in such a way that a highly concentrated organic chemical can be put into a convenient-to-use and effective form for field use by blending it with additives and inert carriers. The formulation must be easy and economical to use, do the job it is meant for, have an adequate shelf-life, and have no undesirable side effects. In solid-based formulations, the inert materials used, called diluents or carriers, can be either botanicals (e.g., ground corn cobs, walnut shells), synthetics (both organic and inorganic), or minerals (carbonates, oxides, and clays). In 1976 nearly 300,000 tons of various clays were delivered to pesticide manufacturers in the United States alone for use in pesticide formulations (U.S. Depart-
ment of Agriculture 1976). Of this amount, over 65% was attapulgite. The predominance of attapulgite in the formulation of pesticides in preference to more common clay minerals such as kaolinite and montmorillonite stems from the fact that it is not easily flocculated by electrolytes and does not cake at high relative humidities but remains free-flowing (HADEN and SCHWINT 1967).

Despite their widespread use only little information is available in the scientific literature on the interaction of attapulgite with pesticides. The present review covers the existing knowledge in this field and uses our own results to illustrate the mechanism of attapulite-pesticides surface reactions.

II. Attapulgite

While it is not our intent to present a detailed mineralogical discussion of attapulgite, it is necessary to be aware of the properties of this clay in order to understand its interactions with organic compounds. For those interested in a more detailed description of attapulgite, reference can be made to several recent reviews on the subject (HENIN and CAILLERE 1975, ZELAZNY and CALHOUN 1977).

a) Historical survey and nomenclature

The name of the mineral under discussion is a source of dispute among clay mineralogists. The mineral was first described by BRONGNIART (1807) (see CAILLERE and HENIN 1961) as asbestes suberiformes and was subsequently called paper and fossil skin, mountain cork, and mountain leather. In 1862 SSAFTCHENKOV (see CAILLERE and HENIN 1961) gave this mineral form the name palygorskite after the name of the area in Russia, Palygorsk, where it was mined. In describing the major component of Fuller's earth from both France and the United States, DE LAPPARENT (1935) designated the mineral as attapulgite after Attapulgus, Georgia. It was later found that these two minerals, attapulgite and palygorskite, were identical and, on this basis, CAILLERE and HENIN (1961) stated that palygorskite should be preferred as it predates attapulgite. Recently, however, WEAVER and POLLARD (1973) have observed in reviewing the literature on these and other clay minerals that the minerals from Palygorsk, U.S.S.R., differ from those of Attapulgus, Georgia, U.S.A., both in the length of the fibers and in the amount of iron found in the structure. Although structurally similar, they differ somewhat chemically so that it seems desirable to retain both names since future work might indicate that they are distinct fibrous species. No differences have been observed, however, between the two clays as to their physical or chemical properties. In light of this, the name attapulgite will be used throughout this review.

b) Structure, water status, and chemical properties of attapulgite

Attapulgite is a crystalline hydrated magnesium aluminum silicate with unusual colloidal and sorptive properties. The structure of attapul-