ULTRA-LOW-VOLUME GROUND AEROSOL AS A SUPPLEMENTARY ANTI-VECTOR MEASURE IN THE SOLOMON ISLANDS MALARIA ERADICATION PROGRAMME

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ABSTRACT. A trial programme of ground applications of ULV malathion spray was evaluated as a supplementary measure to reduce *Anopheles* density in the "problem area" of the Solomon Islands Malaria Eradication Programme. From the entomological assessment and from a consideration of the situational constraints encountered it was concluded that ULV spraying has limited practicability.

INTRODUCTION

The north coast of the island of Guadalcanal is a problem area for malaria eradication in the Solomons. Here, the classical eradication methodology (house spraying with DDT and radical treatment of malaria cases) has failed to interrupt transmission. In other areas of the Solomons the MEP has been largely successful in eradicating malaria, but the situation is under constant threat of reintroduction of malaria from north Guadalcanal. Ultimate success largely hinges, therefore, upon a resolution of the problem area.

The principal causes of continuing transmission are: 1) High densities of the main vector, *Anopheles farauti*. The population is mostly concentrated in coastal areas where numerous jungle-covered creeks and swamps form an extensive mosquito breeding area. 2) Marked outdoor biting tendency coinciding with man's maximum outdoor evening activities. To reduce mosquito density supplementary measures in the form of larviciding, source reduction and ULV spraying were carried out. The following is a description of a trial programme of night-time ULV malathion peridomestic spraying to evaluate this measure under local field conditions.

MATERIALS AND METHODS

Two types of spray machines were used: a Leco® HD ULV cold aerosol generator and a Fontan® R12 motorized knapsack sprayer with ULV nozzle attachment. The Leco model was mounted on a wooden base which slotted onto the bed of a Landrover. The control panel was mounted onto the same bed in a position such that the controls could easily be read and manipulated by the operator in the vehicle cab through the sliding rear window. This arrangement was preferred to having the control panel in the cab itself because the vehicle had to be used for other duties during the day and with the whole unit mounted on a single base this could easily be removed without dismantling the parts. Also it was realized that the driver could not drive the vehicle and at the same time operate the controls of the spray machine in view of the difficult road conditions and the fact that spraying had to be carried out at night. A minor modification was made to the machine: the lower section of the remote control stand was welded to its base socket to overcome the initial problem of this continually shaking loose due to excessive vibration.

Spraying was restricted to village areas (the breeding/day-time resting places being to all intents and purposes inaccessible) and was carried out at night between 6:30 and 8:30 pm—the time when mosquitoes are active, concentrated in village

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compounds (human blood being virtually the sole source of food) and displaying maximum biting activity.

The Leco was used where villages are accessible by road. For villages adjacent to the road the technique was to spray while driving alongside, starting 50 yards before the compound and ending 50 yards after; and for villages set back from the road to drive, wherever possible, right into the village compound and spray around the houses. Malathion (technical grade, 96% w/v) was applied at a dosage of 60 ml/min., discharged perpendicularly to the direction of the vehicle at an upward angle of 45° and at a vehicle speed of 7 mph. The operational area was divided into 6 sectors and in each 6 spray rounds were carried out at 10-day intervals, one sector sprayed per night. Altogether, 102 villages (pop. 2608) were covered by the Leco trial, and these included 5 of the 12 major foci of malaria in north Guadalcanal.

The Fontan sprayer was used in one focus where villages are inaccessible by road. Here, the operational procedure was for the sprayer to zig-zag between houses, directing the spray around and underneath, followed by a single pass around the village perimeter. A dilute formulation of 13% malathion in dieseline was applied at a dosage of 28 ml/min. at a walking speed of 3 mph. 4 sectors were each sprayed (using 2 machines) for 8 rounds at 7 day intervals, one sector per night. Forty villages (pop. 1137) were covered by the Fontan operation.

During the trial, evaluation was made of the performance of the spray machines under the local conditions. Also, determinations of droplet size and density were made by impinging droplets on magnesium-oxide treated glass microscope slides passed perpendicularly to the direction of the swath at 3 meters distance from the nozzle.

Entomological assessment was by bioassay and by man-biting collections. Bioassay, of the Leco spray only, was carried out using mosquitoes from man-biting collections made the night previously since no facilities for rearing exist. These were allowed to feed before capture and were subsequently transferred to holding cages containing sugar solution in a laboratory. Two mosquito gauze cages (30 x 25 x 25 cms) containing *An. farauti* were hung on poles above ground in an open plot in a village 50 and 200 ft away from the line of travel of the spray machine. A control cage was similiarly placed outside the trial area. The cages were positioned half an hour before spraying commenced and any recently dead mosquitoes removed. After spraying they were left exposed for 1.5 hr. then returned to the laboratory—a half-hour journey where mortality counts were made. To assess the effectiveness of ULV spray in reducing mosquito density nightly (6.30–8.30 pm) outdoor manbiting collections were made in a village before, during and for several days after spraying. This assessment was done for both Leco and Fontan sprays.

RESULTS

OPERATIONAL EVALUATION. Of the 36 scheduled Leco treatments only one was missed completely. Delays occurred on 5 occasions because of vehicle breakdown (tire punctures, due to a combination of the heavy weight of the spray machine on the vehicle back axle and poor road conditions) and equipment malfunction (blocked control valve and faulty cap leaking pressure from the insecticide tank). Bad weather was encountered on 6 occasions. Heavy rain and strong wind probably nullified the effect of the spray, but because rain often tended to be in the form of localised heavy showers it was not possible to predict whether or not spraying was worthwhile on a given night. In practice, once spraying began it was continued regardless of the local weather conditions.

A major drawback was that it was frequently impossible to position the spray machine favorably with respect to the village and the wind direction. When the wind was adverse and where it was not possible to drive into the compound, spray could be distributed only downwind of the

village. There was also considerable difficulty experienced in maneuvering the vehicle around the village compound, and this made it impossible to maintain correct vehicle speed for desired insecticide dosage. Another unfavorable factor was the probable loss of spray through deposition of droplets on the considerable vegetation normally present in and around villages.

The Fontan operation was fully carried out; bad weather was encountered on 6 occasions but spraying continued despite this. Problems with equipment function included leaking solution taps and minor things like loose bolts and nozzle blockage. Being more maneuverable it was easier to spray inside villages with this machine than with the Leco. Due to the unavailability of suitable co-solvents there was also the problem of the malathion and dieseline tending to settle out of solution; it was necessary to stop frequently and strongly agitate the mixture. On the whole, both machines functioned reasonably well mechanically—a positive factor, in view of the limited repair facilities and back-up services available.

Droplet size, corrected for the spread factor, was calculated from over 200 measurements of MgO craters using a calibrated Porton G12 ocular micrometer. The volume median diameters of droplets from the Leco and Fontan machines were 24 μm and 65 μm respectively. The latter therefore technically produces a mist and not a true aerosol. Median droplet density, calculated from counts of droplets per microscope field (7 x 10 mag.) for 100 fields examined, was 49 droplets per field (1921/cm^2) for the Leco spray and 23 (902/cm^2) for the Fontan.

ENTOMOLOGICAL EVALUATION. Bioassay mortalities (Table 1) at both distances range considerably, but the results overall do indicate that the Leco spray was effective in killing mosquitoes at 200 ft distance providing the wind direction is favorable. Under no wind or very slight wind its effectiveness is much reduced, even at 50 ft distance from the spray machine.

The results of the man-biting study (Table 2) show that the *Anopheles* population recovered almost immediately after spray treatment. At best, control extended to the day following the Leco spray only, thereafter the mosquito density attained its original level.

DISCUSSION

The effectiveness of ULV insecticide sprays against *Aedes* and other culicine mosquitoes is well established. The application of the technique to anophelines however is fairly recent, and no data are currently available, as far as the writer is aware, of actual control of malaria vectors using ground equipment. For bioassay of ULV sprays against *Anopheles*, the literature cites examples of good effectiveness of malathion. For instance, Mount et al. (1975) reported a 72% average kill of *An. quadrimaculatus* exposed at 150 and 300 feet to technical malathion at a dosage of 2.15 fl. ozs/min. (60 ml/min.). This seems

Table 1. Bioassay mortalities with Leco ULV spray

Replicates	At 50 ft tested	At 50 ft mort.	At 200 ft tested	At 200 ft mort.	Control tested	Control mort.	Weather conditions
1	26	100%	26	100%	23	8%	fav. wind
2	83	29%	86	28%	83	18%	no wind
3	56	29%	61	18%	79	9%	no wind
4	50	100%	36	28%	50	2%	no wind
5	40	100%	41	100%	39	5%	fav. wind
6	61	64%	61	31%	62	5%	fav. wind
Overall	316	61%	311	41%	336	9%	
Corrected mort.		57%		35%			

Table 2. Man-biting collections to determine the effect of ULV spray on mosquito density.

			Average catch per man/hour (3 replicates)
Leco	Days	3	5.1
	before	2	5.3
	spray	1	3.4
	ULV spray		2.7
	Days	1	1.3
	after	2	6.1
	spray	3	7.8
		4	3.4
		5	7.8
		6	9.5
Fontan	Days before	2	15.5
	spray	1	11.2
	ULV spray		3.7
	Days after	1	10.3
	spray	2	11.2

better than what was achieved here with *An. farauti*, though apart from the dosage which was the same the evaluation method differed in several respects, making comparisons difficult. The finding that ULV spray suppresses the population density only very temporarily is explained by the fact that the population was rapidly replenished by immigration from the peripheral breeding grounds which were untouched by spray. Pant et al. (1973) concluded similarly when it was found that the *Cx. quinque fasciatus (-fatigans)* population in Thailand was reduced for a few days only after each ULV spray treatment.

Judging the trial in terms of its practical aspects, it must be concluded that ULV spraying against *Anopheles* poses special problems, which are further compounded in the Solomon Islands situation where villages are generally very small and scattered over a wide area, with poor communications. The major drawbacks are: 1) *Anopheles* are nightbiting mosquitoes; spraying must therefore be done under difficult night-time conditions. 2) They are actively biting (on the wing) for a short time only—2 hours after dark. The time available for spraying, and thus the area of cover, is therefore quite limited, and leaves little allowance for delays and setbacks due to bad weather and equipment malfunction. 3) With villages being small and scattered, about two-thirds of the time available nightly for spraying was spent travelling between villages and only one-third actually spent spraying. For the Leco sprayer, the difficult road conditions, poor maneuverability inside villages and the frequent impossibility of positioning the spray favorably with respect to the village and the wind direction were further disadvantages. Its advantage over the Fontan sprayer is that it could travel between villages quicker, and thus cover a much wider area nightly. It is worth noting however, that whereas here the Leco could spray about three times more houses a night than the Fontan, in Thailand (Pant et al. 1973), under more urbanized conditions, a Leco could spray 30–40 times more houses a day than a Fontan. For villages inaccessible by road the Fontan has obvious advantages.

To conclude, it is considered that conditions here are unsuited to a programme of ULV spraying aimed at reducing *Anopheles* density in the long term and over a wide area. Instead, short term control in limited areas will be attempted in future. For this 2 or 3 applications of malathion will be made at 2-day intervals in villages producing malaria cases, in the expectation that the ULV spray will at least kill some of the infective mosquitoes maintaining transmission through their outdoor biting habit, and thus, in conjunction with other remedial measures (focal spraying with DDT, mass drug administrations, larviciding) to eliminate the focus.

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PREDATION ON MOSQUITO LARVAE BY BEETLE LARVAE, *HYDROPHILUS TRIANGULARIS* AND *DYTISCUS MARGINALIS*

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ABSTRACT. The predators, *Hydrophilus triangularis* (Say) and *Dytiscus marginalis* were offered *Culex quinquefasciatus* larvae at densities of 4, 12, 36, 80, 120 and 200. With one exception, a greater number of mosquito larvae were eaten when the beetle larvae were hungry and more mosquito larvae were consumed when more were available. Although there was some variability in the data which may have been simply due to chance, *D. marginalis* was consistently more effective than *H. triangularis*.

INTRODUCTION

Larvae of predaceous diving beetles, Dytiscidae and water scavengers, Hydrophilidae were found together occupying lentic habitats on the Mississippi Gulf Coast during the summers of 1975 and 1976. Larvae of water scavengers differed from those of water tigers (Dytiscidae) by having a single tarsal claw and toothed mandibles. Larvae of both groups of beetles prey on a wide variety of aquatic organisms and may be cannibalistic. The value of certain aquatic Coleoptera as predators has been investigated both under laboratory and field conditions. Arnett (1963) stated that both the adults and larvae of dytiscids are highly predaceous to some aquatic invertebrates and vertebrates. Chidester (1917) reported that the larvae of dytiscids are important enemies of mosquitoes, especially when they are present in large numbers in small pools. A similar result was noted for hydrophilid larvae, Nielsen and Nielsen (1953). Twinn (1931) found that among the Coleoptera, Dytiscidae have the most potential as biological control agents. In laboratory and field studies James (1964) reported that *Laccophilus*, and *Maculosus* fed on larvae of the rockpool mosquito, thus reducing their numbers considerably. Also, he found that when equal number of chironomid and mosquito larvae were exposed together, similar numbers of each were eaten, but the mosquito larvae were consumed faster than chironomid larvae. Field assessment of predation by species of *Dytiscus, Laccophilus, Agabus* and *Rhantus,* has been reported by a number of workers (James 1965, Kuhlhorn 1961, Lee 1967, Roberts et al. 1967, Sailer et al. 1954, Young 1967). Also, larvae of species of *Dytiscus, Hydrophilus,* and *Dineutus,* were found preying on small fish, Hurst (1945) and tadpoles, Williams (1936). The objective of this study was to determine the reliability of *H. triangularis* and *D. marginalis* as biological control agents of mosquito larvae, *Culex quinquefasciatus* say.