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Peridomestic Deposition of Ultra-Low Volume Malathion Applied as a Mosquito Adulticide

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In Florida, many mosquito control districts routinely apply ultra-low volume (ULV) organophosphates and pyrethroids as adulticides in residential areas, particularly when larvicides are ineffective or impractical. Ground or aerially- applied adulticides form swaths which drift through the residential habitat where they either impinge upon mosquitoes, settle out or continue to drift. Terrestrial nontarget organisms are exposed to concentrated insecticide residues through direct contact with drifting or deposited droplets. Tietze et al (1994) reported a concentration of 33.4 ng/cm^2 malathion deposited 5 m from the spray head. This amounted to about 6% of the total mass of insecticide expected to deposit within an 0.404 ha “target zone” based on a 91.4 m swath (Tietze et al. 1994). Similar results were reported for fenthion by Wang et al. (1987).

In structurally heterogeneous environments such as residential areas, spray drift and deposition patterns are probably very different from that of open field areas as suggested by studies that compared mosquito kill in these two areas (Floore et al. 1991). Understanding the distribution of residues is needed to help assess and predict potential impacts to nontarget organisms occurring in residential areas. Nontarget effects in the peridomestic environment have not received much attention when considering that this area is the primary target site for most mosquito adulticide applications. In north Florida, it is not unusual to find backyard operations in aquaculture, cricket farming, catalpa worm rearing and bee keeping, all of which are potentially impacted by adulticide sprays.

One technique for detecting environmental contamination is via bioindicator species. Bioindicators are organisms used as sentinels for environmental quality; where a decline in their survival may suggest the presence of certain contaminants. A good bioindicator may be a common inhabitant to the habitat of interest, but most importantly, needs to be sensitive to the xenobiotic chemical of concern. Crickets have been considered as bioindicators (Harris 1966, Tu 1970) because they are common (Arnett 1985), easy to rear (Parajulee et al. 1993) and

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susceptible to certain pesticides (Harris 1966, Tu 1970). The field cricket, Acheta pennsylvanicus (Burmeister) was utilized as a bioindicator for soil contaminated with organophosphates and other pesticides (Harris 1966, Tu 1970).

This study investigated deposition of ULV malathion around houses resulting from ground-based, ULV sprays with the goal of assessing exposure to nontarget organisms. In addition, the house cricket, A. domesticus (Linn.) was evaluated as a bioindicator for determining spray distribution. This cricket is worldwide in distribution and is often found overwintering in homes in the eastern U.S. (Arnett 1985) and is commercially available as fish bait or food for insectivorous pets.

MATERIALS AND METHODS

A residential area (St. Andrew) of Panama City, Florida was selected as the study area due to the consistent arrangement of rectangular city blocks aligned in a regular pattern (Figure 1). This arrangement was chosen to

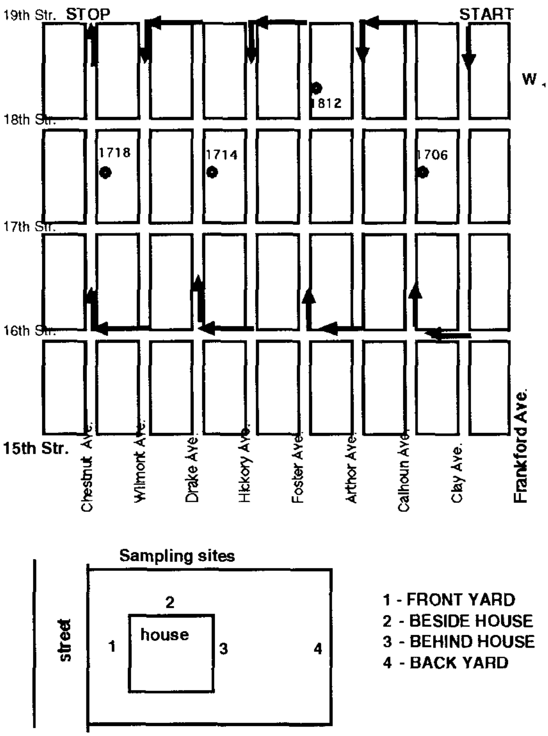

Figure 1. Map of St. Andrew study sites and peridomestic sampling sites in Panama City, Florida. Circles indicate houses used in study. Arrows denote route of spray truck.

base sprays on westerly winds known to occur in that area. Four houses, each located on the western side of alternating blocks were selected for the study (Figure 1) and permission was obtained from each household. The study area was moderately vegetated with oak, magnolia, pine and various shrubbery commonly found in residential areas. Four peridomestic sampling sites were established around each house: front yard, beside house, behind house and back yard. Since each house was unique in terms of shape and distance from the street, sampling sites for the front, side and behind the house were positioned on the ground at the middle of each facade and about 2.4 m away from the structure; the back yard sampling site was positioned about 2.4 m from the fence delineating the property line (Figure 1). During each test, the distance from the street curb to sampling sites was determined using a measuring wheel (Rolatape Corporation, Spokane, WA). The study was conducted from June through September of 1994.

Insecticide applications were made by the Bay County Mosquito Control District using a Tuthill Corp. (M. and D. Pneumatics Div. Springfield, MO) blower powered by a 18 hp twin cylinder Briggs and Stratton (Milwaukee, WI) motor mounted on a pickup truck with the spray head extended to 2.13 m above the ground and angled at 45° above horizontal. An Adapco Monitor and Modular Flow Control Pump (Adapco Inc., Sanford, FL) was used to deliver spray at a constant rate of 127 ml/min (4.3 fluid oz/min) by automatically adjusting for vehicle speed. The Adapco system automatically shut off the sprayer when vehicle speed was less than 3.2 km/h or was manually shut off when pedestrians were present. Material used was malathion or Cythion® ULV concentrate 95% A.I. (American Cyanamid Co., Wayne, NJ). Prior to each test, droplets generated by this system were sampled using the swing slide technique (Rathburn 1970) and analyzed using the computer program Biomeasurement Droplet Analysis (Vectec, Inc., Orlando, FL) using a spread factor or 0.69. This was done to validate proper droplet size requirements (Cyanamid 1992). During each spray test, the Adapco system recorded distance and volume sprayed, average speed traveled and duration of spray interval. Applications were initiated between 1900 to 1930 hours and followed the route illustrated in Figure 1.

Malathion deposits were sampled at each peridomestic site using a filter paper placed horizontally at ground-level as described in Moore et al. (1993). Filter papers were immediately folded and placed into pre-cleaned 150-ml Qorpak bottles and immersed in 100 ml American Chemical Society certified acetone. During each test, a single sample was spiked to form 300 ppb malathion to determine percent recovery; another sample was filled with acetone to serve as a blank. Bottles were stored overnight at 4 °C. Mass deposited per cm2 was determined for each sampling site by means of gas chromatography as described by Tietze et al. (1994). To sample the relative abundance of droplets and their mass median diameter (MMD), a rotating impinger (John W. Hock Co., Gainesville, Florida) fitted with Teflon-coated slides (Vectec Inc., Orlando, Florida) was placed adjacent to the filter paper on the side of each house. The impingers were further fitted with threaded stakes to secure them directly into the ground with the blades rotating about 10 cm above the ground. Samples were collected about 30 to 55 minutes post-application. Droplet abundances were determined at the edge and near the middle of each slide as described by Tietze et al. (1994). Droplet size was assessed as described above for swing slides.

House crickets (A. domesticus) were colonized in rearing chambers at the John A. Mulrennan, Sr. Research Laboratory using locally bought specimens and reared on Cricket and Worm Feed (Flint River Mills, Inc., Bainbridge, GA). Cricket eggs were collected from rearing chambers (75 liter terraria) using glass 0.95 l jars half-filled with moist sand as an oviposition medium. After 2-4 days the oviposition jars were transferred to clean chambers where hatching occurred. About 15, first instar A. domesticus were aspirated into 0.473 l paper cartons (Saxon Industries, Inc. Union, NJ) and covered with a loose-mesh cloth (mesh size =9.05/cm). Because the immature crickets were capable of crawling up the side of the carton and through the cloth, it was necessary to line the inside periphery with 5.1 cm wide cellophane tape. One carton of crickets was placed adjacent to the filter paper at each peridomestic sampling site. Four cartons of controls were maintained in the laboratory. Treatment crickets were returned to the laboratory after at least 30 minutes of exposure. Both control and treatment crickets were fed a piece of sliced vegetable (apple, potato or zucchini) to prevent desiccation during overnight periods. Cricket mortality was assessed after 12 h by visually inspecting each carton.

To assess efficacy of malathion against mosquitoes about 25 adult, female Culex quinquefasciatus Say were aspirated into steel cages (Rathburn et al 1989). Mosquito cages were hung on stands at a height of 0.3 m on the north side of each house. One cage of mosquitoes was kept at the laboratory as a control. Treated mosquitoes were transported back to laboratory and held in the same cages for 12 h before mortality was assessed. Wet cotton mats were draped over the cages to minimize mosquito desiccation. Mortality was expressed as a percentage or total number dead divided by total number exposed and multiplied by 100.

Malathion deposit data and arcsine transformed cricket mortality were compared among houses and between peridomestic sites using general linear models and Student Newman Keuls mean separation tests (SAS Institute, Inc. 1990). In addition, orthogonal contrasts were used to compare cricket mortality between peridomestic sites. The relationship between distance from the street and amount of malathion deposited was modeled and compared to results of previously conducted open field tests (Tietze et al 1994). Stepwise regressions using maximum R^2 improvement were used to find which variable(s) (cricket mortality, droplet size, droplet density, and distance from the street) best predicted mass deposited. Graphs were made using CA-Cricket Graph III (Computer Associates International Inc., Islandia, NY).

RESULTS AND DISCUSSION

Five spray tests were completed using the same spray truck as summarized by the Adapco Monitor (Table 1). Wind speed was usually too low (0 to 4 km/h) for reliable measurement using an anemometer, but drift was generally out of the west. Air temperature averaged (±SE) 25.5 (2.1) °C. Relative humidity averaged 70.8 (4.2) %. Distance from the street to sampling sites, in front of, beside and behind house and back yard averaged 11.0 (0.8), 19.9 (0.7), 28.6 (0.8) and 42.8 (0.3) m, respectively. Mosquito mortality during the tests averaged 90.2 (6.11) % while control mortality was 0%. This less than optimal degree of mosquito mortality may be expected in vegetated residential communities (Floore et al 1991). The mass median diameter of droplets sampled on the rotating impinger averaged 12.1 (0.53) µm. Density of droplets impinged on slides averaged 8.69 (1.19) per mm^2 near the edge of the slide and 0.36 (0.06) per mm2 near the middle of the slide. Recovery of malathion in spiked samples averaged 90%. Malathion was never detected in blanks.

Table 1. Adapco Monitor trip data and droplet size as sampled per spray test.

Date of Application	Spray Distance (km)	Volume Sprayed (l)	Avg Speed (km/hr)	Spray Time (min)	Droplet MMD[a] (µm)
June 14, 1994	5.5	3.28	22.0	18	17.1
June 21, 1994	4.7	2.81	21.1	16	15.1
June 28, 1994	5.3	3.19	23.2	17	14.3
Aug. 30, 1994	5.7	3.48	23.9	18	13.3
Sept. 26, 1994	5.5	3.25	25.4	16	17.0

[a]Mass median diameter as determined using swing slide technique

Overall, malathion deposition did not vary significantly (df=3; F-value=1.71; P >0.05) between front yard, side of house, behind house and back yard due to the large degree of variation between samples. Average (±SE) malathion deposition for the front yard, side of house, behind house and back yard was 88.8 (24.9) 56.8 (11.7), 62.5 (23.4) and 29.9 (7.8) ng/cm^2, respectively. The mean mass deposited generally decreased with distance from the street (Figure 2). When viewed by house, deposits were greatest at Foster Avenue compared to the remaining three sites (Figure 3). This house was closest to the street with the front yard site 6.4 m from the curb. The high degree of variation in deposition at the Foster house was caused by its location near an intersection where the spray truck driver was forced to slow prior to turning due to oncoming traffic. The latter episode was observed on one occasion and coincided with the highest recorded deposits of the study, 442 and 473 ng/cm^2 in the front yard and behind the house, respectively. There was no evidence supporting the compounding of spray swaths made on alternating streets.

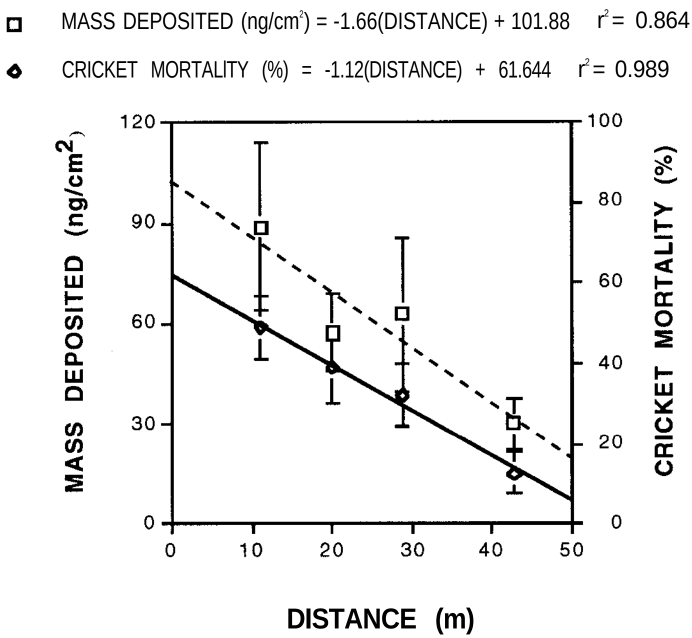

Figure 2. Mass of malathion deposited and cricket mortality both as a function of distance from the street curb. Bars denote standard error of the mean.

Cricket mortality averaged 48.7 (8.1), 38.7 (8.9), 31.9 (7.8), 12.5 (5.4) % at the sites, front yard, side of house, behind house and back yard, respectively. There was no mortality for crickets in control cartons. Cricket mortality decreased with distance from the street (Figure 2). Stepwise regressions using maximum R^2 improvement identified cricket mortality as the best single predictor of deposition (df=1; F-value=23.01; P<0.001; R^2=0.56); the best two-variable model was cricket mortality and droplet density near the middle of the impinger slide (df=2; F-value=15.02; p<0.001; R^2=0.64). Orthogonal contrasts comparing cricket mortality between peridomestic sites were significant (df=1 ; F-value=7.32; P=0.01).

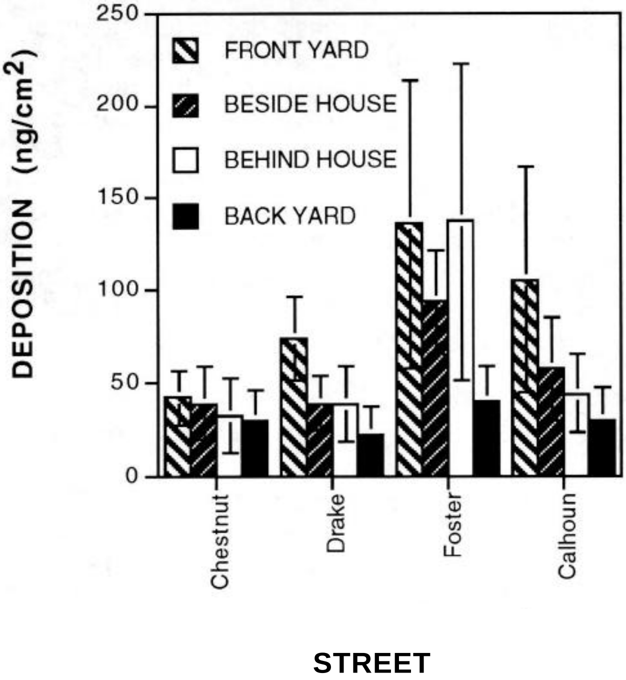

Figure 3. Mean mass of malathion deposited as a function of house and peridomestic site sampled. Bars denote standard error of the mean.

The site behind the house had less mortality than the average of in front of and beside the house. Other comparisons were not significant (P>0.05).

No significant differences (P>0.05) were detected when dependent variables, mass deposited and cricket mortality were sorted by peridomestic site and compared between houses. Similarly, no significant differences (P>0.05) were detected when the same two dependent variables were sorted by house and compared between peridomestic sites.

Although deposition of malathion in the peridomestic environment was variable, general trends suggested decreasing amounts with distance from the spray head. Overall, these values were considerably higher than those collected in a previous open field spray study (Tietze et al. 1994) where the maximum mass of malathion was 33.4 ng/cm^2, 5 m from the spray head. In comparison, malathion deposits in front yards or about 11 m from the street averaged 2.6x (88.8 ng/cm^2) higher than that recovered in open field tests. This disparity may in part be attributed to differences in application equipment. Spray equipment used in open field tests produced on average, smaller droplets (12.7 µm versus 15.4 µm in current study), probably due to a higher blower pressure of 0.387 to 0.422 kg/cm^2 compared to about 0.366 kg/cm^2 of the current study. This suggests a very important relationship exists between droplet size and mass of insecticide deposited that warrants further investigation. Another cause for higher deposition observed in this study may be attributed to the effects of vegetation and structures that impede continuous drift through the habitat. Slower drift would be expected to allow larger numbers of droplets to settle out per unit area. Hypothetically, another effect of large structures, such as houses and large trees, cause the drifting spray cloud to channel around these areas, concentrating droplets in open spaces or into “drift corridors”. Structures may be viewed as a “concentrating factor”, where the structure has effectively reduced the area (or volume) available for drift and deposition to occur. One final cause for increased deposition of this study may be linked to problems inherent to applications within a busy residential area where oncoming traffic slows the truck down (without shutting off the Adapco Monitor).

Crickets were found to be good bioindicators for malathion deposition because they were the best predictor variable for deposition rates. Physical factors such as droplet size and density, and distance drifted, although important determinants for deposition, were not as suitable for predicting deposition as the biological indicator. This may be explained by the presence of overriding factors such as wind speed and direction, which probably greatly influenced the pattern of deposition, regardless of droplet size, droplet density or distance from the spray head. The finding of density of droplets near the middle of the impinger slide as part of the best 2-variable model agrees with results in open field tests (Tietze et al. 1994). Since a greater proportion of larger droplets impinge near the middle of the slide, it is reasonable to expect that the density of larger droplets would be a better predictor for mass deposited than that of smaller droplets collected along the slide edges.

While this study found that to a degree, caged house crickets were killed by mosquito control applications, care must be taken not to extrapolate these data to assume the same to be true for wild crickets. Deployment of house crickets using cartons was not an attempt to simulate natural field conditions, but rather as a means for evaluating this species for use as bioindicators. Further studies evaluating the effects of mosquito adulticide sprays on wild crickets and other inhabitants of the peridomestic habitat are warranted.

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