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The lifestyle of immature forms of the mosquito in water is highly dependent upon the properties of the air-water interface. Nonionic monomolecular organic films, which reduce surface tension and increase the wettability of breathing structures, produced high cumulative mortalities and mortality rates in fourth-instar larvae of *Anopheles quadrimaculatus*. These results were demonstrated both in the laboratory and in field studies of 4-m^2 ponds in a natural paludal setting. Effective surface films were maintained for at least 24 h with an initial application of only

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0.04 ml of film-forming liquid per square meter of water surface. Two of the compounds, isostearyl alcohol (2 oxyethylene groups) and sorbitan monooleate, were 100% effective against these larvae in the field, each experiment involving about 5,000 organisms. Although laboratory research indicated that larvae of *Aedes aegypti* were not killed by the surface films studied, their development rate was greatly retarded. Three of the surface films caused 100% cumulative mortalities to pupae and emerging adults of this species.

The mechanisms by which the film-induced surface affects the life cycle of the mosquito are discussed. Optimum properties of film-forming materials for practical mosquito-control applications are itemized and related to chemical structural considerations. The applicability and limitations of this approach to mosquito control are reviewed.

CONTENTS

MOSQUITO CONTROL IN THE AQUATIC ENVIRONMENT WITH MONOMOLECULAR ORGANIC SURFACE FILMS

BACKGROUND

The adult mosquito is a disease vector of malaria, filariasis, yellow fever, dengue, and various strains of encephalitis. Adulticiding accounts for only about 10% of the budget of mosquito-control districts in the United States [1], while antilarval approaches to mosquito control are used to a much greater extent to eliminate the insect in its aquatic breeding grounds prior to its emergence as an adult. A multiplicity of methods is in current use, either separately or in combination, against mosquito larvae and pupae. One of these, source reduction, is defined as a planned modification of the environment which eliminates water bodies in which mosquitos may develop. Source reduction is accomplished by draining, filling, ditching to alleviate stagnation, and other landscaping techniques. Chemical control methods include the use of pesticides, antilarval petroleum-based oils, and occasionally herbicides, the latter used to eliminate vegetation and expose larvae to predation by their natural enemies. Stocking of permanent water bodies with nonnative larvivorous fish is also pursued on a limited scale as a naturalistic control method, although there has been recent concern over the possibility of producing ecosystem imbalances by this approach.

Renewed interest in the undesirable biological impacts and public health hazards of insecticides has led to the curtailed use of a number of chemicals which have been important in the control of mosquitos. In addition, resistance to DDT in vector species of the Anopheline mosquito has reached levels that have reduced the operational value of this chemical. Resistance to some of the replacement organophosphorus insecticides has begun to appear in some species. Consequently, there is a need for alternative control methods which do not insult the environment or pose a health hazard to man. Alternatives presently under development are primarily biological control techniques, i.e., the action of parasites, predators, or pathogens to reduce the population density of the mosquito. These include larvivorous fish, bacteria, fungi, nematodes, protozoa, viruses, and predatory insects. Genetic control is also possible through radio- or chemosterilization of adult males. New materials with biological activity include insect growth regulators (e.g. juvenile hormone mimics) which inhibit development of immature stages. Insect attractants and pheromones are also being studied as lures to entrap adults.

One long-used approach to mosquito control has been to prevent the emergence of the adult from its aquatic breeding sites through the use of petroleum-based oils. These antilarval oils presumably suffocate the larvae by preventing access to oxygen at the air-water interface. Nonvolatile hydrocarbon films containing only alkanes and cycloalkanes are slow in their physical impact on larvae. More rapid toxic effects appear to derive mainly from volatile aromatics and other toxic compounds drawn into the larval breathing

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tube (trachea) during respiration [2]. Oil-soluble, surface-active agents are often added to petroleum oils to promote uniform spreading over the water surface against natural organic films, and to enhance respreading after disruption by wind.

Another organic film approach to the control of the mosquito in water may be through the physicochemical modification of the aquatic surface with adsorbed monomolecular films. The impact of reduced surface tension on the lifestyle of the mosquito in water caused by various concentrations of water-soluble, surface-active chemicals has been the subject of several entomological studies [3-8]. The wetting and sinking of eggs laid at the surface was demonstrated, as well as the inability of pupae to maintain a proper breathing orientation at the water surface. Larvae had difficulty remaining in the surface when the surface tension had been reduced to a critical value, which varied between 0.027 and 0.036 N/m (27 and 36 dyn/cm) and was species dependent. In general, lower surface tensions produced greater mortality rates. Pupal mortalities occurred at slightly higher surface tension values of from 0.036 to 0.041 N/m (36 to 41 dyn/cm).

The surface effects literature through 1967 was reviewed in detail by Wiltzius [9] in a report concerned with the ecological effects of monomolecular films of commercial mixtures of *n*-alkanols used for the reduction of evaporation from reservoirs. Mosquito mortalities induced by the fatty alcohol monolayers in laboratory studies of *Aedes* were due primarily to effects on the pupae [9]. A similar conclusion was reported by McMullen and Hill [10], who reported a 100% rate of mortality to pupae of *Aedes aegypti* in laboratory studies with insoluble monolayers of various natural lipids. These lipid films produced little effect on the larvae of this species. Lauryl alcohol (1-dodecanol) monolayers were found to be variably effective against larvae and pupae of *Culex quinquefasciatus* [11]. Cumulative mortalities of 100% were realized after 72 hrs, since adults were not able to emerge successfully from pupae at the water surface covered with the film of lauryl alcohol. In this study it was determined that *n*-octanol did not produce a stable film, and that *n*-hexadecanol was ineffective. In many of these studies the mortalities were attributed to physical effects of the surface-active chemical rather than to toxic influences.

RESEARCH METHODS AND RESULTS

Selection of Mosquito-Control Film

Previous research has been performed primarily in the laboratory where the maintenance of a one-molecule-thick film in a small tray presents no problem. In the real environment monomolecular films would be subjected to a number of dispersive forces which act continuously to degrade an additive film. Air flow and surface currents are several of these factors, which also displace petroleum-based larvicidal oils. However, since mosquito-control films will be utilized primarily in relatively small, stagnant water bodies, the rate of film loss will be low for nonvolatile, water-insoluble compounds in the absence of strong winds.

It is necessary for film-forming chemicals and the surface films which they form to have certain physicochemical properties to assure not only effectiveness against aquatic forms of the mosquito, but also ease of application and persistence. These properties, listed below, are essential for optimum performance:

- Highly surface active—reduction of water surface tension, wetting of hydrophobic surfaces, displacement of natural films and scum

- Liquid—easily and rapidly spread onto water surface

- Nonvolatile—relatively high molecular weight

- Nonionic—little reaction with saline water

- Low water solubility—large hydrophobic group in molecule

- Fluid monomolecular film—rapid, spontaneous spreading, high respreading potential

- Low freezing point

- Commercially available at reasonable cost

- Nontoxic, noncorrosive

A relatively high molecular weight is required to ensure surface-film durability by providing low volatility and a low rate of dissolution into water. A nonionic structure is essential to prevent solubility losses into saline water due to the formation of soluble organic salts. Fluidity is desirable in the bulk material for ease of spraying and in the surface film for enhancing its rate of spread. Fluid films maintain a more uniformly reduced surface tension than rigid monolayers and respread readily after disruption by wind and waves when these stresses are relaxed. Highly branched hydrocarbon chains or chains which are permanently bent due to chemical unsaturation (cis isomers) increase fluidity in both the liquid and its surface film. Autophobicity is another important property of many of the liquid, water-insoluble, surface-active compounds; that is, they do not spread over their own monomolecular films. The excess liquid remains as a thick, oil-like lens in equilibrium with the spread film. When portions of the film have been degraded or displaced by natural forces, the excess material in the lens ("reservoir") immediately and spontaneously spreads to restore the equilibrium between the film and the excess bulk liquid, thereby maintaining uniform coverage and film pressure. Maintenance of fluidity at low temperatures is important because the surface spreading of liquids is orders of magnitude faster than that of solids.

As previously discussed, lowered surface tension may prevent the hanging of larvae, disrupt the upright orientation of pupae, sink floating eggs of certain species, and interfere with adult emergence. The reduction of the surface tension of water by a monomolecular film is a function of the balance between the hydrophobic and hydrophilic groups in the molecule as well as the chemical constitution of the outermost groups (toward the air) of the hydrophobic segment when the film is at its equilibrium spread condition. The water surface tension may be reduced to as low as 0.015 N/m (15 dyn/cm) by perfluorooctanoic acid, and surface tensions almost as low are obtained with other highly fluorinated compounds [12]. However, toxicity and cost considerations preclude the use of such materials in the aquatic environment.

Table 1—Monomolecular Organic Surface Films and Surface Tensions

Liquid	Film Composition	Surface Tension	
		N/m	dyn/cm
A	Diethylene glycol monolaurate	0.0276	27.6
B	Sorbitan monooleate, 75%; 2-ethyl butanol, 25%	0.0289	28.9
C	Sorbitan monooleate, 37.5% lauryl ether containing 4 oxyethylene groups, 50% 2-ethyl butanol, 12.5%	0.0283	28.3
D	Isostearyl alcohol containing 2 oxyethylene groups	0.0282	28.2
E	Lauryl ether containing 4 oxyethylene groups	0.0271	27.1

Greatly lowered surface tension may be essential to produce larvicidal and pupicidal effects for another reason. Wetting of the internal hydrophobic structure of pupal and larval tracheae can lead to liquid blockage and interfere with respiration. This will occur if the liquid surface tension is equal to or less than the critical surface tension of the solid (tracheal wall) in question. For example, Watson [13] reported that the lining of the tracheae of Anopholine larvae appears to be a waxy substance. According to Zisman [14], the critical surface tension of polyethylene (-CH_2-surface structure) is 0.031 N/m (31 dyn/cm) at 25°C. Since the internal tracheal wall will not be more hydrophobic than polyethylene, and since the chemicals used in this study reduced surface tensions below 0.029 N/m (29 dyn/cm), water blockage effects and wettability of waxy surfaces of larval and pupal tracheae are possible.

In consideration of the requirements just discussed, and of previously reported properties of a number of surface-active liquids [15,16], several nonionic organic liquids were selected as likely candidates for these mosquito-control studies. Distilled water was covered with a film of the liquid in equilibrium with a small excess lens. Surface tensions were measured at 25°C by the ring method using a Kruss du Nouy tensiometer. Surface tensions of the film-covered water remained essentially constant over a period of 24 hrs for the following liquid compounds and formulations used in this research (Table 1).

In both laboratory and field experiments the films were applied at a surface concentration of 40 $\mu\ell/m^2$. This value is greater than 10 times that required for a single monomolecular layer, and was used to provide an excess of chemical to resupply losses from the film. As mentioned previously, the excess material did not spread over its own film, but remained as an unspread patch or liquid lens which acted as a reservior to maintain complete coverage of the water surface. At this surface concentration it was possible to maintain an effective film under the conditions of these experiments for at least 24 hrs.

Influence of Surface Films on *Anopheles quadrimaculatus*

Films of liquids A, B, C, and D were spread over water in polyethylene-lined trays (25 × 51 cm) in the laboratory and onto the surface of four similar ponds in a natural paludal setting. An additional control tray and pond were maintained in both laboratory and field experiments, with the exception of the terminal studies where the control organisms were treated with a film of isostearyl alcohol (2 oxyethylene groups) to provide additional data. Fourth-instar larvae of *Anopheles quadrimaculatus* had been placed into the trays and ponds several hours prior to application of the film-forming liquids to allow time for the larvae to adjust to the new environment. The field ponds had a surface area of about 4 m^2 and were created in a drainage ditch with wooden barriers to segregate the five equal areas. The ponds were lined with a polyethylene sheet to prevent water and chemical exchange between them and to facilitate larval mortality counts.

The laboratory data (Table 2) indicate 100% larval mortality for films of liquids C and D as well as total effectiveness against pupae by film C. Films of A and B were less effective, although cumulative mortalities after 72 hrs were 83.8 and 95.0%, respectively. Although these data are tabulated for 24-hr intervals, mortalities to fourth-instar larvae occurred rapidly with films of B, C, and D (Table 3). After film emplacement most larvae were unable to attach at the film-covered water surface and exhibited an intense hyperactivity until death occurred. Third-instar larvae survived for longer periods of time, and in the case of film B, five of these larvae remained alive after 72 hrs. Larvae which were able to remain at the surface did not attach in their normal horizontal mode, but hung at a steep angle with their spiracles at the water surface. Pupae could not maintain their hydrostatic balance and turned over onto their sides. The pupae made repeated efforts to dive underwater so that upward flotation would restore a proper breathing orientation. Ultimate death may have been due to water wetting and entering their trumpets, thereby causing anoxia [2].

Field research (Table 4) indicates high cumulative mortalities for all of the films examined. Films of B and D had caused total larval mortality at 24 hrs, although it was difficult to determine the exact time at which total mortality was effected. On the basis of the laboratory studies listed in Table 3, it is possible that many larvae expired a short time after emplacement of the organic surface films. Films of A and C demonstrated lower larvicidal rates, but at 120 hrs their cumulative mortalities were 98.8% and 96.8% respectively. Most control larvae which had been maintained on two separate ponds remained viable for 72 hrs, at which time they were treated with films of B and D to provide additional data. Larval mortalities of 100% were recorded in both film-covered ponds within 24 hrs in the terminal studies with films of B and D.

Surface Film Effects on *Aedes aegypti*

Aedes aegypti larvae, pupae, and emerging adults were adversely affected by monomolecular films of various organic liquids. However, in contrast to the previously reported film-induced mortalities in larvae of *Anopheles quadrimaculatus*, larvae of *Ae. aegypti* were not killed by the surface films included in the present study. Some fourth-instar larvae were able to hang vertically in a normal breathing mode at film-covered water surfaces. Earlier larval stages were unable to attach themselves to the water surface

Table 2 — Laboratory Data, Effect of Monomolecular Films on Immature Stages of *Anopheles quadrimaculatus*

Liquid	Film Composition	Number Larvae, Pupae Used	Cumulative Mortality After Indicated Hours of Posttreatment Exposure			Percent Total Mortality
			Hours	Larvae	Pupae	
A	Diethylene glycol monolaurate	322 Larvae	24 48 72	247 264 269	0 1 1	76.7 82.3* 83.8
B	Sorbitan monooleate, 75% 2-ethyl butanol, 25%	100 Larvae	24 48 72	95 95 95	0 0 0	95.0 95.0 95.0
B	Sorbitan monooleate, 75% 2-ethyl butanol, 25%	23 Pupae	24 48	— —	13 13	56.5 56.5†
C	Sorbitan monooleate, 37.5% Lauryl ether (4 oxyethylene groups) 50% 2-ethyl butanol, 12.5%	435 Larvae	24	435	0	100.0
D	Isostearyl alcohol (2 oxyethylene groups)	462 Larvae	24	462	0	100.0
D	Isostearyl alcohol (2 oxyethylene groups)	25 Pupae	24	—	25	100.0
	Controls	462 Larvae	24-72	0	0	0.0

*One (1) Adult successfully eclosed after 48 hrs.
†Two (2) and eight (8) adults successfully eclosed after 24 and 48 hrs, respectively. Pupae had been added to SMO 75/2EB used in previous study with 100 larvae; film was 20 hrs old at time of emplacement.

Table 3 — Laboratory Data, Rapid Effect of Monomolecular Films on Larval Stages of *Anopheles quadrimaculatus*

Liquid	Film Composition	Time (Min)	Live Larvae
C	Sorbitan monooleate, 37.5%	0	25
	Lauryl ether (4 oxyethylene groups), 50%	7	10
		13	4
	2-Ethyl butanol, 12.5%	15	1 (3rd instar)
B	Sorbitan monooleate, 75%	0	100
	2-Ethyl butanol, 25%	16	16
		26	7
		41	5 (3rd instar)
D	Isostearyl Alcohol	0	462
	(2 oxyethylene groups)	15	20
		20	3 (3rd instar)
		35	3
		45	1
		24 hrs	0

as a result of lowered surface tension. It is possible that the fourth-instar larvae were stronger or possessed greater buoyancy than the lower larval stages.

There was no deleterious flooding of the larval respiratory siphons, one of the possible mechanisms postulated for the mortality of *A. quadrimaculatus* larvae. This fact was clearly demonstrated by the following observations. One-day-old larvae were placed into two identical polymethylpentane cylindrical dishes (11 cm diameter, 7 cm high). Water depth was 3 cm, and the experimental room was maintained at 25° ± 1°C. Approximately 100 larvae and appropriate nourishment were placed into distilled water in each dish. A film of isostearyl alcohol containing two oxyethylene groups (ISA-2) was spread over the surface of the water in one of the containers, the other dish being reserved as a control. The monomolecular film of ISA-2 reduced the surface tension to 0.0282 N/m (28.2 dyn/cm). No larvae were able to attach to the water surface in a normal manner at any time during the long duration of this experiment. However, in spite of this effect, 50% of the larvae remained alive for 16 days. Remarkably, 12% lived for 28 days under these unusual circumstances. They adapted to this situation by continually breaking the water with their siphons, using a thrashing motion to thrust through the water surface. Small particles of dust on the surface were moved during these attempts to respire, indicating that the larvae were breaking the surface for momentary breaths of air. Apparently enough oxygen was obtained in this manner to sustain life. Curiously, however, these larvae developed very slowly, eventually reaching the fourth-instar before dying, while the control larvae in an adjacent container pupated in 6 to 7 days and behaved normally during this period. None of the larvae pupated in the film-covered container. It is possible that the larvae spent so much time in attempts to breathe that the rate of nourishment was lessened, or that the available food energy was expended in an effort to survive rather than being utilized for growth. Whatever the reason for the retarded growth rate, it is important to note that the surface film was not

Table 4 — Field Data, Effect of Monomolecular Films on Larval Stages of *Anopheles quadrimaculatus**

Liquid	Film Composition	Hours of Exposure	Cumulative Larval Mortality	Percent Total Mortality
A	Diethylene glycol monolaruate	24 48 72 120	3554 3786 4065 4942(*)	71.1 75.7 81.3 98.8
B	Sorbitan monooleate, 75% 2-ethyl butanol, 25%	24	5000	100.0
C	Sorbitan monooleate, 37.5% Lauryl ether (4 oxyethylene groups), 50% 2-ethyl butanol, 12.5%	24 48 72 120	3850 4156 4365 4842	77.0 83.1 87.3 96.8
D	Isostearyl alcohol (2 oxyethylene groups)	24	10,000†	100.0
	Controls	24 48 72	0 0 55	0.0 0.0 1.1

*Observed mortality after 72 hrs may be partially due to unknown causes. Water striders were active on pools 48 hrs after treatment. No controls available for comparison after 72 hrs.
†Reflects the results of two (2) replicates of 5,000 larvae each.

toxic to the organism in a chemical sense, but by altering the physical character of the water surface, the organism's lifestyle was drastically modified.

An additional experiment was performed to determine whether the treated larvae could follow a normal development pattern after exposure to the surface film. After 15 days under the influence of the isostearyl alcohol (2 oxyethylene groups), 10 larvae were transferred to a container of distilled water and fed. These larvae were able to attach to the water surface immediately and remain alive for 10 to 16 days after emplacement in the film-free water. In spite of this, however, they died before pupating. Possibly, their previous experience in the film-covered container affected their ability to mature further.

Although the impact of a thin surface film on larave of *Ae. aegypti* is scientifically interesting, this effect cannot be the basis of a larval-control technique. On the other hand, pupae of *Ae. aegypti* were significantly affected by the water-insoluble films formed from four selected nonionic surface-active liquids (Table 5). Pupae were taken from the rearing tray and placed into distilled water in the plastic dishes previously described. Most pupae, especially the larger ones, had difficulty maintaining an upright orientation with both trumpets through the water surface. This condition increased with time and eventually the pupae, suffering from anoxia, were no longer able to propel themselves to

Table 5 — Influence of Monomolecular Surface Films on Pupae and Emerging Adults of *Aedes aegypti*

Surface Film	Number of Pupae	24-Hour Mortality			48-Hour Mortality		
		Pupae	Adults	Percent*	Pupae	Adults	Percent*
Isostearyl alcohol containing two oxyethylene groups	96	78	0	81.2	93	3	100
Sorbitan monooleate, 75% 2-ethyl butanol, 25%	124	88	7	76.6	89	31	96.8†
Lauryl ether containing four oxyethylene groups	80	80	0	100	80	0	100
Sorbitan monooleate	106	81	10	85.8	81	25	100
Control	50	0	0	0	1	0	2

*Percent total mortality (pupae and adults).
†Four successful eclosions.

the surface and expired. Flooding of the trumpets with water as a result of decreased surface tension is a likely cause of the anoxia. In these experiments the water surface tension was lower than the critical surface tension for wetting the hydrophobic internal surface of the pupal tracheae.

A surface film of lauryl ether (4 oxyethylene groups) was 100% fatal to pupae within 24 hrs (Table 5). As shown in Fig. 1, pupal mortality occurred before any eclosions could take place. The photographs show the dead pupae at the bottom of the container. A 27.5% pupal mortality had occurred at a posttreatment time of 6 hrs. Sorbitan monooleate and isostearyl alcohol (2 oxyethylene groups) films produced total mortalities of 100% at 48 hrs exposure time which included some unsuccessful eclosions. The adults which emerged drowned before takeoff (Figs. 2, 3). In many instances they were still attached to their pupal cases. Two eclosions were observed in which the adult was wetted and drawn down into the water once its legs made contact with and were wetted by the water surface. Most pupae floated at the sides of the containers, perhaps using the water meniscus or the solid wall of the dish as a support. The emerging adult was in one instance observed to use the side of the container to effect successful eclosion. Perhaps this escape technique accounts for the four successful emergences which occurred in the experiment with sorbitan monooleate (ethyl butanol solvent) yielding a 48 hr total mortality of 96.8%.

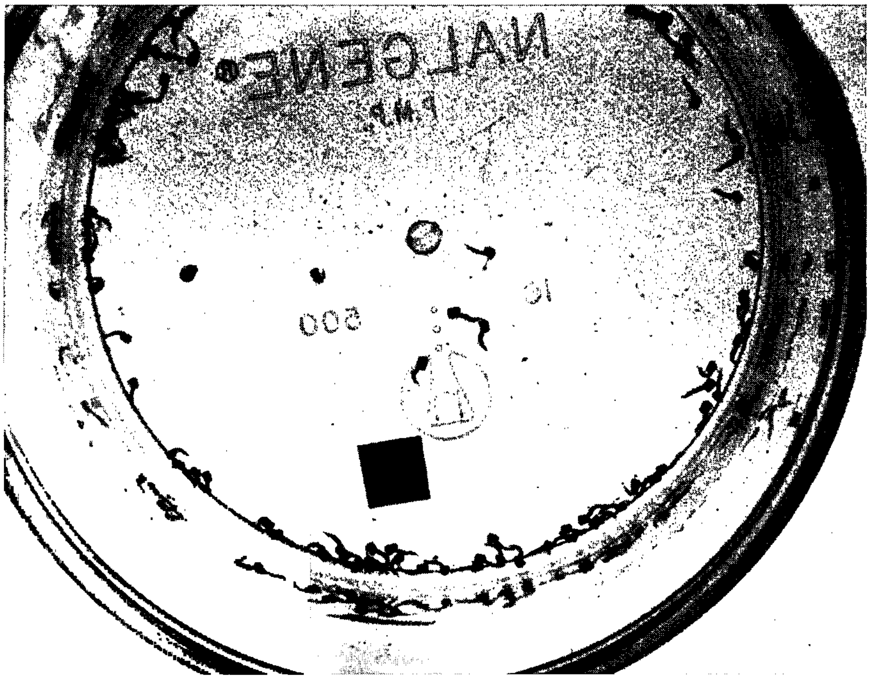

Fig. 1 — Total pupal mortality after 24-hr exposure to monomolecular film of lauryl ether (4 oxyethylene groups)

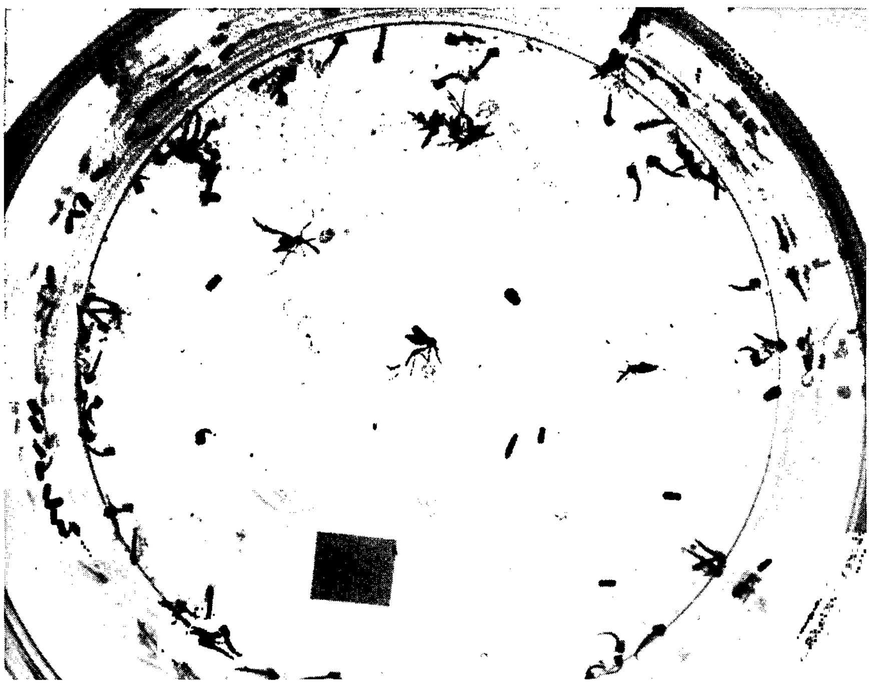

Fig. 2 — Effect of surface film of sorbitan monooleate on pupae and eclosed adults of *Aedes aegypti* after 24 hrs

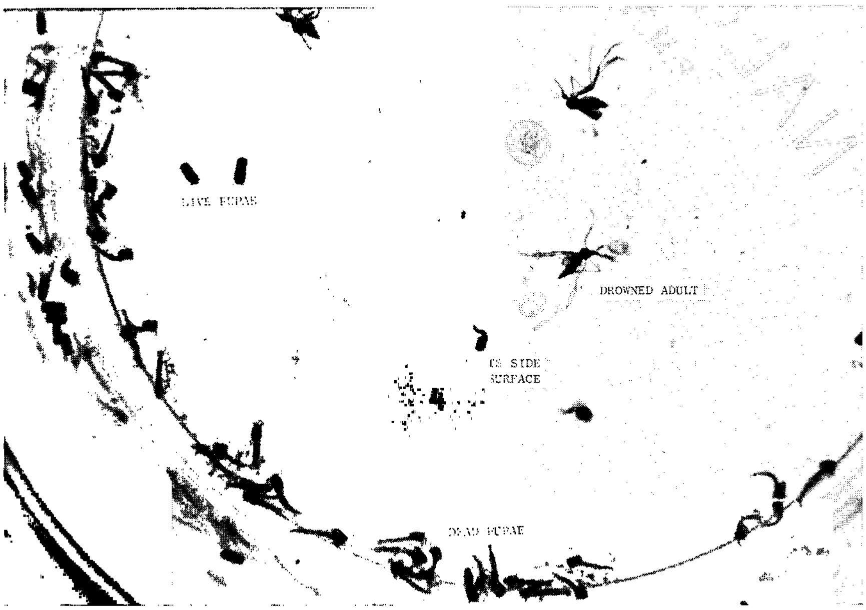

Fig. 3 — Effect of surface film of sorbitan monooleate on pupae and eclosed adults of *Aedes aegypti* after 24 hrs. Dead pupae, pupae still alive in a proper breathing orientation, drowned adults and a pupa on its side due to lowered surface tension are identified

A dish containing 50 pupae was maintained as a control until all pupae had eclosed. There was only one pupal mortality and all adults emerged successfully. The adult mosquitos could stand on the untreated water surface as well as take off and land on it. The adult stood high on the water with only small depressions where the legs contacted the surface (Fig. 4). This ability to rest on a water surface is reminiscent of the Gerrid water strider, which brushes a hydrophobic substance obtained from its glands onto its tibial bristles to prevent wetting of its legs [17].

POTENTIALITIES AND LIMITATIONS

In the field studies the film-forming liquids were applied at a surface concentration of 0.04 ml/m^2, about ten times that required for a monomolecular layer. This is a very small surface concentration when compared to the commonly used dosages of petroleum oils. Early techniques using petroleum as larvicidal oils required 45 ml/m^2, and recent advances through the use of spreading agents have reduced the effective petroleum dosages to between 4.5 and 18 ml/m^2 (2). Thus, there is a material advantage in using surface-active films of at least 2 orders of magnitude. This material advantage can be translated into reduced transportation and application costs as well as providing freedom from possible environmental insults which may occur from the use of petroleum products.

The present research indicates that this approach to mosquito control would be highly successful against larvae and pupae of Anopheline mosquitos, although species

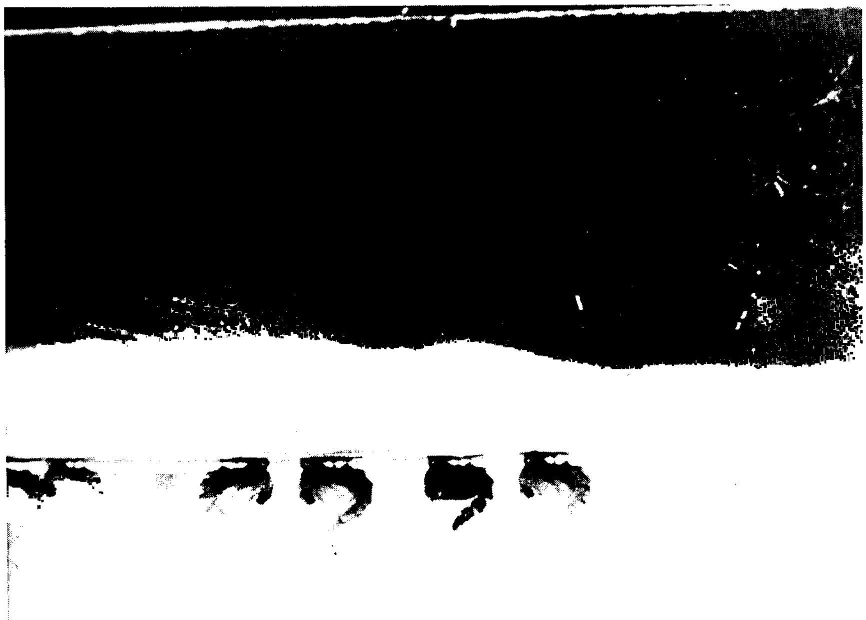

Fig. 4 — Close-up of pupae of *Aedes aegypti* at water surface in the untreated control. An adult mosquito standing on the water appears in the upper far right

variations may produce variability in effectiveness. Control of *Aedes* pupae and emerging adults is also possible. However, treatment of water bodies would have to be repeated every 2 or 3 days since the pupal form has a 2-day existence prior to becoming an adult. Thus, when *Aedes* are involved, the surface-film technique is more limited and the water bodies would have to be monitored more closely. More experimentation with *Culex* and other mosquito genera as well as additional species of *Anopheles* and *Aedes* is required to develop the areas of applicability of the surface-film approach to mosquito control.

One of the limitations of this method is the maintenance of complete coverage of a large body of water. Experience gained at this Laboratory during the development of such water-insoluble surface films as oil-control agents and seamarkers [15,16] can be applied to this mosquito-control method. Because of the film-dispersive influences of wind and waves, total coverage of a large exposed water surface is difficult, especially when there is a long and constant wind fetch. Surface films are driven downwind, and unless film-forming material is continuously applied at the upwind end, the film is removed from large areas of the water surface. On the other hand, most mosquito larvae develop in small stagnant bodies of water. These include potholes, drainage ditches, discarded containers and tires, and small areas which are filled by rain or high tides. In swamps and marshes vegetation would protect the additive surface film against dispersal by wind. Thus, there are numerous possibilities for the use of mosquito-control surface films. Considerable additional experience is required under carefully monitored conditions to delineate the potentialities and limitations of this approach.

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