

The Quality of Drinking Water in North Carolina Farmworker Camps

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Water is the essence of human life, part of every cell and vital for every function of our body. The World Health Organization has declared access to a regular supply of safe water a basic human right which has to be respected, protected, and fulfilled.¹ The consequences of failing to do so are alarming: diarrheal diseases causing 2 million annual deaths worldwide; outbreaks of cholera, legionella, and other waterborne pathogens; and cancer and tooth and skeletal damage because of unsafe levels of arsenic and fluoride.² Developing countries carry the main burden of these diseases. However, provision of safe water is a global responsibility shared by individuals as well as local, state, and federal governments. For this purpose, international and local guidelines and regulations have been created to ensure drinking water quality.^{3–5}

Migrant farmworkers represent a particularly vulnerable population within the US for diseases resulting from unsafe drinking water, in conjunction with other environmental and occupational hazards.⁶ The large number of migrant farmworkers that labor in the United States has little control of their living environments, including the water available for drinking, bathing, and laundry.⁷ Although federal and state regulations have been developed to ensure adequate and safe housing for migrant farmworkers, the standards are often not met.⁸ The few studies published on water quality indicate that contamination of drinking water is a continuing concern.⁹ Although pesticides and nitrates contained in drinking water represent a recognized problem, this study focuses on fecal contamination of water.¹⁰ Total coliform were found in drinking water of half of 30 farmworker camps tested in North Carolina in 1989.¹¹ A US Environmental Protection Agency (EPA) investigation into the drinking water quality of migrant camps in Wisconsin revealed that water in 67% of camps contained total coliform bacteria in 1997.¹² Two of 5

Objectives. The purpose of this study was to assess water quality in migrant farmworker camps in North Carolina and determine associations of water quality with migrant farmworker housing characteristics.

Methods. We collected data from 181 farmworker camps in eastern North Carolina during the 2010 agricultural season. Water samples were tested using the Total Coliform Rule (TCR) and housing characteristics were assessed using North Carolina Department of Labor standards.

Results. A total of 61 (34%) of 181 camps failed the TCR. Total coliform bacteria were found in all 61 camps, with *Escherichia coli* also being detected in 2. Water quality was not associated with farmworker housing characteristics or with access to registered public water supplies. Multiple official violations of water quality standards had been reported for the registered public water supplies.

Conclusions. Water supplied to farmworker camps often does not comply with current standards and poses a great risk to the physical health of farmworkers and surrounding communities. Expansion of water monitoring to more camps and changes to the regulations such as testing during occupancy and stronger enforcement are needed to secure water safety. (*Am J Public Health.* 2012;102:e49–e54. doi:10.2105/AJPH.2012.300738)

farmworker camps located in Colorado were also tested positive for total coliform in 2002.¹³ Breaches in water safety are persistent and widespread.⁹

This study describes the quality of drinking water and tests its association to housing characteristics and living conditions in 181 migrant farmworker camps located in eastern North Carolina during the 2010 agricultural season. The results are further compared with previously published data of water quality.¹¹

METHODS

This project was based on a conceptually based model of community-based participatory research for involving community members in the assessment of farmworker housing and water quality, and using research results to address public health policy. This model of community-based participatory research operationalizes participation, including differentiating modes of community participation in research, and delineates the domains of research in which community members are involved, such

as consultation, strategic planning, implementation, and dissemination. It defines community-based participatory research as translational science in which results are provided to community members in a usable format and are used to address public health policy.^{14,15}

We used a cross-sectional study design to document housing quality and exposures to contaminated water, pesticides, and allergens in farmworker camps and homes. The presented data focus on the quality of water provided to migrant farmworkers and the characteristics of their respective residences.

Migrant Farmworkers

A migrant farmworker is defined by having established a temporary, mostly seasonal residence for work in agriculture. Although the exact number of migrant farmworkers is not known, approximately 1.01 million hired farmworkers work in the United States based on data from the 2006 Current Population Survey.¹⁶ The majority are Hispanic or Latino, with 84% of migrant and seasonal farmworkers in the United States self-identified as

Hispanics, and 75% of all farmworkers having been born in Mexico, 23% in the United States, 2% in Central America, and 1% in other countries.¹⁷ The challenges facing migrant farmworkers are multifaceted; lack of social support, stress of adaptation, discrimination, economic and material difficulties, rootlessness, language and literacy barriers, and limited or no access to health care all contribute to the vulnerability of this group.^{6-8,11} These factors are further amplified by the unauthorized work status of about half of these farmworkers.¹⁸

Selection of Camp Settings and Recruitment of Farmworkers

A total of 186 migrant farmworker camps were surveyed during the 2010 growing season (June to October 2010) in 16 eastern North Carolina counties: Caswell, Craven, Cumberland, Duplin, Edgecombe, Greene, Halifax, Harnett, Johnston, Lenoir, Nash, Person, Sampson, Wake, Wayne, and Wilson. Camps were defined as residence areas occupied largely by unaccompanied male workers. These dwellings included barracks and other communal residences or clusters of residences where workers shared housing facilities. Lists of camps were obtained from the North Carolina Farmworkers Project and partnering clinics (Carolina Family Health Center, Kinston Community Health Center, Piedmont Health Services, Inc.). Over the course of data collection, field supervisors expanded the list as they encountered new camps. All identified camps were contacted to participate in the study by directly approaching the farmworkers residing in the camp. The farmworkers were informed about the study, including the goals, involvement expected, and risks of participation. Individuals agreeing to participate gave written consent. Reasons for refusal by individual farmworkers were documented, if provided.

Data Collection

Trained staff members, who were fluent Spanish speakers, completed interviews, housing assessments, and water sampling. Interviews were performed with 2 residents in each participating camp, and a camp assessment was conducted with the assistance of a third resident farmworker. Interviews assessed demographic information, housing features, and

perceptions of housing quality. 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 pretested with 4 male migrant farmworkers. All materials were revised based on the field test.

Interviews assessed participant personal characteristics, housing features, and perceptions of housing quality. Farmworkers who completed the interviews assisted with an assessment of their sleeping rooms. Interviews took approximately 90 minutes to complete.

For the housing assessment, data collectors 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 included a 129-item housing assessment form to assess compliance with 32 North Carolina Department of Labor (NCDOL) Migrant Housing Inspection standards.¹⁸ Thirteen additional NCDOL standards were not assessed because of seasonality (e.g., heating) or practicability (e.g., hot water supply testing requiring prior usage). The 32 standards tested were divided into the categories:

1. housing site,
2. structures,
3. kitchen,
4. toilets,
5. laundry and bathing,
6. heating,
7. water and sewer,
8. garbage,
9. pests (cockroach, rodents),
10. health, and
11. general duty.

The posting of the migrant housing certificate in a place accessible to all the migrant residents as mandated by Section 0200 of the North Carolina Administrative Code was documented.¹⁸ Data collectors also assessed 49 nonmandated housing items such as public-registered water source, proximity of residences to livestock, standing water on the camp grounds, and overall camp cleanliness.

Water samples were collected according to the guidelines outlined by the Public Water Supply Section of the North Carolina Department of Environment and Natural Resources.¹⁹ Samples were collected from the kitchen faucet or another faucet if the kitchen faucet was not accessible. Data collectors first cleaned the faucet with an alcohol wipe and then let the water run for 5 minutes before sampling. Water was collected in sterile laboratory-provided containers. The containers were opened at the time of collection, and data collectors were trained to avoid contamination by not touching the inside of the lid, rim, or container with either their fingers or the faucet itself. Housing assessment and water collection took approximately 60 minutes.

Measures

Water quality is the outcome measure for this study. The water samples were delivered to state-certified laboratories within 24 hours, where the samples were tested for total coliforms and *Escherichia coli* following standard method 9223 (total coliform rule [TCR]).²⁰ The labs used a selective and differential medium for the determination of the presence or absence of total coliforms and *E. coli* in drinking water based on enzyme activity (Colilert [IDEXX Laboratories, Inc, Westbrook, Maine], Colitag [CPI International, Santa Rosa, CA]).^{21,22} Both tests are EPA certified and standardized.

Quality control procedures consisted of a total of 23 duplicates (13% of the entire sample) collected across the counties. Actual samples and duplicate samples were obtained simultaneously, and then a special identification was created to blind the laboratory. The purpose of the repeat measures was to test the laboratories' accuracy and the potential of sample contamination.

Camp water sources were identified as non-transient, noncommunity public (NTNC) water systems and other systems using the Web-accessible water registry data and geographic information system (GIS) coordinates for the individual camps.¹⁹ An NTNC public water system is not a community system, but regularly serves at least 25 of the same people for more than 6 months per year. They are regulated by the Safe Drinking Water Act of the EPA and the North Carolina Rules

Governing Public Water Systems.^{4,23} The identification of NTNC and other systems using GIS data and public records allowed comparison of the water quality data by system set-up without revealing the identity of the camp locations to second parties. The Web-accessible data also provided data on previously reported water-quality violations for each NTNC.²⁴

The North Carolina Retrieval and Observations Network of the Southeast Database (CRONOS) requested a rainfall data set for all the counties in the study (<http://www.nc-climate.ncsu.edu/cronos>). The data set contained information from various weather sensors spread across the study counties. A near analysis in ESRI ArcInfo (Version 9.3 ESRI Redlands, CA) was performed to determine which sensor was the closest to each respective camp location. The near analysis was conducted in the GIS lab at the Center for Community Safety at Winston-Salem State University. A rainfall summation (total in inches) for the 7 days prior to data collection per closest sensor for each camp was calculated and compared with the water quality data. Furthermore, the location of each camp was mapped to assess potential geographic clustering based on water testing results.

Several additional camp characteristic measures were included in the analysis as potential correlates of water quality. Data collection time had the values of early season (June through mid-July), mid-season (mid-July through August), and late season (September and October) for when the camp was assessed. Housing type was based on the presence or absence of barracks in the camp. Camps with barracks could also have nonbarrack housing, such as houses and trailers. Nonbarracks camps had only houses or trailers. Number of camp residents was divided into 3 categories: 1 to 10, 11 to 20, and 21 or more. The number of housing units in the camp had the assigned values of 1, 2, and 3 or more. Presence of female residents was a dichotomous measure. H-2A status was a dichotomous measure indicating whether any farmworkers with H-2A visas were living in the camp. The H-2A program is currently the only agricultural guest-worker program in the US allowing individuals' employment in specific agricultural areas for a predetermined time period. Although the

number of H-2A visa holders varies by state, North Carolina has a relatively large group of farmworkers working under this visa program. North Carolina Department of Labor (NCDOL) inspection certificate posted was a dichotomous measure. All camps inspected by the NCDOL should post the inspection certificate; because all of the camps included in this study housed migrant farmworkers, all should have been inspected. Camp violations of NCDOL standards had the values 4 to 10, 11 or 12, and 13 or more.²⁵ Overall cleanliness of dwelling was a dichotomous measure based on the data collector's evaluation. Pest infestation was a dichotomous measure indicating the presence of cockroaches or rodents in the dwelling. Standing water in camp was a dichotomous measure indicating whether the data collector observed standing water. Proximity to livestock shelters was also a dichotomous measure indicating whether livestock shelters were visible from the camp.

Statistical Analysis

Descriptive statistics (frequencies and percentages) were used to describe the camp characteristics. We used the χ^2 test to examine bivariate associations between camp characteristics and water quality. A *P* value of less than .05 was considered statistically significant. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

A total of 186 camps were enrolled in the study. Residents in an additional 36 camps declined to participate, and the grower refused to permit participation in another 4 camps. The resulting camp participation rate was 82.3% (186/226). In 5 of the 186 participating camps data collection was not completed because of intervention by the grower. Therefore, the final sample for this analysis included 181 (80%) camps. Reasons given by individual farmworkers for nonparticipation ranged from being too tired or not interested, to cooking, eating, or drinking, to no reason.

Table 1 summarizes the characteristics of the enrolled camps. Camps having an NTNC public water source had more housing units (NTNC 76% \geq 3 housing units vs non-NTNC 11% \geq 3 housing units), and more occupants

(NTNC 80% $>$ 20 occupants vs non-NTNC 18% $>$ 20 occupants) living in barracks (NTNC 90% barracks vs non-NTNC 23% barracks) than non-NTNC camps (*P* $<$.05). No difference was detected in posting frequency of the NCDOL certificate (NTNC 33% posted vs non-NTNC 35% posted; *P* $>$.05).

Water Testing Results

A total of 61 (34%) out of 181 camps failed the North Carolina water quality requirements. Total coliform bacteria were found in the water of all 61 of these camps, and *E. coli* was detected in 2. The 23 quality control samples matched the results (14 repeated samples negative, 9 repeated samples positive) found in the original probes.

Associations between Water Quality and Camp Characteristics

Bivariate analyses of the water testing results (outcome) and camp characteristics are summarized in Table 1. None showed statistically significant associations including NCDOL certification or having an NTNC public water source. Of the 21 camps that received water from the NTNC system, 18 (86%) had at least 1 monitoring violation and 15 (71%) had at least 1 positive TCR test results for the years 2009 and 2010. Only 1 NTNC camp passed the water testing requirements. No geographic clustering of camps failing the water testing was found.

DISCUSSION

Testing the quality of drinking water is essential to protect the public from communicable diseases.⁴ The purpose of this project was to assess the housing conditions of migrant farmworkers in eastern North Carolina. As part of the assessment, the drinking water available to workers in their residences was tested. The Migrant Housing Act of North Carolina § 95–225 (c) Adoption of standards and interpretations outlines that

the Commission for Public Health shall adopt and the Department of Environment and Natural Resources shall enforce rules that establish water quality and water sanitation standards for migrant housing under this Article.¹⁸

Providers of the housing are responsible for supplying adequate and sanitary water.¹⁸ Drinking water was tested using the TCR, monitoring

TABLE 1—Water Testing Results (TCR) by Selected Variables for Data Collection Time, and Camp Characteristics, Migrant Farmworkers, Eastern North Carolina, 2010

Camp Characteristics	Total, No. (%)	TCR Passed, No. (%)	TCR Failed, No. (%)
Water source*			
NTNC systems	21 (12)	14 (67)	7 (33)
Other systems	160 (88)	105 (66)	55 (34)
Total rainfall 1 wk prior to water sampling,* in			
≤ 1	106 (59)	68 (64)	38 (36)
> 1	69 (41)	47 (68)	22 (32)
Data collection time*			
Early season (June–mid-July)	50 (28)	34 (68)	16 (32)
Mid season (mid-July–August)	83 (45)	55 (66)	28 (34)
Late season (September–October)	48 (27)	30 (63)	18 (37)
Housing type*			
Barracks	55 (31)	38 (70)	17 (31)
Nonbarracks	126 (69)	81 (64)	45 (36)
Occupants*			
1–10	88 (49)	62 (70)	26 (30)
11–20	47 (26)	25 (53)	22 (47)
≥ 21	46 (25)	32 (70)	14 (30)
Housing units in camp*			
1	112 (61)	72 (64)	40 (36)
2	36 (20)	26 (72)	10 (28)
≥ 3	33 (19)	21 (64)	12 (36)
Female residents present*	44 (24)	26 (59)	18 (41)
Workers with H-2A visas present*	123 (68)	85 (69)	38 (31)
NCDOL certificate of inspection posted*	62 (34)	39 (63)	23 (37)
Camp violations** of NCDOL standards*			
4–10	64 (35)	43 (67)	21 (33)
11–12	56 (31)	39 (70)	17 (30)
≥ 13	61 (34)	37 (61)	24 (39)
Overall cleanliness rated clean*	115 (64)	75 (65)	40 (35)
Pest Infestation Present*	44 (24)	26 (59)	18 (41)
Standing Water in Camp Present*	9 (5)	6 (67)	3 (33)
Livestock Shelters Visible from Camp*	21 (12)	14 (67)	7 (33)

Note. NTNC = nontransient, noncommunity public; TCR = Total Coliform Rule. The sample size was n = 181 camps.

*P > .05 in bivariate analysis—not significant.

**Excluding Water Violations (TCR)

for total coliform and *E. coli* contamination.^{18,26} Using the standardized water testing procedure during the growing season, our study revealed that one third of residences failed the TCR. Coliform bacteria and *E. coli* were detected indicating water contamination with human pathogens. This not only affects farmworkers but also puts the surrounding community consuming water from the same sources at risk.

The literature describing water quality in migrant farmworker camps is sparse.^{9,11–13}

Vela-Acosta et al. reported total coliform in 2 out of 5 farmworker camps located in Colorado in 2002.¹³ In 1988 and 1989 Ciesielski et al. found total coliform in 44% and 50% (second year) of 27 and 30 farmworker camps in North Carolina.¹¹ Our study confirms the findings and indicates the persistence of this problem over 2 decades.

The consequences of consuming contaminated water are dire. In a review of drinking-water-associated outbreaks from 1971 to

2006 in the United States, more than 577 000 persons were affected in 780 outbreaks.²⁷ Most suffered from gastrointestinal illnesses (685 [88%]) such as diarrhea or vomiting, followed by hepatitis A (29 [4%]), and acute respiratory illnesses (24 [3%]) (e.g., legionellosis). There were also rare illness types (15%) ranging from change in hair color to miscarriages. Water samples contained parasites (18%), nonlegionella bacteria (14%), chemicals (12%), viruses (8%), legionella (3%), and mixed causes (< 1%). However, no cause could be detected in most outbreaks (45%). Unfortunately, information regarding how farmworkers are affected by unsanitary water is very limited. One documented outbreak of typhoid fever occurred in a migrant farmworker camp in Dade County, Florida in 1973.²⁸ Two-hundred and forty-six individuals required hospitalization during the outbreak but, fortunately, none died. The water supply system was later identified as the source. The lack of reports does not rule out the existence of outbreaks. Reasons may be small camp sites resulting in low case counts, the often self-limiting character of the diseases, the legal status of farmworkers combined with barriers to health care access, or the nonexistence of a public reporting and documentation system for these settings.

Using the data collected during housing assessments, associations between camp site characteristics and water system failures were considered. None showed a significant connection with the water-testing outcomes. This is surprising for camps with NCDOL standard certification, and also for registered NTNC public water supply sources. NCDOL standards require water testing before occupancy. However, display of the NCDOL preoccupancy certification did not ensure sanitary water quality during occupancy. More than 2 decades ago Ciesielski et al. reported similar findings.¹¹ Only 1 camp inspected by the NCDOL before occupancy was cited for water violations followed by 44% and 50% camp failure rates during the 2 seasons studied. Receiving water from an NTNC registered source was also expected to provide higher quality water because of more frequent testing and control. However, there was no difference between failure rates of NTNC (7 of 21) and other water supplies (55 of 160). Citations for water

violations in the NTNC sources further revealed that more than 70% of the camps had at least 1 positive TCR result and 1 or more monitoring violations (TCR tests not performed) in 2009 and 2010. Only 1 of the 21 NTNC camps passed the requirements.

Why the 2 regulatory tools, NCDOL and NTNC standards, failed to protect farmworkers from contaminated water is not fully understood. Two factors may have contributed: timing of testing and enforcement of the rules. Inspecting camps only before occupancy did not ensure water safety. Therefore, testing during the growing season may improve compliance with the standards. For NTNC water supplies, more frequent testing is already part of the regulations. But enforcement appears to be weak, allowing providers to ignore water safety breaches or just not test at all. The scale of the penalties should urge providers to choose protection of consumers over indifference. Finding contaminated water in registered public water supply systems may also point toward substantial risks for the general community using similar sources.

There are limitations. The primary goal of this project was to assess the housing characteristics of migrant farmworkers in North Carolina including extensive sampling of the living spaces and exposure risks from infestation to pesticides. However, the water supply set-up was not documented in detail. This leaves open why water systems failed. The risk of water sample contamination during collection was minimized by following the standardized water collection protocol and repeated testing of the samples. The cross-sectional design provides a snapshot of the conditions found in the camps in 1 region over 1 season. Generalizations of the outcomes to other regions and seasons should be made with caution. However, the high number of recent TCR violations noted in registered NTNC camps over a 2-year period and similar results found in an investigation in North Carolina executed 2 decades ago point to a persistence of these problems.¹¹

This study revealed a major breach in housing safety for migrant farmworkers in rural North Carolina. One third of the camp sites investigated failed the TCR indicating a high likelihood of exposure to contaminated drinking water. The risk of physical harm further threatens the already vulnerable

population of migrant farmworkers but also residents in adjacent communities using similar water supply systems. Based on a previous assessment in the 1980s and our current findings in a much larger sample, it appears that existing regulations continue to fall short in securing mandated water safety requirements.^{9,11} Covering all migrant housing by NCDOL inspections, amending the regulations to water quality testing not only before but also during occupancy, and strengthening enforcement of these regulations may be the first steps to improve the water quality of migrant farmworker housing and their surrounding communities. ■

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This article was accepted February 9, 2012.

Contributors

W. E. Bischoff developed the study aim for water testing within the governing housing project, guided the data analysis and interpretation, and served as the lead author and editor of the article. M. Weir was the project manager, coordinated data collection, coding, and summaries, and critically reviewed and revised drafts of the article. P. Summers collected data, performed the GIS location analysis, and contributed to the revision of the article. H. Chen served as the biostatistician, performed the data analysis and drafted the statistical analysis section. S.A. Quandt contributed to the study design and interpretation of the findings, and critically reviewed and revised the article. A. K. Liebman provided essential insights in migrant farmworker policies and their interpretation, and critically reviewed and revised the article. T.A. Arcury was the principal investigator of the governing housing project; developed the study idea, design, and methodology; provided guidance of the data collection and analysis; and critically reviewed and provided feedback on the article.

Acknowledgments

Funding for the study was provided by the National Institute of Environmental Health Sciences (grant R01-ES012358).

Human Participant Protection

Institutional review board approval was obtained from the Wake Forest School of Medicine.

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