THE USE OF SAND AND GRANULAR FERTILIZERS TO PREPARE GRANULES CONTAINING PIRIMIPHOS-METHYL FOR THE CONTROL OF MOSQUITO LARVAE

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ABSTRACT. Sand and granulated fertilizers were used as carriers in the preparation of granular formulations containing pirimiphos-methyl for the control of larvae of *Culex pipiens molestus, Aedes cantans, Ae. vexans* and *Ae. sticticus*. The formulations were prepared by adding 1 volume 'Actellic' 50 EC (containing 50% w/v pirimiphos-methyl) to 50 volumes of carrier. Laboratory-determined LD_{99}s for 4th instar *Cx. p. molestus* larvae were 4.0, 1.2 and 2.0 g/m^3 for granular formulations based on sand, ammonium nitrate and a combined fertilizer, respectively. LD_{100}s determined in field conditions, ranged from 2-20g/m^3 depending on the type of granular formulation, biotype, the instar and species of larvae. The effects of granules on non-target water fauna, e.g. *Tubifex tubifex, Rhynchelmis* sp., Mollusca, Turbellaria, *Cyclops* sp., *Daphnia* sp., Ostracoda, *Asellus aquaticus, Hydrachna* sp., *Gerris lacustris*, adult Dytiscidae, Helodidae (larvae), *Dixella* sp. (larvae), *Chaoborus* sp. (larvae) and Trichoptera (larvae) are discussed.

INTRODUCTION

The use of granular synthetic insecticides to control mosquito larvae dates back to the late forties (Horsfall 1946, Uphold 1947, etc.). Granular larvicides based on organophosphorus chemicals have been used in Czechoslovakia since 1972 for the control of *Aedes* larvae along the rivers Elbe and Morava (Novak 1972; Rettich and Privora 1972, 1973, 1975).

Mulla et al. (WHO unpublished) used fertilizer granules to make granular formulation of chlorpyriphos and fenthion. Dickinson and Carpenter (1977) used dry sand, urea and ammonium sulphate for their "home-made" granular formulation for the application of herbicides and lindane. The use of sand as a carrier of temephos in Abate 1SG is widely known; this granular formulation has proved to be highly active (Brooks et al. 1965, Lake et al. 1967, Laws et al. 1968).

As manufactured granules are not always readily available we decided to prepare our own granular formulation from sand or granular fertilizers and an EC formulation of an insecticide. From the two organophosphorus insecticides currently used in Czechoslovakia for the control of mosquitoes, Metathion E 50 (fenitrothion) and 'Actellic' 50 EC (pirimiphos-methyl) it was decided to use 'Actellic' 50 EC containing 50% pirimiphos-methyl w/v in the view of its good larvicidal activity against mosquitoes (Rettich 1977, 1979) and good toxicological properties.

Although granular fertilizers are more expensive than other carriers, such as sand, in general they are not expensive. Other commonly used carriers, for example bentonite, are not readily available in granular form.

METHOD

For the preparation of the granular formulation of pirimiphos-methyl, coarse grade river sand, or granular ammonium nitrate (containing 30% nitrogen), or granular combined fertilizer (11.5% N, 11.3% P_2O_5 and 14.7% K_2O) were used as the carriers. No surfactant was added. The ingredients were mixed in 1:50 v/v ratio in a plastic bag, or for large scale trials in a concrete mixer. The activity of 3 formulations against mosquito larvae was tested both in the laboratory and field.

Fourth instar *Culex pipiens molestus*

(Forskal) larvae were used in the laboratory tests. Glass tanks were filled with 10–20 liters of water and 50 mosquito larvae were placed in each tank. Weighed quantities of the granular formulation were dropped into the tanks. The mortality of the larvae was recorded after 48 hours. Water temperature was 20 ± 2°C during the trial. The efficacy of granules was tested on the day of their preparation and after storage for one month in PVC bags at 20 ± 4°C.

Field trials were carried out in the breeding places of *Aedes cantans* (Meigen) near Podebrady (Central Bohemia) in March and April, in breeding places of *Ae. sticticus* (Meigen) in Majdalena flooded forest (South Bohemia) in July, and in breeding places of *Ae. vexans* (Meigen) in artificially irrigated meadows near Hradec Kralove (East Bohemia) in June. The number of larvae was determined by 5–10 dips with a 30 × 30 cm plastic pan before and after the manual application of granules. Dips were carried out in various parts of each breeding area and the average number of larvae was calculated. The volume of water in each breeding place was calculated by multiplying the average depth by the area of the breeding place.

At the same time the presence of non-target water fauna was monitored before and after the application.

RESULTS

Table 1 gives the summary of the values of LD_{50}, LD_{90} and LD_{99} for the granules containing 'Actellic' 50 EC with sand and 2 kinds of granular fertilizers as carriers, for the control of 4th instar *Cx. pipiens molestus* larvae after 48 hours' exposure. The lowest values of LD_{99} were found in the case of granular ammonium nitrate at 1.2g/m³, and then for the granular combined fertilizer at 2.0g/m³. Owing to the fact that sand is approximately twice as heavy as both types of granular fertilisers, and that the insecticide and carrier were mixed on a volume/volume basis, the LD_{99} of sand granules at 4.0g/m³ was much higher than the other 2 formulations. No significant drop in activity of 'Actellic' 50 EC when mixed with granular ammonium nitrate was recorded after storage for 1 month (LD_{99} dropped from 1.2 to 1.3g/m³), but a slight decrease in activity was recorded where sand was used as a carrier (LD_{99} from 4.0 to 5.2g/m³). In the case of granular combined fertilizer the activity decreased significantly (LD_{99} from 2.0 to 8.5g/m³). The mortality of mosquito larvae in the field after the application of 'Actellic' 50 EC mixed with various carriers is summarized in Table 2. The rate of 2g/m³ of sand granules gave 100% control of 1st instar *Ae. cantans* larvae and the LD_{100} was 10g/m³ for the 2nd and 3rd instar; 5g/m³ gave 98.8% mortality of these instars. The rate of 20g/m³ gave a complete kill of 4th instar larvae; the rates of 5 and 10g/m³ gave high mortalities of 98.0 and 99.9% respectively. In order to achieve 100% mortality of *Ae. vexans* larvae in breeding places in artificially irrigated meadows a rate of 20g/m³ had to be applied, the rate of 10g/m³ giving 99.1% kill of 2nd and 3rd instars and 77.2% mortality of 4th instar larvae.

At a rate of 2g/m³, granules with granular ammonium nitrate as the carrier gave 100% mortality of 2nd and 4th instars of *Ae. cantans* larvae and 97.4% mortality of 3rd instar *Ae. sticticus* larvae.

Table 1. Toxicity of 'Actellic' 50 EC on admixture with sand and granular fertilizers to *Culex pipiens molestus* in laboratory tests. The values for LD_{50}, LD_{90}, LD_{99} are in g granular material per m³ water.

Carrier		LD_{50}	LD_{90}	LD_{99}
Sand	A	0.6	1.7	4.0
	B	0.7	2.0	5.2
Ammonium nitrate	A	0.4	0.7	1.2
	B	0.5	0.8	1.3
Combined fertiliser	A	0.8	1.3	2.0
	B	3.4	5.7	8.5

A = granules used immediately.
B = granules used after 1 month of storage.

Table 2. Toxicity of 'Actellic' 50 EC on admixture with sand and granular fertilizers to mosquito larvae in field conditions.

Species	Instar	Days after treatment	% mortality at the following rates of admixture (g/m³) 1	2	5	10	20
SAND							
Ae. cantans	I	28	0	100	100	100	100
Ae. cantans	II-III	12	—	68.8	98.8	100	100
Ae. cantans	IV	6	60.0	93.8	98.0	99.9	100
Ae. vexans	II-III	3	58.0	74.0	85.0	99.1	100
Ae. vexans	IV	3	—	—	0	77.2	100
AMMONIUM NITRATE							
Ae. cantans	II	14	95.9*	100	100	100	—
Ae. cantans	IV	14	0	100	100	100	—
Ae. sticticus	III	3	—	97.4	98.4	100	—
Ae. vexans	IV	3	—	0	95.0	100	—
COMBINED FERTILIZER							
Ae. cantans	II	14	0	99.5	100	100	—
Ae. cantans	IV	14	65.0	93.3	99.6	100	—

* = + 7 days.

In order to achieve a 100% kill of 4th instar *Ae. vexans* larvae, it was necessary in this instance to use a rate of 10g/m³.

The effect of pirimiphos-methyl on non-target species is summarized in Table 3. The concentration of 0.1 ppm from all types of carrier was harmless to *Tubifex tubifex*, *Rhychelmis* sp, Mollusca, Turbellaria, *Asellus aquaticus*, *Hyrachna* sp, *Gerris lacustris* and the larvae of midges *Dixella* sp. A concentration of 0.05 ppm, which is sufficient for the control of *Ae. cantans* larvae, gave partial kill of *Cyclops* sp., Ostracoda, Dytiscidae adults, the larvae of Helodidae and *Chaoborus* sp. while these concentrations of pirimiphos-methyl killed all *Daphnia* sp. and the larvae of Trichoptera.

DISCUSSION

The toxicity of pirimiphos-methyl mixed with sand or granular fertilizers was similar to the toxicity of technical material determined under laboratory conditions (Rettich 1977) and of 'Actellic' 50 EC applied as spray (Rettich 1979). The described method of application does not therefore result in any significant reduction of insecticidal activity of the product.

The activity of 'Actellic' 50 EC in mixture with sand and granular ammonium nitrate was not significantly reduced after 1 month of storage. However, the efficacy of 'Actellic' 50 EC based on the combined fertilizer dropped considerably. It is possible that this reduction was due to instability on this carrier. Mulla et al. (WHO unpublished) who used a chemical fertilizer with chlorpyriphos or fenthion also recorded shorter stability of fenthion on fertilizer based granules.

A 100% control of all larval stages of *Ae. cantans* was achieved with the rate of 10g/m³ of "home-made" granules, based on sand and 'Actellic' 50 EC, applied to flooded forest. Under the same conditions 100% control of *Aedes* sp. larvae was achieved with 0.4-2g/m³ of granular materials containing bromophos-methyl (5% ai), fenthion (2% ai), and temephos (1% ai) (Rettich and Privora 1972, 1973, 1975). However, as these latter formulations contained higher concentrations of the insecticides, the amounts of granules

Table 3. The effects of 'Actellic' 50 EC, applied when mixed with granular fertilizers, on the non-target water fauna.

Rate g mixture/m³	Concentration in ppm	*Tubifex tubifex*	*Rhynchelmis* sp.	Mollusca	Turbellaria	*Cyclops* sp.	*Daphnia* sp.	Ostracoda	*Asellus aquaticus*	*Hydrachna* sp.	*Gerris lacustris*	Dytiscidae-adults	Helodidae-larvae	*Dixella* sp.-larvae	Ephemeroptera-larvae	*Chaoborus* sp.-larvae	Trichoptera-larvae
1	0.01	+	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+
2	0.02	+	+	+	+	+	?	+	+	+	+	x	+	+	+	+	+
5	0.05	+	+	+	+	x	−	x	+	+	+	x	x	+	+	x	−
10	0.1	+	+	+	+	−	−	x	+	+	+	x	−	+	?	?	−

+ = species survives.
− = species is killed.
x = part of population is killed.
? = effects not determined.

used were considerably lower than those of the granules made with 'Actellic.'

In control of *Ae. vexans* larvae breeding in places with high content of organic material such as decaying grass, it was necessary to nearly double the rates of application. This corresponds with other published results (Bransby-Williams 1965, 1966).

The concentration of pirimiphos-methyl of 0.05 ppm, sufficient for the control of mosquito larvae, also kills *Daphnia* sp, and the larvae of Trichoptera, and gives partial kill of the population of *Cyclops* sp., Ostracoda, adult Dytiscidae and the larvae of Helodidae and *Chaoborus* sp. These results correspond to some extent with the toxicity of 'Actellic' 50 EC applied as spray (Rettich 1979). Considerably lower mortality of *Gerris lacustris* was recorded in the case of granular formulations. This species, which lives on the water surface, is not affected by the application of granules, but is affected by sprays.

At the maximum recommended application rate of the ammonium nitrate granular formulation, the increase in nitrogen content in the treated water would be approximately 3 ppm, compared with the accepted norm of 50 ppm. Thus, the contamination of water supplies with such a treatment would be negligible. This method of distributing the larvicide is primarily intended for irrigated pastures and rice fields where the carrier fertilizer will be used to advantage.

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