
Effects of laundry detergents on *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, and *Euroglyphus maynei*

DiAnn L. Vyszenski-Moher, MS; Larry G. Arlian, PhD; and Jacqueline S. Neal, BS

Background: House-dust mites in clothing and bedding are the source of major allergens. Based on studies of *Dermatophagoides pteronyssinus* only, weekly washing in hot water is recommended to kill dust mites and remove allergens from clothing and bedding. However, in the United States, washing is most often done in warm or cold water, and other mite species are involved.

Objective: The purpose of this study was to investigate the lethal effects of various temperatures of hot water alone and hot, warm, and cold water containing detergents and chlorine bleach on *Dermatophagoides farinae*, *D. pteronyssinus*, and *Euroglyphus maynei*.

Methods: Mites were soaked in test solutions at various temperatures and for various lengths of time, allowed time to recover, and then analyzed for survival.

Results: *D. farinae* was the most temperature-sensitive and chlorine bleach-sensitive of the three species. In 50° C water alone, 100% mortality for *D. farinae* was obtained in 10 minutes, whereas most *D. pteronyssinus* and *E. maynei* survived. However, 53° C-soaks for 12 and 5 minutes were needed to kill all *D. pteronyssinus* and *E. maynei*, respectively. Laundry detergents at their recommended and doubled concentrations and chlorine bleach generally increased mite mortalities over water alone for the three species. Soaking for 4 hours in warm water containing various detergents alone induced mortalities of 19 to 50%, 2 to 35%, and 14 to 46% for *D. farinae*, *D. pteronyssinus*, and *E. maynei*, respectively.

Conclusions: Washing bed linens weekly in warm water with a 4-hour presoak containing most detergents and bleach will kill most *D. farinae* and, depending on the detergent brand, moderate numbers of *D. pteronyssinus*. Four-hour soaks in warm water containing the recommended concentrations of various detergents alone also kills moderate numbers of *D. farinae*, *D. pteronyssinus*, and *E. maynei*. Therefore, the cumulative effect of weekly washing with long presoaks should significantly reduce mite levels over time in bed linens, particularly when mattresses and pillows are encased to prevent reinfestation.

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INTRODUCTION

The house-dust mites *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, and *Euroglyphus maynei* are the major sources of indoor allergens and are therefore considered important health problems worldwide. Many allergic individuals (hay fever,

asthma, atopic dermatitis) are sensitive to these mites. In humid climates, most homes contain one or more species of these house-dust mites. In the United States, most homes contain both *D. farinae* and *D. pteronyssinus*.¹ In addition, significant numbers of *E. maynei* occur in some areas.^{1,2}

Carpets, mattresses, bedding, pillows, pillow covers, stuffed animals, and clothing may contain breeding populations of house-dust mites. Washing bedding and clothing items weekly at ≥54° C (130° F) is recommended to kill dust mites.³ However,

this recommendation is made based on a study of *D. pteronyssinus*.⁴ Survival of *D. farinae* and *E. maynei* in hot, warm, or cold water with and without laundry detergent until now has not been investigated. In addition, in the United States, it is recommended that water heaters not be set above approximately 49° C (120° F) to prevent scalding.³ Further, most wash loads in the United States are done in warm or cold water, not hot water, to prevent fabric shrinkage and preserve fabric color. If washing is to be a recommendation to kill dust mites, it is important to determine the survival of all species of dust mites in hot, warm, and cold wash water with and without detergent. No studies have investigated the miticidal effects of hot water (≥54° C) without and with the addition of laundry detergents and/or bleach for brands that are available in the United States.

The purpose of this study was to systematically investigate survival of *D. farinae*, *D. pteronyssinus*, and *E. maynei* when soaked in selected detergent and/or chlorine bleach solutions in cold (15° C), warm (35° C), and hot (50° C) water for specified lengths of time to determine whether these additives would increase mortalities during washing.

METHODS

D. farinae, *D. pteronyssinus*, and *E. maynei* used for experimentation were obtained from thriving pure laboratory cultures, that were fed a high-protein diet, and maintained at 21° to 22° C and 75% relative humidity. Female mites were selected randomly from thriving cultures and confined in cages in groups of approximately 25 mites. The cages consisted of glass tubes (4

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mm ID $\times$ 25 mm) closed at each end with 35- μ m nylon mesh as previously described.⁵ Caged mites were held at 21° to 22° C and 75% relative humidity in ventilated containers. At least four sets of caged mites (n $\sim$ 100 mites) were used for each variable.

Effects of Water at Various Warm/Hot Temperatures on D. farinae Survival

Caged *D. farinae* mites were soaked in water at temperatures of 40°, 45°, 50°, 60°, 70°, and 80° C. Approximately 300 mL of glass distilled water was equilibrated in a calibrated temperature-controlled chamber set to maintain the desired temperature. Sets of caged mites were then soaked in the equilibrated water carefully so as to prevent air bubbles. At specific times the cages were removed and the mites were analyzed after 3 to 24 hours (allowing time for the mites to recover) for the numbers of live (moving) and dead. Mites were considered dead when no activity was evident even when they were touched with a probe. Data are presented as total percent mortality.

Effects of Laundry Detergents on Mite Survival

These tests were performed as previously described except that US commercially available detergents were added to the glass distilled water. Representative detergents were selected that contained various combinations of cleaning agents (anionic and nonionic surfactants, enzymes); water softeners; stabilizing (propylene glycol), soil suspending and/or color protecting agents; suds suppressors; fabric whiteners; perfumes; and colorants. All detergents were liquids unless stated otherwise. The concentrations of the detergents that were tested were those that were recommended on the package instructions for use in top-loading normal washers with regular loads. Therefore, concentrations were based on adding purchased detergents to a standard 68-L wash load. The brand names of the detergents and the concentrations in wash water that were used included Ajax (0.16%; Colgate-Palmo-

live, New York, NY), All Hypoallergenic (0.18%; Lever Brothers, Greenwich, CT), All-Temp Ultra-Top Crest (0.13%; Topco Assoc., Skokie, IL), Arm & Hammer (0.14%; Arm and Hammer, Princeton, NJ), Bold Plus (0.14%; Procter & Gamble, Cincinnati, OH), Dreft (0.14%; Procter & Gamble), Tide Ultra (0.15%; Procter & Gamble), Purex Ultra (0.15%; Dial, Scottsdale, AZ), Yes Ultra (0.14%; Dow Brands, Indianapolis, IN), Wisk (0.15%; Lever Brothers), Oxydol (0.12%; powder; Procter & Gamble), Tide with Bleach (0.16%; powder; Procter & Gamble), and Tide H₂O₂ (0.13%; powder; Procter & Gamble). In addition, chlorine bleach (Clorox; Clorox, Oakland, CA) was tested both alone at the recommended (0.35%) and the disinfecting (10%) concentrations, and also in conjunction with selected detergents. Mites were soaked in detergents and/or bleach and water alone at temperatures representing cold (15° C), warm (35° C), and hot (50° C) wash cycles on standard American washing machines. Aquachek Test Strips (Environmental Test Systems, Elkhart, IN) were used to determine the total chlorine, free chlorine, total hardness, pH, and total alkalinity of each detergent and Clorox solution.

RESULTS

Survival of D. farinae in Water at Various Temperatures between 40° and 80° C (Control)

Survival times were inversely related to the water temperature over the 40° to 80° C range. At 40° C, 10 hours of soaking were required to kill all mites. Whereas, at 48° to 49° and 50° C, 20 and 100% mortalities, respectively, were obtained by 10 minutes. At water temperatures of 60°, 70°, or 80° C, a complete extermination of *D. farinae* occurred in <1 minute.

Survival of D. farinae, D. pteronyssinus, and E. maynei in Water with or without Laundry Detergents at 50° C

Soaking in hot water alone (50° C) killed 87% *D. farinae* mites within 7.5

minutes (Table 1). In contrast, *D. pteronyssinus* and *E. maynei* showed greater resistance to 50° C temperatures, and both exhibited only 11% mortality after 10-minute soaks. However, *D. pteronyssinus* exhibited 100% mortality after a 12-minute soak in water at 53° C and a 2.5-minute soak in 55° C water. *E. maynei* exhibited 100% mortality after 5 minutes in water at 53° C. Generally, *D. pteronyssinus* seemed to be the most tolerant mite species to hot water temperatures, followed by *E. maynei* and *D. farinae*.

Mortalities for *D. farinae*, *D. pteronyssinus*, and *E. maynei* were greater using hot water (50° C) containing the recommended concentrations of most of the laundry detergents compared with 50° C water alone (Table 1). Doubling the recommended concentrations of the laundry detergents reduced the mortality by 12 to 84% when *D. farinae* were submerged for 2.5 and 5 minutes at 50° C (compared with recommended concentrations; Table 2). At longer exposures, doubling the concentrations had little effect on *D. farinae* because water alone at this temperature was lethal. In contrast, when female *D. pteronyssinus* mites were subjected to doubling concentrations of all tested laundry detergents at 50° C for 30 minutes, the mortality increased from 20 to 890% compared with the percent mortalities when they were soaked in recommended detergent concentrations at 50° C.

Survival of D. farinae, D. pteronyssinus, and E. maynei in Warm Water (35° C)

Mortalities among all three species after 12-minute and 1-hour soaks in warm water at 35° C were insignificant. Likewise, mortalities were low after 1-hour soaks in the recommended concentration of Clorox bleach (0.35%). When all three species were soaked for 4 hours in warm water (35° C) with the recommended concentrations of laundry detergents, moderate increases in mortalities were observed compared with those for 4-hour soaks in 35° C water alone (Table

Table 1. Percent Mortalities for *D. farinae* (DF), *D. pteronyssinus* (DP), and *E. maynei* (EM) after Soaking for 2.5, 5, 7.5, 10, 12, and 30 Minutes in Various Detergents (Manufacturers' Recommended Concentrations) at 50°C

Detergent brand Name	Type*	Percentage of Mortality																	
		2.5 min			5 min			7.5 min			10 min			12 min			30 min		
		DF	DP	EM	DF	DP	EM	DF	DP	EM	DF	DP	EM	DF	DP	EM	DF	DP	EM
Ajax	L	28	0	-	91	1	-	100	2	56	-	-	59	-	-	89	-	64	-
All Hypoallergenic	L	19	0	-	96	1	-	100	10	42	-	-	75	-	-	88	-	10	-
All-Temp Ultra-Top Crest	L	12	0	-	68	1	-	98	3	46	-	-	66	-	-	83	-	75	-
Arm & Hammer	L	20	1	9	96	2	9	100	2	53	-	-	76	-	-	97	-	76	-
Bold Plus	L	45	2	14	82	5	40	100	3	79	-	-	90	-	-	90	-	77	-
Dreft	L	9	2	-	79	3	20	97	10	66	-	-	85	-	-	87	-	22	-
Oxydol	P	36	1	-	91	13	-	100	8	16	-	-	53	-	-	70	-	22	-
Tide Ultra	L	14	0	21	92	1	17	99	0	64	-	-	75	-	-	95	-	11	-
Tide with Bleach	P	-	-	-	-	-	-	100	15	22	100	66	76	100	80	89	-	-	-
Tide H ₂ O ₂	P	-	-	-	-	-	-	100	34	93	100	36	95	100	66	94	-	-	-
Purex Ultra	L	3	0	-	47	5	-	89	0	45	-	-	71	-	-	75	-	13	-
Yes Ultra	L	40	0	-	92	0	-	100	3	67	-	-	80	-	-	93	-	27	-
Wisk	L	8	0	2	78	3	7	100	13	56	-	-	82	-	-	92	-	41	-
Clorox (0.35%)	L	82	36	71	99	51	78	99	91	61	99	99	86	-	98	99	-	-	-
Water (50°C)	L	11	0	6	51	1	8	87	0	9	100	11	11	-	-	28	-	1	-
Water (53°C)	L	-	13	99	-	50	100	-	78	-	-	84	-	-	100	-	-	-	-
Water (55°C)	L	-	100	-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-

*L/P = liquid or powder – = not done

Table 2. Percentage of mortalities for *D. farinae* and *D. pteronyssinus* after Soaking for Various Lengths of Time in the Manufacturers' Recommended (Rec) and Doubling (2X) Concentrations of Selected Detergents at 50°C

Detergent brand name	<i>D. farinae</i>						<i>D. pteronyssinus</i>							
	Percent mortality						Percent mortality							
	2.5 min		5 min		7.5 min		2.5 min		5 min		7.5 min		30 min	
	Rec	2X	Rec	2X	Rec	2X	Rec	2X	Rec	2X	Rec	2X	Rec	2X
Ajax	28	17	91	80	100	96	0	3	1	15	2	21	64	79
All Hypoallergenic	19	3	96	78	100	98	0	4	1	53	10	90	10	99
All-Temp Ultra Top Crest	12	12	65	66	98	96	0	4	1	24	3	49	75	94
Bold Plus	45	12	82	68	100	95	2	10	5	53	3	46	77	92
Oxydol	36	25	91	78	100	87	1	5	13	8	8	7	22	61
Tide Ultra	14	40	92	95	99	99	0	4	1	8	0	69	11	97
Purex Ultra	3	19	47	74	89	87	0	2	5	7	0	7	13	45
Yes Ultra	40	9	92	59	100	85	0	0	0	8	3	11	27	91
Water	11		52		82		0		1		0		11	

3). When soaked for 4 hours at 35° C in the recommended concentration of Clorox bleach (0.35%; no detergent), *D. farinae* exhibited 100% mortality. In comparison, *D. pteronyssinus* and *E. maynei* exhibited 32 and 26% mortalities under these same conditions.

Those detergents that gave the greatest mortality after 4-hour soaks at 35° C in detergents alone (manufacturers' recommended concentrations) were selected for testing using

detergent/bleach combinations. *D. farinae* and *D. pteronyssinus* were soaked in selected laundry detergents (manufacturers' recommended concentrations) along with chlorine bleach (manufacturer's recommended concentration) for 1 and 4 hours at 35° C (Table 4). Percentage of mortalities ranged from 10 to 55% and 4 to 14% after 1-hour soaks under these conditions for *D. farinae* and *D. pteronyssinus*, respectively.

Four-hour soaks in detergents plus chlorine bleach increased the percentage of mortalities for *D. farinae* with one exception to ≥95% mortality, whereas *D. pteronyssinus* showed only slightly higher mortalities (range 17 to 34%) than detergents alone. One hundred percent mortality was reached by both mite species after 4 hours in a disinfecting concentration of chlorine bleach (10%) at 35° C.

Table 3. Percentage of Mortalities for *D. farinae*, *D. pteronyssinus*, and *E. maynei* after 4-Hour Soaks in Various Detergents (Manufacturers' Recommended Concentrations) Plus Controls for 35°C, then Held for 24 Hours before Analysis

Detergent brand name	Type*	Percentage of Mortality		
		<i>D. farinae</i>	<i>D. pteronyssinus</i>	<i>E. maynei</i>
Ajax	L	24	18	30
All Hypoallergenic	L	16	22	14
All-Temp Ultra Top Crest	L	20	14	21
Arm & Hammer	L	50	17	29
Bold Plus	L	33	35	34
Dreft	L	43	30	15
Oxydol	P	28	2	23
Tide Ultra	L	28	19	46
Tide with Bleach	P	-	-	21
Tide H ₂ O ₂	P	-	-	15
Purex Ultra	L	16	10	22
Ultra Yes	L	45	11	32
Wisk	L	19	9	30
Clorox (0.35%)	L	100	32	26
Water	L	6	2	5

*L/P = liquid or powder – = not done

Table 4. Percentage of Mortalities for *D. farinae* and *D. pteronyssinus* after 1- and 4-hour Soaks in Various Detergents and Detergents Plus Clorox (0.35%) and Controls at 35°C, then Held for 24 Hours before Analysis

Detergent brand name	Percentage of Mortality			
	1-Hour soak		4-Hour soak	
	<i>D. farinae</i>	<i>D. pteronyssinus</i>	<i>D. farinae</i>	<i>D. pteronyssinus</i>
Ajax			24	18
Ajax + Clorox	32	4	96	17
Arm & Hammer			50	17
Arm & Hammer + Clorox	10	14	98	28
Bold Plus			33	35
Bold Plus + Clorox	55	13	99	17
Dreft			43	30
Dreft + Clorox	49	4	95	22
Purex Ultra			16	10
Purex Ultra + Clorox	46	10	96	34
Yes Ultra			45	11
Yes Ultra + Clorox	29	6	72	22
Clorox (0.35%)	84	16	100	44
Clorox (10%)	100	98	100	100
Water	3	2	6	2

Survival of *D. farinae* and *D.*

pteronysinus in Cold Water (15° C)

D. farinae and *D. pteronyssinus* were soaked in selected detergent solutions (Arm & Hammer, Dreft, and Yes; manufacturers' recommended concentrations), Clorox (0.35 and 10%), and water alone at 15° C. Four-hour soaks of *D. farinae* and *D. pteronyssinus* in all three detergents or a 0.35% solution of Clorox resulted in 1 to 6% mortality, whereas water alone caused no

mortality. A 4-hour soak in a disinfecting solution of Clorox (10%) caused 88.1% mortality in *D. pteronyssinus*, whereas *D. farinae* had 100% mortality after only a 2.5-minute soak.

DISCUSSION

In this study we found that the thermal death point of *D. farinae* was lower than those for *D. pteronyssinus* or *E. maynei*. A 10-minute soak in hot water at 50° C (hot wash load) killed 100%

of *D. farinae*, whereas at 48° to 49° C, only 20% were killed. This suggests that with a 10-minute soak, the critical water temperature for *D. farinae* is approximately 50° C. The length of the wash cycle on US washing machines ranges from 8 to 12 minutes, and therefore could effectively eliminate this species with hot-water washing at ≥50° C. In contrast, only moderate mortalities (≤11%) were achieved for *D. pteronyssinus* and *E. maynei* soaked

for 10 minutes at 50° C. A higher water temperature of 53° C for 12 and 5 minutes was necessary to kill 100% of *D. pteronyssinus* and *E. maynei*, respectively. All *D. pteronyssinus* died after only 7.5 minutes in 55° C water.

Normal washing at any temperature usually includes a detergent or laundry additive. Our results showed that use of the recommended concentrations of most US commercially available detergents in hot water (50° C) greatly increased mortalities of *D. farinae* and *E. maynei* compared with water alone at comparable wash water temperatures with normal wash times (Table 1). In contrast, *D. pteronyssinus* was much less affected by detergent, and mortalities did not exceed 34% in any detergent after a 7.5-minute soak (Tables 1 and 2). Doubling the manufacturers' recommended concentrations of most of the detergents at 50° C increased the mortality of *D. pteronyssinus* compared with the mortality observed using the recommended concentrations (Table 2), particularly after exposures of 7.5 and 30 minutes.

Mortalities for all species in detergent or water alone at 35° C (warm water) were not significant after 12-minute and 1-hour soaks. However, 4-hour soaks in detergent resulted in moderate mortality (range 9 to 52%). Therefore, long soaks in warm water containing some detergents have some benefit. If the washing of bed linens with long presoaks were done weekly, one would expect that the live mite population would decline exponentially over time.

Two previous studies conducted by Andersen and Roesen⁶ in Denmark and McDonald and Tovey⁴ in Australia examined the survival of *D. pteronyssinus* in water and detergent solutions. Andersen and Roesen⁶ reported 87.2 to 99.7% mortality for *D. pteronyssinus* at 10 to 50° C (17-minute wash cycle including prewash, wash, and four rinses) regardless of whether or not soap was used. Thus, they attributed most of the mortality to drowning. McDonald and Tovey,⁴ using detergents available in Australia, found that after 10 minutes in water at 55° and 50° C,

100 and 47% mortalities, respectively, were induced for *D. pteronyssinus*, which is consistent with the results of our study. The addition of detergent or laundry products in the 50° C-soak did not increase the proportion of *D. pteronyssinus* killed compared with the water control. In fact, mortality was lower in the detergent/laundry solutions compared with water alone and suggested these products had a protective effect near the critical temperature. In contrast to the results of these two studies, we found that detergent resulted in greater mortality for *D. farinae*, *D. pteronyssinus*, and *E. maynei* compared with water alone. Doubling the concentration increased the mortality of *D. pteronyssinus* and, for some detergents, slightly lowered mortality of *D. farinae*. We attribute the different results to the fact that we were using detergents sold in the United States, not the ones used in the other countries.

In contrast to soaking in laundry detergents alone, soaking *D. farinae* in the manufacturer's recommended concentration of chlorine bleach (0.35%) in water at 35° C had a profound effect. After 4-hour soaks in a recommended concentration of chlorine bleach and also in bleach plus selected detergents, except for one, 95 to 100% mortalities were observed in warm water. However, *D. pteronyssinus* was only slightly to moderately affected (range 17 to 44% mortality) by the chlorine bleach. Therefore, long soaks in warm water containing bleach is effective in killing *D. farinae*, but moderately effective in killing *D. pteronyssinus*.

Our experiments determined the mortalities of *D. farinae*, *D. pteronyssinus*, and *E. maynei* under controlled laboratory conditions. Thus, no variables such as the effect of different fabrics or the possibility of trapped air in these fabrics were evaluated. However, our results should be good representations of what would happen in a washing machine. Even though air bubbles may be trapped in clothing and bedding while washing, the live mites adhere to the surface of fabrics and would be submerged in a film of de-

tergent solution. The air temperature in bubbles likely equilibrates with the temperature of the wash water. Studies by Chang et al,⁷ coupled with our study, show that the thermal death temperature for mites in air and water are the same. Fabrics should equilibrate with the wash water temperature regardless of type. Additional studies are needed to determine whether water hardness influences mite survival.

In our study, we did not measure the effects of washing on removal of allergens from fabrics. However, a recent study by Tovey et al⁸ reported that washing with detergents extracted more Der p 1 allergen than water alone, and almost all allergens were extracted within 5 minutes at 25° C. Therefore, the results of the study by Tovey et al,⁸ combined with the results of our study, show that washing in detergent both kills mites and removes mite allergens.

CONCLUSION

Washing bed linens weekly in hot water (54° C) containing detergent will kill *D. farinae*, *D. pteronyssinus*, and *E. maynei* mites. A 4-hour presoak in warm water (35° C) containing laundry detergent and bleach will moderately reduce live mite levels. The amount of reduction depends on the detergent brand that is used. However, the cumulative effect of weekly washing in warm water with most brands should significantly reduce dust mite levels in bed linens over time, particularly if the mattress and pillows are encased to prevent reinfestation.

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- Requests for reprints should be addressed to:
Dr. Larry G. Arlian, PhD
Department of Biological Sciences
Wright State University
Dayton, Ohio 45435-0001
E-mail: larry.arlian@wright.edu*
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