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Abstract

Background: Recent advances in molecular source tracking make answering questions from residents regarding their exposure to microbial contaminants from industrial hog operations (IHOs) possible. Associations between residential distance to IHOs and exposure can be addressed by measuring livestock-associated (*Staphylococcus aureus*) and pig-specific bacteria in the air, on household surfaces, and in participants' nasal and saliva swabs.

Objectives: Here we assess the mechanics, feasibility, capacity-building, and lessons learned during a pilot study employing this novel technology in community-based participatory research of bacterial exposure and human health.

Methods: Together, our team of academics and community members designed a field- and laboratory-based pilot study. Air samples, surface and human swabs, and questionnaires from households at varying distances from IHOs were collected. Data were assessed for completeness and quality by two independent reviewers. These metrics were defined as: missingness (completeness), incorrect data type (validity), out of range (validity), and outliers (accuracy).

Lessons Learned: While critical field equipment was obtained, and knowledge exchange occurred, leading to an increased capacity for future work, after review, 38 of 49 households were deemed eligible for inclusion in the study. Of eligible participants, 98% of required electronic survey questions were complete and 100% were valid; an improvement over prior work which employed paper surveys. While all human microbial and air samples were collected from

(abstract continues)

eligible households (n = 231), (5%) of environmental swabs were reported missing.

Conclusions: Using community-appropriate sampling protocols, a pilot study of residential exposure to bacteria from IHOs was completed. While high-quality data was collected from those eligible, we learned the necessity of early and continual data review.

Keywords

Industrial hog operation, Concentrated animal feeding operation, CAFO, Pig, Swine, Microbial source tracking environmental exposures, *Staphylococcus aureus*, Pig-2-Bac, Community-based participatory research

In rural southeastern North Carolina, residents have a litany of questions about how airborne contaminants from industrial hog operations (IHOs) impact their health and epidemiologists have also identified this as a research priority.[1] While researchers have attempted to determine a "safe" distance from IHO plumes, large differences in the distance at which bacteria and gases can be recovered have been reported.[2,3] With advances in molecular source tracking,[4] there is an opportunity to measure community exposure to livestock-associated (e.g., *Staphylococcus aureus*) and swine-specific (e.g., pig-specific bacteria [Pig-2-bac]) bacteria and subsequently the association between these markers and the prevalence of human health outcomes.[5] We used community-based participatory research (CBPR) to begin to fill this knowledge gap.

CBPR brings together academics and residents to solve community problems via science. A key tenet of CBPR is that stakeholder groups share equally in every iterative step from research design to dissemination (Figure 1). CBPR requires methodologies and skills different from traditional epidemiologic research, resulting in a dearth of publications,[6] even though CBPR collaborations can be exceedingly synergistic.

In our work, for example, academics at University of North Carolina at Chapel Hill first partnered with the Rural Empowerment Association for Community Help (REACH) to explore environmental justice issues in 2005.[7–10] Since then, we have added researchers from Johns Hopkins University to the collaboration due to an institutional change by a team member. A by-product of bringing in this additional academic institution was the ability to address added technical issues, as complementary Johns Hopkins faculty brought onboard have expertise in One Health and microbial air sampling. Based on recent work, researchers and the community now better understand the impact of *S. aureus* on skin and soft-tissue infections,[11,12] how IHO worker mask usage can modify that relationship,[13] how on-IHO conditions impact worker health,[14,15] and what modifiable factors IHOs can employ to protect those in close contact with pigs.[14,15]

The goal of this article is to report on the study design and methods, data quality and completeness, capacity-building, and lessons learned from a CBPR pilot study employing molecular source tracking to assess the distance bacteria can travel from an IHO and how that might impact neighboring

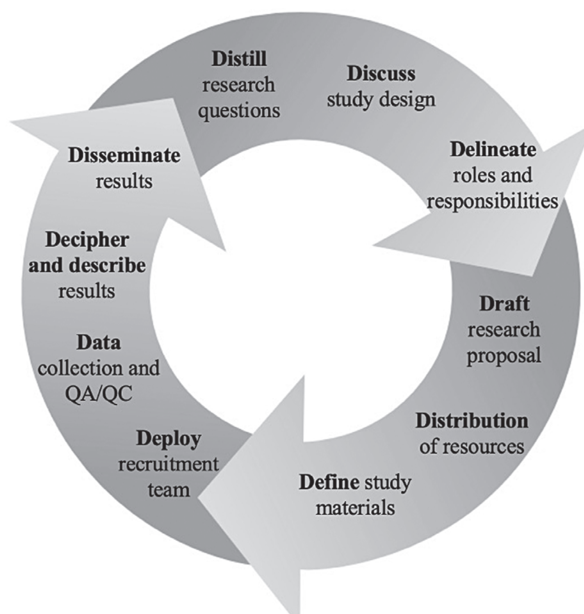

Figure 1. Iterative process used in a community-based participatory research pilot project, North Carolina 2017–2018.

Note. Process started with the distillation of research questions.

residents' health. We hope that by reporting on our work others undertaking similar research can do so more efficiently.

RESEARCH METHODS AND LESSONS LEARNED THROUGH THE ITERATIVE CBPR PROCESS

Make Research Questions Practical and Answerable

A critical component of this study was vetting each research question and balancing scientific rigor with feasibility. REACH initially envisioned deploying a data collection team when neighbors observed waste spraying or experienced malodor. But based on scientific knowledge and statistical power, employing a cross-sectional design with comparison groups was ultimately agreed upon.

Of particular importance to the community were the following testable hypotheses: 1) more markers of hog waste would be found outside homes than inside; 2) more markers of hog waste would be found in and on homes closer to IHOs than farther away; 3) at similar distances from an operation, more markers of hog waste would be found inside homes where an IHO worker lived than in homes without an IHO worker; and 4) those living closer to IHOs would have more health symptoms than those living farther away.

Community members were also concerned about their pets' health from IHO microbial contamination. Researchers were likewise interested in the carriage of *S. aureus* of companion animals and to what extent it might impact the household microbial community. No hypotheses were established for this exploratory data collection.

Partners Should Be Established in the Community and Respected

Based on principles of empowerment and equal rights, REACH was founded in 2002 and is run by community leaders.[16] Having a well-established community partner is one of the main strengths of this collaboration. Local members acutely understand the politics of the area and can navigate situations based on experience.

Thanks to past studies with many of the same collaborators,[17–19] community members felt assured that their identities would be kept confidential and that this work aimed to help the community. One REACH researcher was bilingual, ensuring Spanish-speaking households could be enrolled in the study. This person was also a former IHO worker, which, anecdotally, gave IHO-working participants an additional sense of comfort. Retaliatory job loss was a major concern in this project and maintaining participant confidentiality was of utmost importance.

Clearly Delineate the Roles and Responsibilities of Each Partner

We held meetings to explore the roles and responsibilities of each partner group during the initial stages of this new research. Collectively, we decided that the academic collaborators would present data collection options, secure funding, submit institutional review board (IRB) paperwork, conduct quality control of data, conduct laboratory work, and perform data analyses, while REACH remained responsible to define study materials, collect data, transport materials, and disseminate results to the community. IRB approval was obtained from the Johns Hopkins University IRB (#IRB00005253).

Draft a Research Protocol

In subsequent meetings, academics demonstrated possible research tools: sampling equipment and printouts of tests that had been used previously, as well as new options (Figure 2). Johns Hopkins researchers arrived with veterinarians to discuss gathering *S. aureus* pet carriage data and brought a dog to demonstrate sampling. After viewing all possibilities, REACH offered feedback on what would be accepted in the community (Figure 3).

REACH decided that they would need more discrete sampling equipment, faster protocols, and less intrusive environmental testing than previously employed. For example, in Baltimore, researchers vacuum in between bed sheets to determine the composition of household dust.[20] REACH felt such an intimate level of data collection would deter household participation and might embarrass those without a bed or sheets. Many households in the area are below the poverty line and some live without electricity. The lack of electricity and cost of monthly bills was taken into careful consideration when selecting sampling equipment. For example, a high-volume air sampler that runs for 8 hours a day from a household outlet was deemed too costly and conspicuous for this community.

Previously, REACH had run low-volume button aerosol samplers (SKC, Eighty Four, Pennsylvania) for 8 hours. While

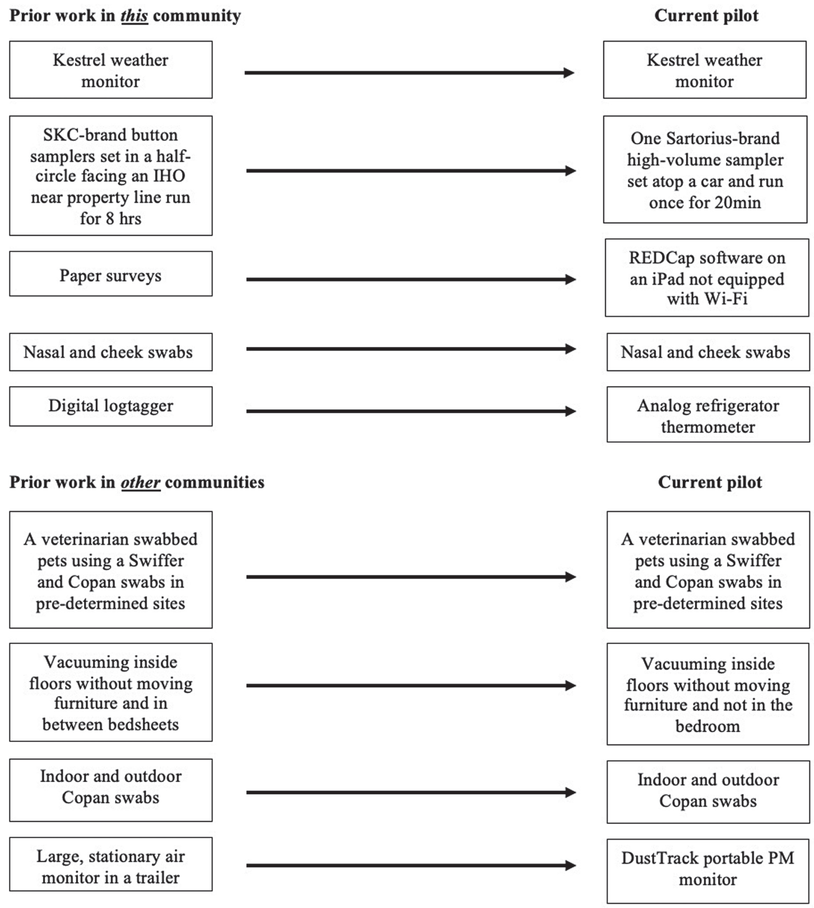

Figure 2. Sampling equipment decisions and rationale in prior and current community-based participatory research.

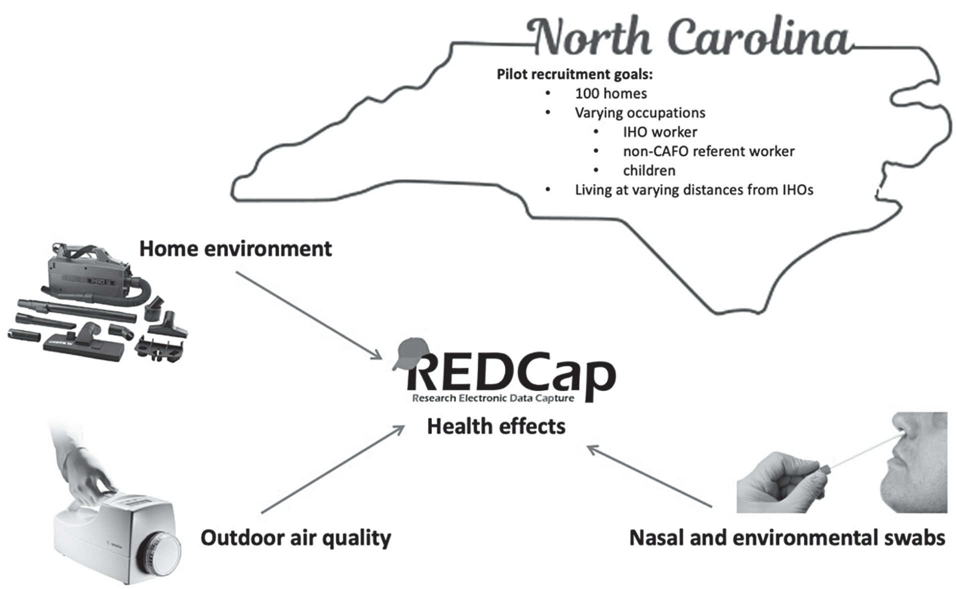

Figure 3. Goals and equipment used in a community-based participatory research pilot project, North Carolina 2017–2018.

small and battery-operated, these devices have drawbacks. They involve precise assembly and sterilization and can only draw a maximum of 4 L of air per minute. Instead of the button aerosol samplers, we opted to purchase a new battery-operated high-volume (50 L/min) sampler [=(AirPort MD8, Sartorius, Goettingen, Germany) with presterilized filters.

Another key factor in the research design was time. Executing every desirable option would have taken too long for organizers and participants. Another key factor was privacy. REACH raised concerns about neighbors recognizing that a household was participating in a scientific study. IHO workers fear employer reprisal for engaging in anything perceived as anti-IHO research, and having equipment assembled and in plain view could create problems. The final sampling protocol and decisions for research in this specific community are detailed in Figures 2 and 3.

After research design adjustments were made and protocols reviewed, a second meeting took place. We retrained on the selected equipment and allowed time for community researchers to ask questions. The third meeting allowed for REACH to demonstrate the final protocol through mock sampling runs.

Capacity-building and the Need for Repeated Training Should Continue Until All Partners Are Ready to Execute the Protocol

Capacity-building was a main goal of this project. At each training session academic partners not only demonstrated how a technology could be used but also explained why. Science education is one of REACH's organizational goals and they are now better versed in the science behind the tools and have applied this knowledge in other work.

In previous CBPR with REACH the need for better training and more frequent input from researchers on data collection practices was noted.[17] To ensure scientific rigor was achieved and data collection techniques remained appropriate, we conducted reciprocal training of academic and community organizers three times before sampling began.

Because the CBPR framework is iterative, we remained flexible to tweak protocols as needed. For example, saliva collection swabs require the participant to rub a sponge on the inside of their mouth for two minutes. Instead of asking community researchers to use a wristwatch to time the maneuver, inexpensive plastic sand timers were purchased (Figure 2). These had the benefit of showing participants how close they were to completing the task. It was also decided to print out step-by-step instructions and tape them on each air sampling instrument so that instructions were handy in case a reminder of how to operate the device was needed.

Distribute Resources to Community Partners

Although we were unable to purchase some of the more expensive air monitoring equipment used in past work[9] funding was secured to provide REACH with two iPads (Apple Inc., Cupertino, CA), weather stations, and GPS units for data collection (Figure 2). We also obtained funding to pay REACH's community data collectors and cover participant incentives.

Define Study Materials That Meet Partners' Needs—They Do Not Necessarily Need To Be Fancy

While capacity-building was critical for REACH (i.e., learning new technologies and data collection tools) researchers often found themselves reverting to older, low-tech choices (e.g., sand timers, print-offs of pictures). In resource-limited situations, this may be an advantage. It was also found that REACH preferred "plug and play" devices (e.g., Sartorius Airport MD8 and DustTrak) and that training non-technical community organizers to deploy them was easier. Extra gadgets (e.g., the iPad Apple pencil) were never used and would not be purchased again.

Deploy a Well-trained Recruitment and Data Collection Team

After we established a final protocol, participants were recruited on a rolling basis from the top-10 hog producing counties in North Carolina. Weekly partnership phone calls ensured that balanced numbers of IHO-employed and community-referent households were recruited.

Data were collected from November 2017 through April 2018, with two to three homes sampled per week (the maximum capacity of our laboratory partners). Teams of two community organizers were deployed to each home at a pre-scheduled time when an adult (either an IHO worker or a person not employed at any concentrated animal feeding operation) and a child under the age of 7 who lived in the house were present. Once consent/assent forms were signed, the first community organizer remained in the home while the second moved outside.

Data Collection Inside the Home. According to the established protocol, the order of operations inside the home was to collect 1) adult and child surveys regarding work and personal activities, potential exposures, and health outcomes via iPads loaded with REDCap software; 2) flocked environmental swabs (Copan Diagnostics Inc., Murrieta, CA) from up to six surfaces using prior studies as a guide to locations,[21] as well as a field blank; 3) house dust via vacuum collection of a common room floor[20]; 4) flocked nasal swabs (Copan Diagnostics Inc.); and 5) oral fluid sponge-like swabs to examine the prevalence of antibodies to microbial markers. The REDCap software was intended to display only relevant questions (e.g., "If 'yes,' then please describe"), force a participant to respond with at least "refused to answer," and to accept only logical data (e.g., birth date could not be more than 120 years ago). The environmental swabs, human swabs, and floor dust collection was used to assess the home environment for *S. aureus* and Pig-2-bac. Ideal places for environmental swabs included the refrigerator and refrigerator handle, TV and remote controls, air-conditioning units, and windowsills; however, organizers were instructed to use these locations as a guide, allowing flexibility to collect swabs in alternative locations if needed.

Data Collection Outside the Home. In order, data collection outside the home consisted of: 1) setting up a weather monitor (Kestral 5500 Weather Meter, Kestral Instruments, Boothwyn, PA) away from any obstructions in the yard and out of sight of neighbors; 2) a high-volume air sampler (Airport MD8, Sartorius, Goettingen, Germany) run for 20 minutes (1,000 L); 3) six flocked environmental swabs and a field blank (Copan Diagnostics Inc.); and 4) a particulate matter monitor (DustTrak DRX Aerosol Monitor 8533, TSI, Shoreview, MN). To keep a low profile, we placed the airport atop the organizer's car. It was determined that ideal locations to recover *S. aureus* and Pig-2-bac would be out of direct sunlight, the direction of the IHO, and where rainfall would not likely wash away the bacteria. Organizers were therefore instructed to swab a 12-in^2 area under air conditioning units, under windowsills, and along the underside of siding planks on the IHO-facing portion of the residence. To assess airborne particulate matter distance decay from IHOs to participant homes, organizers walked transects across the property, away from the IHO, using the DustTrak.

To record each outdoor sampling site, a handheld Garmin GPS unit was used to mark waypoints and a paper record sheet was used to link the waypoint number and activity. Preprinted labels (Avery 5160) were used to note organizer, time, date, and sample type and number. We affixed them to samples as well as log sheets. Anecdotally, the organizers noted that the labels aided in organization and efficiency.

Data collection outside the home could have benefitted from another community organizer to assist in labelling and record keeping. In addition, the GPS unit's knob was difficult for organizers to use; in future work, a different device would be selected. The original plan also called for the collection of hydrogen sulfide and ammonia measurements, but the available tools were either cost-prohibitive or did not read low enough concentrations for our purposes. During training sessions we found that temporary plastic fence-post stakes (e.g., Powerfields Poly Step In Post) worked better and were less expensive than the tripods REACH staff had used to mount weather monitors.

Data Collection of Companion Animals. Survey data and companion animal samples were gathered from a subset of three pet-owning homes. In total, six dogs were sampled by veterinarians from Johns Hopkins using an established protocol.[22] The research team warned that it was inadvisable for community organizers to conduct this work due to risk of personal injury.

RESULTS AND LESSONS LEARNED THROUGH THE ITERATIVE CBPR PROCESS

Evaluate Data Completeness and Quality Early and Often

Eighteen eligible IHO worker and 20 eligible community referent households were enrolled (Table 1). Eleven households were deemed ineligible after data review as we inadvertently enrolled a child who was 7 years old, instead of under 7 per the Johns Hopkins University-approved IRB protocol. There were differences between eligible and ineligible participants, but these are likely due to small numbers (Table 2). There is a steep learning curve with REDCap and those new to the platform

Table 1. Number of Physical Samples Collected and Missing among All Eligible Households Compared with Those That Were Ineligible in a Community-Based Participatory Research Pilot Project, North Carolina 2017–2018

	Eligible Households		Ineligible Households[a]	
Characteristic	Industrial Hog Operation	Community Referent	Industrial Hog Operation	Community Referent
Total, *n*	18	20	8	3
High volume outdoor air, *n* (%)	18 (100)	20 (100)	8 (100)	3 (100)
Environmental swabs,[b] *n* (%)				
Outdoor	105	115	47	17
Missing	3 (3)	5 (4)	3 (6)	1 (6)
Indoor	102	109	48	18
Missing	6 (6)	11 (9)	1 (2)	0 (0)
Human swabs, *n* (%)				
Nasal	36	41	16	6
Microbiome	36	41	16	6
Viral	36	41	16	6

[a] After data review it was determined that some household enrolled were not eligible for the study based on the criteria that a child under age 7 participate. Some 7-year-olds were recruited.

[b] At three ineligible industrial hog operation worker households seven environmental swabs were collected (either indoor or outdoor, but not both from the same household), when six were instructed to be collected.

Table 2. Demographics of Eligible Compared with Ineligible Participants in a Community-based Participatory Research Pilot Project, North Carolina, 2017–2018

	Eligible Industrial Hog Operation Households		Eligible Community Referent Households		Ineligible Industrial Hog Operation Households[a]		Ineligible Community Referent Households	
Characteristic	Workers	Children	Workers	Children	Workers	Children[b]	Workers	Children
Recruited, *n* (%)	18 (100)	18 (100)	20 (100)	21 (100)	8 (100)	7 (100)	3 (100)	3 (100)
Age in years, mean (SD)	41 (12)	3 (2)	34 (10)	4 (2)	42 (10)	7 (0)	43 (14)	7 (0)
Years worked on any IHO, mean (SD)	10 (8)	—	—	—	9 (5)	—	—	—
Sex, *n* (%)								
Male	6 (33)	11 (61)	1 (5)	15 (71)	4 (67)	4 (67)	2 (67)	2 (67)
Female	12 (67)	7 (39)	19 (95)	6 (29)	2 (33)	2 (33)	1 (33)	1 (33)
Race/ethnicity, *n* (%)								
Hispanic, non-Black	10 (56)	9 (50)	10 (50)	10 (48)	3 (43)	4 (57)	1 (33)	1 (33)
Black	6 (33)	6 (33)	10 (50)	11 (52)	1 (14)	1 (14)	2 (67)	2 (67)
Other	2 (11)	3 (17)	0 (0)	0 (0)	3 (43)	2 (29)	0 (0)	0 (0)
Current cigarette smoker, *n* (%)								
Yes	3 (17)	—	20 (100)	—	1 (13)	—	1 (33)	—
No	15 (83)	—	0 (0)	—	7 (88)	—	2 (67)	—
Health insurance, *n* (%)								
Yes	12 (67)	18 (100)	14 (70)	21 (100)	6 (86)	6 (86)	3 (100)	3 (100)
No	6 (33)	0 (0)	6 (30)	0 (0)	1 (14)	1 (14)	0 (0)	0 (0)

[a] After data review it was determined that some household enrolled were not eligible for the study based on the criteria that a child under age 7 participate. Some 7-year-olds were recruited.

[b] The questionnaire was not completed for one of the eight ineligible industrial hog operation worker children, but a nasal swab sample was collected.

should work closely with a consultant to create surveys that can be reviewed and analyzed easily. In subsequent work it would be advisable to check the eligibility of each participant prior to starting data collection and to check data at regular intervals for completeness and quality.

Community organizers were also encouraged to recruit as many people in the household as possible, but only one household with more than the minimum (i.e., one adult and one child) was enrolled. This is likely due to the length of the surveys, with approximately 400 questions per adult and approximately 100 per child depending on responses to questions with branching logic. Additionally, incentives were based on household enrollment, not per person.

The spatial distribution of eligible households was highly clustered to particular neighborhoods, due to participant recruitment by community organizers from within their own networks. Additionally, the households selected may only represent the impacts of a few IHOs and may not fully capture the variability of the impact of these operations on nearby residents.

Decipher and Describe Results for Community Reporting and as a Learning Tool

None of the human swab samples were missing; however, 24 of 455 environmental swabs (5.3%) from eligible households were reported missing by the laboratories (Table 1). Overall, REDCap data was missing in 2.4% of 18,932 total records (Table 3). Using χ^2 analyses (StataCorp, LP, Stata Statistical Software: Release 15, College Station, TX), missingness did not differ by eligibility or household type. Missing data were most common for those questions inquiring if participants had any questions (n = 65), to identify body parts affected (n = 42), and to specify something related a prior answer (n = 40). Missing data were less common after weekly data checks began in the tenth week (11 questions on average vs. 4) (Figure 3).

Data were less complete for surveys and environmental swabs compared to nasal/saliva swabs and dust samples. This may have been due to prior work with nasal swabs compared to electronic survey administration and a lack of recognized surfaces that could be swabbed. REACH also logged swab inventories before shipments to the universities for processing. While REDCap data were checked by Johns Hopkins researchers, based on IRB protocol, participants could not be recontacted.

In comparing missingness between data here and a 2014 study using identical questions, but on paper, we saw an improvement in data completeness, especially regarding current smoking status, where 24% of paper responses were blank, compared to 0% with REDCap (Table 4). While the missingness in both studies is relatively minimal, it is an indication that the use of the electronic survey was successful in gathering more complete records. Although REDCap eliminated both the time-consuming hand entry of data and multiple rounds of checking for entry errors, it still necessitated extensive reviews. In an ideal situation, we would have reviewed data weekly as more data were missing in weeks when reviews did not happen.

Table 3. Data Completeness and Quality for REDCap Survey Questions in a Community-based Participatory Research Pilot Project, North Carolina 2017–2018

	Eligible Industrial Hog Operation Households		Eligible Community Referent Households		Ineligible Industrial Hog Operation Households[a]		Ineligible Community Referent Households	
Characteristic	Workers	Children	Workers	Children	Workers	Children	Workers	Children
Number recruited, n	18	18	20	21	8	7	3	3
Total required questions, n	4698	2916	3680	3381	1827	1134	552	483
Missing, n (%)	112 (2)	71 (2)	125 (3)	45 (1)	68 (4)	37 (3)	30 (5)	12 (3)
Invalid,[b] n (%)	2 (0)	0 (0)	13 (0)	0 (0)	2 (0)	1 (0)	2 (0)	0 (0)

Invalid = errors in response values outside of pre-specified ranges or type mismatch from what was programmed in as acceptable in REDCap surveys.

[a] After data review it was determined that some household enrolled were not eligible for the study based on the criteria that a child under age 7 participate. Some 7-year-olds were recruited.

[b] Percentage calculated using the number of invalid responses over the total required questions minus the missing questions.

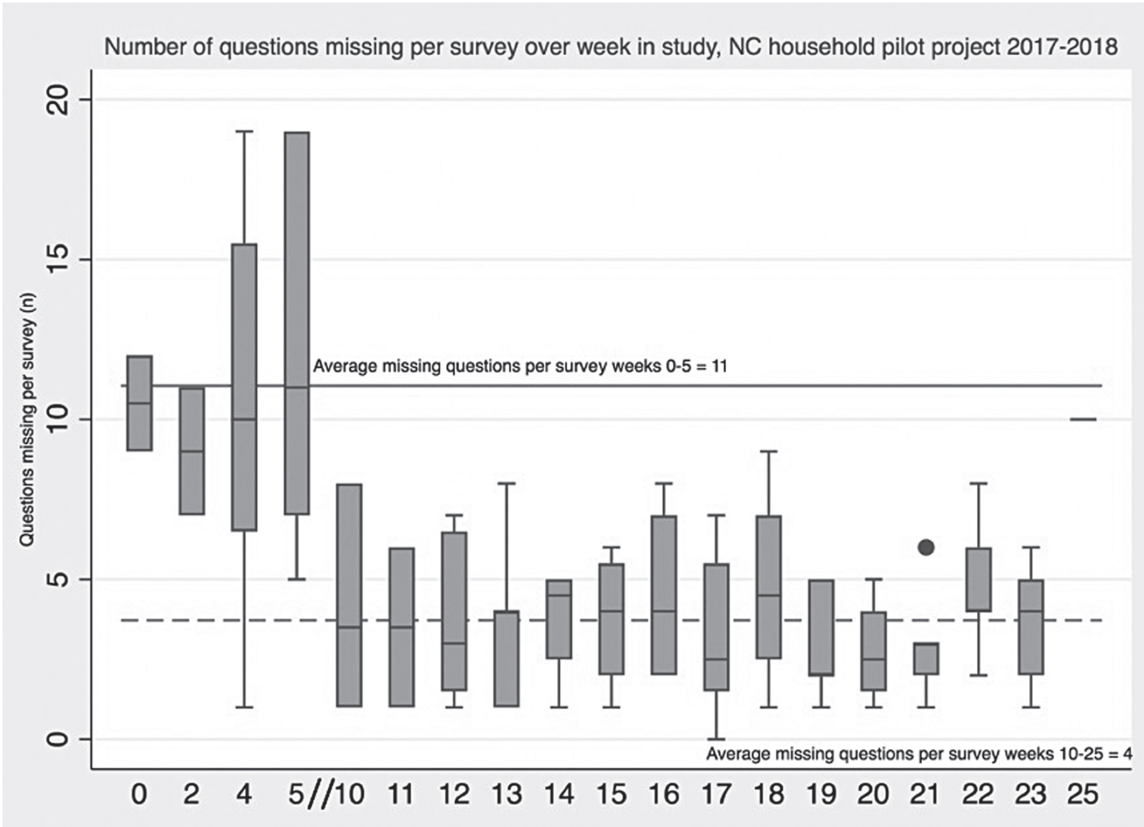

Figure 4. Box and whisker plots of missing required REDCap questions each week in study during a community-based participatory research pilot project, North Carolina 2017–2018.

Note. The box and whisker plot demonstrates the median of the data (middle of the box), Q1 and Q3 (the bottom and top of the box), and the maximum and minimum values (the whiskers), while the dashed line indicates the average number missing during weeks 10–25 of the study after more rigorous weekly data checks were performed.

Drawbacks to the use of REDCap stemmed from a lack of prior use. For example, photos of mask and infection types were uploaded within REDCap, but researchers reported difficulty accessing them and resorted to using printed handouts. Difficulties were also demonstrated by the ineligibility of 11 households due to the enrollment of children age 7 (Table 5). Had the field been set up correctly, the survey should have stopped after an organizer entered "7" into the child's age field. Otherwise, REDCap did eliminate other data entry errors such as incorrect data type (i.e., letters instead of numbers) and data out of range (i.e., a birth more than 120 years ago) (Table 3).

Through describing the results as an ongoing process and not just at the end of data collection, information can be used in subsequent training followed by additional sampling events. This calls for adaptive, iterative approaches whereby previous sampling events, data input, and data review can provide insights about the types of samples, participants, and recruitment that are occurring.

CONCLUSIONS

Using the tenets of CBPR, academic and community partners expanded upon a long-standing collaboration to begin answering novel questions about swine-specific microbial contamination at residences neighboring IHOs. Microbial source tracking represents a powerful tool that was shown to be implementable in a CBPR setting; an effective approach to investigate questions of IHO workers without endangering participants' job security. This pilot demonstrated how community members could collect largely complete and

Table 4. Demographics of Eligible IHO Worker Participants in Two Studies, North Carolina, 2017–2018

Characteristic	2014 Paper Survey[a]	2018 REDCap Survey
Workers in cohort, *n* (%)	103 (100)	18 (100)
Age in years, mean ± SD	38 (11)	41 (12)
Missing, *n* (%)	6 (6)	1 (6)
Sex, *n* (%)		
Male	55 (53)	6 (33)
Female	46 (45)	12 (67)
Missing	2 (2)	0 (0)
Race/ethnicity, *n* (%)		
Hispanic, non-Black	88 (85)	10 (33)
Black	12 (12)	6 (56)
Other	0 (0)	2 (11)
Missing	3 (3)	0 (0)
Education status, *n* (%)		
Less than high school education	47 (46)	4 (22)
High school degree/GED or higher or other	52 (50)	14 (78)
Missing	4 (4)	0 (0)
Current cigarette smoker, *n* (%)		
Yes	13 (13)	3 (17)
No	65 (63)	15 (83)
Missing	25 (24)	0 (0)
Health insurance, *n* (%)		
Yes	48 (47)	12 (67)
No	52 (50)	6 (33)
Missing	3 (3)	0 (0)
Lived on same property as an IHO, *n* (%)		
Yes	8 (8)	0 (0)
No	89 (86)	18 (100)
Missing	6 (6)	0 (0)

IHO = Industrial hog operation.

[a] Coffman et al.[14]

Table 5. Data Quality of the Age Variable, a Determining Factor for Eligibility in a Community-based Participatory Research Project, North Carolina, 2017–2018

	Eligible Industrial Hog Operation Households		Eligible Community Referent Households		Ineligible Industrial Hog Operation Households[a]		Ineligible Community Referent Households	
	Workers	Children	Workers	Children	Workers	Children	Workers	Children
Number recruited	18	18	20	21	8	7	3	3
Age, *n* (%)	17 (94)	18 (100)	20 (100)	21 (100)	5 (63)	6 (86)	3 (100)	3 (100)
Missing, *n* (%)	1 (6)	0 (0)	0 (0)	0 (0)	3 (38)	1 (14)	0 (0)	0 (0)
Incorrect data type, *n* (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Out of range,[b] *n* (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (100)	0 (0)	3 (100)
Outliers, *n* (%)	0 (0)	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	0 (0)	0 (0)

[a]After data review it was determined that some household enrolled were not eligible for the study based on the criteria that a child under age 7 participate. Some 7-year-olds were recruited.

[b] Out of range defined as the child's age being 7 years or older for the child that determined the household's eligibility

high-quality data in the field. Because this approach involved training citizen scientists it also built capacity. In the future this work can be expanded and implemented in other communities who want to understand relationships between sources of microbial contamination and residences nearby. In addition, without the use of the CBPR approach, this research could not have been conducted. Community buy-in was paramount and achieved not only through collaboration throughout the process. As noted above, the use of CBPR in environmental epidemiology is rare but can be exceedingly beneficial, particularly when coupled with the advances in microbial source tracking.

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