INSECTICIDE KNOCKDOWN AND RECOVERY IN MOSQUITOES AND ITS POSSIBLE SIGNIFICANCE IN CONTROL[1]

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INTRODUCTION. The term "knockdown" as applied in entomology denotes paralysis in insects whether reversible or not. The word was originally introduced to describe the rather quick induction of paralytic symptoms produced by pyrethrins, but its usage was eventually extended to all cases of insect paralysis by chemicals. It is most often used in connection with time required for the onset of paralytic symptoms in a certain fraction of the test population (e.g., KD_{50}, KD_{95}, etc.).

Recovery from knockdown has been observed in a number of insect species. It has most frequently been attributed to either detoxication mechanisms, as in the case of pyrethrins and DDT poisoning, or in addition, to incomplete and reversible enzyme inhibition as in the case of carbamate poisoning.

Quick knockdown action is of concern in pest control as it may terminate the exposure of the insect to the toxic residue in cases involving contact, or it may result in interruption of flight and consequently in lower pickup of insecticide from impact with aerosol or mist particles. When recovery from poisoning is biochemically possible, quick knockdown enhances the chances of recovery by limiting the amount of toxic material absorbed by the insect. The speed of recovery also becomes important since it limits the length of time during which the insect remains on the ground defenseless to the action of predators, or other adverse factors. Thus speed and duration of knockdown and the possibility and extent of recovery from it, are important considerations in pest control technology.

The knockdown and recovery of mosquitoes from the action of pyrethrins has been thoroughly explored in the pa (Richardson 1931); these phenomen have also been studied for DDT and r lated compounds. Little, however, known regarding knockdown and reco ery from organophosphorus and carb mate poisoning in mosquitoes. Since the two groups include candidate compoun for malaria eradication (International C operation Administration Expert Panel o Malaria, 1961) more information on the is essential. In the course of a study the comparative toxicity of numerous ne compounds against mosquitoes (Georghio & Metcalf 1961a, 1961b, Metcalf & Geor hiou 1962) the author had the opportuni to observe the progression to toxic sym toms in *Culex pipiens quinquefasciat* Say and *Anopheles albimanus* Wied. Th paper presents results obtained with Ba tex® (*O,O*-dimethyl *O*-(3-methyl-4-methy thiophenyl) phosphorothionate), *m*-is propylphenyl *N*-methylcarbamate[2] a *m-sec*-butylphenyl *N*-methylcarbamate Results with DDT are included for co parison.

MATERIALS AND METHODS. In these stu ies 2- to 3-day old unsexed adult *Cul pipiens quinquefasciatus,* fed on 10 pe cent sucrose solution, were used. The rea ing and testing methods have previous been described (Georghiou & Metca 1961b). After exposure of one hour to t insecticide residue on filter paper at 74° F the mosquitoes were transferred to u waxed paper cups fitted with transpare plastic lids and were supplied with a pie of dental cotton roll saturated with 10 pe cent sucrose solution. The insects we then kept for 24 hours at 60° or 80°

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[2] Hercules AC-5727 and Union Carbide U 10854.

[3] California Chemical RE 5305.

nd records were kept of the progress of evelopment of toxic symptoms. In all intances, a number of the insects went hrough various stages of locomotor hyperctivity, ataxy and prostration. In the final tage they were considered as "knocked own." The number of insects recoverng from knockdown, as evidenced by bility to stand on their legs, was also reorded. There were twenty insects per reatment and each treatment was replited 3 to 5 times. The test was repeated wice and the results were averaged.

The compounds used were in the purest btainable form, or they were purified by crystallization. All insecticides were sted at concentrations which at 60° F. ormally produce 40 to 80 percent mortaly. The compound *m*-isopropylphenyl -methylcarbamate was also tested in comination with piperonyl butoxide (1:5 atio) which was found earlier to be a eak synergist of carbamates against mosuitoes (Georghiou & Metcalf 1961a).

RESULTS AND DISCUSSION. The results btained are summarized in Figures 1–4. t the concentrations of insecticide used, stest knockdown was produced by the rbamates, the KD_{50} point having been ached 48 and 50 minutes after initiation f exposure to *m*-isopropylphenyl and -*sec*-butylphenyl *N*-methylcarbamate, reectively. Corresponding values for DDT nd Baytex were 54 and 110 minutes, spectively.

The holding temperature had the proundest effect on DDT activity, less effect n the carbamates and considerably less on aytex. DDT and the carbamates showed negative temperature coefficient of acon, the percentage of knockdown and ortality being greater at the lower temerature, while Baytex showed a positive mperature coefficient of action. This beavior of DDT has been demonstrated ith *Aedes aegypti* L. larvae by Richards Cutkomp (1946), and with adults of *nopheles quadrimaculatus* Say and *Culex uinquefasciatus* Say by Lindquist *et al.* 1946).

The mosquitoes paralyzed by DDT owed extensive recovery when kept at

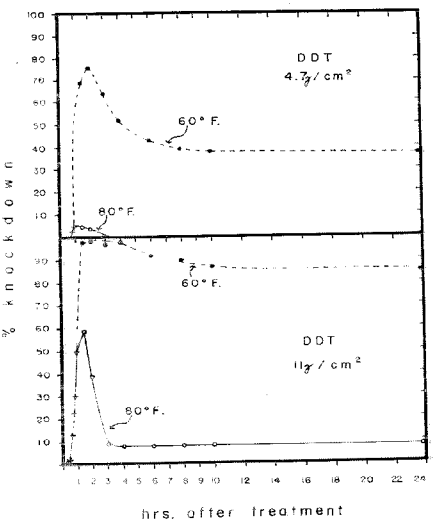

FIG. 1.—Progress of knockdown and recovery in *Culex pipiens quinquefasciatus* exposed for one hour to DDT residue at 74° F. and subsequently held at 60° and 80° F.

80° F., 88 percent of those knocked down by a deposit of 11 γ/cm² having recovered; the process was completed within two hours after the insects were removed from further contact with the toxicant. In contrast, recovery in those placed at 60° F. amounted to only 12 percent and required at least 8 hours for its completion. A lower deposit of DDT (4.7 γ/cm² yielded full recovery at 80° F., and 51 percent at 60° F. (Figure 1). Recovery from *m*-isopropylphenyl *N*-methylcarbamate paralysis was less extensive and required a considerably longer time than was the case for DDT; 52 percent of the knocked-down insects recovered at 80° F., and 35 percent recovered at 60° F. Recovery at 80° F. was completed within 12 hours but at 60° F. it continued for 24 hours (Figure 2). Similar percentages of recovery were obtained with *m*-*sec*-butylphenyl *N*-methylcarbamate, but recovery was completed within 8 hours at both temperatures (Figure 3). Use of piperonyl butoxide in com-

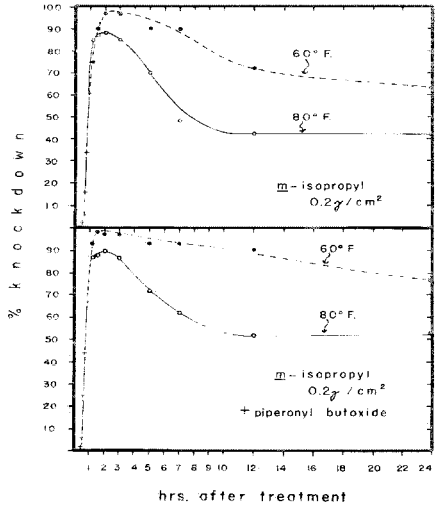

FIG. 2.—Progress of knockdown and recovery in *Culex pipiens quinquefasciatus* exposed for one hour to *m*-isopropylphenyl *N*-methylcarbamate residue, (upper) and in combination with piperonyl butoxide (lower) at 74° F. and subsequently held at 60° and 80° F.

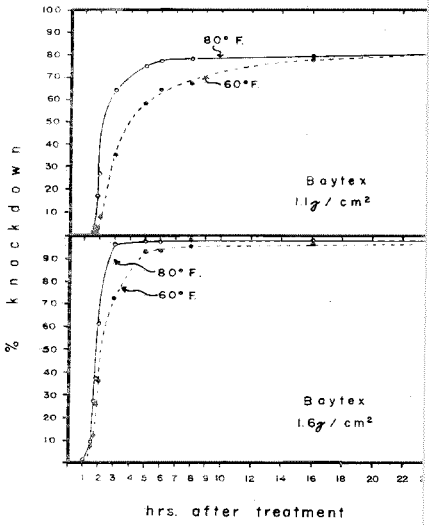

FIG. 4.—Progress of knockdown in *Culex pipiens quinquefasciatus* exposed for one hour to Baytex residue at 74° F. and subsequently held at 60° and 80° F.

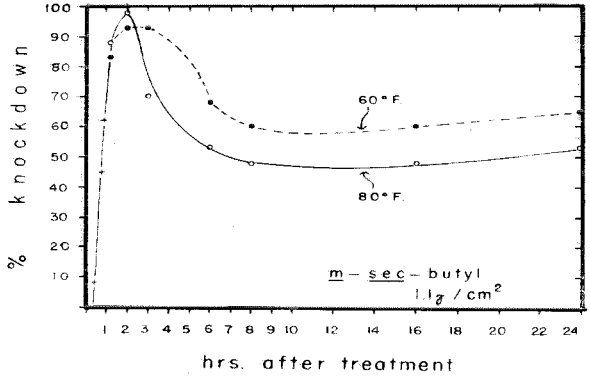

FIG. 3.—Progress of knockdown and recovery in *Culex pipiens quinquefasciatus* exposed for one hour to *m-sec*-butylphenyl N-methylcarbamate residue at 74° F. and subsequently held at 60° and 80° F.

ation with *m*-isopropylphenyl *N*-methyl-
bamate apparently did not affect the
ed of knockdown action of the carba-
te or the rate of recovery of the
insects, although the total recovery
approximately 10 percent lower than
en the carbamate was used alone (Fig-
2). There was no recovery from
ckdown in mosquitoes exposed to Bay-
(Figure 4).

The significance of the speed of knock-
vn action and of recovery from it, may
examined in two different situations.
first concerns the application of non-
dual space treatments, such as aerosol
ays in houses and aerosol or fogging
tments outdoors, as practiced by indi-
uals or communities for the suppression
easonal mosquito epidemics. The sec-
situation concerns disease eradication
ough control of vector species, such as
malaria eradication program of the
rld Health Organization.

n the case of non-residual treatments,
insect is relied upon to accumulate
thal dose mainly by flying through the
ted space. Therefore, anything that
ses an interruption of flight will also
l to reduce the insect's chances of ac-
nulating a lethal dose. This point was
gnized in the case of pyrethrins, and
id & Bracey (1947) have shown that
min, sesame oil, and isobutyl undecy-
mide reduce the rate of pyrethrin
ckdown in *Aedes aegypti* (L.). No
n compound is yet known for the car-
nates, and research in this field is ur-
tly needed.

n the case of residual sprays, such as
e applied for malaria eradication, the
cticide is usually sprayed on walls of
ses where the insect will normally rest
several minutes after it has obtained
lood meal, and before it leaves the
ding. Again, quick knockdown will
l to reduce the chances of acquiring
thal dose, since the insect loses con-
with the residue as soon as hyper-
activity symptoms appear. However, since the toxic residue remains active for several months, the chances of the insect surviving repeated cases of knockdown are very remote.

The problem, therefore, appears to be of concern mainly in connection with irregular, space spray applications.

A further consideration is the relation of knockdown to insecticide resistance. If recovery from knockdown is due entirely or in part to the same physiological mechanisms as insecticide resistance, it may be expected that changes in the degree of resistance will have a definite effect on susceptibility to knockdown and on the degree of recovery from it. This question has been investigated in detail with house flies and the results will be presented in a separate paper.

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