Community Aerial Mosquito Control and Naled Exposure

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COMMUNITY AERIAL MOSQUITO CONTROL AND NALED EXPOSURE

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ABSTRACT. In October 2004, the Florida Department of Health (FLDOH) and the Centers for Disease Control and Prevention (CDC) assessed human exposure to ultra-low volume (ULV) aerial application of naled. Teams administered activity questionnaires regarding pesticide exposure and obtained baseline urine samples to quantify prespray naled metabolite levels. Following the spray event, participants were asked to collect postspray urine specimens within 12 h of the spray event and at 8-h intervals for up to 40 h. Upon completion, a postspray activity questionnaire was administered to study participants. Two hundred five (87%) participants completed the study. The urine analysis showed that although 67% of prespray urine samples had detectable levels of a naled metabolite, the majority of postspray samples were below the limit of detection (<LOD). Only at the "postspray 6" time period, which corresponds to a time greater than 5 half-lives (>40 h) following exposure, the number of samples with detectable levels exceeded 50%. There was a significant decrease in naled metabolites from prespray to postspray (=.02), perhaps associated with a significant reduction (≤0.05) in some participants that may have resulted in pesticide exposure by means other than the mosquito control operations. These data suggest that aerial spraying of naled does not result in increased levels of naled in humans, provided the naled is used according to label instructions.

KEY WORDS Mosquito control, naled, exposure assessment, pesticide, ULV application

INTRODUCTION

Hurricanes and tropical storms often have a significant impact on mosquito-borne diseases because of an increase in mosquito breeding habitats from flooding. In 2004, Florida experienced an extraordinary hurricane season with 4 major hurricanes traversing the state within 3 months. Because of the potential increase in arboviral disease, including West Nile virus (WNV) and eastern equine encephalitis, ultra-low volume (ULV) aerial spraying with the organophosphorus pesticide naled (Dibrom®) was initiated for the control of mosquitoes in areas with known arboviral activity. Although naled has been associated with adverse human health effects after ULV aerial spraying (CDC 2003a), the extent to which humans are exposed to naled during large-scale aerial mosquito control activities has yet to be accurately quantified.

In large-scale mosquito control programs, naled is typically applied via aircraft-mounted sprayers with the inert carrier, naphtha. The ULV pesticide applications use small quantities of active ingredient in relation to the size of the area treated. For effective mosquito control, the maximum rate for ULV surface and aerial application typically is ≤3 oz (85 ml) active ingredient (AI)/acre. These ULV applications aerosolize into very fine droplets that stay aloft and kill mosquitoes on contact. ULV pesticide application is utilized to minimize exposure and risks to people, wildlife, and the environment (U.S. Environmental Protection Agency [EPA] 2002).

Naled is practically nonpersistent in the environment. It rapidly degrades in the presence of sunlight to dichlorvos (Kidd and James 1991). Dichlorvos degrades rapidly with a half-life of less than 8 h in soil and less than 25 h in water (U.S. EPA 1998).

In humans, naled and dichlorvos are rapidly absorbed through the skin and mucous membranes of the digestive and respiratory system and are delivered through the circulatory system to various body tissues. This pesticide is metabolized to a nonspecific organophosphate metabolite, dimethylphosphate (DMP), which is eliminated in the urine within a few days of exposure (National Institutes of Health 2004). Acute

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toxicity of naled is low based on LC_{50} values for dermal, oral, and inhalation exposures in animal studies.

Exposure in humans who remained outside during aerial spraying with a naled and temephos mixture for mosquito control demonstrated urinary DMP increase from a maximum of 60 μg/liter to a maximum of 500 μg/liter within 3 h after spraying (Kutz and Strassman 1977). In a CDC study that involved background levels of 148 environmental chemicals in 2518 urine samples, the median (50th percentile) level for DMP was less than the limit of detection (0.5 μg/liter). The 95th percentile (95% confidence interval) was reported as 13.4 μg/liter (10.9 μg/liter–15.6 μg/liter) (CDC 2003b).

Results from previous studies in Virginia and North Carolina (CDC 2005) suggest that large-scale aerial spraying with naled during mosquito-control activities does not result in significant exposure to pesticides for human populations; however, these studies had statistical limitations. In October 2004, the Florida Department of Health (FLDOH) invited the CDC's National Center for Environmental Health (NCEH) to assess exposure of humans to ULV aerial application of naled in a posthurricane flooded area of Florida. The objectives of this study were to quantify human exposure to naled applied as a ULV aerial pesticide and to overcome statistical limitations of previous similar studies, by increasing the sample size and using participants as their own controls.

MATERIALS AND METHODS

This study was conducted in St. Johns County, FL, October 2–7, 2004. We employed a prospective cohort study design, and planned to recruit 208 households based on a sample size calculation for adequate statistical power (80%) at the significance level of 0.05. We increased this number to 240 to account for an anticipated attrition rate of 10–15%. Households were chosen from each of the 5 proposed spray zones within St. John's County based on cluster sampling, utilizing census blocks. Thirty-two census blocks (and 5 replacements) were randomly chosen; 7–8 households were surveyed in each of the census blocks. Environmental testing was not part of this study because of the short environmental half-life of naled.

Twelve teams of CDC and FLDOH personnel recruited study participants by going door-to-door within each of the randomly selected census blocks. These teams obtained informed consent from the head of household (or proxy for the head of household), administered questionnaires about household and occupational exposure to pesticides, and obtained a baseline spot urine sample to quantify the concentration of naled metabolites prior to the pesticide spraying. Because DMP is a nonspecific marker of organophosphate exposure, we collected questionnaire data to determine participants' exposure to other pesticides from household or occupational use.

On the evening of October 4, we contacted each participant to inform them of the time of the spray and to ask them to collect postexposure urine specimens on the following day, within 12 h of the spray, and at 8-h intervals for up to 40 h following the spray event. We asked study participants to refrigerate their urine specimens until our teams returned to collect their submissions.

Participants were also asked to note the exact date and time of the urine sample collection. Collection cups were prescreened for pesticides and their degradation products before use in this investigation by CDC laboratories. Once entered into the database, each urine sample was coded into 6 time segment groups of approximately 8-h blocks.

On October 6, teams returned to participant households to collect urine submissions from all study participants and to administer a postspray questionnaire that inquired about their activities during the time since the spraying took place, including any household or occupational exposures to pesticides and any health effects experienced since the spray occurred. Pre- and post-spray activities were compared with the use of SAS 9.0, McNemar's test (SAS Institute Inc., Cary, NC), to analyze data from matched pairs of subjects with dichotomous responses. The association between naled metabolite levels and activities was assessed with the use of a Wilcoxon rank sum test. Logistic regression was used to compare the number of increases in naled metabolite levels with the number of decreases; subjects with no change were eliminated from the analysis.

By October 7, all of the urine specimens were sent to the CDC laboratory where they were analyzed for the naled metabolite DMP with the use of gas-tandem mass spectrometry with isotope-dilution quantification. This method can detect differences in the concentration of metabolites at very low levels (micrograms/liter or parts per billion). The use of stable isotope analogues of the metabolites measured also allowed for sample-specific recovery adjustments, producing highly precise results (Bravo et al. 2004). The limit of detection using this method for DMP is 0.5 μg/liter.

RESULTS

We approached 626 St. John's County residents about volunteering for the study; 235 (43%) agreed to participate. Of these, 205 (87%) participants completed all parts of the study.

Table 1. Ethnicity of St. John's County census versus study participants.

Ethnicity	2000 census of St. John's County	2004 St. John's study
White	90.92%	88.3%
African American	6.29%	6.8%
Hispanic/Latino	2.6%	3.4%
Native American	0.26%	1.0%
Asian	0.95%	0.5%
Pacific Islander	0.05%	0.0%

The mean age of participants was 50.2 years (range 18–76); 44.9% were male. Table 1 compares the ethnicity of the St. John's County census (U.S. Census 2000) with that of our study participants.

Results of the laboratory analysis of urine samples for DMP show that 67% of prespray urine samples had detectable levels of DMP, whereas the majority of postspray samples were below the limit of detection (<LOD) (Table 2). Only at the "postspray 6" time period, which corresponds to a time greater than 5 half-lives following exposure, does the number of samples with detectable levels again exceed 50%. Therefore, the median for the other time periods is less than the limit of detection. Individual changes in urine metabolite levels from pre- to postspray showed a significant decrease in DMP from prespray to postspray samples ($P = 0.02$); 61 individuals showed decreased levels, whereas 38 individuals showed an increase in levels.

Some participants engaged in activities that could potentially lead to other pesticide exposures producing DMP as a metabolite during the time of our study (Table 3). Some activities were reported more often by participants before the spraying occurred than after. For example, more participants handled pesticides, did lawn work, and applied flea products to their pets prior to spraying than after it occurred ($P \leq 0.05$).

Prior to spraying, the most commonly reported activity that could potentially increase urinary pesticide levels was eating fresh produce, with 148 (72.2%) participants reporting that they ate fruits and/or vegetables within 3 days prior to the spray event (51 reported eating no fruits and/or vegetables, 1 was unknown, and 5 values were missing). The 148 participants who reported eating fresh produce prior to spraying had higher median baseline levels of DMP (3.56 μg/liter) than the 51 participants who did not (1.83 μg/liter, $P = 0.03$). Other reported activities were not associated, or only weakly associated, with baseline DMP values.

During our study, several participants reported experiencing nonspecific health-related symptoms. In general, more symptoms were reported by participants prior to the spray event (Table 4) than following it; however, differences are small, except possibly for headaches (Odds ratio = 1.5, $P = 0.07$).

DISCUSSION

Our study findings suggest that aerial application of naled for large-scale mosquito control did not contribute to urinary DMP levels in the study population. This is consistent with previous findings of studies conducted in North Carolina and Virginia (CDC 2005). Another important finding is that the number of study participants with self-reported symptoms consistent with pesticide poisoning was as large or larger before rather than after the aerial pesticide application. This is consistent with the finding that the acute human-health risks from residential exposure to mosquito insecticides are not expected to exceed levels of concern when they are applied according to labeling guidelines (Peterson et al. 2005).

The findings in this report are subject to several limitations. First, we did not conduct environmental sampling to confirm the presence of the pesticide in or around the homes of study participants. Instead, we obtained projected spray areas from DACS prior to choosing the census tracts in which the study participants were selected. Furthermore, the GIS tracking system on the airplane verified that the study participants were in the spray zone. Our use of self-

Table 2. Sample size, percent detects, and median DMP (dimethyl phosphate) values by sample time period.

Time period[1]	Number of samples collected	Percent with detectable levels of DMP	Median level of DMP (μg/liter)
Baseline (prespray)	229	67.25	3.14
Postspray 1	123	47.97	<LOD
Postspray 2	218	40.83	<LOD
Postspray 3	223	41.70	<LOD
Postspray 4	112	41.07	<LOD
Postspray 5	149	32.89	<LOD
Postspray 6	28	57.14	1.85

[1] Posttime values as follows: Postspray 1: midnight–0759 h on October 5, 2004, postspray 2: 0800–1559 h on October 5, 2004, postspray 3: 1600–2359 h on October 5, 2004, postspray 4: midnight–0759 h October 6, 2004, postspray 5: 0800–1559 h on October 6, 2004, postspray 6: all later values.

Table 3. Activities associated with potential pesticides exposures, pre- and postspraying.

Activities (number of total responses)	Total persons engaged in activity, prespray *n* (%)	Total persons engaged in activity, postspray *n* (%)	Subset engaged in activity, pre- and postspray *n* (%)	*P* value[1]
Handling pesticides ($n = 203$)	37 (18.2)	17 (8.4)	6 (3.0)	0.003
Doing field/farm work ($n = 203$)	7 (3.5)	4 (2.0)	3 (1.5)	0.38
Working in produce stand ($n = 202$)	1 (0.5)	1 (0.5)	0 (0)	1.00
Doing lawn work ($n = 203$)	72 (35.5)	40 (19.7)	27 (13.3)	<0.01
Applying flea products to pets ($n = 202$)	16 (7.9)	7 (3.5)	3 (1.5)	0.05
Eating fresh produce ($n = 185$)	136 (73.5)	133 (71.9)	116 (62.7)	0.74

[1] From SAS 9.0, McNemar's test (SAS Institute Inc., Cary, NC).

reported questionnaire data on potential pesticide exposures limits the ability to quantify actual home or occupational pesticide exposure and may have resulted in reduced background exposure during postspray by encouraging residents to avoid these activities that they just learned resulted in pesticide exposure. The lack of increase in DMP urine levels following aerial spraying could be because study participants were told when the spraying was going to occur and these participants could have modified their activities (i.e., stayed indoors, turned air conditioning to recirculate, etc.) to avoid exposure.

Some participants had measurable levels of DMP prior to spraying, which suggests that participants had been exposed to pesticides or their environmental degradation products at home or at work (Grey et al. 2005). A study by Lewis et al. (1994) demonstrated exposure to pesticides in the home through household dust and soil exposure containing pesticides. Schools, playgrounds, day-care, and commercial business settings, especially with recent pesticide application, also represent potential exposure sites (Krieger et al. 2001; Alarcon et al. 2005). Dietary intake, such as eating fresh fruits and vegetables, can also be a significant pathway of environmental exposure to pesticides (Pang et al. 2002). The studies' findings of increased baseline levels of DMP in persons who reported eating fresh produce (3.56 μg/liter) to persons who did not report consumption of fresh produce (1.83 μg/liter) were comparable to findings published in CDC, 2005 (3.2 μg/liter and 1.4 μg/liter, respectively).

Although toxicity of mosquito-control adulticides is relatively low, the public perception of the health risks associated with mosquito control is quite high (Roche 2002). Although monitoring potential human exposure to pesticides from aerial spraying is important for communities with large-scale mosquito-control efforts, our study suggests that emergency aerial spraying with ULV naled was not associated with an increase in urine pesticide metabolite concentrations in residents within the spray area when these residents were provided advance notification of the aerial pesticide application.

The Florida Pesticide Surveillance Program (PESP) received 2 reports of people living within the study area who experienced symptoms possibly related to exposure to mosquito control activities during the time of our study. In the first report, a 14-yr-old male experienced burning of the skin and eye irritation moments after the aerial spraying event and reported direct contact with droplets. The second report detailed a female aged 7 years with a history of asthma who experienced a rash, breathing problems, and chest pain while waiting for the bus the morning after the spray event. The symptoms reported by the 14-year-old were mild and resolved without any medical intervention. The 7-year-old female required medical treatment, after which her symptoms resolved. Both cases were classified as possible pesticide poisonings with the use of the CDC/NIOSH (National Institute of Occupational Safety and Health) classification (Krieger et al. 2001). Neither of these people were subjects in our study and we did not have urinary DMP

Table 4. Reported symptoms associated with potential pesticide exposure, pre- and post spraying.

Symptom (number of total responses)	Total persons reporting symptom, prespray *n* (%)	Total persons reporting symptom, postspray *n* (%)	Subset reporting symptoms pre- and postspray *N* (%)	*P* value[1]
Nausea ($n = 196$)	10 (5.1)	10 (5.1)	4 (2.0)	1.0
Vomiting ($n = 197$)	3 (1.5)	2 (1.0)	1 (0.5)	1.0
Diarrhea ($n = 196$)	3 (1.5)	4 (2.0)	1 (0.5)	1.0
Abdominal cramps ($n = 196$)	10 (5.1)	9 (4.6)	5 (2.6)	1.0
Headache ($n = 199$)	37 (18.6)	26 (13.0)	16 (8.0)	0.07
Trembling ($n = 197$)	6 (3.0)	3 (1.5)	3 (1.5)	0.25

[1] from McNemar's test.

levels on either of them. No other cases were reported.

These possible pesticide exposures highlight the importance of alerting populations living in areas where ULV pesticides will be applied of the planned spray event so they make take actions to limit their exposure. This is particularly important for vulnerable populations, such as young children or people with established sensitivity, as they may be more susceptible to adverse reactions from exposure than healthy adults.

The ULV applications of mosquito control pesticides, both aerial and truck mounted, are an important tool in the public health response to arboviruses. Future studies are needed to address the long-term safety of low-concentration chronic exposure to naled and other mosquito control pesticides such as pyrethrins and pyrethroids. In addition, public health interventions that reduce home and workplace exposure to pesticides may be needed.

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