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I. INTRODUCTION

The "carbamate" class of pesticides is quickly gaining importance in the field of pest control. Due to the persistence of the organochlorine pesticides and the toxicity of the organophosphorus pesticides and their metabolites, the carbamates offer a viable alternative. Generally the carbamate insecticides demonstrate a high insect toxicity, but have a low toxicity towards warm blooded nontarget species, are more biodegradable and less persistent than the O.C. pesticides, and have relatively less toxic decomposition products. The biological activity of synthetic carbamate pesticides is due to the type of substitution to the basic carbamate moiety that results in these compounds being effective insecticides, herbicides, fungicides, nematicides, miticides, and molluscsides. The insecticidal carbamates are derivatives of carbamic acid and are therefore structurally related. Most of the herbicidal and fungicidal carbamates differ structurally from the carbamate insecticides, being primarily thiocarbamates and dithiocarbamates, respectively.

Although a naturally occurring carbamate ester, the alkaloid physostigmine in calabar seeds, is biologically active, all the carbamate pesticides are synthetic compounds. As early as 1931, the E.I. du Pont de Nemours Company showed that some derivatives of dithiocarbamic acid could control insects, but their superior fungicidal activity resulted in their development as the most widely used class of fungicides; among these compounds are the dithiocarbamates like ferbam, and the ethylenebisdithiocarbamates like zineb and maneb. In the late 1940s and early 1950s, Geigy Chemical Company found that heterocyclic enolic esters of dimethylcarbamic acid possessed insecticidal properties, and this led to the development of the N,N-dimethylcarbamate insecticides such as isolan and dimetilan. Union Carbide Corporation substituted aryl groups for the enols and methylcarbamic acid for the dimethylcarbamic acid and synthesized carbaril in 1953. Investigators at the University of California, Riverside, examining structure-activity relationships, established the superior insecticidal activity of aryl N-methylcarbamates. It is this group of compounds (e.g., carbaril, carbofuran) that accounts for most of the production and study among the carbamate pesticides. Biological effects of esters of carbanilic acid (carbamates) were reported by Friesen in 1929, but the herbicidal activity of N-phenylcarbamates (IPC) was not reported until 1945. About 1956, certain dithiocarbamates such as CDEC were shown to be herbicidally active by Monsanto Chemical Company, and subsequently around 1959, Stauffer Chemical Company produced many of the thiocarbamate herbicides (EPTC, butylate). Finally, in 1967, oxime carbamates (aldicarb) were introduced by Union Carbide following their work to synthesize N-methylcarbamates with a spatial resemblance to acetylcholine.

Growth of pesticide production and sales soared in the 1960s, but greater environmental awareness and stricter Federal laws limited this growth in the 1970s. Registrations were restricted or banned for many O.C. pesticides (DDT, aldrin) and use patterns shifted to more specific, less persistent insecticides such as the carbamates. Herbicides