USE OF ELEVATED TEMPERATURES TO KILL *AEDES ALBOPICTUS* AND *AE. AEGYPTI*

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Before *Aedes albopictus* (Skuse) was discovered in Houston, Texas in 1985 (Sprenger and Wuithiranyagool 1986), the species had been found twice in United States ports in shipments of used tires from Asian countries (Pratt et al. 1946, Eads 1972). In 1986 *Ae. albopictus* was again found, along with 4 other species of mosquitoes, in used tires that had just arrived from Japan (Craven et al. 1988).

Large numbers of used tire casings are currently imported into the United States from Japan and other countries within the natural range of *Ae. albopictus* (Reiter and Sprenger 1987). These shipments pose a high risk for future introductions of exotic mosquitoes and underline the need for effective prevention. Most of the used tire casings are shipped in standard seagoing steel containers. Methods are needed to disinsect the tires before they are removed from the sealed containers.

Bailey et al. (1965) found that elevated temperatures rapidly kill adult mosquitoes. They used a portable electric heater to raise the temperature in the enclosed truck where collection bags were being held. Upper lethal temperatures for different species of mosquitoes have been reported. Temperatures of 40–45°C for a short period are lethal to most mosquito larvae (Christophers 1960), and a temperature of 43°C for 5 minutes was lethal to all immature stages of several anopheline species (Clements 1963). The purpose of this study was to establish the minimum upper temperature lethal to 100% of all life stages of *Ae. albopictus* and *Ae. aegypti* (Linnaeus) mosquitoes.

All stages of the 2 species were from colonies of U.S. strains maintained at the Division of Vector-Borne Viral Diseases, Centers for Disease Control, laboratory in Fort Collins, Colorado. Each stage was exposed to temperatures between 40.5–51.7°C (105–125°F) in 2.8°C (5°F) increments.

Paper strips containing 100 or more eggs were placed into previously heated glass vials for different lengths of time to expose eggs to dry and moist air at different temperatures. A few drops of water were added to the vials if moist air was needed. To prevent the egg strips from contacting the water, glass beads were added to a depth greater than the water before placing the egg strips in the vials. After exposure, half of the eggs were immediately flooded in deoxygenated water, the other half were held for at least 12 hours before being flooded. Twenty-four hours after flooding, the egg strips were removed, allowed to dry, and then reflooded to obtain maximum hatching.

Pupae and 1st instar larvae were pipeted into vials containing preheated water to expose them to the desired temperatures. During each exposure the vials were stoppered and held in a water bath to prevent heat loss due to evaporation. After exposure the vials were removed from the waterbath, and a small amount of water was added to reduce the temperature to near room temperature.

Adults were exposed to various moist and dry air temperatures in small screen cages suspended in preheated stoppered flasks. Water saturated pads were added to the flask when moist air was required.

Mortality rates for larvae, pupae, and adults were recorded 24 hours after exposure. The hatching success of treated eggs was recorded as hatched or not hatched 48 hours after flooding. Three or more replicates were used for each test condition of eggs, larvae, and pupae. Only 1 or 2 replicates were used to test adults at each condition.

Results of exposure to the selected temperatures ranged from little or no mortality at 40.6°C (105°F) for 2 hours to 100% mortality of all stages at 46.1°C (115°F) for 30 minutes. The exposure time needed at each temperature to achieve 100% mortality for each stage is shown in Table 1.

Insufficient data was obtained from dry and moist air treatment of eggs and adults to allow statistical comparison of the 2 methods. However, 100% mortality did occur when eggs were exposed to temperatures of 48.9°C (120°F), 46.1°C (115°F) and 43.3°C (110°F) for 2, 10 and 120 minutes respectively. Adults were unable to survive 10 minutes at a temperature of 48.9°C (120°F) or for 30 minutes at a temperature of 43.3°C (110°F) or 46.1°C (115°F).

Testing of larvae was limited to 1st instars after initial testing indicated that 4th instar larvae were killed significantly faster than 1st

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instar larvae ($P < .001$; $\chi^2 = 25.9$ for *Ae. aegypti*, $\chi^2 = 20.4$ for *Ae. albopictus*). Table 2 summarizes the mean percent mortality of 1st instar larvae, pupae, and adults exposed to 3 selected temperatures for various lengths of time. Insufficient numbers of adults were treated at each test condition to calculate the standard error.

Some differences were noted in the time needed to kill different stages at temperatures of 43.3°C (110°F), however, an exposure of 15 minutes to a temperature of 46.1°C (115°F) was 100% lethal to all aquatic stages of both species.

The relatively modest temperatures needed to kill all stages of *Ae. albopictus* and *Ae. aegypti* offer a potential cost-effective means to disinsect tires without removal from the shipping containers. The use of heat eliminates problems associated with fumigation because no dangerous toxicants are involved and no delay for gas dissipation is required once the treatment is completed.

Table 1. Time (minutes) needed at various temperatures for 100% mortality.

Temperature °C/°F	Life stage			
	Egg*	Larva	Pupa	Adult*
Ae. albopictus				
51.7/125	<2	<2	<2	<10
48.9/120	<2	<2	5	10
46.1/115	10	10	10	30
43.3/110	120	>180	30	30
40.6/105	>240	>180	>120	>60
Ae. aegypti				
51.7/125	<2	<2	<2	<2
48.9/120	<2	5	5	15
46.1/115	15	15	10	30
43.3/110	120	>180	120	30
40.6/105	>240	>180	>120	>240

* Combined results of moist and dry air treatment.

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Table 2. Comparison of mean percent mortality of *Aedes albopictus* and *Ae. aegypti* larvae, pupae, and adult stages after exposure to various temperatures and time periods.

Temperature	Minutes exposure time	Percent mortality (±SE)					
		Ae. albopictus			*Ae. aegypti*		
		Larva	Pupa	Adult	Larva	Pupa	Adult
48.8°C (120°F)	2	100	82 (7.6)	...	95 (5.0)	68 (14.3)	...
	5	100	100	...	100	100	...
	10	100	...	100	100	...	92
	15	...	...	...	...	...	100
46.1°C (115°F)	2	13 (3.0)	25 (15.8)	...	26 (7.2)	48 (12.4)	...
	5	77 (16.1)	50 (22.4)	...	58 (7.2)	83 (6.7)	...
	10	100	100	...	90 (4.0)	100	...
	15	100	100	82	100	100	62
	30	100	100	100	100	100	100
43.3°C (110°F)	2	...	13 (2.3)	...	...	...	...
	5	...	50 (3.2)	...	...	...	...
	10	...	73 (3.3)	...	25 (5.0)	6 (6.6)	92
	15	5 (5.0)	60 (3.2)	57	5 (5.0)	6 (6.6)	100
	30	10 (5.8)	100	100	5 (5.0)	60 (8.1)	...
	60	15 (5.0)	100	...	0	71 (12.2)	...
	120	0	...	...	7 (5.1)	100	...