SOME FACTORS REGULATING THE EFFECTIVENESS OF GRANULAR INSECTICIDES IN MOSQUITO CONTROL[1]

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Granular formulations of insecticides have an important place in the control programs instituted against certain terrestrial and aquatic human and animal insect pests. Such formulations have been employed in experimental control trials against mosquito larvae breeding in rice fields (Whitehead 1951). Their effectiveness was demonstrated against bottom-feeding larvae of *Mansonia* spp. which could not be controlled by spray applications (Chapman 1955). BHC and dieldrin granules were successfully employed against sand fly larvae (LaBrecque & Goulding 1954).

Comparative trials were made using 10, 20 and 35 percent DDT on attapulgite granules and sprays, both applied to soil in the laboratory against *Hippelates collusor* (Tsnd.). The initial effectiveness and the effectiveness after three months' storage of the soil treated with the granules were found to be lower than with the soil treated with the sprays (Mulla 1960). In addition, the effectiveness of the granular formulations decreased as the concentration of DDT increased. The poor performance of the granular formulations could be attributed to either slow release of the toxicant from the pellets or poor distribution of the toxicant in the soil.

Comparative performance data on the effectiveness of various types of granular insecticides against mosquito larvae in the field are lacking. These formulations, although having several advantages over sprays (Mulla & Axelrod 1959), have not been considered in large-scale mosquito-larviciding programs until recently. This lag in the general use of granular insecticides in mosquito control has been attributed to the lack of a formulation that releases the toxicant rapidly. A survey of commercial granular parathion and malathion formulated for mosquito control in California substantiated this lack (Mulla & Axelrod 1959). Some of the formulations released the toxicant slowly; others released the toxicant almost exclusively at the bottom of a water column.

The erratic results obtained with the impregnated type of granular insecticides were to be expected in view of recent information about the role played by the petroleum solvents in impregnation (Mulla & Axelrod 1960). Type and mesh size of the carrier pellets, the kind and concentration of the insecticide, as well as the kind and concentration of the solvent in the granular formulation are expected to influence the speed of release of the toxicant from the granular particles. Some of these aspects of granular formulations of parathion are discussed below.

METHODS AND MATERIALS

The granular formulations were prepared and evaluated in the laboratory as discussed by Mulla and Axelrod (1960). The solvents were used at a concentration of 10 percent based on the weight of the finished product. Attapulgite granules (Floridin Company, Tallahassee, Florida) were used in all the tests. The prepared granules were dropped into a gallon mayonnaise jar containing 3500 ml. of tap water (pH 8–8.5). The height of the water column in the jar was 8.25 inches. At intervals of 8, 24, 48 and 72 hours, 5 to 10 ml. of water were aspirated from both the top and the bottom (1 inch above the granules) of the jar and composited for further dilution. The details of the initial concentration of parathion in the jar and final concentration in 100 ml. of water in

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the pint-size paper cup (replicated three times) to which 25 fourth instar larvae of *Culex quinquefasciatus* Say were added, are included in the tables. Since temperature has a profound effect on the speed of release of a toxicant (Mulla & Axelrod 1960a), the water treated with the granules was maintained at 85° F. The mosquito larvae during the exposure period to the toxicant were kept at 75° to 78° F. and the mortality was read 24 hours after start of the exposure period. The extent of mortality was an indication of the magnitude of release and the percent release was calculated from the observed mortality of larvae in reference to a dosage-mortality line established for parathion against the larvae.

RESULTS AND DISCUSSION

PETROLEUM SOLVENTS. In the preparation of granular formulations, it is usually desirable to impregnate the granules with the toxicant by means of an organic solvent. Uniform and more efficient formulations are obtained by this method than by simply impregnating the granules with the liquid toxicant. Petroleum solvents are usually cheaper and safer to use for this purpose than other kinds of solvents. Because of the availability of a large number of these solvents, it is difficult to select one that is suitable for a particular type of granular formulation. Using a solvent without knowing its role in granular insecticides could lead to formulations of poor performance.

The release of parathion into water from attapulgite granules was observed to be greatly affected by the solvent used for impregnation (Table 1). After 48 hours certain solvents resulted in slow release of parathion into the water; others resulted in rapid release. Formulations prepared with AR-60, Panasol AN-3, Cyclo-Sol 68W, AR-50, Aromatic Solvent 42, AR-55 and Panasol AN-1 released parathion very slowly. On the other hand, solvents such as Panasol RX-3, AR-35, Panasol RX-4, Cyclo-Sol 27 and Cyclo-Sol 37 released the toxicant much faster. Release of parathion from formulations prepared with AR-60, AR-55, and AR-50 would have remained undetected if the formulations had been tested at 0.02 p.p.m. in the cups.

From the physical properties of these solvents (see Table 1) it is obvious that the extent and speed of release of parathion from the granules is related to these properties of the solvents. Solvents characterized by higher flash points, higher initial and maximum boiling points, and wider distillation ranges released the toxicant

TABLE 1.—The relationship between some physical properties of petroleum solvents and the efficiency of 2 percent parathion granules (30/60 AA-LVM attapulgite) [a]

Solvent and source	Flash point (° F.)	Initial boil. point (° F.)	Maximum boil. point (° F.)	Distill. interval (° F.)	Percent release into water at 48 hours
AR–60 (Velsicol) [b]	220	460	560	100	7
Panasol AN–3 (Amoco)	220	450	534	84	9
Cyclo-Sol 68W (Shell)	151	364	418	54	13
AR–50 (Velsicol) [b]	200	415	550	135	14
Aromatic Sol. 42 (Shell)	164	383	498	115	17
AR–55 (Velsicol) [b]	180	390	550	160	18
Panasol AN–1 (Amoco)	165	400	494	94	20
Panasol RX–3 (Amoco)	81	276	360	84	58
AR–35 (Velsicol)	<40	214	278	64	60+
Panasol RX–4 (Amoco)	81	282	320	38	60+
Cyclo-Sol 27 (Shell)	35	212	229	17	60+
Cyclo-Sol 37 (Shell)	75	269	282	13	60+

[a] The theoretical concentration of parathion in the gallon jar was adjusted to 5 p.p.m. All formulations were tested fresh.

[b] Tested at 0.05 p.p.m. in cups. All others tested at 0.02 p.p.m.

slower than those characterized by lower values for these properties. It thus becomes obvious that an inverse relationship exists between the magnitude of release of parathion (after 48 hours in this case) and the values of these physical properties of the solvents.

The flash points and initial boiling points of Panasol RX-3 and RX-4 are essentially the same, but the maximum boiling point of the former solvent is higher. This difference results in a wider range of distillation for RX-3 than for RX-4, and, therefore, a slower release of the toxicant by RX-3 than by RX-4.

Selection of a solvent for preparing a granular formulation will depend on whether a fast- or slow-releasing formulation is required, and on the economics of the situation. Both fast- and slow-releasing materials have places in mosquito control, and the decision to use one or the other should be determined by the available information concerning specific conditions.

Safety is a factor that is also involved. Solvents with low flash points constitute fire hazards and should be stored and handled as dictated by safety rules and regulations.

RATE OF APPLICATION. Increasing the rate of application of the toxicant means an increase in the number of granular particles per unit area or per unit volume of the treated water. Variation in number of granular particles per unit area or per unit volume within limits influences the release of parathion to a great extent. At the 2 and 5 p.p.m. concentrations (parathion is soluble up to 20 p.p.m. at the temperature used here) parathion release was proportionately lower than at the 0.5 and 1 p.p.m. concentrations (Table 2). Also at the 0.5 p.p.m. concentration the percent release (after 8 hours) was greater than the release at the 1 p.p.m. concentrations for both solvents. After 24 hours the AR-60 formulation released parathion faster at the 0.5 p.p.m. than at the 1 p.p.m. concentration.

An inverse relationship between proportionate release of parathion and its concentration in the treated water was observed for the 8-hour interval for both formulations prepared with Chevron Light Solvent (Standard Oil Company of California) and AR-60. Formulation prepared with Chevron Light Solvent released the insecticide faster than the formulation prepared with AR-60. After 48 hours the proportionate release for the 0.5 and 1 p.p.m. concentrations was the same for the formulation prepared with Chevron Light Solvent. Similarly, the release for the 0.5 and 1 p.p.m. concentrations was the same for

TABLE 2.—Release of toxicant from 2 percent parathion granules (30/60 AA-LVM attapulgite) applied to water at various rates

Solvent	Toxicant rate [a] (p.p.m.)	Avg. percent mortality of larvae at intervals (hours) 8	24	48	Percent release at 48 hours
Chevron Light Solvent [b]	5.0	0	33	59	39
	2.0	3	81	87	60
	1.0	4	97	98	96
	0.5	28	97	98	96
AR–60 [c]	5.0	3	0	61	12
	2.0	4	0	95	24
	1.0	8	8	100	30–35
	0.5	19	25	100	30–35

[a] The rate applies to the gallon jar containing 3500 ml. of water.

[b] The formulation was 4 months old, and tested at 0.0125 p.p.m. final theoretical concentration.

[c] The formulation was 7 months old, and tested at 0.04 p.p.m. final theoretical concentration in the cups.

the formulation prepared with AR-60 solvent.

In mosquito control, under normal conditions, parathion is usually applied at rates lower than 0.1 p.p.m. Therefore, the proportionate release from granular materials will more likely be higher than the highest releases (prior to total release) obtained here at the 0.5 p.p.m. concentrations. Nevertheless the relationship between rate of application and speed of release shows important trends. This trend might have more practicable applications for other types of granular formulations.

Toxicant Concentration. Toxicant concentration in a granular formulation has economic implications in the use of granular insecticides. Increasing the toxicant in a formulation will decrease the cost per unit of the formulated toxicant. Cost factors and performance of formulations of various concentrations have to be weighed before making a decision to use any one concentration.

The relationship between the toxicant concentration in a granular formulation and its release from the material is not a simple one. The picture is complicated by the type of solvent used for impregnation. Formulations prepared with a highly volatile solvent (Chevron Light Solvent) indicated an inverse relationship between concentration of the toxicant and release of the toxicant from the granules (Table 3). But a low-volatile solvent (AR-60) produced different results that indicated a direct relationship between concentration of parathion in the formulations and release of it from the granules. The over-all efficiency of all concentrations prepared with the high-volatile solvent was greater than that of the formulations prepared with the low-volatile solvent. The 5- and 10-percent formulations prepared with Chevron Light Solvent released the toxicant slower at all intervals than the 1- and 2-percent formulations. On the other hand, the 5- (except for the 8-hour interval) and 10-percent formulations prepared with AR-60 solvent gave faster release at all intervals than the 1- and 2-percent formulations.

Further studies on the effect of concentration of parathion on its release were carried on using various mesh sizes of granules and employing Chevron Light Solvent for impregnation. An inverse relationship between concentration of parathion used and its release was also observed

TABLE 3.—The effect of concentration of toxicant in formulations on the efficiency of parathion granules (30/60 AA-LVM attapulgite) [a]

Solvent	Percent parathion conc.	Avg. percent mortality of larvae at intervals (hours) 8	24	48 [b]	72
Chevron Light Solvent [c]	10	0	21	23	48
	5	0	97	98	98
	2	53	100	100	100
	1	73	100	100	100
AR–60 [d]	10	51	48	67	100
	5	0	5	39	81
	2	0	0	4	21
	1	0	3	0	7

[a] The theoretical concentration of parathion in the jar for all the formulations was adjusted to 1 p.p.m.

[b] The magnitude of release at this interval for all concentrations except the 10 percent prepared with Chevron Light Solvent was about 100 percent. For the AR–60 formulations the highest release of parathion was 54 percent for the 10 percent parathion formulation. The rest of the formulations prepared with this solvent were very poor.

[c] All the formulations prepared with this solvent were tested at 0.0125 p.p.m. theoretical concentration in the cups.

[d] Formulations prepared with this solvent were tested at 0.02 p.p.m. in the cups.

here. However, the lag in release of 1- and 0.5-percent formulations on the 30/60 mesh granules was very little compared to the lag between the releases of these two formulations utilizing coarser mesh granules (see Table 4).

To investigate this relationship, three grades of AA-LVM attapulgite granules were employed. These were in the standard mesh sizes of 30/60, 20/40, and 16/30, the last having the coarsest particles.

These granules were impregnated with

TABLE 4.—The effect of toxicant concentration in the formulation and of granule size on the efficiency of parathion granules [a]

Granule size	Percent parathion conc.	Avg. percent mortality of larvae at intervals (hours)			
		8	24	48 [b]	72
30/60	1.0	45	100	96	100
	0.5	65	100	97	100
20/40	1.0	17	64	85	98
	0.5	68	92	100	98
16/30	1.0	8	21	49	98
	0.5	25	32	92	96

[a] The parathion concentration was adjusted to 1 p.p.m. in the jar and further diluted and tested at 0.01 p.p.m. in the cups against the larvae. The carrier was AA-LVM attapulgite granules and the solvent used in impregnation was Chevron Light Solvent.

[b] Percent release of parathion at this interval for the 0.5 percent formulations ranged from 86 to 100 percent. The finer-mesh granules released 100 percent while the coarsest mesh released 86 percent of the toxicant.

GRANULE SIZE. Particle size plays an important role in the use of granular insecticides. Large particles have physical advantages and are cheaper and easy to distribute with either ground equipment or aircraft. Large granules have a small amount of fines and most of the particles carrying the toxicant are liable to penetrate through a plant canopy, leaving very little toxic residues on the plants. Finer-mesh granules (e.g., 30/60 mesh) contain anywhere from 2 to 10 percent fine particles which would lodge on plant surfaces or drift away from the locale where treatment is carried out.

Coarse materials, on the other hand, have fewer particles per unit weight than finer-mesh materials. Treatment with coarser-mesh materials at rates equal to finer-mesh materials would undoubtedly result in poor distribution, incomplete coverage of the treated area, and fewer particles of the material per unit area. Above all these considerations, the relationship between particle size and release of the toxicant must also be elucidated.

parathion at 1- and 0.5-percent concentrations using Chevron Light Solvent. The results of this study indicated that particle size markedly influenced the speed of release of parathion. For both the 1- and 0.5-percent formulations the percent release of the toxicant generally decreased as the particle size increased (Table 4). Within the range of experimental variation, the extent of release of the 0.5-percent formulations on 30/60 mesh and 20/40 mesh granules at all intervals was essentially the same. The 0.5-percent formulation both on the 20/40 mesh and 16/30 mesh granules released parathion faster at the 8-, 24- and 48-hour intervals than the 1-percent formulations on these carriers. The difference between the two concentrations on the 30/60 mesh granules was slight and was obvious only at the 8-hour interval.

Selection of a specific size granule for mosquito control would depend on the speed desired for release of the toxicant and on the type of breeding grounds to be treated. For quick control in breeding grounds without food and forage crop stands or without dense emergent plant canopy, the finer-mesh materials (30/60) can be employed advantageously. Where treatment of forage and food crop stands is contemplated for mosquito control, the coarser materials (20/40 and 16/30 mesh) should be considered. For reasons explained above, the use of materials coarser than the 16/30 grade should be discouraged where quick mosquito larval reduction is desired.

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