Control of American Cockroaches (Dictyoptera: Blattidae) in Sewers

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ABSTRACT Baits, dusts, and aqueous sprays were applied to sewer shafts to control American cockroaches, *Periplaneta americana* (L.). Boric acid and hydramethylnon baits failed to provide consistent control because of problems with mold on the baits and because large populations of cockroaches depleted the bait. Bendiocarb, boric acid powder, and a powder mixture of silica gel + synergized pyrethrins provided excellent control for at least 1 mo, but cockroaches reinfested treated shafts within 3–6 mo. Treatments made in the fall when adult cockroach populations were lowest (about 26%) provided best results. Aqueous sprays of wettable powder chlorpyrifos and microencapsulated diazinon provided outstanding control for at least 9 mo. Microencapsulated and emulsifiable concentrate chlorpyrifos sprays provided >94% reductions for a year.

KEY WORDS Insecta, sewers, control, *Periplaneta americana*

AMERICAN COCKROACHES, *Periplaneta americana* (L.), frequently inhabit sewers, steam tunnels, and drainage systems. They are also common in warehouses and other kinds of storage facilities. They can develop to enormous numbers, >5,000 sometimes being found in individual sewer manholes. Besides being a nuisance and soiling items with their excrement, their association with human waste (Haines & Palmer 1955, Burgess et al. 1974) and diseases, and their ability to move from sewers into homes and commercial establishments (Eads et al. 1954, Mackie 1969) pose a potential public health problem wherever they exist. At least 22 species of pathogenic human bacteria, virus, fungi, and protozoans, as well as five species of helminthic worms, have been isolated from field-collected *P. americana* (L.) (as reviewed by Roth & Willis 1960 and Brenner et al. 1987).

Baits, dusts, sprays, and fogging have been proposed to control *P. americana* in sewers, steam tunnels, warehouses, and outdoor areas (Cornwell 1976). Wagner et al. (1966), McCollum & Danker (1969), and Wright et al. (1972) reported on the successful use of pyrethrin dust (i.e., silica aerogel + synergized pyrethrins) in sewers. Mackie (1969) found that a band of 5% chlordane spray around the top 0.9 m (3 ft) of the manhole provided about 95% control of cockroaches in sewers for 13 mo. Monthly thermal fogging with *d*-phenothrin and allethrin reportedly provided control of American cockroaches for up to 3 mo in Singapore (Chadwick & Shaw 1974, Chadwick et al. 1977), and baits containing kepone provided good control for up to 2 mo (Eversole 1971, Wright et al. 1973). The registration of many of these active ingredients has been revoked and only a limited number of products are currently available for sewer treatment.

The objective of this study was to investigate the long-term efficacy of aqueous sprays, baits, and dusts against *P. americana* when the chemicals were applied to sewer shafts. Certain materials or formulations were included in the study because of their low mammalian toxicity, current registration for use to control cockroaches or similar pest insects, and the likelihood of causing minimal environmental effect, especially in sewage treatment facilities or filter ponds.

Materials and Methods

Test Site. At the request of the Public Works Department of Avenal, Calif., a cooperative project was started to control an increasing problem with cockroaches in their sewer system. Avenal is a town with about 8,350 residents located about 90 km northwest of Bakersfield (36°00'N, 120°07'W), in the Lost Hills, a region of dryland farming and oil production. Average summer and winter maximum temperatures exceed 34.4°C (94°F) and 14.7°C (58.5°F), respectively. Winter minimums exceed 5°C (41°F). Avenal receives only 18.5 cm (7.3 in.) annual rainfall, making it an unlikely area to encounter heavy infestations of American cockroaches. With the construction of a new prison nearby, Avenal has become one of the fastest growing areas in California, and there was concern that a known cockroach problem in the city sewers might spread to the prison when the prison was connected to the city system.

The pattern of the city sewer system consists of a network of 20.3 cm (8 in.) main lines under paved streets and 15.2 cm (6 in.) lateral lines located under

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unpaved alleys. There are 135 manholes in the system, of which we were able to gain access to 125. The manholes are 79 cm diameter and their average depth on main lines is 2.7 m and about 1.8 m on lateral lines. Most of the manhole shafts are made of brick and mortar, and their stable moderate warmth and high humidity provide excellent conditions for cockroaches.

Survey and Counting. All accessible manholes were visually inspected. The cast-iron covers were removed from each manhole; the species of cockroach infesting the shaft was noted, and the adults and nymphs were counted and recorded. Powerful flashlights or mirrors to reflect sunlight into the manholes were used to facilitate counting. For shafts with >300 cockroaches, the number of cockroaches was estimated by counting 0.25-m^2 sections of the shaft and multiplying by the number of sections infested. Counts were arranged from high to low and each sewer shaft was randomly assigned to one of eight treatments. Each manhole was identified on a map of the system, and its treatment was coded with spraypaint on the manhole cover.

Many of the manholes were inspected 1 and 7 d after treatment to determine the effectiveness of the treatments. The manhole shafts were inspected 1, 3, 6, 9, and 12 mo after treatment. After 6 mo, several manholes that were initially treated with baits or dust were retreated with either boric acid dust or Drione. Pre- and posttreatment counts were analyzed with a Wilcoxon's signed-ranks test (Sokal & Rohlf 1969).

Insecticides and Application Equipment. The dust formulations tested included 40% silica gel + 1% pyrethrins + 10% piperonyl butoxide (Drione; Fairfield American, Newark, N.J.), 1% bendiocarb (Ficam D; NOR-AM Chemical, Wilmington, Del.), and 67% boric acid (Boron #101; HJH Chemical, Phoenix, Ariz.). Aqueous sprays included 0.5% chlorpyrifos (Dursban 50 wettable powder [WP]; Dursban 1 microencapsulated emulsion [ME]; Dursban 2 emulsifiable concentrate [EC]; Dow Chemical U.S.A., Midland, Mich.) and 0.5% diazinon (Knox Out 2 flowable microencapsulated emulsion [FM]; Pennwalt Chemical, Philadelphia). Baits tested included 1.88% hydramethylnon (American Cyanamid, Clifton, N.J.) and 20% boric acid (Chesebrough-Pond's, Trumbull, Conn.).

Dusts were applied through a flexible hose (27 cm diameter by 6.1 m) connected to the exhaust port of a ventilating blower (Homelite, Division Textron, Charlotte, N.C.) that produced 40.44 m^3 of air per minute (1,428 ft^3/ min). The output end of the hose was clamped over a cast-iron pipe sleeve fitting (27 cm diameter) placed over the opening in the middle of a 1.9-cm-thick plywood disk cut to fit snugly to the top of the sewer shaft when the manhole cover was removed. The dusts were applied according to label recommendations: Drione, 170 g (6 oz); Ficam D, 198 g (7 oz); and Boron 101, 454 g (1 lb) per manhole. Dusts blown into the manholes in this manner resulted in thorough coverage of the walls of the shaft and penetration into main or lateral lines.

Aqueous sprays were applied with a 116-liter (30 gal) power compression sprayer equipped with 7.6 m (25 ft) of hose and a 1.8-m (6 ft) stainless steel tubular spray tip extension on the handle grip. The nozzle at the end of the extension provided a horizontal 360° spray pattern. The diameter of the extension tube and tip was small enough to fit through the holes of the manhole covers. This often allowed spray treatment without having to remove the cover. The sprayer delivered 63 ml/s. For treatments, the extension tube was lowered almost to the bottom of the shaft and spray was applied as the tip was raised upwards at a uniform rate of about 0.08 m/s. This technique resulted in sprays applied, barely to runoff, at 1,800 ml per 1.8-m manhole shaft. A 0.5% spray, therefore, provided about 1.74 g active ingredient/m^2.

Bait tests began in June. Individual commercial plastic bait stations for large cockroaches were tied to pieces of wire and lowered to a dry ledge at the bottom of the shafts. The wire was tied to the manhole cover for easy retrieval. In a second set of trials, bait on a float system was lowered to the bottom of the manhole. Plastic stations or bait in 5-cm-diameter PVC pipe were affixed to wood on platforms (20 × 20 × 2.54 cm). A sheet of 5-cm-thick Styrofoam was stapled to the underside of the platforms. The Styrofoam permitted the baits to float and stay upright if water rose in the shaft. Approximately 10 g of hydramethylnon or boric acid bait was secured to each platform. The floats were lowered into the shafts with a pole so that they rested on a dry ledge at the bottom of the shaft.

Results and Discussion

Initial inspection of sewer shafts revealed that about 85% of them were infested with cockroaches. Of infested manholes, American cockroaches were the sole species in 89.7%, whereas only oriental cockroaches, *Blatta orientalis* (L.), were found in 7.1%. Both species were found together in 3% of the shafts, corroborating Mackie's (1969) observation that these species are rarely found together. Temperature appears to be an important factor in maintaining their allopatry. We measured midday temperatures inside the shafts in July and August of >34°C. *B. orientalis* is the most common cockroach species in England (Cornwell 1976), and this suggests that they prefer cooler conditions than do *P. americana*. Similarly, Appel et al. (1983) found that *P. americana* can withstand higher temperatures than can *B. orientalis*. German cockroaches, *Blattella germanica* (L.), were found in only one sewer. Firebrats, crickets, and native fire ants, *Solenopsis* spp., also were encountered occasionally in the sewers, but never in large numbers.

Many dead cockroaches were observed at the bottom of the shafts 1 and 7 d after treatment; only

Table 1. Percentage of reductions of American cockroaches in sewers in Avenal, Calif.

Toxicant	Form	Mo applied[a]	*n*	No. roaches	Range	% Reduction at mo[b]				
						1	3	6	9	12
Bendiocarb	2 D	June	10	1,132	10–475	96.9**	44.9	0	Discontinued	
Drione	D	June	10	2,582	27–550	85.1**	36.9	0	Discontinued	
Chlorpyrifos	ME	June	10	1,838	25–850	100.0**	100.0**	99.1**	100.0**	99.6**
	2 E	June	9	1,249	4–500	100.0**	100.0**	99.9**	100.0**	94.4**
	50 WP	June	20	3,310	20–400	99.9**	99.9**	99.9**	99.9**	81.9**
Diazinon	2 FM	June	10	1,325	10–400	99.5**	99.7**	95.3**	98.4**	56.5
Boric acid	D	Nov.	8	1,800	30–700	100.0**	94.9**	70.8*	—	—
Drione	D	Nov.	8	1,551	46–670	98.7**	93.3**	82.6**	—	—
Untreated	—	June	11	1,535	5–350	0	0	0	0	0

[a] Treatments applied 3 June 1986 and 23 November 1986.
[b] *, $P < 0.05$; **, $P < 0.01$; Wilcoxon's signed-ranks test (Sokal & Rohlf 1969).

a few live cockroaches were observed. Aqueous sprays of chlorpyrifos applied to the entire manhole shaft provided >80% reductions of *P. americana* for at least 1 yr (Table 1). Pyrethrins and boric acid dusts applied in November provided significant reductions for at least 6 mo. Pyrethrins and bendiocarb dusts applied in June only provided significant reductions for 1 mo.

Because of the prolonged period of nymphal development, the large numbers of adult cockroaches within 1–3 mo after treatment (Table 2) suggests that adults were returning from untreated refugia. This is contrary to Schoof & Siverly (1954) who reported that cockroaches did not move from release sites in each sewer. Mackie (1969) observed considerable movement aboveground in and out of individual manholes and felt that movement through lateral lines was limited. Pyrethrins are repellent and are used for flushing. It appears that Drione killed some cockroaches but flushed many into lateral lines where they escaped lethal exposures. On occasion, after treatment, we found crushed American adult cockroaches on the street, but we frequently observed cockroaches moving in and out of connecting lines. It is hot and dry during the summer and fall in Avenal, and it is more likely that cockroaches reinfested treated manholes from lateral lines than by moving across exposed surfaces of the ground or streets.

Pyrethrins or boric acid dusts applied in November provided considerably better long-term control than did applications made in June. It should be noted that the overall percentage of adults in untreated shafts was declining in late November (33%) and that the movement of adult cockroaches also decreased in the fall and winter. Our findings corroborate Haines & Palmer (1955), who found that in Georgia and highest number of adult *P. americana* were trapped in the spring and summer. The timing of dust applications may be important in providing best long-term control. It may be advantageous to apply dusts after nymphs have molted into adults and in the fall when numbers of adults are declining.

Results with baiting were variable, and none were consistently successful (Table 3). Most of the baits became moldy within 1 to 2 wk, even though the baits contained a mold inhibitor. Placing baits on the Styrofoam float helped keep the baits dry and prevented them from blocking the effluent. *P. americana* often deposited oothecae in the Styrofoam and frequently nymphs were observed hiding under the bait barge.

In some cases the cockroaches quickly consumed all the bait that was placed in the shafts, and it was difficult and time-consuming to replace it. Better bait station designs with larger bait reservoirs might improve effectiveness and reduce the number of times that bait stations would need to be serviced.

Chlorpyrifos and diazinon sprays provided outstanding control for at least 9 mo (Table 1). The inability of *P. americana* to reestablish in manholes

Table 2. Total number and percentage of adult *P. americana* before and after treatment in the sewers

Toxicant	Form	Mo applied[a]	*n*	No. cockroaches (% adults) at mo					
				Pretreatment	1	3	6	9	12
Bendiocarb	2 D	June	10	1,132 (26)	35 (26)	624 (41)	1,151 (24)	Discontinued	
Drione	D	June	10	2,582 (42)	384 (58)	1,630 (57)	2,060 (42)	Discontinued	
Chlorpyrifos	ME	June	10	1,838 (25)	0	0	17 (35)	0	6 (50)
Chlorpyrifos	2 EC	June	9	1,249 (48)	0	0	2 (100)	0	70 (29)
Chlorpyrifos	50 WP	June	20	3,310 (37)	3 (67)	1 (100)	3 (100)	5 (0)	601 (54)
Diazinon	2 FM	June	10	1,325 (25)	7 (57)	4 (75)	62 (13)	21 (29)	577 (36)
Boric acid	D	Nov.	8	1,800 (25)	0	92 (1)	525 (26)	—	—
Drione	D	Nov.	8	1,551 (26)	20 (15)	103 (26)	270 (27)	—	—
Untreated	—	June	11	1,535 (39)	1,665 (57)	2,142 (48)	2,361 (33)	2,336 (29)	2,576 (26)

[a] Treatments applied 3 June 1986 and 23 November 1986.

Table 3. Reduction of *P. americana* in sewers treated with baits

Treatment	*n*	No. roaches before	Range	% Reduction at mo[a]		
				1	2	3
Hydramethylnon	4	951	90–350	49.0	—	52.0
Hydramethylnon	6	941	21–475	—	80.4*	73.5[b]
Boric acid	6	231	2–103	55.5	0[c]	—

[a] *, $P < 0.05$; Wilcoxon's signed-ranks test (Sokal & Rohlf 1969).
[b] 4 months.
[c] 2.5 months.

treated with chlorpyrifos or diazinon indicates that there was considerable residual activity attributable to the sprays. In all the dust treatments, cockroaches began reinfesting the manholes within 6 mo. Spraying with the extended spray tip wand provided a convenient, fast, and effective means of applying spray. With a minimum of two people with one truck-mounted sprayer, infested portions of a sewer system could be treated quickly. It was particularly helpful not to have to remove the manhole cover for spray treatments. The ease of application and the efficacy of sprays applied with the extended spray tip wand indicate that this method is an appropriate method of controlling cockroaches in a sewer system.

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