Prevention of Tick Exposure in Environmental Health Specialists Working in the Piedmont Region of North Carolina

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Abstract **Environmental health specialists (EHS) conduct many occupational activities outdoors that may place them at increased risk for contracting a vectorborne disease. We conducted a risk assessment for tick exposure in EHS by analyzing job description, tick exposure, and the extent to which personal protective measures (PPM) were used. This pilot study focuses on eight counties in the central Piedmont region of North Carolina and follows 29 EHS during May through August 2014. A survey was administered to participants at the beginning of the study and showed that participants used PPM while working outdoors in environments conducive to tick exposure. Participants reported wearing PPM only 16% of the time they spent working outdoors. More than 28% of respondents self-reported having previously experienced a tickborne disease (primarily Rocky Mountain spotted fever) and one participant reported receiving medical treatment for a tickborne disease during the course of the study. Participants were exposed to two tick species (*Amblyomma americanum Linnaeus; Dermacentor variabilis* Say) and 279 ticks were submitted to researchers during the study. Although 70% of respondents reported being knowledgeable about tickborne disease, low PPM usage indicates either EHS do not believe the threat is significant, or they believe PPM available to them are ineffective.**

Introduction

Environmental health specialists (EHS) perform a variety of outdoor work-related tasks including, but not limited to soil and site evaluations for onsite wastewater disposal systems, site evaluations for well construction, complaint investigations for vectors, and solid and hazardous waste disposal (North Carolina Department of Health and Human Services [NCDHHS], 2013). These job functions come with risks, such as vectorborne diseases, as EHS work in the same kind of conditions as other outdoor workers such as foresters (Piacentino & Schwartz, 2002).

A study involving 460 National Park Service (NPS) employees showed that 81% of participants reported arthropod bites during the duration of the 1-year study and 32% of the participants found ticks on skin or clothing (Adjemian et al., 2012). Piacentino and Schwartz (2002) showed that outdoor workers may be at an increased risk of exposure to *Borrelia burgdorferi,* the causative agent of Lyme disease. Another study reviewed data on foresters in Europe, Japan, Spain, Southeast Asia, South America, and the U.S. and showed that workers are at a higher risk for infectious disease than the general public (Covert & Langley, 2002). A Polish study found that 14.7% of 129 asymptomatic foresters tested positive to antibodies from spotted fever group rickettsiae, 15.5% to *Anaplasma phagocytophilum* antibodies, and 34% to *B. burgdorferi* antibodies (Podsiadly, Chmielewski, Karbowiak, Kedra, & Tylewska-Wierzbanowska, 2011).

A North Carolina study found widespread distribution of *Ixodes affinis* Neumann, a subspecies of *I. ricinus* L. complex that contains most of the primary vectors for Lyme borreliosis, as well as other human pathogens (Harrison et al., 2010). Others have shown 155 *I. affinis* and 298 *I. scapularis* Say were collected from four coastal counties in North Carolina (Maggi, Reichelt, Toliver, & Engber, 2010). It was concluded that *I. affinis* is important in the maintenance of the enzootic transmission cycle of *Borrelia* spp. in North Carolina (Maggi et al., 2010).

Rickettsia rickettsii, the infectious agent that causes Rocky Mountain spotted fever (RMSF), and *R. parkeri* are known to cause human disease in the southeastern U.S. (Varela-Stokes, Paddock, Engber, & Toliver, 2011). North Carolina reports >20% of total RMSF cases in the U.S.; however, <10% of these cases obtain a species- (pathogen-) specific diagnosis (Varela-Stokes et al., 2011).

Guitierrez and Decker (2012) report that various tick bite prevention and control measures can be effective, such as treatment of the environment with acaricide, pesticides that kill ticks and mites; wearing repellents on skin and/or on clothing; wearing light-colored clothing that covers skin; and tucking pants into boots and socks. After potential exposure to ticks, body inspection and appropriate removal of attached ticks should be carried out. If ticks are removed quickly, this reduces the chance of pathogen transmission that causes disease; however, the tick

TABLE 1

Tickborne Diseases Reported by Survey Respondents

Question: Have you ever had a tickborne disease (e.g., Lyme disease, Rocky Mountain spotted fever, southern tick-associated rash illness, ehrlichiosis, anaplasmosis, or other tickborne disease)?

Answer Options	Response %	Response Count
None	76.2	32
Rocky Mountain spotted fever	16.7	7
Other (tickborne disease)	4.8	2
Anaplasmosis	2.4	1
Lyme disease	2.4	1
Southern tick-associated rash illness	2.4	1
Ehrlichiosis	0.0	0
Answered question		42
Skipped question		2

attachment times necessary for transmission vary between tick-pathogen systems.

Repellents can be used on the skin and/or on clothing. At concentrations >20%, DEET, picaridin, and ethyl butylacetylaminopropionate (IR3535) effectively repel *A. americanum* (Cisak, Wojcik-Fatla, Zajac, & Dutkiewicz, 2012). Semmler and co-authors (2011) evaluated the efficacy of several tick repellents and showed that essential oils have minimal repellency, while concentrated DEET effectively repels ticks. Another study tested the efficacy of BioUD (active ingredient 2-undecanone synthesized from wild tomato plants) against *I. scapularis, A. americanum,* and *D. variabilis* (Bissinger, Apperson, Sonenshine, Watson, & Roe, 2008) and found that both DEET and BioUD effectively repelled the three species. Zhang and co-authors (2009) compared DEET to the compound isolongifolenone that is used in the cosmetic industry. At concentrations 10 times greater than needed to repel *I. scapularis*, neither compound repelled all *A. americanum*.

A major advancement in the protection of outdoor workers, travelers, and soldiers has been the development of methodology for impregnating repellents and insecticides into clothing, tents, and netting (Faulde & Uedelhoven, 2006). Several treatment techniques exist to bind the pesticides to fabrics including absorption (reported to last up to 70 washes), polymer coating (reported to last up to 100 washes), and microencapsulation (no known efficacy studies) (Banks, Murray, Wilder-Smith, & Logan, 2014).

Before fabrics were washed, permethrin-impregnated fabrics (battle dress uniforms impregnated using the polymer coating technique) showed 100% *I. ricinus* knockdown times after approximately 8 minutes of tick exposure to fabric (Faulde & Uedelhoven, 2006). After fabrics were washed 100 times, the same study showed 100% knockdown after approximately 231 minutes of exposure. A similar test was performed on military uniforms worn in Afghanistan that were visibly worn and had been washed 70–100 times (laundering was performed every 1–2 days using commercial washers and detergents by ECOLOG International) (Faulde, Uedelhoven, Malerius, & Robbins, 2006). The study concluded that repellency was achieved for the life of the garment (70–100 launderings) (Faulde et al., 2006). A study conducted in Germany where subjects wearing permethrin-treated uniforms (122 mg/m^2) were exposed to tick-infested areas outdoors for 36 hours showed that permethrin-impregnated uniforms repelled 95% of ticks (Faulde, Scharninghausen, & Tisch, 2008).

The French military implemented a vector-control program that included permethrin-impregnated uniforms (impregnation method not described other than "industrial") and the application of 50% DEET to exposed skin (Deparis et al., 2004). The same study showed some protection against *Anopheles* mosquitoes using the combination of DEET and permethrin-impregnated clothing; however, malaria incidence in soldiers wearing treated uniforms was not lower than those not wearing treated uniforms.

Permethrin-treated clothing was evaluated in North Carolina Division of Water Quality employees and a 93% reduction in tick bites was found in treatment compared to control participants (Vaughn & Meshnick, 2011). Another study found that permethrin-impregnated uniforms were highly effective in preventing tick bites for at least 1 year, leading the authors to recommend that this clothing should be included as a standard tick bite prevention measure with retreatment or replacement of those garments annually if worn on a regular basis (Vaughn et al., 2014).

Balanay and co-authors (2014) surveyed working college students and found 26.7% had experienced a disease or some ill effect from workplace conditions. The number two adverse health effect these working college students reported was mosquito and tick bites. That same study also found that 56.2% of participants had been trained by their employer how to use personal protective equipment.

Several studies have investigated tick exposures in foresters and military personnel; however, no such studies have focused on EHS in North Carolina. Consequently, the objectives of this study of EHS in the central Piedmont region of North Carolina are to: 1) determine the extent to which personal protective measures (PPM) are used for prevention of tick bites; 2) investigate the relationship between job description, tick exposure, and vectorborne disease; and 3) report tick species to which EHS are exposed.

Methods

Participants

Participants were EHS employees in the Piedmont region of North Carolina potentially at risk of acquiring tickborne diseases while carrying out their duties as authorized agents of the state. In North Carolina, there are 845 practicing EHS (NCDHHS, 2014). Eight counties of Stokes, Rockingham, Caswell, Alamance, Guilford, Forsyth, Randolph, and Davidson were chosen for this study and employ 126 EHS. As job descriptions may impact tick exposure, duties were grouped into four categories: 1) onsite water protection (OSWP) including site evaluations for well and septic; 2) multiple job duties (MULTI); 3)

TABLE 2

Days Missed From Work as a Result of Tickborne Disease

Question: How many days have you missed from work as a result of a tickborne disease or a tick bite(s) while employed as an environmental health specialist?		
Answer Options	**Response %**	**Response Count**
None or do not recall	85.4	35
1–3 days	4.9	2
4–6 days	2.4	1
7–10 days	4.9	2
>10 days	2.4	1
Answered question		41
Skipped question		3

TABLE 3

Primary Job Duties as an Environmental Health Specialist (EHS)

Question: What are your primary duties as an EHS? Please list specific authorizations as well as any other required duties.		
Answer Options	**Response %**	**Response Count**
Onsite wastewater	90.0	36
Private drinking water wells	72.5	29
Swimming pool inspections	47.5	19
Migrant housing	45.0	18
Food lodging and institutional sanitation	30.0	12
Local vector control program	25.0	10
Tattoo inspection	25.0	10
Solid and/or hazardous waste	20.0	8
Child care and school sanitation	10.0	4
Other (please specify)	10.0	4
Childhood lead poisoning prevention program	7.5	3
Answered question		40
Skipped question		4

indoor inspections of food, lodging, and institutional (FLI) sites; and 4) job duty not specified (UNSPECIFIED). Approval from the East Carolina University & Medical Center Institutional Review Board was obtained prior to conducting the study (UMCIRB 14-000433).

Survey and Log Books

A 19-item online survey was administered to participants to assess history of tickborne disease and lost work due to tick-related illness, type of PPM used to prevent tick exposure, outdoor recreational activities, sex, and job function(s). The study took place from May through August 2014.

Participants were asked to keep weekly logs of hours worked outdoors, job function performed, date of tick exposure, county where exposure occurred, whether tick was attached or crawling, specific PPM used, number of hours missed from work as result of tick-related incident, and if treated for tickborne disease during the study period.

Tick Collection and Identification

Sixteen 1.5 mL microcentrifuge tubes containing 1.0 mL 70% ethanol were provided to each participant to store weekly tick collections. Ticks were sent to researchers by courier service monthly. An online pictorial key identification (www.tickencounter.org/tick_identification) was used to identify ticks in conjunction with a standard taxonomic key (Keirans & Litwak, 1989).

Statistical Analyses

SPSS Statistics 20 was used for statistical analyses ($p < .05$). A tick exposure was defined as the sum of crawling and biting ticks. Bar graphs were used to visualize trends in tick exposure by species, month, county, PPM usage, and job duty. To determine if there was an association between tick exposure and categorical variables (i.e., species, month, county, PPM usage, and job duty), Pearson chi-square test was used. Continuous variables (i.e., hours using PPM and hours working outdoors) were analyzed using Pearson correlation coefficient, bivariate correlation for continuous variables, and t-test.

Results and Discussion

Out of 126 possible participants in the study counties, 44 responded to the survey and 43 (34%) gave informed consent. We received 280 weekly log sheets (36% of the possible log sheets) from 29 participants logging 3,927 hours outdoors performing EHS job duties (135 hours per person).

Survey results are listed in Tables 1–4. Most respondents (71%) had not experienced a tickborne disease (Table 1); however, 29% of the respondents reported being diagnosed with at least one tickborne disease in their lifetime. Two participants did not answer this question. Of the participants who answered this question, 15% had missed some work as a result of tickborne disease (Table 2). Many participants have multifunctional roles at their respective agencies and those who work with onsite wastewater had the highest number of respondents (90%) (Table 3).

Respondents who use PPM primarily use repellents containing DEET (42.5%), while some participants (33%) did not use any PPM (Table 4). Participants reported using PPM to prevent tick exposure 45% of the time at work.

Outdoor recreational activities of participants primarily include hiking (58%), hunting (50%), and camping (45%). Ninety percent of participants acknowledged tick exposure outside work hours and 48% reported that they used some form of PPM at least sometimes. Most respondents (70%)

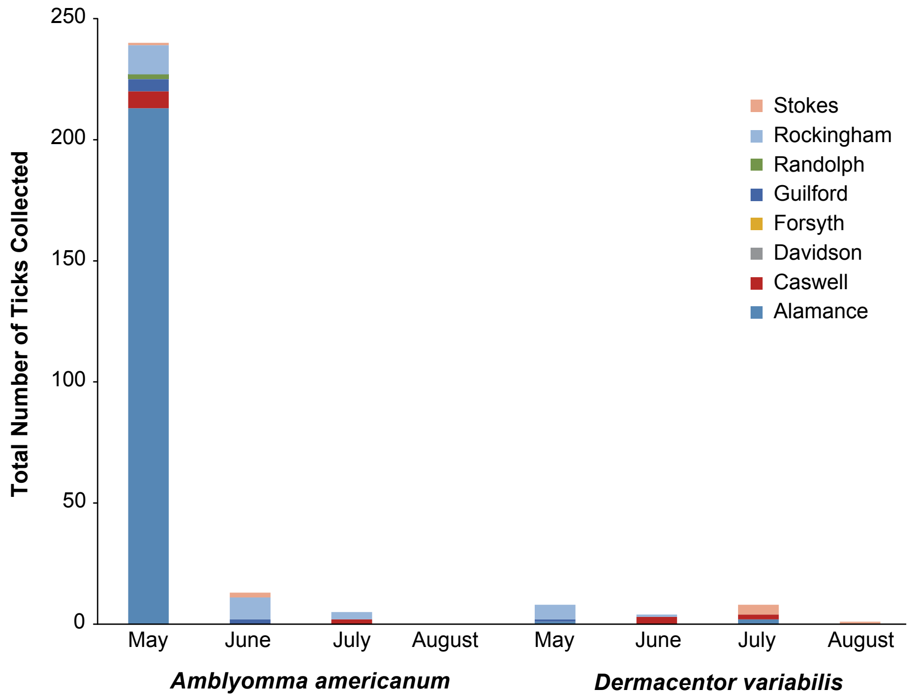
TABLE **4**

Types of Repellents Used by Environmental Health Specialists

Question: What kind of personal protective measures do you normally wear/use for prevention of tick exposure at work?		
Answer Options	**Response %**	**Response Count**
DEET	42.5	17
None	32.5	13
Permethrin	22.5	9
Permethrin-impregnated clothing	15.0	6
Other	15.0	6
Permanone	7.5	3
BioUD	2.5	1
IR3535	0.0	0
Picaridin	0.0	0
Other botanical	0.0	0
Answered question		40
Skipped question		4

FIGURE **1**

Ticks Submitted by Environmental Health Specialists by Month and County



considered themselves knowledgeable about tickborne disease and 80% would like to see specialized occupational training in tickborne diseases and other vectorborne diseases.

Observational Study

Over the study period May through August 2014, participants submitted a total of 279 ticks. A total of 57 attached ticks and 206 crawling ticks were recorded; however, the remaining 16 ticks submitted by participants were not classified as crawling or attached. The highest number of ticks were received from respondents in May (n = 248) and Alamance County personnel submitted the highest number (n = 216) of ticks for the duration of the study (Figure 1). From June through August, tick submissions and reported exposure declined. *Amblyomma americanum* were submitted most frequently (n = 258). The numbers of ticks collected from each species did not change significantly between months (*A. americanum*, p = .242; *D. variabilis*, p = .263). We observed no significant difference in tick species collected from different counties used in this study (*A. americanum*, p = .243; *D. variabilis*, p = .271).

Based on the survey, repellent use by participants is summarized in Table 4 and shows that 42.5% of respondents used DEET while 32.5% used nothing. PPM use by participants during the study is summarized in Table 5 and shows that 80% used nothing. The comparison of reported tick exposures to time working outdoors wearing PPM is shown in Figure 2. The mean number of hours (with standard deviations in parentheses) spent outside for the duration of the study not wearing PPM was 114.6 hours (126.1) and wearing PPM was 21.0 hours (41.5). There was no correlation between tick exposures and total hours spent working outdoors by job duty (combined time regardless of PPM usage) (p = .438, r = -.150) or without PPM (p = .475, r = -.138) (Figure 2). In contrast, the number of hours spent outside with PPM (Figure 2) compared to exposure was associated (p = .005, df = 144), that is, those working outdoors while wearing PPM had lower tick exposure, indicating some effectiveness of using PPM. There was no correlation between tick exposure and work performed (p = .589, df = 36), county (p = .176, df = 96), or sex (p = .831, df = 12).

Participants logging 50–150 hours working outside without PPM had the highest tick exposure (n = 9 ticks per person) for the duration of the study. Participants conducting jobs related to OSWP were exposed to ticks most frequently; however, tick exposures were not significantly different than other job descriptions (i.e., MULTI, FLI, and UNSPECIFIED) (p = .243, df = 11)

TABLE **5**

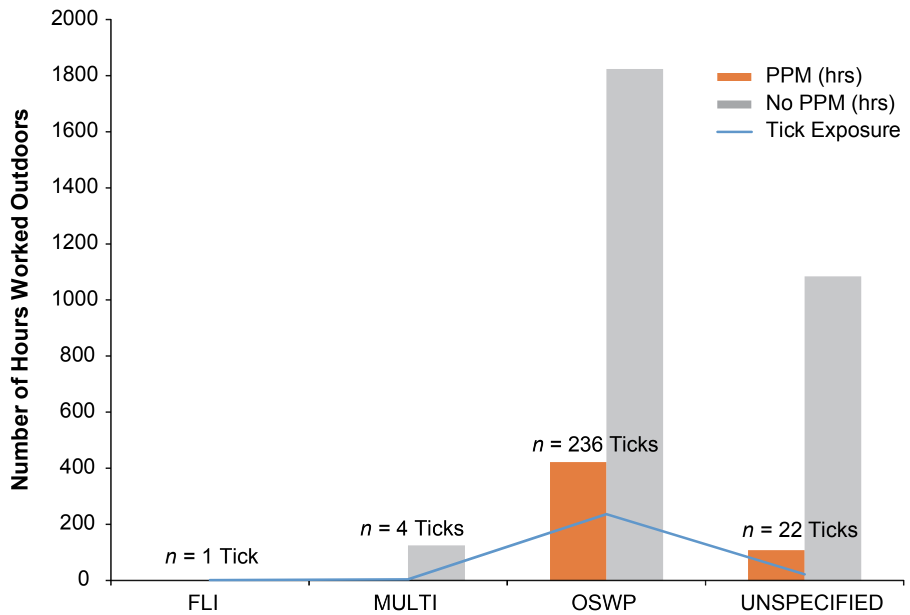
Personal Protective Measures (PPM) Used by Participants During the Study (*N* = 326)*

Product Type	%
No answer	0.3
10% DEET	0.3
15% DEET	0.3
DEET	10.4
DEET Backwoods	0.3
Gaiters	0.3
Gaiters/DEET	0.3
Illegible	0.3
Insect shield hat and socks	0.3
Insect shield pants	0.3
Lemon eucalyptus	0.6
None	80.1
OFF Deep Woods	0.3
OFF/DEET	0.3
Permethrin	4.3
Permethrin-covered socks	0.9
Socks over jeans	0.3
Total	100

*Participants logged 326 entries of PPM usage over course of study 3,926.5 outdoor work hours.

FIGURE **2**

Exposure to Ticks per Working Hour Outdoors



PPM = personal protective measures; FLI = food, lodging, and institutional; MULTI = multiple job duties; OSWP = onsite water protection; UNSPECIFIED = job duty not specified.

(Figure 2). Although survey results (*n* = 43 respondents) indicate that participants use PPM 45% of the time at work, log sheets submitted (*n* = 29 respondents) show that EHS do not wear PPM for the prevention of tick bites ($p = .010$). During this study, participants wore PPM only 16% (610/3,927 hours) of the time working outdoors. This discrepancy may be explained by the unequal number of respondents participating in the survey compared to parts of the study that included collecting and submitting ticks and filling out the log books.

During the course of the current study, no participants missed work due to a tickborne disease; however, one participant indicated that he was being treated for a tickborne illness during the study. This individual did not indicate whether there had been any exposure over the course of the study, nor did he indicate any PPM usage or what his major job function was during the study. On the survey, this participant indicated that his main duties were multiple authorizations, including OSWP. This participant also indicated on the survey that he had been treated in the past for a tickborne disease and did not wear PPM for prevention of tick bites.

Limitations

The survey indicated that 28% of participants had history of tickborne disease. It is not known if these diagnoses were clinically confirmed. Furthermore, we do not know if these illnesses were acquired in the workplace. The survey had 44 participants out of 126 possible; however, only 43 gave informed consent. One participant noted that he was treated for tickborne illness during the course of the study. It is not known for what disease this individual was treated, or what specific job this individual was performing. Rockingham County, residence of the principal investigator, showed the highest number of participant submittal of log sheets indicating a potential bias, even though the participants were blinded from the principal investigator. A survey question asking about outdoor recreational activities was potentially biased in that "none" was not a choice.

Conclusion

Although the data here did not show a significant association between tick exposure, PPM usage, and job description, OSWP workers logged the most exposures compared to other EHS duties. Ticks were collected and submitted by participants; hence investigators depended on participants to accurately record exposures and PPM usage. Although tick exposure was low (either due to poor reporting or low tick activity), reported PPM usage was also low.

Outdoor workers are at increased risk of tickborne disease compared to the general public (Podsiadly et al., 2011). Although 70% of respondents in the current study reported being knowledgeable about tickborne disease, low PPM usage here indicates either EHS do not believe the threat is significant, or they believe PPM are ineffective. Schofield and co-authors (2012) surveyed 678 Canadian military deployed to Afghanistan and showed a positive relationship between perceived risk and use of PPM (e.g., repellent, bednet, insecticide-treated clothing). Their study suggested that reminders increased the odds of personnel using PPM and emphasized that education of personnel would increase use of PPM. This should be studied further in environmental health personnel. Effective methods exist to protect outdoor workers from arthropod exposure and, subsequently, vectorborne disease (Cisak et al., 2012). EHS who work in tick-infested areas should use PPM to protect themselves. Permethrin-treated EHS uniforms could provide an easy-to-use alternative to repellents that require repeated applications. A cost-effectiveness analysis is needed to determine the appropriateness of permethrin-treated clothing for EHS personnel.

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continued on page 7

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