Factors influencing the adsorption, desorption, and movement of pesticides in soil

By

GEORGE W. BAILEY* and JOE L. WHITE**

Contents

I. Introduction.......................................................... 30
II. Nature and properties of soil colloids............................... 31
III. Adsorption models.................................................. 35
   a) Langmuir adsorption equation................................... 35
   b) Freundlich adsorption equation.................................. 37
   c) Brunauer, Emmett, and Teller (BET) adsorption theory........ 38
   d) Gibbs adsorption isotherm........................................ 39
IV. Factors influencing adsorption and desorption...................... 40
   a) Physico-chemical character of the adsorbent.................... 40
   b) Physico-chemical character of adsorbate........................ 43
   c) Soil reaction.......................................................... 53
   d) Surface acidity...................................................... 55
   e) Temperature............................................................ 62
   f) Electric potential of clay surface................................... 63
   g) Nature of formulation............................................... 64
V. Mechanisms of adsorption............................................ 65
   a) Physical adsorption.................................................. 65
   b) Chemical adsorption................................................ 66
   c) Hydrogen bonding..................................................... 70
   d) Coordination......................................................... 71
VI. Role of spectroscopy in adsorption studies......................... 73
VII. Leaching and movement of pesticides in soils..................... 74
    a) Role of physical properties of soil on pesticide movement... 74
    b) Role of climatic forces on pesticide movement................ 77
Summary............................................................................. 80
Résumé............................................................................... 80
Zusammenfassung............................................................ 81
References............................................................................ 83

* Southeast Water Laboratory, Federal Water Pollution Control Administra-
  tion, U.S. Department of the Interior, Athens, Georgia.
** Department of Agronomy, Purdue University, Lafayette, Indiana. Journal
  Paper No. 3656 of Purdue University Agricultural Experiment Station.
I. Introduction

Seven factors are known to influence the fate and behavior of pesticides in soil systems: (1) chemical decomposition, (2) photochemical decomposition, (3) microbial decomposition, (4) volatilization, (5) movement, (6) plant or organism uptake, and (7) adsorption. The phenomenon of adsorption-desorption directly or indirectly influences the magnitude of the effect of the other six factors. Adsorption, therefore, appears to be one of the major factors affecting the interactions occurring between pesticides and soil colloids.

There have been several review articles recently concerned with the overall behavior of insecticides (ENO 1958, EDWARDS 1964), herbicides (ENNIS 1954, ALDRICH 1953, NEWMAN and DOWNING 1958, SHEETS and DANIELSON 1960, WOODFORD and SAGAR 1960, HARTLEY 1961 and 1964, UPCHURCH 1964, HOLLY 1965, SHEETS 1964, KEARNEY et al. 1965, ALEXANDER 1966, DUSTMAN and STICKLE 1966, KAUFMAN 1966, MARTIN 1966) and soil fumigants (NEWHALL 1946, TAYLOR 1951, McBeth 1954, Dieter 1959, GORING 1962, DOMSCH 1964) in soil systems. These articles discuss the general role of adsorption as it influences the fate and behavior of pesticides in soil. The specific topic of adsorption and desorption of organic pesticides by soil colloids and/or clay minerals has been recently reviewed (BAILEY and WHITE 1964, KUNZE 1966). The movement of pesticides in soils has been reviewed by LEGRAND (1966) from a hydrological viewpoint and by HARTLEY (1961 and 1964) and BAILEY (1966) from a physical-chemical viewpoint, with particular emphasis on the role of adsorption on pesticide movement in soils. The nature of clay-organic complexes has been treated by MACEWAN (1962), CALVET (1963), and GREENLAND (1965).

In a previous review article (BAILEY and WHITE 1964), it was shown that such factors as soil or colloid type, physical-chemical nature of the pesticide, soil reaction, temperature, nature of the saturating cation on the colloid exchange sites, and nature of the formulation directly influence the adsorption-desorption of pesticides by soil systems. These topics and their role in adsorption will be re-examined in light of current literature. In addition, such topics as (1) mathematical models describing adsorption processes, (2) detailed examination of adsorption mechanisms, (3) the nature and role of surface forces and surface acidity in pesticide-soil colloid interactions, (4) role of spectroscopy in elucidation of pesticide-soil colloid complexes, and (5) movement of pesticides through and off of soil surfaces are treated. For sake of convenience the topics (1) adsorption and desorption of pesticides by soil colloids and (2) leaching and movement of pesticides in, through, and over soil surfaces will be treated separately.

A portion of the literature to be cited concerns the reactivity of soil constituents with organic compounds that are not currently recognized as pesticides. However, in general, pesticides are only organic com-