Published in final edited form as:

Am J Ind Med. 2014 March ; 57(3): 323–337. doi:10.1002/ajim.22284.

Pesticide Exposures to Migrant Farmworkers in Eastern NC: Detection of metabolites in farmworker urine associated with housing violations and camp characteristics

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Abstract

Background—The purpose of this paper is to present and evaluate descriptively bivariate associations between urinary metabolites of pesticides and herbicides and migrant camp conditions, violations and personal worker behaviors at home for farmworkers who do not apply pesticides.

Methods—We studied 183 migrant farmworker camps in eastern North Carolina in 2010. Data and urine samples were collected from 371 men. Predictor measures included violations in six domains of housing regulations and nonviolation characteristics and personal behaviors that might impact urinary metabolites.

Results—Cockroaches and bathroom violations were predictive of increased exposure to pyrethroids and cyfluthrin/chlorpyrifos, respectively. Changing and storing clothing and shoes in sleeping rooms increased the number of detects for the diazinon metabolite.

Conclusions—Farmworkers had exposures to multiple chemicals. No single housing domain was identified as critical to mitigating housing-related exposure; specific attention should be paid to changing and storing soiled clothing in sleeping rooms, and insect infestations.

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Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Institutions at which work was performed: RTI International, Wake Forest School of Medicine

INTRODUCTION

Farmworkers who are occupationally exposed to chemicals can carry these chemicals into their homes [Curwin 2006; Fenske et al. 2005; Quandt et al. 2004, 2002; Lu et al. 2000;]. Pesticides that contaminate a farmworker's skin, clothing, or shoes may be shed from soiled clothing and shoes onto indoor surfaces, generally as particulates, including dirt or plant remnants, or transferred by physical contact of contaminated skin with surfaces, including furnishings. Pesticides and other chemicals that are transported into the home in this manner can expose nonfarmworker residents of the home, including spouses and children, to these chemicals [Bradman et al. 2011; Curwin, 2006; Arcury et al. 2005; Fenske 2005; Curl et al. 2002; Lu et al. 2000]. Once a pesticide has migrated into the home, children are at increased risk of intake from both dietary and nondietary ingestion [Egeghy et al. 2011; Melnyk et al. 2011]. When most, if not all, of the residents of the home are farmworkers, each person can each contribute to the indoor chemical load, and thus increase the nonwork-related exposures of each resident [Arcury et al. 2005; McCauley et al. 2001]. Quandt et al. [2006] reviewed the workplace, household, and personal predictors of pesticide exposure for farmworkers. Their review clearly showed that the home and workplace environment interact with workplace and household behaviors to impact exposure and, presumably, the risk of adverse health outcomes.

Even if the agricultural chemicals are nonpersistent in the outdoor environment, substantial data indicate that these compounds persist indoors [DHHS 2009; Whyatt et al. 2007]. Thus, significant accumulation of pesticides indoors can occur and contribute to additional and on-going in-home exposure. Once in the home, chemicals can migrate throughout by vapor-phase transport for volatile chemicals, such as many of the organophosphorus (OP) pesticides, or by migration of dust, to which many of the low-vapor pressure chemicals, such as pyrethroids, are adsorbed [Morgan et al., 2007]. In addition, pesticides, including many of the pyrethroids, are often applied indoors to reduce insect or rodent infestations, and these pesticides add to the indoor load.

Best practice indicates that work clothes and shoes should be removed prior to entering the home after work and should be stored where they will not be handled prior to laundering [Curwin, 2006; U.S. Environmental Protection Agency, 2013]. In addition, farmworkers should be able to shower after work so that (1) residual chemicals on skin can be washed away to reduce the source for ongoing dermal absorption, and (2) transfer of residues from the body to interior spaces can be minimized. The extent to which facilities enable changing, storage/laundry, and hygiene practices has a direct impact on indoor chemical concentrations. Furthermore, housing factors play a major role in the extent to which exposures to indoor pesticides contribute to total pesticide exposures of farmworkers [Quandt et al. 2006]. Thus, housing quality is an important variable because it impacts how occupational chemicals can be transferred into farmworkers' homes.

The quality of housing available to migrant farmworkers can vary substantially and presents both ethical and practical concerns. Adequate housing has been stated as a basic human right [WHO 2006] and is instrumental in helping to protect the health and safety of farmworkers [Bradman et al. 2011; Kreiger and Higgins 2002; Collins 1993]. The Migrant and Seasonal

Agricultural Workers' Protection Act (MSPA) was enacted in 1983 to provide a regulatory basis for ensuring some standard of housing quality [U.S Department of Labor 2012]. Vallejos et al. [2011] showed that in 2007 and 2008, substandard conditions in migrant farmworker camps in North Carolina were common. In 2007, between 11% and 44% of camps had inadequate bathing, laundry, or storage facilities, and 2008 data showed that 89% of camps had more than one condition that violated the North Carolina Migrant Housing Act, which was enacted in 1989. Substandard housing will impact a farmworker's ability to mitigate occupational exposure and could contribute to nonoccupational exposure.

In 2010, Arcury et al. [2012] undertook a study to evaluate farmworker housing in east-central North Carolina; the results presented in this paper represent a component of that study. As described more fully in the Methods section, urine samples were collected from each participant and analyzed to provide data on individual exposures to agricultural chemicals. Previous studies with NC migrant farmworkers have shown that farmworker urine contains pesticides, or metabolites thereof, used in agriculture [e.g., Arcury et al. 2010; Quandt et al. 2006]. We sought to learn here whether or not housing factors can increase the exposures of workers who do not apply pesticides/herbicides in their work but who live in camps. Although earlier studies have demonstrated the importance of hygiene, the safe handling of dirty laundry and the number of occupants in the home, among other factors, as determinants of pesticide exposure [Quandt et al. 2006], our current analyses seek to clarify the potential linkages (bivariate associations) between housing conditions (as measured by violations) and chemical exposures (as measured by the frequency of detection of agricultural chemicals or their metabolites).

This analysis delineates the potential linkages of violations in migrant housing regulations with the detection of pesticide urinary metabolites for OP and pyrethroid insecticides and the detection of urinary metabolites for triazine and chlorophenoxy herbicides. Detection of pesticide urinary metabolites for OP and pyrethroid insecticides was also used to evaluate linkages of pesticide exposure with general housing conditions not governed by migrant housing regulations. As a result of this analysis, we sought to identify conditions that contribute to nonoccupational farmworker exposure to pesticides. Once these conditions are identified, policy decisions can direct resources to correct those housing characteristics or personal behaviors that can have the greatest impact on reducing nonwork-related exposures of farmworkers.

METHODS

Overview

The study is part of a program of community-based participatory research that involves investigators at Wake Forest School of Medicine, the North Carolina Farmworkers Project, Student Action with Farmworkers, and other clinics and organizations serving farmworkers in North Carolina. Data were collected from June through October 2010. The research protocol was approved by the Wake Forest School of Medicine Institutional Review Board.

Sample

Participants were recruited in 16 counties in east-central North Carolina in which a large number of migrant farmworkers are employed. Counties included Caswell, Craven, Cumberland, Duplin, Edgecombe, Greene, Halifax, Harnett, Johnston, Lenoir, Nash, Person, Sampson, Wake, Wayne, and Wilson. The larger study focused on housing occupied by migrant farmworkers. All participants resided in employer-provided housing. The participant recruitment process included three steps. First, partner organizations (North Carolina Farmworkers Project, Carolina Family Health Center, Kinston Community Health Center, and Piedmont Health Services) provided lists of camps in their service areas. Over the course of data collection, the list of camps was expanded as new camps were encountered. Second, project staff traveled to each camp and explained the nature of the study to the resident farmworkers. The farmworkers were asked to assemble and meet with the project staff who made a presentation about the project; participation in this presentation was at the choice of the individual residents. If the farmworkers in a camp agreed to participate, a camp census was conducted to assess general camp characteristics and to determine eligibility. A total of 186 camps were enrolled in the study. Residents in 36 other camps declined to participate, and the grower or contractor refused to permit participation in four other camps. The camp participation rate was 82.3% (186/226). In five of the 186 participating camps, data collection was not completed due to the intervention by the grower. For three of these camps, insufficient information was collected, and they could not be included in this analysis. Therefore, the final sample for this analysis included 183 camps. Camps participating in the study were given a volley ball as a token of appreciation.

Third, up to three residents at each camp who listened to a presentation describing the study volunteered to be study participants. Random selection of camp residents was not possible as not all camp residents attended the presentation and residents who choose not to participate could stay in their rooms, walk away from the camp, or in other ways not make themselves available. Inclusion criteria were being male, currently employed as a farmworker, migrating for employment, and residence in the camp. With one exception, two farmworkers in each camp agreed to complete an interview questionnaire, help with assessing their sleeping rooms, and provide biological samples; in one camp, only one farmworker agreed to participate in this component of data collection, resulting in 371 participants in the 186 camps. Generally, one additional farmworker in each camp assisted with the camp assessment (but did not complete an interview questionnaire or provide a biological sample); in four camps, one of the interview respondents assisted with the camp assessment, resulting in 182 participants who assisted with camp assessment.

The final sample included 371 men who completed interviews and 182 men who assisted in the camp assessment, for a total of 553 participants. A total of 231 men refused to participate when asked. The participation rate was 70.5% (553/784); however, the rate could be lower as individuals who did not want to participate could have avoided the recruiters. The farmworkers who completed the interviews and who helped with the camp assessment were each given a \$30 cash incentive. All participants provided written informed consent.

This analysis is limited to 361 of the 371 men who completed interviews. Six of the farmworkers were residents of the three camps excluded from this analysis. Four

farmworkers were excluded because they had no urine sample available for analysis. Three of these four men could not produce a urine sample. The urine sample for the tenth farmworker was taken by the wife of his employer, and she would not return it.

Data Collection

Data for this analysis are based on three components of the research: (1) interviews with two farmworkers in each camp; (2) analysis of urine samples for pesticide metabolites for up to two farmworkers, who were not pesticide applicators, in each camp; and (3) camp assessments assisted by one of the resident farmworkers. All data collection forms were developed in English and translated into Spanish by a native Spanish speaker familiar with Mexican Spanish. The forms were reviewed by staff members of the community partners who were native Spanish speakers. Revised forms were field tested, with the interview questionnaires being pre-tested with four male migrant farmworkers. All materials were revised based on the field test.

Interviews were completed by trained staff members who were fluent Spanish speakers. Interview items assessed demographic information, housing features, and perceptions of housing quality. Interviews took approximately 90 minutes to complete.

Each participant who completed an interview was asked to provide a spot urine sample. A standard protocol for urine collection developed by RTI International was used. Participants were given a sterile urine cup with an ID label affixed. Urine cups were placed in a cooler with blue ice until return to a field office. Ten milliliter aliquots were prepared for each sample, and the aliquots were frozen to -20°C. Samples were delivered to the RTI Laboratory for analysis.

Housing assessments were completed by trained staff members who were fluent Spanish speakers with the assistance of a farmworker. During the course of the housing assessment, the inspector observed, asked questions, and used instruments such as a flashlight and an extending mirror to inspect inside cabinets and behind appliances for signs of pest infestation and exposed wires. The housing assessment form consisted of five sections: (1) general camp, (2) toilet facilities, (3) bathing and showering facilities, (4) kitchen/eating area, and (5) laundry facilities. The housing assessment form included 129 items, 79 of which were designed to assess compliance with the standards as summarized in the North Carolina Department of Labor Introduction to Migrant Housing Inspections [2008]. Assessment of the sleeping room was included in the interview and only the bedrooms of the two questionnaire participants were inspected. The sleeping room assessment was included in the questionnaire because, over the course of the interview, the interviewer established the rapport necessary to enter, inspect, and photograph the participants' bedrooms.

Insecticide and Herbicide Selection

A suite of agricultural chemicals, including insecticides and herbicides, was chosen for analysis based on historic and contemporary usage, as determined by past and current approved registrations in North Carolina. As described above, pesticides that are considered non-persistent in the outdoor environment can persist for long periods of time indoors, and studies, including the study described here, often apply analytical methods that capture a

wide range of chemicals beyond those in current use. The parent chemicals and their associated metabolites measured in urine for this study are shown in Table I. Also shown in Table I is the number of products with the indicated active ingredient approved for use in North Carolina. In general, the organophosphorus [OP] pesticide products have been used with decreasing frequency; however, chlorpyrifos is still used fairly widely. With the exception of the pyrethroids, all of the insecticides and herbicides are approved for outdoor use only. The pyrethroids are commonly applied indoors to control or prevent household insects, including ants, spiders, and cockroaches.

Sample Preparation and Analysis

Urine samples were extracted according to the method of Olsson et al. [2003]. Two mL of sample were spiked with isotopically labeled internal standards then incubated with β -glucuronidase from *H. pomatia* extracts (to cleave glucuronide and sulfate conjugates). The samples were extracted using automated solid phase extraction [SPE] on a Gilson GX-271 liquid handler. For each sample, an Oasis HLB SPE cartridge (Waters Corp., Milford, MA) was first preconditioned with methanol; a solution of 5% methanol and 1% acetic acid in water was applied; and the sample was loaded at a slow rate. The column was washed with the aqueous conditioning solvent and then eluted with methanol. The methanol elute was concentrated to < 200 μ L under a stream of nitrogen (TurboVap LV) and transferred to an autosampler vial. Samples were analyzed in batches of 17, plus additional samples (blanks, controls, and duplicates) for method quality control. Blanks and controls were prepared from pooled human urine (Bioreclamation, Inc., Hicksville, NY).

Samples were analyzed by UltraPerformance Liquid Chromatography/Mass Spectrometry/Mass Spectrometry using a Waters Acquity UltraPerformance Liquid Chromatography interfaced with an AB-Sciex API-4000 QTRAP mass spectrometer with parameters as given in Tables SI-SIII. Samples were separately injected under positive and negative ion conditions. Sample analysis was preceded by a matrix blank and a 9-point matrix-based calibration curve, with concentrations ranging from 0.125 ng/mL to 50.0 ng/mL of each analyte. Samples were bracketed in the analysis sequence by check standards at 0.500 ng/mL, 1.00 ng/mL (negative ion mode only), and 10.0 ng/mL, in brackets not exceeding 10 samples. Standards were required to show 85% to 115% accuracy, except for 80% to 120% accuracy at the lowest calibration point (lower limit of quantification). Check standards were required to show 70% to 130% accuracy. Standards were allowed to be excluded from calibration curves in cases of poor linearity, as long as 6 points were included.

Measures

Independent measures for this analysis are violations in six domains of housing regulations, as well as general camp characteristics and participant demographic characteristics. The regulated domains pertain to the camp, the sleeping room, the bathroom, the kitchen, the laundry room, and general housing [Arcury et al. 2012]. Within each of these domains, there are a number of subcategories, each with specific items that are inspected and that can result in differing numbers of violations within each domain. Sleeping room violations included size violations (less than 50 square feet per person), proper bed violation (lack of separate raised bed for each person with a clean mattress; triple bunk beds), and total sleeping room

violations. Bathroom violations included showerhead adequacy (at least 1 working showerhead for 15 residents), hand washbasin adequacy (at least 1 working washbasin for 15 residents), and total bathroom violations. Kitchen violations included cleanliness and total kitchen violations. Laundry violation included 1 wash tub or washing machine (per 30 residents) and total laundry violations truncated at 2. A cockroach violation included infestation in bathroom, sleeping rooms, kitchen, or laundry room. A rodent violation included infestation in bathroom, sleeping rooms, kitchen, laundry room, or “other room”. Finally, total camp violations, total general housing violations, and total violations were calculated.

General housing characteristics include housing type (apartment, barracks, house, trailer), number of people in sleeping room (1, 2, 3, 4, or more), and insecticides used in house (yes, no). Farmworker behaviors include the following dichotomous measures: drink tap water, change clothes in sleeping room, store clothes in sleeping room, store shoes in sleeping room, and need to wait to shower due to lack of showerheads or hot water, as well as time to shower after work (0-15 minutes, 16-30 minutes, more than 30 minutes). Participant demographic characteristics include age (18-24 years, 25-29 years, 30-39 years, 40 or more years), education (0-6 years, 7-10 years, 11 or more years), speaks an indigenous language, seasons in U.S. agriculture (less than 2 years, 2-3 years, 4-7 years, 8 or more years), and farmworker visa status (migrant without H2-A visa, migrant with H2-A visas, seasonal).

Basis for Measures Selection—Specific violations and behaviors were selected for analysis here because there is a plausible and explicable link between that violation or behavior and exposure. How the measures can impact exposure is discussed more fully in this section.

Decreased sleeping room size increases the room concentration of any chemicals tracked in, especially as the number of dwelling occupants increases [Quandt et al. 2006]. The use of a bed by more than one person would be expected to increase the amount of chemical on the linens if each person contributed to the residue amount. In addition, beds located on the floor would be subject to greater contamination by dust resuspended by human activities in the room than would beds further off of the floor. Similarly, occupants of the beds on the floor can be exposed to higher concentrations of dust available for inhalation or dermal deposition than would occupants of beds further away from the floor. Indoor dust is resuspended by human activities, and a gradient (decreased dust with increased height) exists [Qian et al. 2008], increasing the likelihood of inhalation exposure as the breathing zone moves closer to the floor. This situation is likely exacerbated if cleaning of the floors is infrequent [Quandt et al. 2006]. These factors increase inhalation exposures.

The adequacy of showerheads and hand washbasins reflect the ease with which a farmworker can wash off any residue brought home from the fields. Laundry tub and washing machine adequacy would be expected to result in a decreased need to store soiled clothing, where additional residues could become dislodged into the indoor environment. Laundry facility availability might also be expected to reduce the time that clothes are worn prior to washing; repeated wearing of unclean clothes could increase the concentration gradient for transfer of residues to the skin. Kitchen cleanliness would be expected to impact

residues available for ingestion. Indeed, unclean kitchens encourage insects and rodent infestations that can also increase the use of chemicals in that room. Chemical residues in kitchens transfer to food preparation surfaces and ultimately to food that is consumed [Melnik et al. 2011]. Furthermore, residues can transfer to eating utensils (plates, silverware, and glasses) and be ingested when those items are used. Dwellings that are easier to clean have been shown to result in lower urinary metabolites of OP pesticides [Arcury et al. 2005].

Finally, insect and rodent infestations contribute to exposures in two ways. First, the animals move throughout the home and carry with them any chemicals present. Second, when insects and rodents are present, pesticides are frequently applied indoors in an attempt to eliminate the infestation. This increases the indoor load and provides more chemicals to migrate around the home. Although none of the chemicals monitored in this study are rodenticides, the pyrethroids that give rise to 4F3PBA and 3-PBA are approved for indoor use for insects.

Statistical Analysis

For participants with metabolite data, descriptive statistics were calculated for all 10 metabolites of interest. Counts and percentages are reported for those greater than or equal to the method detection limits and lower limit of quantitation. Urinary pesticide metabolites were the dependent measures, and these are included as dichotomous measures indicating whether each was present above the detection limit for each individual. This approach was selected to test for possible contributors to exposure because neither the pesticides applied nor the timing of application relative to the collection of urine samples was known. For those measured concentrations greater than or equal to the LLOQ, additional descriptive measures are reported (mean, SD, minimum, maximum, median, and geometric mean). Counts and percentages are reported within each agricultural season for those with and without a metabolite detect, and chi-square tests were used to examine the relationship between season and presence of a metabolite detect. Chi-square tests were also used to determine if the bivariate association of the dependent variable with the selected independent variable was statistically significant. To examine the linkage between urinary metabolites and the grouped violation variables (total camp, sleeping room, bathroom, kitchen, laundry, and general housing violations), we reported the mean and standard deviation for the continuous variables and counts and percentages for the categorical variables. T-tests were used to test the association between the continuous variables and metabolites; chi-square tests were used for the categorical variables. All analyses were done using SAS 9.2 (SAS Institute, Cary, NC), and p-values of less than 0.05 were considered statistically significant. Multivariate analysis was not used here because most of the observation results, e.g., kitchen clean or dirty, were dichotomous and, thus, not well-suited for conventional multivariate approaches.

Our analyses first examined the number of metabolite detects as a function of the season in which samples were collected, followed by specific violations, grouped violations, and finally other selected housing characteristics. This last group included both characteristics and occupant behaviors that could impact exposure to agricultural chemicals in the home.

RESULTS

Characteristics of the study population are shown in Table S-IV. The men in this study ranged from 18 to 40 or more years of age. Over 50% were 30 years of age or older. Nearly 50% fell into the category of 0 to 6 years of formal schooling. Nearly 90% of the workers had 2 years or more of experience in U.S. agriculture, with nearly 37 % having 8 or more years of experience. Summary statistics for the pesticide metabolites in urine are shown in Table II. The insect repellent Diethyltoluamide was the most frequently detected urinary metabolite, with 81% of the measured values greater than or equal to the lower limit of quantitation. The next most frequently measured urinary metabolite was associated with parathion (61% lower limit of quantitation), followed by chlorpyrifos (44%) and the three pyrethroids that all give rise to the same metabolite, 3-phenoxybenzoic acid, (permethrin, cypermethrin, and deltamethrin) at 43%. The herbicide 2,4-D was at or above the LLOQ in 17% of the samples. Finally, the cyfluthrin metabolite was present in 5% of the urine samples; the diazinon metabolite was quantified in 15% of the samples; the pyrimifos metabolite was measured in 4.4% of the samples; and atrazine mercapturate (a conjugation product of atrazine) was detected in 1.9%. The chemical 2,4,5-T was not above the method detection limit in any of the samples.

Table III shows the presence of a detect as a function of early-, mid-, and late-season sampling. Only Diethyltoluamide, 3-phenoxybenzoic acid, and *p*-nitrophenol showed any significant seasonal variation, with the absolute number of detects being highest in the mid-season time period (mid-July through August). Both atrazine mercapturate and 2-(Diethylamino)-6-methylpyrimidin-4-ol/one were excluded from the subsequent statistical analysis because their frequency of detection was less than 5%. Diethyltoluamide was also excluded because it is applied to the skin intentionally and is not an agricultural chemical. There were no associations between participant characteristics and the frequencies of detection of urinary metabolites, except for a possible increase in the frequency of detects for 2,4-D and Trichloropyridinol for farmworkers with an H2A visa and an increase in the frequency of detects for 2,4-D with more education (data not shown).

A subset of factors that contribute to violations (specific violations) was evaluated related to their impact on the frequencies of urinary metabolite detections, as were responses to some specific questions that could impact personal exposure and take-home pesticides, independent of a violation. The subset selected for evaluation here, along with the number of metabolite detects in each case, are shown in Table IV. Although most of the associations were nonsignificant, statistically significant inverse associations were measured with violations for *inadequate sleeping room size* for *p*-nitrophenol ($P = 0.046$) and trichloropyridinol ($P = 0.017$), *improper bed provision (less than one bed per person, bed placed on the floor, triple bunks)* and trichloropyridinol ($P = 0.0081$), and *unclean kitchens* and trichloropyridinol ($P = 0.021$). In other words, there is a higher percentage reporting a violation for those who do not have a metabolite detect compared to those who do show a metabolite detection (refer to Table IV). However, *cockroach infestation* was positively associated with 3-phenoxybenzoic acid ($P = 0.039$), 4-fluoro-3-phenoxybenzoic acid ($P = 0.029$), and *p*-nitrophenol ($P = 0.039$) and *unclean kitchens* was positively associated with 3-phenoxybenzoic acid ($P = 0.028$).

When violations are grouped at the domain level, the number of violations did show associations with the frequency of detection for some of the urinary metabolites (Table V). An increase in the number of bathroom violations was associated with frequencies of detection of 4-fluoro-3-phenoxybenzoic acid and trichloropyridinol in urine. The detection frequency of 4-fluoro-3-phenoxybenzoic acid was also associated with increases in both general housing violations and total violations; *p*-nitrophenol was also associated with total violations.

The summary of nonviolation housing characteristics and individual behaviors and metabolite detects is shown in Table VI. The only comparisons that had any level of significance were the detects of urinary 2-Isopropyl-4-methyl-6-hydroxypyrimidine as impacted by changing clothes in the sleeping room ($P = 0.017$) and storing clothes ($P = 0.031$) or shoes ($P = 0.041$) in the sleeping room. Engaging in the behaviors was associated with small increases in the percentage of urine samples that provided measureable concentrations.

DISCUSSION

Urinary metabolite concentrations measured in the farmworker population study (Table II) were generally higher than those measured in the general U.S. population (Table I). The geometric mean for urinary 3-phenoxybenzoic acid was nearly an order of magnitude higher in the farmworker population than in the general population (2.29 vs. 0.31 ng/mL). The geometric mean for trichloropyridinol in the current study was not substantially different than that in the general population (4.5 vs. 1.8 ng/mL). The distributions generally showed maximum values an order of magnitude or more above the minimum values and were skewed to higher concentrations. For the most frequently detected chemicals (diethyltoluamide and *p*-nitrophenol), the difference between the minimum and maximum was over two orders of magnitude. The high values of diethyltoluamide reflect heavy use of the insect repellent in the agricultural setting; the geometric mean was 2.23 ng/mL, which is more than an order of magnitude higher than the 95th percentile for the general population. Although *p*-nitrophenol was frequently detected, the limited use of methyl-parathion and ethyl-parathion is inconsistent with this measurement. However, it remains frequently detected [Arcury et al. 2009; DHHS 2009]. Urinary *p*-nitrophenol can also be the result of exposure to breakdown products of parathion or to nitrobenzene in the environment [DHHS 2009].

All of the participants in this study were tobacco farmworkers; almost all were involved in topping (removing the flower from the top of the plant) or harvesting. None of the participants in this study were pesticide applicators. The frequencies of detection of trichlorophenol and 3-phenoxybenzoic acid are comparable to those reported by Arcury et al. [2010] for any single monitoring event, and the general distributions of detection were similar to data published earlier, where *p*-nitrophenol, trichloropyridinol, 3-phenoxybenzoic acid, and 2,4-D were the most frequently detected metabolites [Arcury et al. 2009]. Urinary metabolite concentrations of diazinon and chlorpyrifos in this study were substantially lower than concentrations measured in 1999 in an Oregon farmworker study (331 and 200 ng/g urine, respectively) [Rothlein et al. 2006]. This could be the result of both decreased usage

of these chemicals over time and the crops with which the farmworkers worked, i.e., they were not applied to the crops being grown in the current study.

Any temporal or seasonal impact on the frequency of urine chemical detections might mask bivariate associations. Some dependence of detection frequency on season was identified, even though each of the farmworkers was sampled only once, and no attempt was made to identify which, if any, chemicals were in use at the time of sample collection. Detection of urinary metabolites for 3-PBA as a function of season would be expected depending on when these chemicals are applied, the crops to which they are applied, and when the sample collections were performed. Urinary measures would be expected to track chemical use on the farm. Exposure to multiple chemicals and at differing relative amounts could also be experienced by farmworkers if significant seasonal trends existed. Such might be the case for co-exposure to diethyltoluamide, where the percentage of farmworkers with measureable urinary metabolites of diethyltoluamide increased from 89% in the early season to 100% by late season.

The use of diethyltoluamide would not be expected to be dependent on any crop/pesticide/herbicide use pattern but rather be a function of the presence of biting insects. However, the co-exposures to the various farm chemicals and to large amounts of diethyltoluamide suggest the need for a careful evaluation of health outcome data when co-exposure occurs. Diethyltoluamide is known to have toxic effects on its own, including neurological outcomes alone and in combination with other pesticides with known neurologic impacts e.g., organophosphates and pyrethroids (Abou-Donia et al. 2004). Such time-dependent exposures were not considered in the current analysis.

Our study found that some of the specific violations shown in Table IV were associated with the frequency of metabolite detections in urine. Inadequate sleeping room size and improper bed provision were associated with decreased detects of trichloropyridinol. This suggests that exposures in the sleeping room do not contribute in a significant way to the total farmworker exposure. Dirty kitchens were associated with decreased detection of trichloropyridinol, which suggests that this factor is not important for chlorpyrifos. A small increase in the frequency of 3-phenoxybenzoic acid (pyrethroid metabolite) detection was found when dirty kitchens were reported. Pyrethroids are applied indoors and a dirty kitchen could result in contamination of food with pyrethroids that would otherwise be removed by cleaning. Roach infestations were associated with 4-fluoro-3-phenoxybenzoic acid and 3-phenoxybenzoic acid, and this would be consistent with pyrethroid application to kill the insects. These results show that although there are significant relationships, the resulting exposures would not likely to add to the occupational exposures of the farmworkers, although a more detailed analysis would be needed to define any fractional increase in exposure.

When the violations are viewed at the grouped, or domain, level (Table V), there is no striking evidence that any specific domain is key. Rather, as seen from our analysis, specific inputs, e.g., to the sleeping room or kitchen, should be the focus of housing-related contributions to farmworker exposure to farm chemicals.

Regarding specific nonviolation housing characteristics and individual behaviors and metabolite detects (Table VI), there is only a modest suggestion that changing and storing clothes and shoes in the sleeping room influences urinary 2-isopropyl-4-methyl-6-hydroxypyrimidine. The frequency of detection for this chemical is quite low (15%), and this could call into question the meaning of these associations. Further, the number of comparisons made here could result in apparent significance for some predictor/outcome pairs attributable to random variation. Such occurrences are not considered highly informative in this paper because of the descriptive focus.

Finally, the statistical analyses in this paper combines (pools) all of the data to test potential relationships of categorical pesticide detections to behaviors and violations aggregated across all study participants; the subtleties that impact the individual are lost. Knowledge of individual factors, i.e., personal behaviors and housing violations specifically experienced by an individual, could be very important to improve our understanding of how exposure, as reflected by urinary measurements, might be impacted. To the extent possible based on data available and sample size, future analyses should make use of the individual characteristics and behaviors on an individual farmworker/house basis.

CONCLUSIONS

The farmworker population in this study had exposures to multiple pesticides. The magnitude of the exposure in the home relative to the magnitude of the occupational exposure cannot be unambiguously defined in this study, but the evidence supports a chronic component of exposure via the housing, even if it is small relative to the total pesticide exposure. Although no single housing domain was identified as critical to mitigating housing-related exposure, specific attention should be paid to changing clothes and storing soiled clothing and shoes in sleeping rooms, kitchen cleanliness, and insect infestations. Multiple and concurrent exposures to the chemicals targeted, especially when diethyltoluamide is considered, also suggest more careful analysis of how such co-exposures impact health outcomes.

The data also justify continued vigilance to improve housing quality given the conditions that were associated with non-field work-related exposures. Educational efforts should continue to ensure that residents understand ways in which potential exposure pathways can be identified and mitigated.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This work was made possible through grant R01 ES012358 from the National Institute of Environmental Health Sciences to Wake Forest Health Sciences and a subaward to RTI International.

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Table 1
Parent Chemical and Associated Urinary Metabolites

Parent Compound	Chemical Class	Compound Measured in Urine	Geometric Mean Concentration in U.S. Population in ng/mL (survey year) ¹	95th Percentile of Urinary Concentration in U.S. Population in ng/mL (survey year) ¹	Number of Approved Registrations in NC ²
Primiphos-methyl	Organophosphorus pesticide	2-(Diethylamino)-6-methylpyrimidin-4-ol/one (DEAMPY)	NC (01-02)	0.470 (01-02)	3
Diazinon	Organophosphorus pesticide	2-Isopropyl-4-methyl-6-hydroxypyrimidine (IMPY)	NC (01-02)	<7.2 (99-00) <0.7 (01-02)	7
Methyl-parathion and ethyl-parathion	Organophosphorus pesticide	<i>p</i> -Nitrophenol (PNP)	NC (01-02)	3.71 (01-02)	2 (for methyl-parathion only)
Chlorpyrifos and chlorpyrifos-methyl	Organophosphorus pesticide	3,5,6-Trichloro-2-pyridinol (TCPY)	1.77 (99-00) 1.76 (01-02)	10.0 (99-00) 12.4 (01-02)	56 (3 for chlorpyrifos-methyl)
Permethrin, cypermethrin, deltamethrin	Pyrethroid pesticide	3-Phenoxybenzoic acid (3PBA)	0.292 (99-00) 0.321 (01-02)	4.33(99-00) 3.32 (01-02)	>100
Cyfluthrin	Pyrethroid pesticide	4-Fluoro-3-phenoxybenzoic acid (4F3PBA)	NC (01-02)	< 0.2 (99-00; 01-02)	35
N,N-Diethyl- <i>m</i> -toluamide (DEET)	Benzamide insect repellent applied to clothing and skin	DEET	NC (01-02)	0.18 (01-02)	NA
Atrazine	Triazine herbicide	Atrazine mercapturate (AM)	NC (01-02)	< 0.3 (01-02)	>100
2,4-dichlorophenoxyacetic acid (2,4-D)	Chlorophenoxy acid herbicide	2,4-dichlorophenoxyacetic acid (2,4-D)	NC (01-02)	<0.95 (99-00) 1.27 (01-02)	>100 (many chemical forms used)
2,4,5-trichlorophenoxyacetic acid (2,4,5-T)	Chlorophenoxy acid herbicide	2,4,5-trichlorophenoxyacetic acid (2,4,5-T)	NC (01-02)	< 1.2 (99-00) <0.1 (01-02)	0

¹Total amounts measured during the indicated sampling cycle (year) during National Health and Nutrition Examination Survey (NHANES) and reported in the Fourth National Report on Human Exposure to Environmental Chemicals (CDC, 2009). Values not corrected for creatinine. "NC" indicates that the geometric mean could not be calculated because of the large number of non-detects.

²Number of registrations based on searches of the North Carolina Department of Agriculture and Consumer Services, Pesticide Section, Registration Database available at: <http://www.kellysolutions.com/NC/pesticideindex.asp>

Table II
Urinary Metabolite Data Summary Statistics

Agricultural Chemical (Urinary Metabolite)	Data Summary			MDL ¹ (ng/ul)	>= MDL		LLOQ ² (ng/ul)	>= LLOQ		ng/ml for >= LLOQ					
	N	% of data	Missing		N	%		N	%	Mean	SD	Min	Median	Max	Geometric Mean
Pirimiphos (DEAMPY)	360	99.72	1	0.32	55	15.28	1.0	16	4.44	2.81	1.97	1.02	2.16	7.16	— ³
Diazin (IMPY)	360	99.72	1	0.28	87	24.17	0.50	54	15	2.76	6.72	0.51	1.23	47.60	1.45
Parathion (PNP)	361	100	—	0.47	275	76.18	1.0	220	60.94	7.67	42.03	1.00	2.66	457.00	2.94
Chlorpyrifos (TCPY)	361	100	—	0.83	230	63.71	1.0	160	44.32	5.37	3.70	2.03	4.30	20.70	4.50
Permethrin, cypermethrin, deltamethrin (3-PBA)	360	99.72	1	0.30	244	67.78	1.0	154	42.78	3.34	4.49	1.01	1.90	30.70	2.29
Cyfluthrin (4F3PBA)	361	100	—	0.15	45	12.47	0.50	19	5.26	1.33	1.21	0.51	0.81	5.09	—
Diethyltoluamide (DEET)	360	99.72	1	0.16	336	93.33	0.50	293	81.39	7.21	21.68	0.51	1.58	254.00	2.23
Atrazine (AM)	360	99.72	1	0.08	22	6.11	0.25	7	1.94	0.87	1.24	0.25	0.40	3.66	—
2,4-dichlorophenoxyacetic acid (2,4-D)	361	100	—	0.21	138	38.23	0.050	60	16.62	2.05	2.98	0.52	1.05	18.60	1.28
2,4,5-trichlorophenoxyacetic acid (2,4,5-T)	361	100	—	0.26	0	—	0.50	0	—	—	—	—	—	—	—

¹ MDL = Method Detection Limit calculated as 3.14 times the standard deviation of extracts from seven samples of urine spiked to contain 0.25 ng/mL.

² LLOQ = Lower Limit of Quantification defined by the lowest point of the calibration curve.

³ Geometric mean was not calculated because of the % > LLOQ for these analytes.

Table III
Bivariate Associations between Season and Metabolite Detection^a

Metabolite	Detect	n (col%)			p-value
		Early Season (Jun. to mid-Jul.; 100 participants)	Mid-Season (Mid-Jul. to Aug.; 164 participants)	Late Season (Sept. to Oct.; 94 participants)	
Pirimiphos (DEAMPY)	No	89(89.9)	132(80.5)	82(87.2)	0.090
	Yes	10(10.1)	32(19.5)	12(12.8)	
Diazinon (IMPY)	No	82(82.8)	119(72.6)	70(74.5)	0.16
	Yes	17(17.2)	45(27.4)	24(25.5)	
Parathion (PNP)	No	24(24)	31(18.9)	31(33)	0.039
	Yes	76(76)	133(81.1)	63(67)	
Chlorpyrifos (TCPY)	No	32(32)	61(37.2)	38(40.4)	0.47
	Yes	68(68)	103(62.8)	56(59.6)	
Permethrin, cypermethrin, deltamethrin (3-PBA)	No	43(43)	43(26.4)	30(31.9)	0.02
	Yes	57(57)	120(73.6)	64(68.1)	
Cyfluthrin (4F3PBA)	No	92(92)	142(86.6)	80(85.1)	0.29
	Yes	8(8)	22(13.4)	14(14.9)	
Diethyltoluamide (DEET)	No	11(11.1)	12(7.3)	0(0)	0.0059
	Yes	88(88.9)	152(92.7)	94(100)	
Atrazine (AM)	No	93(93.9)	152(92.7)	90(95.7)	0.62
	Yes	6(6.1)	12(7.3)	4(4.3)	
2,4-dichlorophenoxyacetic acid (2,4-D)	No	62(62)	96(58.5)	63(67)	0.40
	Yes	38(38)	68(41.5)	31(33)	

^a Season data were missing for 3 participants.

Table IV
Bivariate Associations between Specific Violations in Each Domain and Metabolite Detects (n = 361 Farmworkers)^a

Violation	IMPY			TCPY			PNP		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
Sleeping Room size ^b : n(%)									
No	193(71.22)	65(75.58)	0.43	85(64.89)	174(76.65)	0.016	55(63.95)	204(75)	0.046
Yes	78(28.78)	21(24.42)		46(35.11)	53(23.35)		31(36.05)	68(25)	
Proper bed provision: n(%)									
No	204(75.28)	64(74.42)	0.87	88(67.18)	181(79.74)	0.0081	67(77.91)	202(74.26)	0.50
Yes	67(24.72)	22(25.58)		43(32.82)	46(20.26)		19(22.09)	70(25.74)	
Showerhead adequacy: n(%)									
No	254(93.73)	82(95.35)	0.58	126(96.18)	211(92.95)	0.21	83(96.51)	254(93.38)	0.28
Yes	17(6.27)	4(4.65)		5(3.82)	16(7.05)		3(3.49)	18(6.62)	
Hand washbasin adequacy: n(%)									
No	209(77.41)	65(76.47)	0.86	107(82.31)	168(74.34)	0.084	70(82.35)	205(75.65)	0.20
Yes	61(22.59)	20(23.53)		23(17.69)	58(25.66)		15(17.65)	66(24.35)	
Kitchen cleanliness: n(%)									
No	210(79.25)	66(76.74)	0.62	93(72.09)	184(82.51)	0.021	70(82.35)	207(77.53)	0.34
Yes	55(20.75)	20(23.26)		36(27.91)	39(17.49)		15(17.65)	60(22.47)	
Laundry tub/washing machine adequacy: n(%)									
No	204(77.27)	59(69.41)	0.14	101(79.53)	162(72.65)	0.15	66(79.52)	197(73.78)	0.29
Yes	60(22.73)	26(30.59)		26(20.47)	61(27.35)		17(20.48)	70(26.22)	
Cockroach infestation in bathroom, sleeping rooms, kitchen, laundry room: n(%)									
No	79(29.15)	18(20.93)	0.13	37(28.24)	61(26.87)	0.78	31(36.05)	67(24.63)	0.038
Yes	192(70.85)	68(79.07)		94(71.76)	166(73.13)		55(63.95)	205(75.37)	
Rodent infestation in bathroom, sleeping rooms, kitchen, laundry room, other room: n(%)									
			0.85			0.75			0.25

Violation	IMPY			TCPY			PNP		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
No	118(44.19)	37(43.02)		55(42.97)	101(44.69)		42(49.41)	114(42.38)	
Yes	149(55.81)	49(56.98)		73(57.03)	125(55.31)		43(50.59)	155(57.62)	
Violation									
3-PBA									
4F3PBA									
2,4-D									
Sleeping Room size ^b : n(%)	No = 116	Yes = 244	P-value	No = 316	Yes = 45	P-value	No = 223	Yes = 138	P-value
No	78(67.24)	180(74.69)	0.14	229(72.93)	30(68.18)	0.51	161(72.85)	98(71.53)	0.79
Yes	38(32.76)	61(25.31)		85(27.07)	14(31.82)		60(27.15)	39(28.47)	
Proper bed provision: n(%)			0.35			0.44			0.31
	91(78.45)	178(73.86)		238(75.8)	31(70.45)		162(73.3)	107(78.1)	
	25(21.55)	63(26.14)		76(24.2)	13(29.55)		59(26.7)	30(21.9)	
Showerhead adequacy: n(%)			0.18			0.69			0.99
	112(96.55)	224(92.95)		295(93.95)	42(95.45)		208(94.12)	129(94.16)	
	4(3.45)	17(7.05)		19(6.05)	2(4.55)		13(5.88)	8(5.84)	
Hand washbasin adequacy: n(%)			0.43			0.70			0.81
	92(80)	183(76.25)		242(77.56)	33(75)		169(76.82)	106(77.94)	
	23(20)	57(23.75)		70(22.44)	11(25)		51(23.18)	30(22.06)	
Kitchen cleanliness: n(%)			0.028			0.98			0.97
	97(85.84)	180(75.63)		244(78.71)	33(78.57)		173(78.64)	104(78.79)	
	16(14.16)	58(24.37)		66(21.29)	9(21.43)		47(21.36)	28(21.21)	
Laundry tub/washing machine adequacy: n(%)			0.40			0.98			0.23
	88(77.88)	174(73.73)		230(75.16)	33(75)		167(77.31)	96(71.64)	
	25(22.12)	62(26.27)		76(24.84)	11(25)		49(22.69)	38(28.36)	
Cockroach infestation in bathroom, sleeping rooms, kitchen, laundry room: n(%)			0.039			0.029			0.71
	40(34.48)	58(24.07)		92(29.3)	6(13.64)		62(28.05)	36(26.28)	

Violation	IMPY			TCPY			PNP		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
Yes	76(65.52)	183(75.93)		222(70.7)	38(86.36)		159(71.95)	101(73.72)	
Rodent infestation in bathroom, sleeping rooms, kitchen, laundry room, other room: n(%)									
No	52(44.83)	104(43.88)		140(45.16)	16(36.36)		98(44.95)	58(42.65)	
Yes	64(55.17)	133(56.12)	0.87	170(54.84)	28(63.64)	0.27	120(55.05)	78(57.35)	0.67

^aNo = no violations; yes = violation noted

^bSleeping room size violation if there is less than 50 square feet per person.

Table V
Bivariate Associations between Number of Grouped Violations and Metabolite Detects (n = 361 Farmworkers)

	IMPY Detect			TCPY Detect			PNP Detect		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
Camp violation: n(%)									
0	19(7.01)	10(11.63)	0.21	10(7.63)	19(8.37)	0.98	12(13.95)	17(6.25)	0.12
1	110(40.59)	40(46.51)		57(43.51)	94(41.41)		37(43.02)	114(41.91)	
2	99(36.53)	22(25.58)		43(32.82)	78(34.36)		25(29.07)	96(35.29)	
3 or 4	43(15.87)	14(16.28)		21(16.03)	36(15.86)		12(13.95)	45(16.54)	
Sleeping room violation: mean(sd)	3.84(1.93)	3.83(2)	0.94	4(1.88)	3.74(1.97)	0.22	3.64(1.93)	3.89(1.94)	0.29
Bathroom violation: mean(sd)	4.45(1.66)	4.76(1.85)	0.15	4.23(1.55)	4.68(1.78)	0.015	4.22(1.57)	4.61(1.75)	0.066
Kitchen violation: mean(sd)	2.25(1.44)	2.36(1.47)	0.56	2.36(1.52)	2.23(1.4)	0.41	2.02(1.53)	2.36(1.41)	0.062
Laundry violation: n(%)									
0	73(26.94)	26(30.23)	0.67	38(29.01)	61(26.87)	0.20	21(24.42)	78(28.68)	0.72
1	125(46.13)	35(40.7)		64(48.85)	96(42.29)		41(47.67)	119(43.75)	
2 to 4	73(26.94)	25(29.07)		29(22.14)	70(30.84)		24(27.91)	75(27.57)	
General housing violation: mean(sd)	3.08(1.57)	3.09(1.39)	0.93	3.11(1.47)	3.06(1.57)	0.79	2.88(1.57)	3.14(1.52)	0.18
Total violations: mean(sd)	11.46(3.3)	11.33(3.02)	0.74	11.53(3.16)	11.35(3.28)	0.62	10.8(3.19)	11.61(3.23)	0.043
3-PBA detect				4F3PBA detect			2,4-D detect		
	No = 116	Yes = 244	P-value	No = 316	Yes = 45	P-value	No = 223	Yes = 138	P-value
Camp violation: n(%)									
0	9(7.76)	20(8.3)	0.34	27(8.6)	2(4.55)	0.81	18(8.14)	11(8.03)	0.58
1	57(49.14)	94(39)		132(42.04)	19(43.18)		99(44.8)	52(37.96)	
2	34(29.31)	87(36.1)		106(33.76)	15(34.09)		72(32.58)	49(35.77)	
3 or 4	16(13.79)	40(16.6)		49(15.61)	8(18.18)		32(14.48)	25(18.25)	
Sleeping room violation: mean(sd)	3.66(1.98)	3.9(1.92)	0.26	3.77(1.92)	4.25(2.09)	0.13	3.81(1.89)	3.86(2.03)	0.82

	IMPY Detect			TCPY Detect			PNP Detect		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
Bathroom violation: mean(sd)	4.29(1.65)	4.62(1.74)	0.093	4.4(1.63)	5.32(2.08)	0.0072	4.57(1.77)	4.44(1.63)	0.49
Kitchen violation: mean(sd)	2.14(1.49)	2.34(1.43)	0.22	2.23(1.43)	2.59(1.56)	0.12	2.22(1.5)	2.37(1.36)	0.33
Laundry violation: n(%)			0.38			0.32			0.76
0	34(29.31)	64(26.56)		91(28.98)	8(18.18)		64(28.96)	35(25.55)	
1	46(39.66)	114(47.3)		138(43.95)	22(50)		96(43.44)	64(46.72)	
2 to 4	36(31.03)	63(26.14)		85(27.07)	14(31.82)		61(27.6)	38(27.74)	
General housing violation: mean(sd)	2.91(1.6)	3.15(1.49)	0.15	3(1.5)	3.64(1.64)	0.0096	3.03(1.53)	3.15(1.53)	0.47
Total violations: mean(sd)	10.96(3.14)	11.61(3.25)	0.071	11.25(3.14)	12.59(3.64)	0.0099	11.35(3.22)	11.53(3.27)	0.62

Table VI
Bivariate Associations between Nonviolation Housing Characteristics or Individual Behaviors and Metabolite Detects (n = 361 Farmworkers)

	IMPY			TCPY			PNP	
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275
Housing Type: n(%)								
Apartment	3(1.1)	1(1.15)	0.74	2(1.53)	2(0.87)	0.31	2(2.33)	2(0.73)
Barracks	87(31.87)	23(26.44)		36(27.48)	74(32.17)		26(30.23)	84(30.55)
House	115(42.12)	37(42.53)		63(48.09)	89(38.7)		38(44.19)	114(41.45)
Trailer	68(24.91)	26(29.89)		30(22.9)	65(28.26)		20(23.26)	75(27.27)
Number of people in sleeping room:								
1	42(15.38)	14(16.09)	0.83	16(12.21)	40(17.39)	0.074	14(16.28)	42(15.27)
2	101(37)	28(32.18)		50(38.17)	79(34.35)		27(31.4)	102(37.09)
3	60(21.98)	19(21.84)		22(16.79)	57(24.78)		15(17.44)	64(23.27)
4 or more	70(25.64)	26(29.89)		43(32.82)	54(23.48)		30(34.88)	67(24.36)
Insecticides used in house: n(%)								
No	180(66.67)	57(67.06)	0.95	86(68.25)	152(66.09)	0.68	60(70.59)	178(65.68)
Yes	90(33.33)	28(32.94)		40(31.75)	78(33.91)		25(29.41)	93(34.32)
Drink Tapwater: n(%)								
No	56(20.59)	17(19.77)	0.87	28(21.54)	45(19.65)	0.67	13(15.29)	60(21.9)
Yes	216(79.41)	69(80.23)		102(78.46)	184(80.35)		72(84.71)	214(78.1)
Change clothes in sleeping room: n(%)								
No	167(61.62)	41(47.13)	0.017	72(55.38)	136(59.39)	0.46	52(61.18)	156(56.93)
Yes	104(38.38)	46(52.87)		58(44.62)	93(40.61)		33(38.82)	118(43.07)
Store clothes in sleeping room: n(%)								
No	164(60.29)	41(47.13)	0.031	82(63.08)	124(53.91)	0.091	54(63.53)	152(55.27)
Yes	108(39.71)	46(52.87)		48(36.92)	106(46.09)		31(36.47)	123(44.73)
Store shoes in sleeping room: n(%)								
			0.041			0.20		
								0.34

	IMPY			TCPY			PNP				
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value		
No	209(76.56)	57(65.52)		102(77.86)	165(71.74)		67(77.91)	200(72.73)			
Yes	64(23.44)	30(34.48)		29(22.14)	65(28.26)		19(22.09)	75(27.27)			
Time until shower: n(%)			0.23			0.32			0.64		
0-15 min	76(27.84)	26(29.89)		33(25.19)	70(30.43)		24(27.91)	79(28.73)			
16-30 min	92(33.7)	21(24.14)		47(35.88)	66(28.7)		24(27.91)	89(32.36)			
>= 31 min	105(38.46)	40(45.98)		51(38.93)	94(40.87)		38(44.19)	107(38.91)			
Need to wait to shower due to lack of showerheads/hot water: n(%)			0.076			0.16			0.61		
No	194(71.06)	53(60.92)		84(64.12)	164(71.3)		61(70.93)	187(68)			
Yes	79(28.94)	34(39.08)		47(35.88)	66(28.7)		25(29.07)	88(32)			
			3-PBA	4F3PBA			2,4-D				
			No = 116	Yes = 244	P-value	No = 316	Yes = 45	P-value	No = 223	Yes = 138	P-value
Housing Type: n(%)			0.40			0.71			0.39		
Apartment	1(0.86)	3(1.23)		3(0.95)	1(2.22)		3(1.35)	1(0.72)			
Barracks	31(26.72)	79(32.38)		95(30.06)	15(33.33)		72(32.29)	38(27.54)			
House	47(40.52)	104(42.62)		136(43.04)	16(35.56)		96(43.05)	56(40.58)			
Trailer	37(31.9)	58(23.77)		82(25.95)	13(28.89)		52(23.32)	43(31.16)			
Number of people in sleeping room:			0.058			0.85			0.083		
1	25(21.55)	31(12.7)		50(15.82)	6(13.33)		26(11.66)	30(21.74)			
2	40(34.48)	89(36.48)		114(36.08)	15(33.33)		84(37.67)	45(32.61)			
3	18(15.52)	61(25)		67(21.2)	12(26.67)		50(22.42)	29(21.01)			
4 or more	33(28.45)	63(25.82)		85(26.9)	12(26.67)		63(28.25)	34(24.64)			
Insecticides used in house: n(%)			0.11			0.59			0.53		
No	83(72.81)	155(64.32)		207(66.35)	31(70.45)		143(65.6)	95(68.84)			
Yes	31(27.19)	86(35.68)		105(33.65)	13(29.55)		75(34.4)	43(31.16)			
Drink Tapwater: n(%)			0.07			0.46			0.65		

	IMPY			TCPY			PNP		
	No = 273	Yes = 87	P-value	No = 131	Yes = 230	P-value	No = 86	Yes = 275	P-value
No	17(14.78)	56(23.05)		62(19.75)	11(24.44)		47(21.08)	26(19.12)	
Yes	98(85.22)	187(76.95)		252(80.25)	34(75.56)		176(78.92)	110(80.88)	
Change clothes in sleeping room: n(%)									
No	69(60)	138(56.79)	0.57	183(58.1)	25(56.82)	0.87	130(58.3)	78(57.35)	0.86
Yes	46(40)	105(43.21)		132(41.9)	19(43.18)		93(41.7)	58(42.65)	
Store clothes in sleeping room: n(%)									
No	67(58.26)	138(56.56)	0.76	180(57.14)	26(57.78)	0.94	122(54.71)	84(61.31)	0.22
Yes	48(41.74)	106(43.44)		135(42.86)	19(42.22)		101(45.29)	53(38.69)	
Store shoes in sleeping room: n(%)									
No	89(76.72)	177(72.54)	0.40	239(75.63)	28(62.22)	0.055	165(73.99)	102(73.91)	0.99
Yes	27(23.28)	67(27.46)		77(24.37)	17(37.78)		58(26.01)	36(26.09)	
Time until shower: n(%)									
0-15 min	33(28.45)	70(28.69)	0.84	90(28.48)	13(28.89)	0.31	63(28.25)	40(28.99)	0.74
16-30 min	34(29.31)	78(31.97)		103(32.59)	10(22.22)		73(32.74)	40(28.99)	
>= 31 min	49(42.24)	96(39.34)		123(38.92)	22(48.89)		87(39.01)	58(42.03)	
Need to wait to shower due to lack of showerheads/hot water: n(%)									
No	78(67.24)	169(69.26)	0.70	215(68.04)	33(73.33)	0.47	153(68.61)	95(68.84)	0.96
Yes	38(32.76)	75(30.74)		101(31.96)	12(26.67)		70(31.39)	43(31.16)	