

Shigellosis Outbreak in Genesee and Saginaw Counties, Michigan, March 2016 – December 2016

Findings from Epidemiologic, Laboratory, and Geospatial Investigations

March 2018

Centers for Disease Control and Prevention
National Center for Emerging and Zoonotic Infectious Diseases
Waterborne Disease Prevention Branch
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Section 1: Background of the Outbreak

I. Introduction to Shigellosis

Shigellosis is a diarrheal illness caused by *Shigella* bacteria. Shigellosis is most often a self-limited illness characterized by fever and enteritis. There are four *Shigella* species; *S. sonnei* is most common cause of shigellosis in the United States. Due to its low infectious dose, *Shigella* is readily transmitted person-to-person through the fecal-oral route; additional modes of transmission include contaminated food, drinking water, and recreational water. Outbreaks occur year-round, with child care facilities being the most common setting. Attention to hygiene, access to safe water, and adequate sanitation are mainstays of prevention. (<https://www.cdc.gov/shigella/prevention-control.html>)

II. Genesee and Saginaw County Background

Genesee County and Saginaw County are neighboring counties in the mid-Eastern section of Michigan (**Figure 1**). Genesee County is the 5th most populated county in Michigan (population 418,654, U.S. Census Bureau, American Community Survey 2011-2014, 5-year estimates) with 24% of residents living in the City of Flint. To the north of Genesee County is Saginaw County (population 197,727, U.S. Census Bureau, American Community Survey 2011-2014, 5-year estimates) with 26% of residents living in the city of Saginaw.

Figure 1: Map of the State of Michigan, featuring Genesee and Saginaw Counties



Source: National Atlas, U.S. Geological Survey, U.S. Department of the Interior

Drinking water is supplied to the two counties via numerous municipal and private drinking water systems, as summarized in Table 1. The Flint municipal water system provides water to a geographic area that includes most of the City of Flint, along with a small number of households outside the city boundaries.

Table 1: Drinking Water Supply, Genesee and Saginaw Counties, MI

	Population (%)
Genesee County ¹	415,376 (--)
Flint municipal water ²	99,763 (24)
Other municipal water systems ²	201,794 (49)
Private well water ³	113,819 (27)
Saginaw County ¹	196,542 (--)
Saginaw municipal water ²	51,508 (26)
Other municipal water systems ²	122,471 (62)
Private well water ³	22,563 (12)

¹ Data from U.S. Census Bureau, 2013.

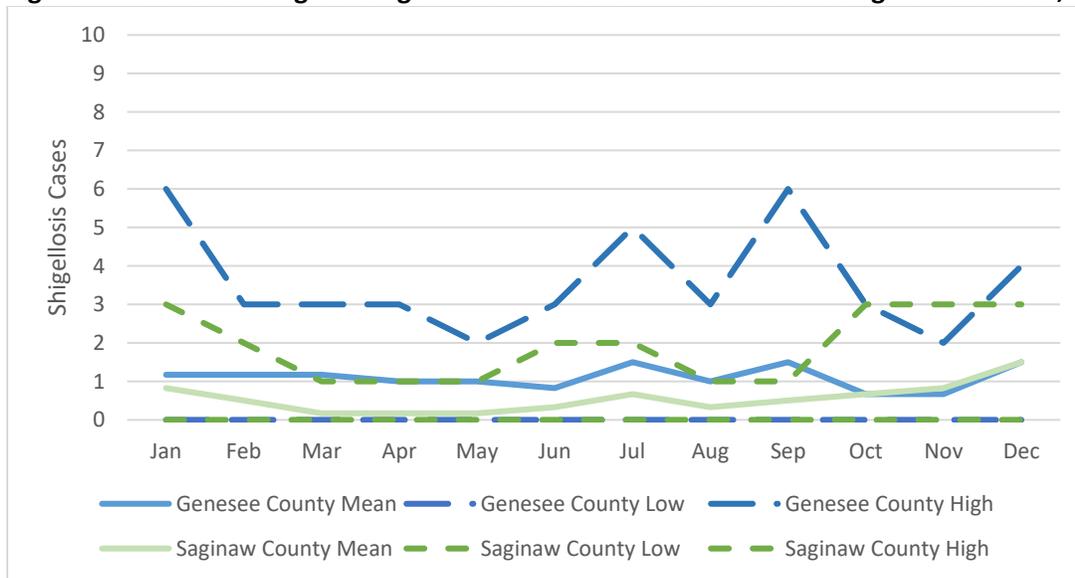
² Data from Michigan DEQ at http://www.michigan.gov/documents/deq/CWS_List_by_County_426701_7.pdf

³ Based on Michigan DEQ guidance, number of private wells estimated using difference between county population and population on community water supplies.

III. Shigellosis in Michigan

From 2011-2015, an average of 392 cases of shigellosis were reported to MDHHS yearly. **Figure 2** shows the mean and range of shigellosis cases reported in Genesee and Saginaw Counties from 2010-2015 by month.

Figure 2: Mean and Range of Shigellosis Case Counts — Genesee and Saginaw Counties, 2010–2015



In contrast to other enteric pathogens, there was a large increase in the number of shigellosis cases reported in 2016 compared to 2013-2015 in Genesee and Saginaw Counties. (**Figures 3 and 4**).

Figure 3: Cases of Enteric Disease Reported to MDHHS – Genesee County, MI, Jan-Oct 2013-2016

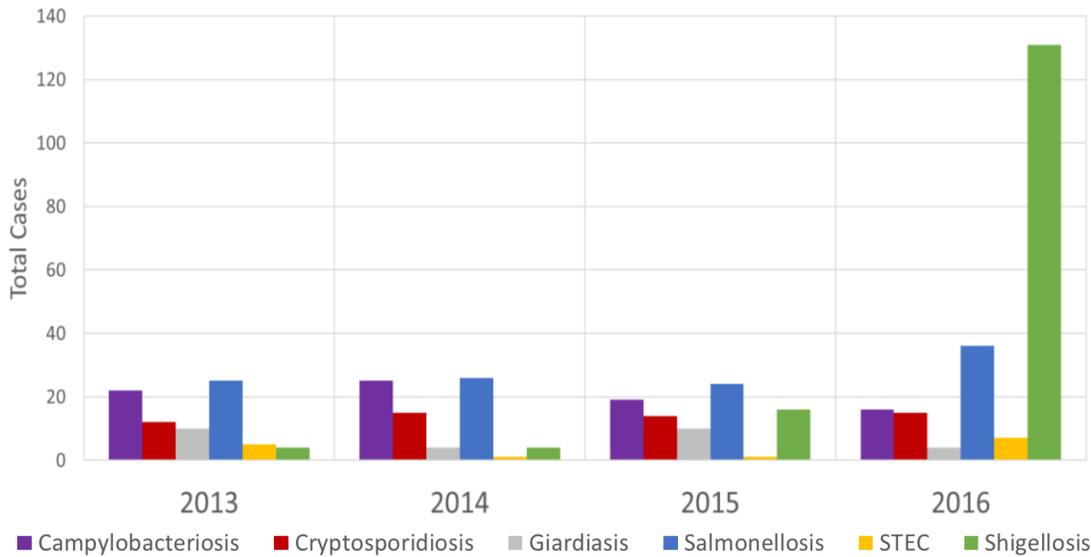
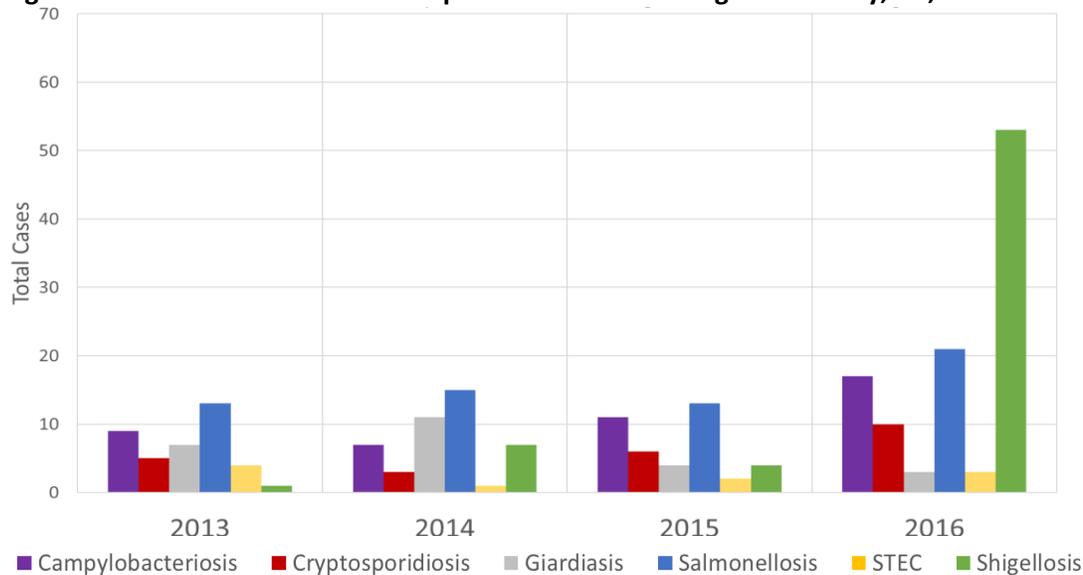


Figure 4: Cases of Enteric Disease Reported to MDHHS – Saginaw County, MI, Jan-Oct 2013-2016



IV. Detection of the Outbreak

In March 2016, the Genesee County Health Department (GCHD) detected an increase in shigellosis cases in Genesee County compared to prior years. Follow-up investigation, including case-patient interviews, did not reveal a common setting, restaurant, or event exposure but did reveal that many cases were children. Additional cases were reported in April and GCHD prepared and circulated a community health alert in May. The Saginaw County Health Department detected an increase in shigellosis cases in Saginaw County starting in May, and conducted a follow-up investigation with findings similar to those from Genesee County. Patient demographic data from the initial Genesee and Saginaw County investigations are summarized in **Table 2**. Of note, the initial hospitalization rate amongst case-patients in both counties exceeded prior statewide averages. Saginaw County health officials also prepared and distributed community health alerts, and both Genesee and Saginaw officials also alerted community healthcare providers about the outbreak as cases continued to be reported throughout June and July 2016.

Table 2: Selected Demographic characteristics from Initial Interviews with Case-Patients Reported to MDSS – Genesee and Saginaw Co., Michigan, March-July, 2017

	Genesee County	Saginaw County
Median age, years		
Outbreak-associated case-patients	12	15
Case-patients 2010-2013	22	7
Case-patients 2014-2015	29	21
General population*	38	39
Sex (% Female)		
Outbreak-associated case-patients	63	52
Case-patients 2010-2013	67	50
Case-patients 2014-2015	46	53
General population*	52	52
Hospitalization (%), outbreak-associated case-patients	38	38

*American Community Survey, U.S. Census Bureau

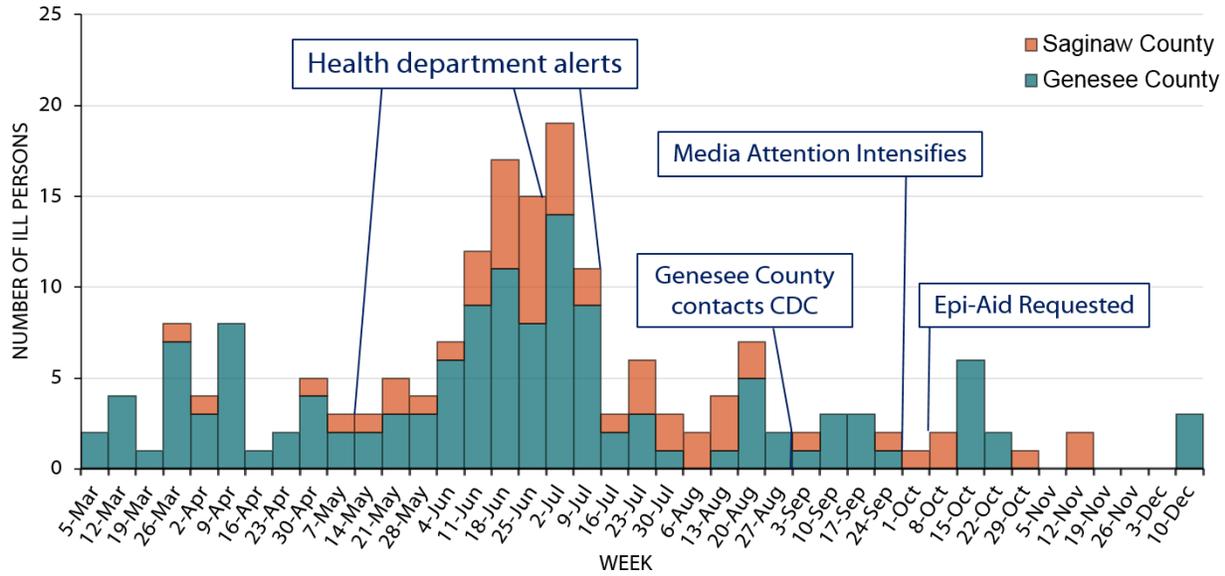
V. CDC Consultation

Figure 5 shows the overall epidemic curve for the shigellosis outbreak in Genesee and Saginaw Counties in 2016 along with key events during the outbreak investigation. By August 2016, the rate of new shigellosis cases began to decline in Genesee and Saginaw Counties, with sustained decreases seen in September and October. However, concerns in the community emerged regarding the cause of the outbreak. This included concern that shigellosis could have spread through the Flint drinking water system, or that avoidance of tap water in Flint as a result of the municipal water crisis may have negatively impacted hand hygiene and increased residents’ risk for acquiring shigellosis.

In late August, GCHD contacted the Waterborne Disease Prevention Branch (WDPB) in the National Center for Emerging and Zoonotic Infectious Disease (NCEZID) at the Centers for Disease Control and Prevention (CDC) to discuss the shigellosis outbreak investigation. A call was arranged with representatives of GCHD and CDC groups including PulseNet USA, the National Antimicrobial Resistance Monitoring System for Enteric Bacteria (NARMS), Outbreak Response and Prevention Branch (ORPB), and WDPB. Available epidemiologic data were discussed, including the likelihood of household and childcare transmission and a hospitalization rate above that typically seen in shigellosis outbreaks. Ongoing prevention and control efforts were discussed and additional health promotion materials were offered and subsequently provided in follow up by the WDPB communication team. Additionally, PulseNet USA and NARMS agreed to analyze a representative number of isolates from the outbreak with pulsed-field gel electrophoresis (PFGE) and antimicrobial susceptibility testing (AST) to better characterize the outbreak. In subsequent conversations, the Michigan Bureau of Labs (MI BOL) agreed to conduct outbreak isolate testing, including PFGE and AST. Follow-up calls were held with staff from CDC, MDHHS, and GCHD, and in September 2016 new PFGE results were obtained showing that isolates from Genesee and Saginaw County patients associated with the outbreak were closely related.

In early October, additional media reports regarding the shigellosis outbreak were published by local and national news outlets. Several reports highlighted concerns regarding the role of water avoidance in Flint in the outbreak. On October 7, MDHHS formally requested Epi-Aid assistance from CDC in investigating the outbreak and responding to these complex community concerns.

Figure 5: Shigellosis cases reported to MDHHS by week — Genesee and Saginaw Co., Michigan, Mar 1–Dec 10, 2016 (N=185)



VI. Epi-Aid Objectives and Determination

A. Investigation Objectives:

The following objectives were proposed for the Epi-Aid:

1. Characterize the full extent of the shigellosis outbreaks including, but not limited to, information on affected household members and close contacts, and clinical treatment and outcomes for patients.
2. Use PFGE and whole genome sequencing methods to understand relatedness of *Shigella* isolates from cases.
3. Characterize exposure to risk factors among case-patients including, but not limited to, living in group housing or participating in group activities, travel, HIV status, and use of water for drinking, cooking, and bathing, among cases of Shigellosis and neighborhood controls.
4. Map existing data related to quality of water from municipal systems, such as disinfectant residuals, sewage and water main breaks, triggered positives for total coliforms, and other aspects of water quality.
5. Assess need for household water testing based on results of epidemiologic investigation.

B. OMB and Human Subjects Determination

1. Office of Management and Budget (OMB) determination: The Epi-Aid was determined to be subject to the Paperwork Reduction Act by the OMB coordinator and was submitted for OMB clearance via the “Emergency Epidemiologic Investigation” OMB mechanism. With assistance from the EIS office, the OMB submission was approved under OMB Control Number 0920-1011. The GenIC number for the investigation was 2017001-003 with expiration date January 10, 2017.
2. Human Subjects Review: The Epi-Aid underwent Human Subjects Review by the human subjects coordinator and received a non-research determination, indicating the investigation did not meet the definition of research under 45 CFR 46.102 (d). The project was assigned HSR #: 101116MK and no further IRB determination was sought.

VII. Timeline of the Investigation

On October 12, 2016, Deputy Division Director Dr. Michael Beach, Medical Epidemiologist Dr. Matt Karwowski, and EIS Officer Dr. Paul McClung departed for Flint, MI to join Michigan-based CEFO Dr. Jevon McFadden, EIS Officer Dr. Caroline Castillo, and CSTE Fellow Ashley Miller.

Upon arrival, the team held several meetings with key stakeholders in the community who had been engaged during the outbreak. Details of the outbreak were reviewed with MDHHS, GCHD and SCHD staff; the Genesee County Medical Society; the Flint Mayor's office; and community members from the Flint recovery meeting and communications subcommittee. Based on these extensive early conversations, CDC and MDHHS determined methods for addressing the objectives of the Epi-Aid while addressing community concerns regarding the outbreak. In the following weeks, a three-part investigation was launched: 1) a follow-up case-household survey, 2) additional laboratory testing of bacterial isolates obtained from case-patients in the outbreak using PFGE and WGS, and 3) a mapping project to investigate the relationship between cases of shigellosis and water quality testing results from the Flint municipal water system. Detailed descriptions of each arm of the investigation are provided below, including methodology and results.

Through routine follow-up meetings with public health officials and with community stakeholders, the investigation team solicited ideas and preferences for the design and implementation of the investigation, including survey methodology and questionnaire design. Telephone interviews involving households affected by the outbreak were conducted from October 25 to November 2, 2016. Throughout the month of October, laboratory and geospatial investigations moved forward with ongoing dialogue between collaborators, review of available data, and initiation of new analyses. Preliminary results of the epidemiologic investigation were shared with public health officials and with the community in November, 2016. Preliminary results from each arm of the Epi-Aid investigation were presented in-person during a community forum on December 15, 2016. By early December, reported cases of shigellosis in Genesee and Saginaw counties had returned to baseline for more than two incubation periods.

VIII. Community Engagement and Health Communication

The field investigation team sought input from members of the community and public health officials in Genesee and Saginaw counties throughout the field investigation. During the planning phase of the investigation, CDC Health Communication specialist Kirsten Yates deployed to the field and participated in community meetings and field team efforts to design the household survey. The field team also received feedback on the household interview questionnaire from community stakeholders in Genesee and Saginaw counties. Throughout the investigation, field team personnel provided updates to MDHHS and to community members, including weekly updates at Flint recovery meetings. Updates related to the investigation were also shared via letters to community members and healthcare providers, and via two presentations of preliminary results from the investigation given in November and December 2016.

Section 2: Case-Household Survey

I. Background and Rationale

The initial outbreak investigation conducted by local health departments found no common exposure among case-patients such as a day care or school, food establishment, recreational activity, community event, or travel destination. To further assess risk factors for acquiring shigellosis, the Epi-Aid team designed a multi-county case-control investigation. Based on sample size calculations, over 300 in-person or telephone interviews were required to achieve statistical significance for the exposures of interest.

Local health departments and community leaders expressed concern that a door-to-door study may be perceived as intrusive and interviewing unaffected households may incite fear within the community. Based on this feedback and the logistical challenge and expense of implementing a community-wide case-control study, the Epi-Aid team and collaborators shifted efforts toward planning a telephone survey of all case-households known to be affected by the outbreak. The goal of this survey was to collect standardized data across the two counties to assess hypotheses regarding the mode of transmission and risk factors for the spread of shigellosis in the outbreak, including activities and exposures outside of the house, and patterns of household water use. Survey results would also help determine whether additional epidemiologic studies or environmental testing were indicated.

II. Study Design

A telephone-based household survey was developed to collect follow-up epidemiologic information. Eligible households included those in Genesee and Saginaw Counties containing one or more cases of shigellosis reported to MDSS with date of illness onset March 1 to October 31, 2017. For our survey, a case was defined as any case-patient reported to MDSS with illness onset March 1 to October 31, 2017, or a household member not reported to MDSS who reported having clinically compatible symptoms and illness onset within 7 days of another household case-patient.

During the time of the outbreak, cases reported to MDSS were classified using the 2012 CSTE shigellosis case definition, which MDSS was using for routine surveillance across the state:

- Confirmed case: Clinical symptoms (defined as: “an illness of variable severity characterized by diarrhea, fever, nausea, cramps, and tenesmus”) and isolation of *Shigella* spp. from a clinical specimen
- Probable case: A clinically compatible case epidemiologically linked to the outbreak (i.e., is a contact of a confirmed case or a member of a risk group defined by public health authorities)
- Suspected case: Clinical symptoms and detection of *Shigella* spp. from a clinical specimen using a non-culture-based method

The goals of the survey were to:

- 1) Assess the magnitude of the outbreak
- 2) Characterize households involved in the outbreak
- 3) Assess exposures associated with the introduction of *Shigella* into the home
- 4) Assess household water source and usage

For the survey, outbreak case-patients identified in eligible households were further classified as either index case-patients or secondary case-patients, defined as follows:

- Index case-patient: The first person to become ill in the household (from March 1 to October 31, 2016)

- Secondary case-patient: A household member with illness onset no more than 7 days after the illness onset date of another case-patient in the household.

Investigators focused on assessing exposures for the first person in each household who become ill (defined as the “index case-patient”). Common exposures among index case-patients might suggest an origin for the outbreak or a modifiable risk factor. Shigellosis spreads easily among close household contacts through person-to-person transmission; thus, interviewing all ill household members would not have provided helpful information towards addressing goal 3, as described above.

Upon first contact with the household, interviewers explained the reason for calling and described the survey including its structure and content. They obtained verbal consent from the household member or a proxy if the household member was a minor. Demographic and illness information was collected for all persons living in the home at the time a household member was ill with shigellosis. Using this information, the interviewer identified the index case-patient. Next, the interviewer asked the index case-patient or their proxy about exposures of interest in the week prior to becoming ill. Finally, the interviewer asked about the water source used for common household activities by all household members in the week before the first household member became ill. All interviews were conducted using a standardized questionnaire, and time was allotted for follow-up questions from respondents. At the end of each interview, respondents were offered additional educational material about shigellosis and thanked for their time.

III. Household Survey Questionnaire

The full questionnaire can be found as **Appendix A**. Prior questionnaires from community outbreaks associated with water, food, and person-to-person transmission were considered in developing this new questionnaire. Additionally, we sought feedback from a wide range of community members about topics to include in the interview, and about the length, language, and flow of the questionnaire. Feedback was received and implemented on a rolling basis during the design phase of the investigation, and a final draft was piloted with community members from the Flint recovery communication subcommittee prior to beginning the study. The questionnaire was divided into the following sections:

- Section 1: Household demographics and illness information
- Section 2: Person-to-person exposures outside the home
- Section 3: Travel
- Section 4: Food
- Section 5: Household Water Uses

Information on household demographics and illness information for all household members was collected in Section 1. Exposures included in sections 2, 3, and 4 were assessed for the index case-patient only. This reflected the priority of assessing exposures and mode of transmission responsible for introducing shigellosis into each household via the index case-patient. Section 5 assessed water sources and uses for the household.

IV. Data Management

Interview data were collected by phone and recorded on paper interview forms, which were assigned to volunteers at the start of an interview day by CDC staff and returned when the interviewer completed an interview or left for the day. All interview forms were supervised by CDC staff and stored overnight in secure locked areas of MDHHS.

An electronic data entry tool was created by CDC staff in Atlanta using EpiInfo 7. Completed interview forms were given to MDHHS staff for scanning and secure distribution to other MDHHS staff persons, who entered all data

into a local desktop version of EpiInfo 7. Completed records were merged and de-identified at MDHHS, and then transmitted via encrypted electronic message to CDC staff, where they were stored electronically in a secured network drive.

CDC staff performed quality assurance and quality control of interview data by examining scanned questionnaires and comparing them to the EpiInfo database created in the initial data entry process. All discrepancies were documented in EpiInfo and subsequent changes were discussed with the review team prior to being finalized. Final data were imported and managed in SAS 9.3.

V. Data Analysis

Data analysis was conducted at CDC using SAS 9.3. Descriptive statistics were generated for household member demographics and illness information, and comparisons were made for households and individual household members in four geographic groups: (1) Genesee County, (2) City of Flint, (3) Genesee County excluding Flint, and (4) Saginaw County, using chi-square, Fisher's exact, Wilcoxon-Mann-Whitney, and t-tests as appropriate. Demographics for case-patients in each exposure group were compared with demographics in the general population for the relevant jurisdiction using data from intercensal estimates and the Census American Community Survey. For exposures in sections 2, 3, 4, and 5 rates were calculated and responses compared between the same jurisdictions.

VI. Conducting Interviews

A. Interviewer Recruitment & Training

Volunteer interviewers were recruited from within Michigan Department of Health and Human Services (MDHHS), the University of Michigan Preventive Medicine Residency, and the Epi-Aid Team. All volunteer interviewers received just-in-time training on conducting telephone interviews and navigating the questionnaire and tracking forms. Interviewers also received an FAQ document to which they could refer to throughout the call. Interviewers used scripts for introducing the study to respondents, obtaining verbal consent, and leaving voice messages. CDC staff were available to answer questions from interviewers at all times during the interview period.

B. Call tracking/Metrics

Each phone conversation or attempt was logged into a tracking form and coded according to outcome. SMS text messaging was also used to establish contact with some households where telephone calls had not yet been successful. Up to 12 attempts were made to contact each case-household by telephone. Interviews were conducted from October 25 through November 2. All calls were made between the hours of 9 AM and 5:30 PM, unless a different time was requested by a household member.

C. Call Center

During the investigation, there were active call centers in the Genesee County Health Department Emergency Operations Center (EOC) and the Michigan Community Health Emergency Coordination Center (CHECC). In Saginaw County, public health department staff made calls in between job duties. Once the majority of case-households had been contacted, follow-up calls for remaining households were made from the MDHHS building by Epi-Aid team members.

D. Educational Material

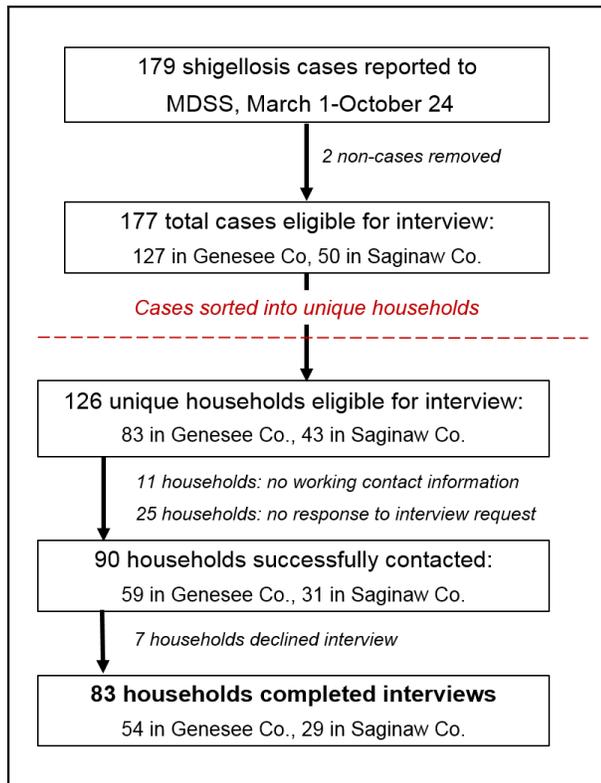
At the conclusion of each interview, the respondent was offered educational materials about shigellosis. If desired, a packet consisting of information regarding shigellosis and prevention was mailed to the confirmed address.

VII. Results

A. Household Recruitment

The investigation team used available demographic information to sort all reported case-patients in the outbreak into households, with many households containing more than one case-patient. **Figure 6** displays the results of sorting eligible case-patients into households and the enrollment and completion of household interviews in the study. In total, 83/126 unique households (65.8%) completed interviews. The proportion of households from Genesee and Saginaw Counties completing interviews closely mirrored the proportion of households identified in the outbreak from each county (affected: 65.8% Genesee / 34.2% Saginaw; interviewed: 65% Genesee / 35% Saginaw).

Figure 6: Case-Households Identified and Interviewed, Genesee and Saginaw Co., Michigan



B. Household Composition

As detailed in **Table 3**, 353 total household members were identified in the 83 households interviewed in this investigation. The mean household size of case-households was 4.1 persons, significantly higher than the mean household size in the general population (2.5 persons per household, U.S. Census Bureau, American Community Survey; $p < 0.001$). No meaningful difference was noted between counties in the size of households affected by the outbreak. Out of all households interviewed, 158 persons reported either illness with shigellosis or diarrheal illness in conjunction with a shigellosis case-patient during the outbreak period. Household interviews identified an additional 42 persons who met the outbreak case definition but were not previously reported to MDSS. In addition to the 83 index case-patients (1 index case per case-household, as defined), 75 secondary case-patients were identified. Overall, 44.8% of all household members met the outbreak case definition, with an overall secondary attack rate of 27.8%. Neither the proportion of household members meeting the outbreak case definition nor the secondary attack rate differed significantly between households in Genesee and Saginaw Counties.

Table 3: Description of survey households, household members, illness status, and secondary attack rate—Genesee & Saginaw Co., Michigan, Mar-Oct 2016

	Genesee County Overall	Flint	Greater Genesee County	Saginaw County	Overall
Total households	54	24	30	29	83
Total household members	234	108	126	119	353
Mean household size (persons)	4.3	4.5	4.2	4.1	4.2
Total ill persons	99	50	49	59	158
Total cases reported to MDSS	82	36	46	33	115
Index case-patients	54	24	30	29	83
Secondary case-patients	45	26	19	30	75
Percent of household members meeting outbreak case definition*	42.3%	46.3%	38.9%	49.6%	44.8%
Secondary attack rate†	25.0%	31.0%	19.8%	33.3%	27.8%

*No significant difference in percent meeting outbreak case definition between Genesee County and Saginaw County (42.3% vs 49.6%, $p=0.1940$, chi-square)

†Secondary attack rate in Genesee County not significantly different from Saginaw County (25.0% vs 33.3%, $p=0.1495$, chi-square)

C. Household Member Demographics

Demographics of household members identified in the investigation are found in **Table 4 and Table 5**. Ill persons in the outbreak were significantly younger (median age 10 vs. 40, $p<0.0001$) and more likely to describe themselves as “Black/African-American” than the general population in Saginaw and Genesee counties, consistent with demographic trends in shigellosis incidence across the United States¹. Ill persons in Genesee County were significantly more likely to be female than the general population, as were secondary case-patients overall. Within affected households, ill persons were significantly younger than non-ill persons (median age 10 years vs 23 years, $p<0.01$, Wilcoxon-Mann-Whitney Test).

Table 4: Demographics of case-patients and general population – Genesee & Saginaw Co., Michigan, Mar-Oct 2016 (N=158)

	Genesee Co. case-patients (N=99)	Genesee Co. Gen Pop*	P-value (GC case-patients vs GC gen pop)	Saginaw Co. case-patients (N=59)	Saginaw Co. Gen Pop*	P-value (SC case-patients vs. SC gen pop)
Age: median (range)	10 (1-73)	39.1	<0.0001	12 (<1-86)	40.0	<0.0001
Black	49 (49%)	20.4%	<0.0001	45 (76%)	18.5%	<0.0001
Female	62 (63%)	51.8%	0.0291	29 (49%)	51.6%	0.7106

*Source: U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates

¹ CDC. Foodborne Diseases Active Surveillance Network (FoodNet): FoodNet 2015 Surveillance Report (Final Data). Atlanta, Georgia: U.S. Department of Health and Human Services, CDC. 2017.

Table 5. Demographics of household members by case status — Genesee & Saginaw Co., Michigan, Mar-Oct 2016 (N=353)

Characteristic	Index case-patients (N=83)	Secondary case-patients (N=75)	Non-ill persons (N=195)
Age (years): median (range)	8 (range 1-86)	15 (range <1-66)	23 (range <1-74)
Sex: n (column %)			
Female	43 (52%)	48 (64%)	106 (55.5%)
Male	40 (48%)	27 (36%)	85 (44.5%)

D. Individual Illness Characteristics

Table 6 includes symptoms reported by ill persons in the investigation. Diarrhea was most commonly reported for all ill persons. Stomachache, urgency to have a bowel movement, and fever were reported by at least half of ill persons overall. The reported duration of illness varied, with a range of 1 – 180 days and a median of 6 days.

Table 6: Symptoms among case-patients — Genesee & Saginaw Co., Michigan, Mar-Oct 2016 (N=158)

Symptom	All Case-patients (N=158)	Index Case-patients (n=83)	Secondary Case-patients (n=75)
Diarrhea	151 (96%)	81 (98%)	70 (93%)
Stomachache	99 (63%)	63 (76%)	36 (48%)
Urgency to have a bowel movement	86 (54%)	51 (61%)	35 (47%)
Fever	86 (54%)	53 (64%)	33 (44%)
Nausea	78 (49%)	46 (55%)	32 (43%)
Vomiting	60 (38%)	38 (46%)	22 (29%)
Bloody stool	52 (33%)	38 (46%)	14 (19%)

Table 7 shows self-reported medical care sought in the outbreak. Seventy-nine percent of all case-patients sought medical care of some sort, including 18% who reported hospitalization and 56% who reported being prescribed antibiotics. A higher percentage of index case-patients sought medical care (93%), were hospitalized (27%), and were prescribed antibiotics (70%).

Table 7: Healthcare utilization among shigellosis case-patients — Genesee & Saginaw Co., Michigan, Mar-Oct 2016 (N=158)

Healthcare utilization*	All case-patients (N=158)	Index case-patients (n=83)	Secondary case-patients (n=75)
Doctor office	47 (30%)	28 (34%)	19 (25%)
Urgent Care	7 (4%)	5 (6%)	2 (3%)
Emergency Department	74 (47%)	48 (58%)	26 (35%)
Hospital	28 (18%)	22 (27%)	6 (8%)
Pharmacy	2 (1%)	1 (1%)	1 (1%)
Natural healer	0 (0%)	0 (0%)	0 (0%)
Prescribed antibiotics	89 (56%)	57 (69%)	32 (43%)
Sought medical care of any kind	125 (79%)	77 (93%)	48 (64%)

* 28 (18%) case-patients reported using more than one healthcare type

E. Index Case Exposures

Among index case-patients identified in the investigation, 60% reported coming into contact with a person wearing diapers in the week prior to becoming ill (**Table 8**). This includes wearing, changing, or coming into contact with a person wearing diapers. No significant difference was seen between index case-patients in Genesee and Saginaw Counties. Among index case-patients, 18% reported coming into contact with a person who they knew had diarrhea, not including their own household members, in the week prior to becoming ill. Overall, 66% reported one or both of these exposures in the week prior to becoming ill. These findings were similar regardless of county of residence.

Table 8: Contact with diapers or persons ill with diarrhea among index case-patients, stratified by location — Genesee & Saginaw Co., Michigan, Mar-Oct 2016

	Genesee County Overall (N=54)	Flint (N=24)	Greater Genesee County (N=30)	Saginaw County (N=29)	Overall (N=83)
Contact with a person wearing diapers, not including other household members	54%	63%	47%	72%	60%
Contact with a person ill with diarrhea who did not live with them	15%	25%	7%	24%	18%
Contact with a person outside the home wearing diapers or having diarrhea	59%	71%	50%	79%	66%

Twenty-four index case-patients were reported to be 4 years old or younger during the outbreak. Of these children, only 9 (38%) attended childcare in the week prior to becoming ill, including daycare centers and in-home childcare. This finding was similar to the initial epidemiologic investigation, which did not reveal a common childcare facility as the source of the outbreak.

Index case-patients were also asked about events attended in the week prior to becoming ill. Attendance at a variety of events was reported 19 times among the 83 index case-patients in the outbreak; no common event was identified. Only one person reported attending an event where another person was known to have diarrhea.

Approximately one-third (N=27, 33%) of index case-patients reported travel within the state of Michigan in the week prior to becoming ill. Nearly all reported travel by private car (as opposed to public transportation). A variety of activities while traveling was reported, including attending community event/gathering (n=7), visiting a friend (n=4), going to work (n=2) and camping or swimming (n=6). Only one index case-patients reported travel outside the state of Michigan in the week prior to becoming ill.

When asked about dining outside the home in the week prior to becoming ill, 52% reported eating at a fast-food establishment, and 31% reported eating at a restaurant. No common restaurant exposure was identified. Few index case-patients reported eating at a deli, street vendor, or concession stand.

Approximately one-third (n=29, 36%) of index case-patients reported exposure to recreational water in the week before becoming ill, with no meaningful difference between counties or Flint residents. Index case-patients most frequently reported swimming in a pool (n=16, 20%), lake/pond/river/stream (n=11, 14%) or water park (n=9, 11%). No common venue was identified.

F. Household water use

We asked about household sources and uses of water for consumption (including drinking, making drinks, or making ice) or for cleaning/hygiene (including handwashing, bathing self, bathing others, cleaning a diaper changing station, dishwashing, counter cleaning, and rinsing fruits, vegetables, and other food).

Table 9 shows results for water consumption. Only 17% of households served by the Flint municipal water system reported consuming filtered or unfiltered tap water during the time of the outbreak, significantly lower than households from surrounding Genesee County and Saginaw County. However, 92% of households served by the Flint municipal water system reported consuming bottled water during this time, significantly higher than households in surrounding Genesee County or Saginaw County.

Table 9: Water consumption among case-households, by location — Genesee & Saginaw Co., Michigan, Mar-Oct 2016

	Tap Water (filtered or unfiltered)	p-value* (Flint, ref)	Bottled water	p-value* (Flint, ref)
Flint (N=24)	17%	-	92%	-
Greater Genesee County (N=30)	60%	0.002	63%	0.0238
Saginaw County (N=29)	100%	<0.0001	45%	0.0004

*Fischer’s Exact Test used for all comparisons

Tables 10 and 11 display results for handwashing and bathing/showering, respectively. Of note, there was no significant difference in the reported use of hand sanitizer or cleaning wipes between households in Flint and other households in the outbreak. Additionally, no significant differences were seen between household water use for bathing and showering. This suggests that households in the outbreak used similar hygiene methods regardless of the source of their tap water.

Table 10: Method of handwashing among households, by location — Genesee & Saginaw Co., Michigan, Mar-Oct 2016

Method of handwashing	Flint (n=24)	Greater Genesee Co. (n=30)	Saginaw Co. (n=29)
Hand sanitizer	21%	23%	31%
Cleaning wipes	0%	10%	3%
Unfiltered tap water	50%	57%	97%
Filtered tap water	42%	7%	0%
Bottled water	8%	0%	0%
Boiled water	4%	0%	0%

Table 11: Method of bathing/showering among case-households, by location — Genesee & Saginaw Co., Michigan, Mar-Oct 2016

Method of bathing/showering	Flint (n=24)	Greater Genesee Co. (n=30)	Saginaw Co. (n=29)
Hand sanitizer	0%	0%	0%
Cleaning wipes	0%	0%	0%
Unfiltered tap water	58%	67%	97%
Filtered tap water	29%	10%	0%
Bottled water	4%	0%	0%
Boiled water	0%	0%	0%

Finally, household members were asked if handwashing and bathing habits had changed as a result of the Flint water crisis (**Table 12**). A similar number of households in Flint and Greater Genesee County reported changes in handwashing habits since the Flint water crisis (38% vs 26%, $p=0.5312$, Fisher’s Exact Test) while significantly more households in Flint reported changes in bathing/showering habits compared to households in Greater Genesee County (52% vs 14%, $p=0.0058$, Fisher’s Exact Test). Flint households were more likely than Saginaw households to report changes to handwashing habits (38% vs 7%, $p=0.0109$, Fisher’s Exact Test) and bathing/showering habits (52% vs 0%, $p<0.0001$, Fisher’s Exact Test) after the Flint water crisis began.

Table 12: Changes in household handwashing and bathing habits since the Flint Water Crisis, by jurisdiction — Genesee & Saginaw Co., Michigan, Mar-Oct 2016

	Flint (n=24)	Greater Genesee Co. (n=30)	Saginaw Co. (n=29)
Changes in handwashing habits	38%	26%	7%
Changes in bathing/showering habits	52%	14%	0%

G. Summary of Results and Discussion

The results of the household survey are consistent with a community-wide person-to-person outbreak of shigellosis. The prolonged outbreak period suggests that secondary transmission likely played an important role in the outbreak and is not consistent with a point source outbreak, which is characterized by a rapid peak and relatively short duration following cessation of exposure. As is seen in community outbreaks of shigellosis, children were most commonly affected by the outbreak (median age of ill persons=10 years); a majority of ill persons reporting contact with a person wearing diapers or a person with diarrhea in the week before becoming sick; and no specific source or setting was identified. These characteristics suggest person-to-person transmission sustained the outbreak over several months. No significant differences were noted in case-patient or case-household characteristics reported by Genesee or Saginaw Counties, suggesting a single outbreak across these counties, with a common mode of transmission.

Results of this survey do not support the hypotheses that shigellosis spread through the Flint municipal water system, or that illness occurred as a result of systematic avoidance of tap water for hygiene. Exposure to Flint water among case-patients living in Flint was low. Fewer than one in five households served by the Flint water system reported consuming tap water during the outbreak period, and over 90% reported drinking bottled water. Though households in the outbreak received drinking water from many different drinking water systems, demographic and exposure information reported by Index cases and households was similar across Genesee and Saginaw Counties. This suggests that exposure to a single drinking water system, such as the Flint municipal water system, was not the cause of the outbreak. Finally, households in Flint, Greater Genesee County, and Saginaw County reported similar uses of tap water, hand sanitizer, and cleaning wipes for hygiene, indicating that Flint residents did not rely more heavily on hand sanitizer and cleaning wipes than residents in Greater Genesee County or Saginaw County. It is unlikely that replacement of handwashing with hand sanitizer or cleaning wipe use caused the outbreak.

By assessing characteristics of household members and potential modes of transmission, this survey indicated person to person transmission was responsible for the outbreak in these communities. To further understand the dynamics of the outbreak, we undertook a laboratory investigation (section III) to assess the relatedness of bacterial isolates obtained from case-patients in the outbreak and in nearby communities. To further consider the role of the Flint municipal water system in the outbreak, we also conducted a geo-spatial investigation (section IV) to examine existing water quality data alongside data from the epidemiologic investigation.

Section III: Laboratory Investigation

A laboratory investigation was conducted to assess the relatedness of bacterial isolates obtained from case-patients residing in geographically distinct areas and whose illness onset dates spanned the eight-month outbreak period. The laboratory investigation also considered how isolates from Genesee and Saginaw counties might be related to other shigellosis isolates collected from patients in Michigan before and during the outbreak period. Primary methods for assessing the relatedness of the bacterial isolates included pulsed-field gel electrophoresis (PFGE) and whole genome sequencing (WGS). Antimicrobial susceptibility testing was conducted on a sample of isolates to assess antimicrobial resistance.

I. Pulsed-Field Gel Electrophoresis (PFGE)

Background:

Pulsed-field gel electrophoresis (PFGE) is a laboratory technique used for typing bacteria isolated from culture. PFGE is the most common method used by public health laboratories in the United States to compare bacterial isolates. During PFGE, DNA from bacterial isolates are cut into pieces and the pieces are separated out using an electrical current passed through an agarose gel to separate the pieces of DNA based on their size. The separated pieces create a pattern that can be visually compared to those from other isolates using analysis software. In PulseNet, isolates with an indistinguishable pattern are given the same pattern number and are thought to be more closely related than those with dissimilar patterns.

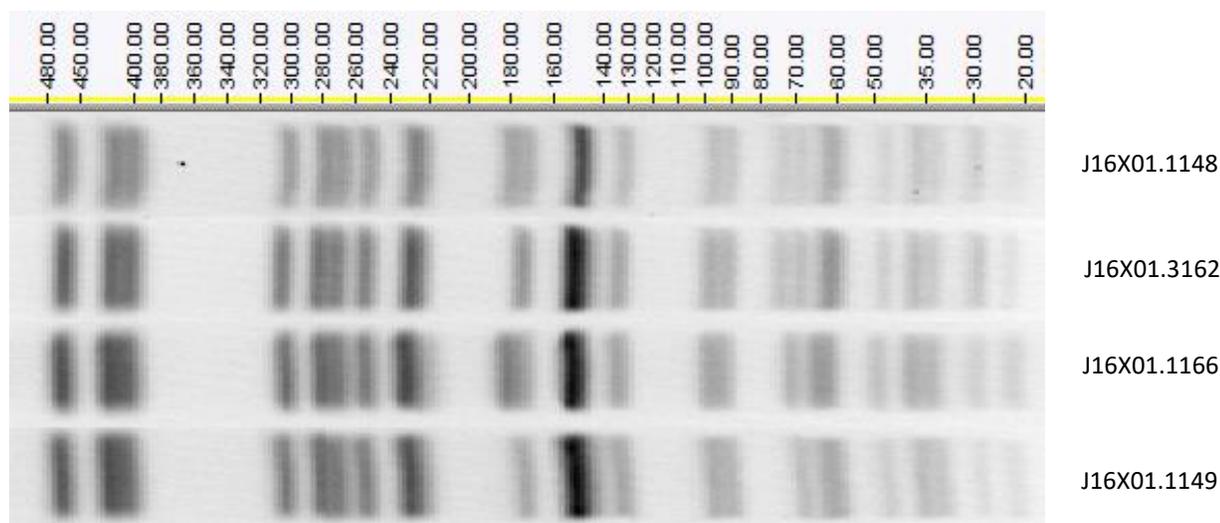
Methods:

A total of 27 bacterial isolates from case-patients in Genesee and Saginaw counties from the outbreak period (March 1, 2016 – December 10, 2016) were selected at random and analyzed using the standard PFGE protocol from CDC's PulseNet program (<https://www.cdc.gov/pulsenet/pdf/ecoli-shigella-salmonella-pfge-protocol-508c.pdf>). Subsequently, 57 additional isolates were selected for comparison with isolates associated with the outbreak. This group of 57 isolates included randomly selected isolates from case-patients in Genesee and Saginaw counties from months prior to the outbreak period (January 1, 2015 – February 29, 2016) along with isolates linked to other small shigellosis outbreaks in nearby counties occurring between January 1, 2015 and December 10, 2016. PFGE testing was conducted by the Michigan Bureau of Laboratories and the analyzed patterns were uploaded to the PulseNet USA national *Shigella* database. The PulseNet USA Database Team compared the resulting PFGE patterns to those collected from other state and local health departments in 2015-2016.

Results:

Among the 27 isolates from case-patients in Genesee and Saginaw counties from the outbreak period, four distinct but nearly identical PFGE patterns were identified during analysis, as displayed in **Figure 7**. These patterns were found among isolates from both Genesee and Saginaw Counties. No other isolates reported to PulseNet USA during this time period matched these four patterns. Among the additional 57 isolates submitted for analysis, 27 isolates had a PFGE pattern matching one of the four PFGE patterns initially detected. Among the other 30 isolates, 19 distinct PFGE patterns were identified.

Figure 7: Four PFGE patterns identified in conjunction with an outbreak of shigellosis in Genesee and Saginaw counties, MI, 2016



Discussion:

These findings suggest that illnesses in Genesee and Saginaw Counties during the outbreak period were caused by highly similar strains. The lack of matching PFGE patterns from contemporary isolates from other states in the national database suggests the strain causing this outbreak was not directly linked to outbreaks in jurisdictions that report shigellosis PFGE patterns to PulseNet. However, additional isolates with matching PFGE patterns were identified from nearby counties and earlier time points, suggesting that the outbreak strain was present in the region before the recognized outbreak in Genesee and Saginaw counties.

II. Whole-Genome Sequencing (WGS)

Background:

Whole-genome sequencing (WGS) is a laboratory technique used to compare the DNA of bacterial isolates in order to understand similarities and differences and determine their genetic relatedness. During WGS, the genome of a bacterial isolate is cut into small pieces and the individual building blocks of the DNA are identified using a sequencing machine. The DNA pieces are then reassembled and the resulting sequences are compared to those from other isolates via computer analysis to identify similarities and differences between individual isolates or groups of isolates. Differences are measured in the number of either alleles or single nucleotide polymorphisms (SNPs). The fewer the differences, the more closely related the isolates are thought to be. WGS results are most commonly displayed on a phylogenetic tree (i.e., dendrogram).

Methods:

To further characterize relatedness, all isolates submitted for PFGE testing were also submitted for whole genome sequencing (WGS). Isolates were sequenced on the Illumina MiSeq using NexteraXT (Illumina Inc.) library preparations and 2x250 bp sequencing chemistry. hqSNP analysis was conducted with Lyve-Set 1.1.4f (<https://github.com/lskatz/lyve-SET>) using closely related PacBio sequences as references with phage regions masked. Reads were trimmed before mapping by SMALT. SNPs were called using Varscan at >20x coverage, with >95% read support, and <5 bp apart. Phylogenetic trees were prepared by the Enteric Diseases Bioinformatics Team at CDC, annotated by the PulseNet USA Database Team and interpreted using epidemiologic data reported to the CDC by state and local health departments. Two additional isolates from another state with PFGE patterns matching the outbreak strains were also included in tree preparation for genetic comparison. A total of 86 isolates were included in the phylogenetic tree.

Results:

The analysis of whole genome sequencing revealed two main clades (**Figure 8**). The largest clade (Clade 1 in Figure 8) contained 62 isolates with SNP differences ranging from 0 to 58. All isolates from Genesee and Saginaw counties obtained during the outbreak period sorted into clade 1. A second clade of 12 isolates was identified with SNP differences of 1-42 (Clade 2 in Figure 8). A smaller number of isolates including two reference isolates from outside Michigan differed from other isolates in the tree by 79-537 SNPs.

Figure 8: hqSNP Analysis of *Shigella sonnei* isolates (N = 86) from Genesee and Saginaw Counties, MI and Surrounding Counties, 2015-2016

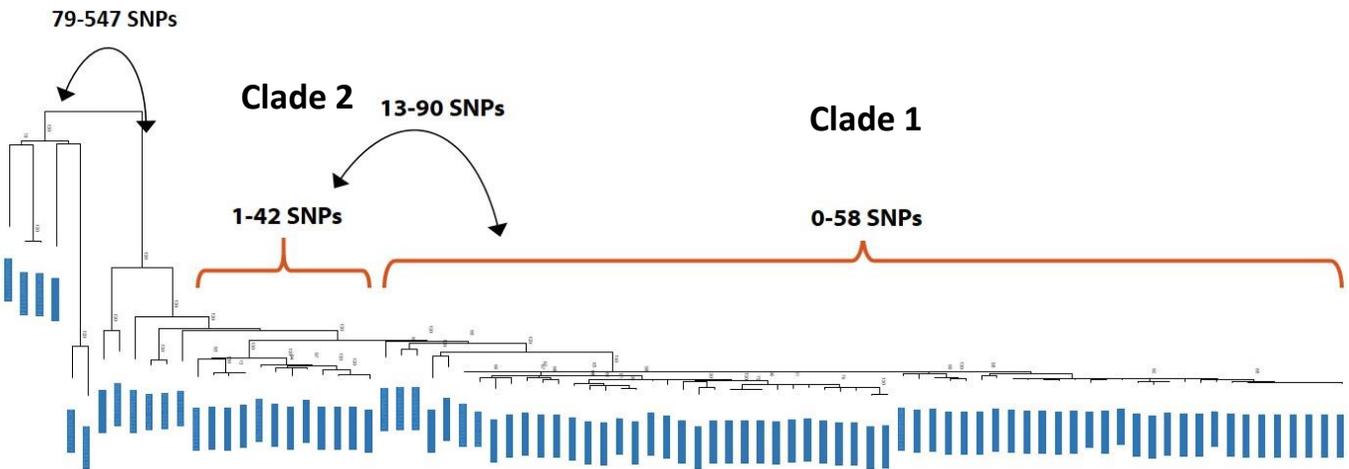
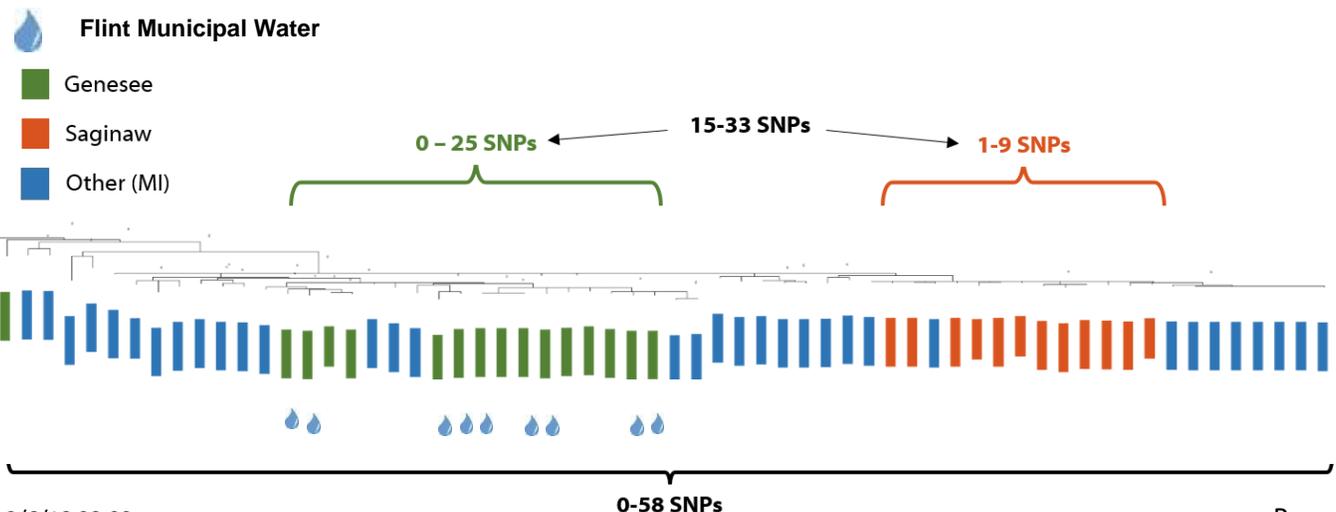


Figure 9 shows the 62 isolates from the largest clade (Clade 1), color-coded by county of residence. Isolates from case-patients in Genesee County obtained during the outbreak period (n=15) differed by 0-25 SNPs, as indicated by the green bracket in Figure 9. Nine of these 15 case-patients from Genesee County lived in Flint and received drinking water from the Flint municipal water system. Isolates from these case-patients also differed by 0-25 SNPs. Isolates from case-patients in Saginaw County obtained during the outbreak period (n=12) differed by 1-9 SNPs, as indicated by the orange bracket in Figure 9. Isolates from Genesee and Saginaw counties obtained during the outbreak period differed by 15-33 SNPs. One isolate from a case-patient in Genesee County from before the outbreak period also sorted into Clade 1, along with 34 isolates from case-patients from other nearby Michigan counties before and during the outbreak period. Overall, isolates in clade 1 differed by 0-58 SNPs.

Figure 9 hqSNP Analysis of *Shigella sonnei* isolates from Clade 1 (n = 62) by Source County and Flint Municipal Water Status -- Michigan, 2015-2016



Discussion:

All isolates from Genesee and Saginaw counties from the outbreak period sorted into a single large clade along with numerous isolates from other nearby counties in Michigan from before or during the outbreak period. This reveals the relatedness of cases across multiple jurisdictions in Michigan during 2015-2016, suggesting that the strain responsible for the outbreak in Genesee and Saginaw Counties was present in the region prior to the recognized beginning of the outbreak in March 2016. This is consistent with our best understanding of shigellosis as a disease that spreads easily through and between communities and is often difficult to control. It is not possible to determine the origin of the outbreak using this information, as only a subset of case-isolates were sequenced and SNP differences alone do not provide information as to the order of spread between geographic areas. The genetic diversity seen amongst the nine outbreak-associated isolates obtained from patients whose household water was supplied by the Flint Municipal Water System is not consistent with point source transmission of an outbreak through a water system, in which case-isolates would be nearly identical with few SNP differences.

III. Antimicrobial Susceptibility Testing (AST)

Background:

Antimicrobial resistance of shigellosis isolates can play a role in treatment failure and the spread of an outbreak. Antimicrobial susceptibility testing (AST) identifies antimicrobial resistance in bacterial isolates obtained from patient specimens. AST of sporadic and outbreak-associated shigellosis isolates is routinely conducted by public health laboratories.

Methods:

Isolates from case-patients in Genesee and Saginaw counties from the outbreak period were selected for antimicrobial susceptibility testing at the Michigan Bureau of Laboratories and CDC. Isolates tested at Michigan Bureau of Laboratories were evaluated for resistance to trimethoprim-sulfamethoxazole, ampicillin, and ciprofloxacin via disk diffusion. Broth microdilution (Sensitre, ThermoFisher Scientific) was also conducted by the National Antimicrobial Resistance Monitoring System (NARMS) at CDC and included phenotypic AST for the following antibiotics: amoxicillin/clavulanic acid, ampicillin, azithromycin, cefoxitin, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, meropenem, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, and trimethoprim/sulfamethoxazole. Resistance was defined by the Clinical and Laboratory Standards Institute (CLSI) interpretive standards, when available. For streptomycin, where no CLSI interpretive criteria for human isolates exist, the resistance breakpoint used was 64 mg/L. Testing was performed according to the manufacturer's instructions.

Results:

Antimicrobial susceptibility testing of 14 outbreak-associated isolates at the Michigan Bureau of Laboratories found 100% (14/14) resistant to trimethoprim/sulfamethoxazole, 21% (3/14) resistant to ampicillin, and 0% (0/14) resistant to ciprofloxacin (**Table 13**). Phenotypic AST performed by NARMS on four outbreak-associated isolates found two isolates resistant to streptomycin only, one isolate resistant to ampicillin and streptomycin with intermediate susceptibility to amoxicillin/clavulanic acid and chloramphenicol, and one isolate resistant to ampicillin and streptomycin with intermediate susceptibility to amoxicillin/clavulanic acid (**Table 14**). The four isolates tested by NARMS were susceptible to the clinically important antibiotics azithromycin, ceftriaxone, ciprofloxacin, and trimethoprim/sulfamethoxazole. One outbreak-associated isolate was tested by both laboratories and found to be resistant to trimethoprim/sulfamethoxazole by disk diffusion (MBOL) but susceptible by broth microdilution (NARMS).

Table 13: Antimicrobial Susceptibility Testing Results from 14 Outbreak-associated Shigellosis Isolates from Michigan, 2016 – Michigan Bureau of Laboratories

Specimen#	Trimethoprim-sulfamethoxazole	Ampicillin	Ciprofloxacin
Specimen 1	R*	S*	S
Specimen 2	R	R	S
Specimen 3	R	S	S
Specimen 4	R	R	S
Specimen 5	R	S	S
Specimen 6	R	S	S
Specimen 7	R	S	S
Specimen 8	R	S	S
Specimen 9	R	S	S
Specimen 10	R	S	S
Specimen 11	R	S	S
Specimen 12	R	R	S
Specimen 13	R	S	S
Specimen 14	R	S	S

Abbreviations: “R” = Resistant; “S” = Susceptible

Table 14: Antimicrobial Susceptibility Testing Results from Four Outbreak-associated Shigellosis Isolates from Michigan, 2016 – National Antimicrobial Resistance Monitoring System, CDC

Antimicrobial	Isolate 1	Isolate 2	Isolate 3	Isolate 4
Amoxicillin/Clavulanic Acid	I	S	S	I
Ampicillin	R	S	S	R
Azithromycin	S	S	S	S
Cefoxitin	S	S	S	S
Ceftriaxone	S	S	S	S
Chloramphenicol	I	S	S	S
Ciprofloxacin	S	S	S	S
Gentamicin	S	S	S	S
Meropenem,	S	S	S	S
Nalidixic Acid	S	S	S	S
Streptomycin	R	R	R	R
Sulfisoxazole	S	S	S	S
Tetracycline	S	S	S	S
Trimethoprim/Sulfamethoxazole	S	S	S	S

Abbreviations: “I” = Intermediate; “R” = Resistant; “S” = Susceptible

Discussion:

Results of antimicrobial susceptibility testing of outbreak-associated isolates demonstrate resistance patterns common to *Shigella sonnei* isolates seen throughout the United States and similar to other isolates from Michigan. All outbreak-associated isolates were found to have susceptibility to commonly used first-line antibiotics, including azithromycin and ciprofloxacin. The discrepancy in trimethoprim-sulfamethoxazole susceptibility for the isolate tested in both laboratories may be due to differences in laboratory methods (disk diffusion vs. broth microdilution). For additional information about development and interpretation of resistance cutoffs, see www.cdc.gov/narms.

Section IV: Spatial-Temporal Investigation

Background and Objectives:

To further assess the possible role of the Flint water system in causing or propagating the outbreak, we investigated the spatial and temporal distribution of shigellosis cases in Flint and analyzed available Flint water quality data to explore whether water quality was associated with incident shigellosis. This portion of the investigation was conducted in collaboration with the Geospatial Research, Analysis, and Services Program (GRASP) in the Agency for Toxic Substances and Disease Registry (ATSDR). In the course of this investigation, data from the City of Flint and the Environmental Protection Agency were carefully considered. The following objectives were developed and studied, with detailed methods and results included below:

- Objective 1: Identify statistically significant space-time clusters of shigellosis among case-households serviced by Flint municipal water.
- Objective 2: Determine whether per capita water use differs between case-households and households from which shigellosis was not reported during the outbreak period.
- Objective 3: Consider the relationship between weekly free-chlorine testing results from 34 monitoring stations across Flint and index shigellosis cases by household per week.
- Objective 4: Examine the relationship of temperature with free chlorine and incident shigellosis.

Objective 1: Space-time Analysis of Shigellosis Cases in Flint

Goal: Identify statistically significant space-time clusters of shigellosis among case-households serviced by Flint municipal water, using SaTScan to conduct Poisson distribution space, temporal and space-time scan statistics.

Methods: The latitude/longitude of households in Genesee County containing at least one case of shigellosis reported to MDSS during the outbreak period were geocoded to house of residence. Geolocations of incident shigellosis cases among households receiving drinking water from the Flint municipal water system were analyzed for clustering using the Kulldorf's Scan Statistic. This method compares the observed distribution in a study areas to a large statistical sample of computer generated random points in the same study area, and identifies a space-time location or time period with a significant excess of cases. Spatial, temporal (by week), and space-time Kulldorf Scan statistics were conducted to examine if these distinct types of clustering were occurring during the outbreak period. Incidence rates by census tract were calculated and mapped for on shigellosis cases reported to MDSS for Genesee and Saginaw counties during the outbreak using US Census estimates.

Results: Initial analysis revealed a statistically significant space-time cluster of shigellosis cases ($p < 0.03$) in the southwest region of the City of Flint from weeks 14-18 of the outbreak. Eleven cases were reported in this cluster, when 2.2 cases were expected. A subsequent analysis looking only for spatial clustering (i.e., not factoring in time) did not reveal any statistically significant clustering. Nineteen cases were reported when 16.50 cases were expected.

A temporal cluster analysis of index cases from households in Flint (not factoring in space) found a statistically significant temporal cluster ($p < 0.006$) between weeks 16-20 of the outbreak (**Figure 10**). Fourteen cases were detected when 4.71 cases were expected. This finding correlates with the

outbreak epidemiologic curve (Section 2, Figure 5), which indicates the peak of the outbreak occurred during weeks 16-20 of the outbreak (June-July 2016). The dark points in Figure 10 represent the reported cases clustered in time while the lighter points illustrate the additional shigellosis cases not clustered in time.

Mapping of shigellosis incidence rates in Genesee and Saginaw Counties revealed higher rates of infection in the urban centers (City of Flint and City of Saginaw) (Figure 11a). However, within these cities, no meaningful clustering was noted to suggest a common geographic source. Specifically, in Flint no clustering corresponding to the municipal water system was observed (Figure 11b).

In summary, no spatial clustering of shigellosis cases was identified in Flint, suggesting that cases did not cluster around a common geographic source such as the Flint municipal water system or a subdivision of the water system. Temporal analysis revealed clustering consistent with the peak of the outbreak.

Figure 10. Temporal Cluster of Shigellosis (reported to MDSS), Saginaw and Genesee Counties, Michigan, Mar 1- Dec 10, 2016

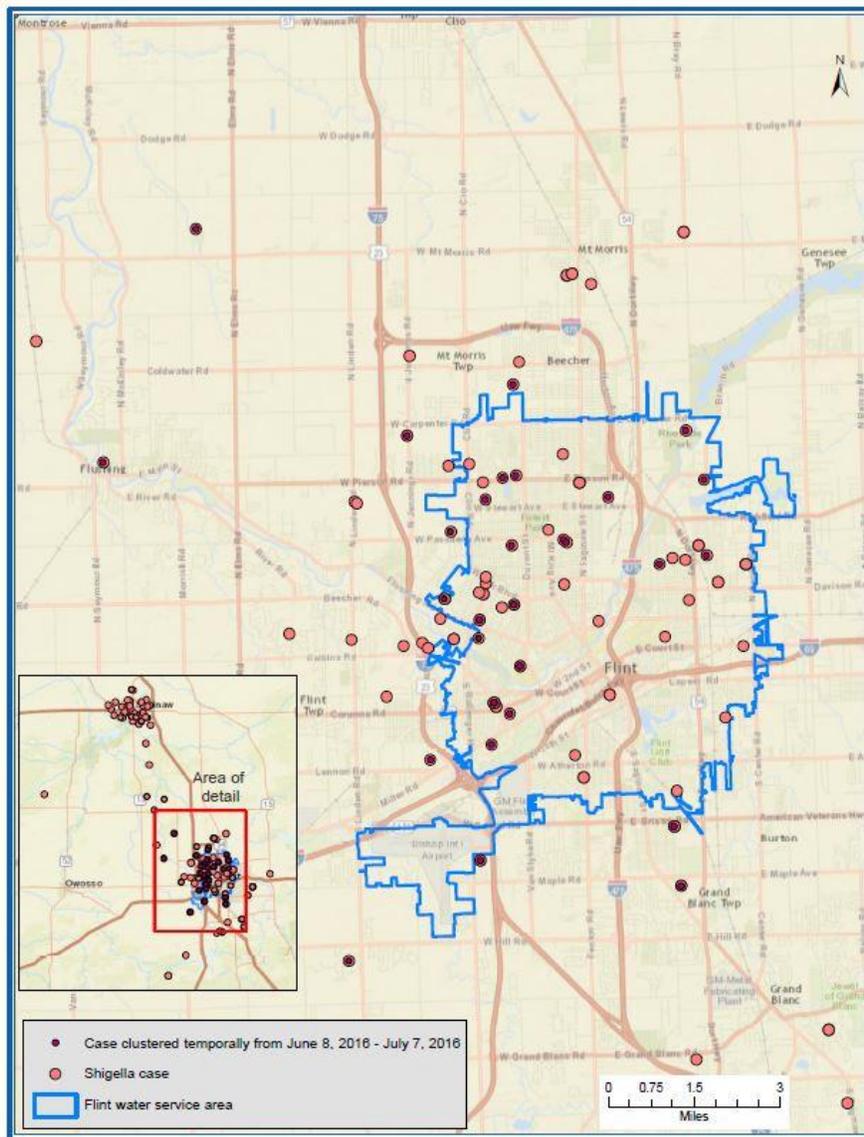
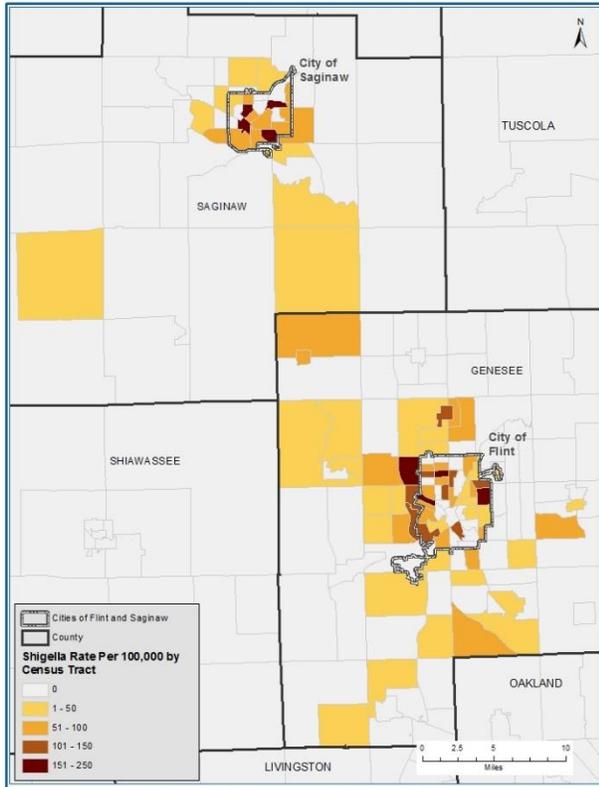
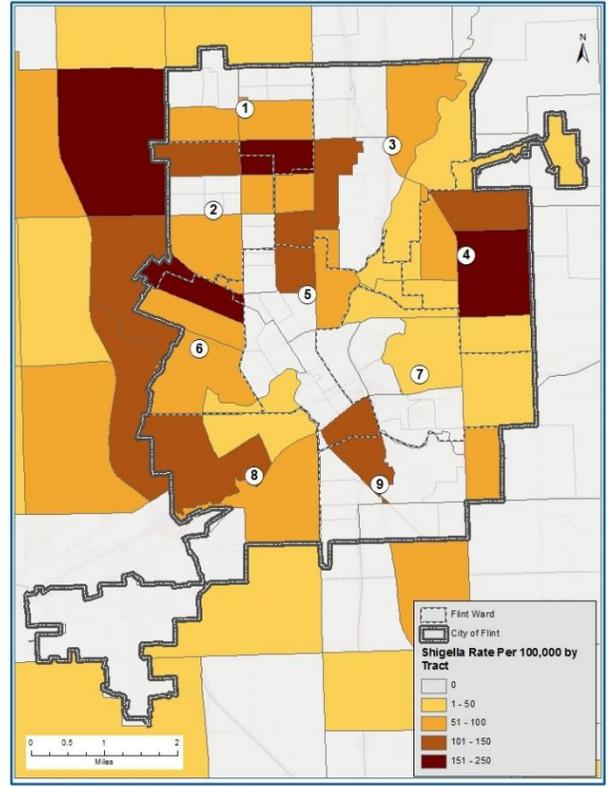


Figure 10a



* U.S. Census Bureau, American Community Survey, 2015
 American Community Survey 5-Year Estimates by Census Tract,
 Data column HC01_EST_VC01, Accessed 8 December 2016.

Figure 10b



* U.S. Census Bureau, American Community Survey, 2015
 American Community Survey 5-Year Estimates by Block Group,
 Table B01001e1, Accessed 8 December 2016.

Figure 11a. Rate of shigellosis per Census tract (reported to MDSS) Saginaw and Genesee Counties, Michigan, Mar 1-Dec 10, 2016

Figure 11b. Rate of shigellosis per Census tract (reported to MDSS) in Flint and surrounding Genesee County, Michigan, Mar 1-Dec 10, 2016

Objective 2: Water use among Flint residents

Goal: Determine whether per capita water use differed between case-households and households from which shigellosis was not reported during the outbreak period.

Methods: Despite extensive exploration of billing data for household water use obtained from the City of Flint, several limitations emerged which precluded us from reliably estimating per capita water use in the week prior to illness onset, which represents the upper limit of the incubation period.

The limitations included:

- i. Data were incomplete or unavailable for a number of case households.
- ii. Billing is measured and reported at different times of the month for different houses, and is not predictable. This includes months where water meter readings are not recorded.
- iii. Water use credits for Flint residents are not clearly accounted for in available data.
- iv. The impact of water flushing campaigns across the city during the time period of interest is unclear.

- v. Exploration of individual household water utility records revealed that water use can vary by multiple orders of magnitude between households in the same neighborhood, and within the same household from one billing cycle to the next.

As a result, this inquiry was suspended with no further plans to resume the analysis.

Objective 3: Water quality measures and shigellosis

Background: *Shigella* is easily inactivated by chlorine, which is commonly added to drinking water systems as part of a comprehensive water disinfection plan. Water utilities and environmental health agencies regularly measure the concentration of free chlorine in drinking water to ensure that levels are adequate for disinfection. In many communities, a level of 0.5 mg/L is set as a minimum free chlorine level for samples obtained from sites in the water distribution system. In other communities, including the City of Flint, a minimum level of 0.2 mg/L has been adopted. Both 0.5 and 0.2 mg/L of free chlorine in the water are consistent with state and federal drinking water standards. EPA and the City of Flint conduct routine monitoring at numerous sites in the distribution system on a weekly or bi-weekly basis.

Goal: Determine whether free chlorine levels correlated with incidence of shigellosis in households receiving drinking water from the Flint municipal drinking water system during the outbreak period.

Methods: Weekly free chlorine residual values were downloaded from ArcGIS online (<https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=b0dd83f57f834625b47ccdb7da81db02>). Free chlorine was measured at 10 locations run by the City of Flint and 24 locations run by the EPA. Data points with measurements of 0.0 mg/ml and no sampling date (n=3) were excluded from the analysis as were the weeks (n=11) where no data was collected at the EPA sample sites (comprising 24 sites out of 34 total).

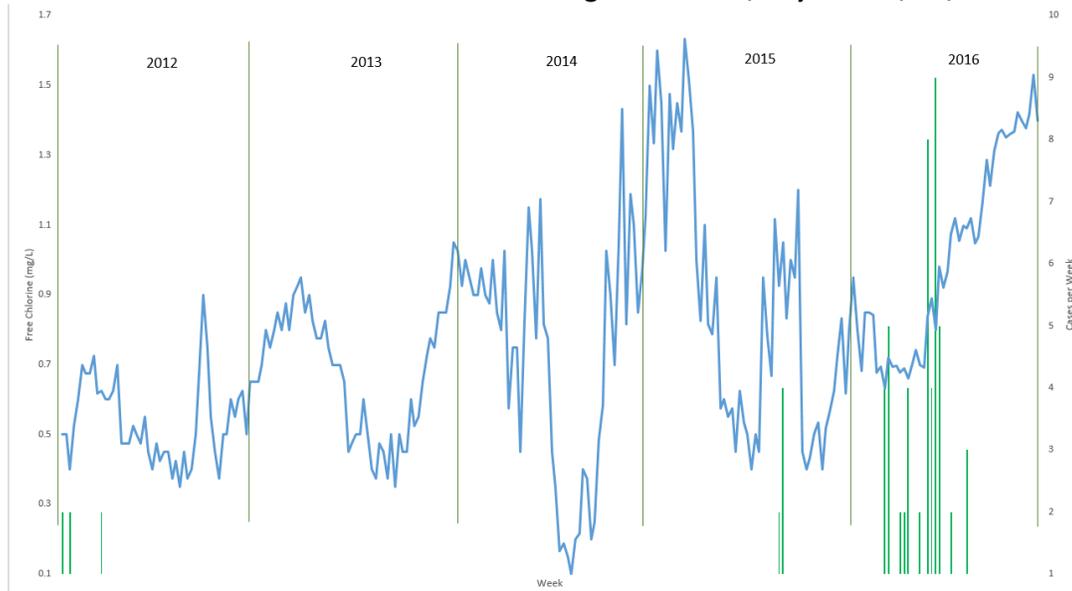
In consultation with EPA and GRASP we explored all available details regarding the location of these water quality monitoring stations and the layout of the Flint municipal water system. Specifically, we explored all possible methods for identifying the relationship between water quality test results at a monitoring station and nearby households. Many factors complicated this exploration, including inability to determine the direction of flow of water within individual pipes or areas of the water system, day-to-day variation in patterns of water flow, relative contribution of various monitoring stations to individual residences in the City of Flint, potential error introduced by storage tanks related to some households in the city, and possible interference caused by local water line failures. As a result, no reliable method was determined to relate individual households to nearby monitoring stations where regular chlorine testing was conducted. Additionally, there were no available data detailing water quality metrics at households affected by the outbreak.

Given these limitations, we calculated average free chlorine levels across the water system to assess for any widespread drops in free chlorine that might indicate a system-wide problem during the outbreak period. We obtained weekly free chlorine residual testing results from the City of Flint municipal water system from the 34 monitoring sites used by EPA and the City of Flint, which includes sites like community buildings or businesses spread across the City of Flint.

Results: Throughout the outbreak, the average free chlorine level measured at monitoring stations in the Flint municipal water system exceeded the minimum requirements established by Flint (0.2 mg/L), and the more conservative value (0.5 mg/L) used by some municipalities (Figure 12).

A review of chlorine testing at City of Flint monitoring stations from 2012-2015 revealed large fluctuations in average free chlorine concentrations without corresponding changes in reported cases of shigellosis in The City of Flint (Figure 12).

Figure 12. Historical Free Chlorine Residuals and Shigellosis Cases, City of Flint, MI, 2012-2016



Objective 4: Water Temperature

Background: Water temperature is inversely associated with free chlorine levels in municipal water systems. Due to the unavailability of municipal water temperature data, we examined a proxy of water temperature, ambient temperature, in relation to free chlorine levels. Warmer ambient temperatures may also lead to exposures, such as recreational swimming, which are potential risk factors for shigellosis. Therefore, we also explored the relationship between ambient temperature and incident shigellosis during the outbreak.

Goal: Examine the relationship between ambient temperature (as a proxy for water temperature), free chlorine levels, and incident shigellosis cases at a household level in The City of Flint during the outbreak period.

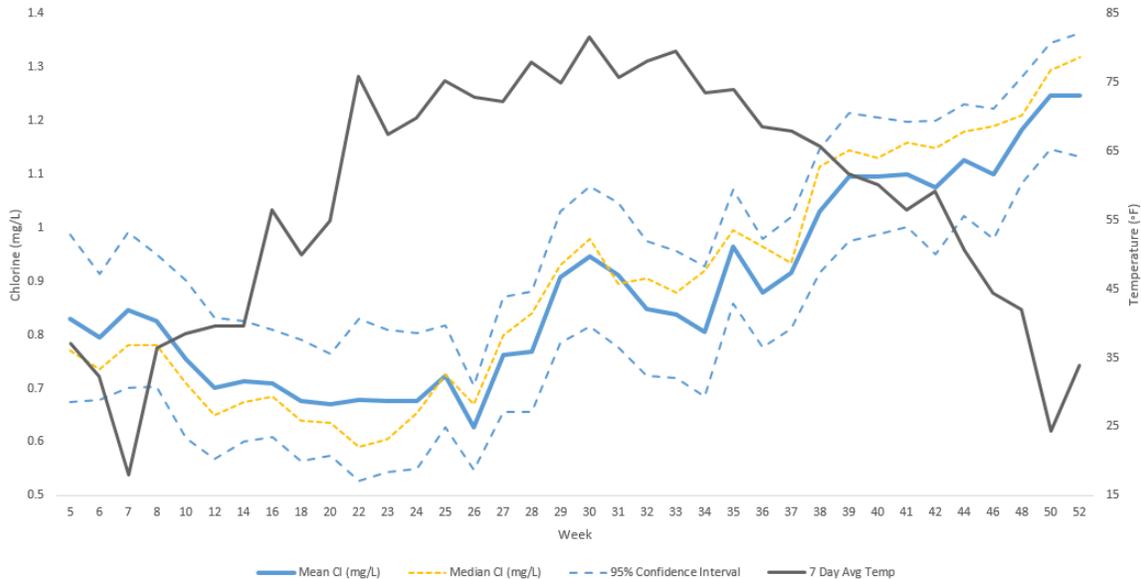
Methods: Weekly free chlorine residual values were downloaded from ArcGIS online (<https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=b0dd83f57f834625b47ccb7da81db02>). Free chlorine was measured at 10 locations run by the City of Flint and 24 locations run by the EPA. Data from 12 weeks were excluded from this analysis because testing was not completed at all locations.

Weekly mean and median free chlorine values were calculated and assigned to index cases based on date of illness onset. Data points with measurements of 0.0 mg/ml and no sampling date (n=3) were excluded from the analysis as were the weeks (n=11) where no data was collected at the EPA sample sites (comprising 24 sites out of 34 total).

Temperature data were obtained from the NOAA National Centers for Environmental Information (<https://www.ncdc.noaa.gov/cdo-web/>). A 7-day average temperature value was calculated for each free chlorine sampling instance using the average daily temperature for the seven days leading up the sampling date. Paired t-tests were used to test for associations between incident shigellosis and ambient temperature; linear regression was used to assess the relationship between free chlorine and ambient temperature.

Results: **Figure 13** depicts variation in weekly mean and median free chlorine levels and 7-day average temperature by week in 2016. There was no statistically significant association between mean free chlorine and weekly mean ambient temperature. For every 0.10 mg/mL increase in free chlorine there was a 2.47 degree Fahrenheit decrease in temperature ($p=0.14$). Additionally, there was no statistically significant difference in mean ambient temperature for weeks with index shigellosis cases and weeks without ($t=0.834$, $p=0.42$).

Figure 13. Mean, 95% confidence intervals, and median free chlorine from 34 City of Flint municipal water testing sites and weekly mean ambient temperature, by 2016 epidemiologic week.



Discussion:

Index cases of shigellosis were dispersed across multiple water systems without evidence of spatial clustering. Free chlorine levels measured at monitoring stations distributed across The City of Flint indicated adequate mean chlorine residuals during the outbreak period. Due to the unavailability of household-level free chlorine residual values, there is insufficient information to address whether household water quality – such as a burst pipe in someone’s home resulting in sewage exposure – played a role in individual infections. Finally, the relative absence of water quality data and the challenges of analyzing and interpreting the water quality data that was available underscore the need to develop approaches to investigating community-wide health events potentially related to water systems.

Case Interview Form

Epi-Aid 2017-003

Shigellosis in Genesee and Saginaw Counties, MI, 2016

Public reporting burden of this collection of information is estimated to average 30-40 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information including suggestions for reducing this burden to CDC/ATSDR Reports Clearance Officer; 1600 Clifton Road NE, MS D-74 Atlanta, Georgia 30333; ATTN: PRA (0920-1011)

Overview and Instructions

This case interview form is a hypothesis-generating tool intended to capture illness information and identify individual- and household-level risk factors for shigellosis among case-patients reported to the Michigan Disease Surveillance System (MDSS) from Saginaw and Genesee County Health Departments between March 1, 2016 and October 23, 2016. It is intended to be administered via phone by local public health officials with support from the Michigan Department of Health and Human Services (MDHHS) and the Centers for Disease Control and Prevention.

This form has received Office of Management and Budget approval for use during Epi-Aid 2017-003 through the Emergency Epidemic Investigation Generic ICR mechanism (0920-1011). Data storage and use, including information in identifiable form, are governed under terms of use. All completed forms will be stored at MDHHS.

This form consists of a front sheet that includes case-patient contact information, an introductory script, and five sections titled: shigellosis, activities outside the home, travel, food, and water. Together, these sections collect information on the case-patient's illness, illness among household members, and risk factors for shigellosis.

As of October 23, 2016, approximately 177 shigellosis case-patients from Genesee and Saginaw counties were reported to MDSS. These case-patients come from about 125 unique households. Interviewers will receive forms that list all the case-patients who reside in each unique household. These forms will also include MDSS ID, name, sex, age, phone number, and illness onset date for each case-patient.

Before initiating a phone call, interviewers will complete four rows (MDSS ID, illness onset date, age, sex) of Table 1 (found on the last page of this packet) for each of the case-patients listed on the pre-printed household forms prepared for interviewers. Table 1 will also be used to collect information about each household member and any other illness in the house. To ease completion of Table 1, interviewers may choose to separate it from this packet.

After pre-populating Table 1, interviewers use the pre-printed household form to identify and call the case-patient with the earliest illness onset date, or their parent/guardian if the case-patient is a minor. If this case-patient (or guardian) is not available, the interviewer will ask to speak with another case-patient (if there are multiple in the house). Once an interviewee (or proxy) is identified, the interviewer will enter this person's information in the 'Interviewee Information' section at the top of page 4.

All call attempts will be logged on page 4, including all phone numbers attempted. A standard script will be used for initial contact with the interviewee, and also when leaving voicemails. Interview attempts will be limited to 12 per household.

Once contact has been initiated, the interviewer commences the interview by reading the script on page 5.

Other Situations

If someone other than the client/guardian answers:

- We cannot give information about the client due to the Data Privacy Act; however, we can say that we are calling from the (Genesee/Saginaw) County Health Department.
- Leave message with our number, and/or schedule a call back based on when they will be home.

If someone else is responding for an adult (>18 years) client

- Every effort should be made to talk to the client directly, but there are situations in which the client is unable to respond or prefers someone else responds to the interview questions.
- You should verify that the person responding has the client's permission to speak on their behalf
- Request to obtain verbal permission from the client to have someone else speak on their behalf
- If speaking to the client directly is not possible, ask the person responding if we have the client's permission to speak on their behalf
- Do we have _____'s permission for you to speak on their behalf?
- If no, then we must at least have permission from the client or to talk with someone that has permission to speak on the client's behalf

Minor Clients (under 18 years)

- Must speak with parent or guardian first. They can give you permission to interview the client directly. Record the parent's name & if they gave you permission to talk to the client directly
- It is ideal to interview older minors (teens) directly or simultaneously with parent. For younger clients, interview the parent.
- It is always ok for a parent to listen if interviewing the case directly

Non-English Speaking Clients

- If you call a client and they do not speak English tell them "Someone who speaks _____ will call you back from the (Genesee/Saginaw) County Health Department."
- If the client has a family member or representative they would prefer to have speak for them, see "If someone else is responding for an adult (>18 years) client" above

Deceased Clients

- If you discover during the initial phone call that the client has died:
- Offer your condolences
- "I'm calling from the (Genesee/Saginaw) County Health Department about Mr/Ms. _____ illness. Now is probably not a good time, but at some point in the near future I'll need to speak with you about _____'s illness. I can call back at a later date. Is this the best phone number to call you back?"
- If possible, we still want to complete the form at some point, but it's important to respect a family's grief.
- If the person answering the phone would like to answer questions at that time, go through the questionnaire

Hostile Clients

- If for any reason the client is verbally aggressive and/or inappropriate and is not answering questions tell the client, "Thank you for your time" and end the conversation.
- Please indicate that the interview was terminated early and reason why on the questionnaire.

SHIGELLOSIS CASE INTERVIEW FORM
GENESEE AND SAGINAW COUNTIES, MI
October 2016

Interviewee Information: Check here if interviewee is a proxy for a case-patient who is a minor

Last name: _____ First name: _____

Relationship to reference case: _____ Person number (from top row of table 1): _____

County of residence: Genesee Saginaw MDSS ID (of minor if proxy interviewer): _____

Telephone numbers (Add as needed; circle successful number)

() ___ - ___	() ___ - ___	() ___ - ___	() ___ - ___	() ___ - ___
---------------	---------------	---------------	---------------	---------------

Telephone Contact History

Call	Date (MM/DD)	Time	Outcome (codes below)	Caller Initials	Interview completed?	IF DIFFERENT TIME REQUESTED:
1	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
2	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
3	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
4	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
5	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
6	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
7	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
8	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
9	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
10	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
11	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)
12	___ / ___	_____ AM / PM			Yes No	___ / ___ (MM/DD) _____ (AM/PM)

OUTCOME CODES:

01 = completed interview

02 = refused interview

03 = no answer

04 = busy tone

05 = non-working number

06 = fax machine

07 = business phone

08 = no eligible respondent

09 = language barrier

10 = interview terminated within questionnaire

11 = physical/mental impairment

12 = answering machine

13 = setting up a better time

99 = unknown

Interview Scripts

Initial Greeting

Hello, is (a parent or guardian of) _____ available?

Hello, my name is _____ and I'm calling on behalf of the (Genesee/Saginaw) County Health Department. Previously, we contacted you about [your/your family member's] *Shigella* (diarrheal) infection. As you may know, over 175 people have been reported to have a *Shigella* infection in Genesee and Saginaw Counties in the past few months. I have a few questions today that may help us to learn why people became sick and to prevent others from becoming ill. Do you have time now for an interview?

- **IF NOT:** try to set up a date/time to call back and complete the interview
 - *Is there a convenient time I can call you back?*
 - **IF NO:** Is there another adult in the household who might like to participate?
Name: _____ Relationship to Reference case: _____
If alternate phone number: _____ (Please copy this to page 3)

IF NO: "Ok, thank you very much for your time. Would you like us to send you information about *Shigella*, the germ that caused you/your family member to get sick?"

IF YES: "We'll get that in the mail right away. Thanks again and have a nice day."

Record address:

IF NO: "Thanks again and have a nice day."

Voicemail

Hello, this is _____ calling on behalf of the (Genesee/Saginaw) County Health Department for (a parent or guardian of) _____. Please call us back at _____. Our hours are _____. Again this is _____ with the (Genesee/Saginaw) County Health Department and our number is _____.

- Do not leave specific information about the case/nature of call in the message.

SECTION 1 Shigellosis

Complete the table on the last page of the packet (Table 1) based on responses to the questions in this section. To make it easier to complete the table, you can detach it from the case interview packet.

“Since I’ll be asking you to answer questions about the time you were sick with diarrhea from *Shigella*, it might be helpful to have a calendar handy. Do you need a moment to grab one?” *Wait until interviewee is ready to continue the interview.* “Ok, I’d like to start by confirming the information we have in our records.”

1. It looks like you first got sick with diarrhea from *Shigella* on ___ / ___ / ___ (MM / DD / YY).” Refer to the MDSS onset date you pre-populated in the table at the end of this packet. “Is that correct or did your symptoms start on a different day?”
2. At the time you were sick, how old were you? [Confirm the information you wrote in Table 1 is correct]

“Now I’d like to know about the people in your house and if any of them also got sick with symptoms like yours.”

3. During the week before you got sick, how many people were living or staying in your household at least 4 nights a week? (include interviewee, if applicable) _____ household members

Complete 3a—3d (in Table 1) for **all household members**, confirming the pre-populated information in Table 1 or adding new entries as needed:

- 3a. How old was the person at the time you got sick?
- 3b. What is this person’s gender or sex?
- 3c. What is this person’s race?
- 3d. What is this person’s ethnicity?

4. Did any of these people get sick with symptoms like yours 2 weeks before or 2 weeks after you got sick?
 No (skip to question 5) Yes (go to 4a)

IF YES: 4a. Without telling me their names, who got sick? You can refer to them by their age and gender or sex. [Write this into table 1]

4b. Who was the first person in the household to get sick? (**select only one person!**)
[This is the “index case” – please check the box for “first person ill” in table 1]

“Now I’ll ask you some questions about [when you were/everyone in your household who got] sick.”

5. For each person in the house who was sick during this time, complete the following questions:
[Write responses into table 1]

5a. Which of the following symptoms did you [or sick member of your household] have? Read options

5b. How many days [were you/was each person] sick?

5c. Did [you/anyone] receive medical care at any of these settings? Read options and mark all the apply

5d. Antibiotics are medicines that are sometimes used to treat infections. [Were you/Was anyone] prescribed antibiotics when [you/they] were sick?

5e. At the time you [and other members of your household] were sick with diarrhea, did [any of] you have a chronic medical condition for which you had to see your doctor or health care provider regularly?

5f. At the time you [*and other members of your household*] were sick with diarrhea, did [*any of*] you have a medical condition that weakens the immune system, or were [*any of*] you receiving treatment that can weaken your immune system? Examples include receiving a transplant, being on cancer treatment, or being diagnosed with HIV/AIDS.

5g. At the time you [*and other members of your household*] were sick with diarrhea, [*were you/was anyone, including children or adults*] wearing diapers?

6. Do you or any adults in your house have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, government plans such as Medicare, or Indian Health Service?

- No Yes Refused

IF NO: skip to question 8.

IF YES: check all that apply:

- | | |
|--|---|
| <input type="checkbox"/> Employer provides | <input type="checkbox"/> A plan that you or someone else buys on your own |
| <input type="checkbox"/> Medicare | <input type="checkbox"/> Medicaid or Healthy Michigan Plan |
| <input type="checkbox"/> Refused | <input type="checkbox"/> Military, CHAMPUS, or the VA |
| <input type="checkbox"/> Don't know | <input type="checkbox"/> Other: _____ |

7. Not including the people counted in the last question, did anyone else stay in your home for at least one night during the week before you got sick?

- No Yes

IF NO: skip to next section.

IF YES: 7a. How many visitors stayed in your home at least one night in the week before you got sick? _____ visitors

7b. Were any of these visitors sick with diarrhea at the time they visited?

- No Yes

SECTION 2 Activities Outside the Home

The following questions are to be asked of the index case-patient. In the event the index case-patient is a minor, a parent or guardian can serve as proxy, preferably one who was a case-patient reported to MDSS. **Once you have determined who will speak for the index case-patient, please indicate in Table 1: "Interviewed:" and also at the top of page 4.**

Check here if talking to the index case-patient:

Continue interview: "Now I'm going to ask you some questions about activities outside the home."

Check here if not talking to the index case-patient:

Continue interview: "Now I'm going to ask you some questions about the first person in your household to get sick. These questions are about activities outside the home. I'd like you to answer them on behalf of the first person who got sick in your household."

1. In the week before you/they became sick, did you/they work or volunteer at a job outside your home?
 No Yes Refused

IF NO: Skip to 2.

IF YES: 1a. Did you/they work in a:

- School (K-12) **IF YES:** What grade level? _____, then skip to 2.
- Healthcare or long-term care facility, continue to 1b.
- Childcare/Day Camp/Daycare, skip to 1c.
- Other: _____, then skip to 2.

1b. What kind of patient care were you/they involved in? Read options, mark all that apply, then skip to 2

- Nurse
- Home health care
- Therapist (PT, ST, OT)
- MA / Patient Care Technician / Nurse's Aid
- Physician/NP/PA
- Other: _____

1c. What kind of childcare did you/they provide? Read options and mark all that apply.

- Daycare center worker
- Baby-sitter or Nanny
- Camp / Day Camp worker
- Other: _____

2. In the week before you/they became sick, did you/they have contact with any children or adults outside the house who were in diapers?

- No Yes

IF NO: Continue to 3.

IF YES: 2a. In the week before you/they became sick, did you/they change any diapers?

- No Yes

SECTION 2 ADDENDUM: Activities Outside the Home

****This question should be asked between questions 1 and 2 in section 2. Please administer question 1 as written regardless of the age of the patient (i.e. if patient is 3 year-old, answer to question 1 will be "No"). Question 1 assesses if you/they are an employee, while question 1.5 assesses if you/they are an attendee.**

Question 1.5: In the week before you/they became sick, did you/they attend any of the following **outside the home**: No Yes

IF Yes: Check all that apply

- School (K-12) – If yes, which grade? _____
- Post-High School education (College, trade school)
- Daycare center/facility
- Childcare in someone's home (not your own)
- Camp or Day Camp

3. In the week before you/they became sick, did you/they spend one or more nights at another address?
 No Yes

IF NO: Skip to 4.

IF YES: 3a. In which city is this place located? _____

3b. At the time you/they stayed there, were any of the household members sick with diarrhea?
 No Yes

4. Not including household members and visitors listed already, in the week before you/they became sick did you/they come in contact with anyone outside your home who had diarrhea? *Prompt for extended family, small children, at church, at work.*
 No Yes

IF NO: Continue to next section.

IF YES: 4a. In which of the following settings did you/they come in contact with a person with diarrhea in the week before you/they got sick? *Read options and check all that apply.*

- Daycare
- Camp / Day camp
- School
- Work / volunteering
- Clinic, hospital, or emergency department
- Church
- House of friend / extended family
- Other: _____

SECTION 3 Travel

The following questions are to be asked of the index case-patient. In the event the index case is a minor, a parent or guardian can serve as proxy, preferably one who was a case-patient reported to MDSS.

If talking to the index case-patient: "Now I'm going to ask you some questions about travel."

If not talking to the index case-patient: "Now I'm going to ask you some questions about whether the first person in your household to get sick traveled anywhere."

1. In the week before you/they became sick, did you/they travel to any other cities in Michigan for work, visit friends, or family, an event, or any other reason?
 No Yes

IF NO: Skip to 2.

IF YES: 1a. Which cities did you/they travel to?

- 1a1. _____
1a2. _____
1a3. _____
1a4. _____
1a5. _____

1b. What type of transportation did you/they use to travel to these cities? *Read options and mark all that apply.*

- Private car
- MTA rideshare / STARS
- Greyhound/AMTRAK
- Uber/Lyft/Taxi/Other rideshare company
- Other: _____

1c. What activities did you/they do while you/they were traveling during this week before you/they became sick? *Read options and mark all that apply.*

- Community gathering (fair, picnic, church, etc)
- Spent the night with friend/family
- Visit a friend/family (not overnight)
- Shower or bathe
- Go to work
- Other: _____

2. In the week before you/they became sick, did you travel outside of Michigan?
 No Yes

IF NO: Skip to 3.

IF YES: 2a. Where did you/they travel? *List city, state, and country if outside the United States.*

- 2a1. _____
2a2. _____
2a3. _____

2a4. _____

2a5. _____

2b. What days were you/they traveling? *Include month and day:* ____ / ____ -- ____ / ____

3. In the week before you/they became ill, did you/they go to any of the following events in your community?

- No (Go to Section 4) Yes (Go to 3a)

3a. Collect additional information about these events in the following table:

#	Event Type (check all that apply)	Location (city, state)	Date of Event	Anyone with diarrhea?
3a	<input type="checkbox"/> Wedding/party/picnic/barbecue <input type="checkbox"/> Fair, carnival, or concert <input type="checkbox"/> Church or School event <input type="checkbox"/> Other: _____		____ / ____ (MM/DD)	Yes No
3b	<input type="checkbox"/> Wedding/party/picnic/barbecue <input type="checkbox"/> Fair, carnival, or concert <input type="checkbox"/> Church or School event <input type="checkbox"/> Other: _____		____ / ____ (MM/DD)	Yes No
3c	<input type="checkbox"/> Wedding/party/picnic/barbecue <input type="checkbox"/> Fair, carnival, or concert <input type="checkbox"/> Church or School event <input type="checkbox"/> Other: _____		____ / ____ (MM/DD)	Yes No
3d	<input type="checkbox"/> Wedding/party/picnic/barbecue <input type="checkbox"/> Fair, carnival, or concert <input type="checkbox"/> Church or School event <input type="checkbox"/> Other: _____		____ / ____ (MM/DD)	Yes No
3e	<input type="checkbox"/> Wedding/party/picnic/barbecue <input type="checkbox"/> Fair, carnival, or concert <input type="checkbox"/> Church or School event <input type="checkbox"/> Other: _____		____ / ____ (MM/DD)	Yes No

SECTION 4 Food

The following questions are to be asked of the index case-patient. In the event the index case is a minor, a parent or guardian can serve as proxy, preferably one who was a case-patient reported to MDSS.

If talking to the index case-patient: "Now I'm going to ask you where you ate during the week before you got sick."

If not talking to the index case-patient: "Now I'm going to ask you where the first person who got sick in your household ate during the week before they got sick. Do your best to answer the questions on their behalf."

1. In the week before you/they became sick, did you/they eat any meals prepared at the following types of food establishments? *Read options and mark all that apply.*

- Restaurant
- Fast-food establishment
- Cafeteria
- Deli
- Street-vended food (food truck, food cart)
- Ready-to-eat food served in a supermarket or department store
- Concession stand at sporting event, snack bar, or gas station

2. Can you tell me more about the food establishments where you ate during the week before you got sick?
Prompt for the following information:

Name: _____ Date: ____ / ____ (MM / DD)
Address: _____ Time: _____ AM / PM
Foods eaten: _____

Name: _____ Date: ____ / ____ (MM / DD)
Address: _____ Time: _____ AM / PM
Foods eaten: _____

Name: _____ Date: ____ / ____ (MM / DD)
Address: _____ Time: _____ AM / PM
Foods eaten: _____

SECTION 5 Water

The following questions are to be asked of the index case-patient. In the event the index case is a minor, a parent or guardian can serve as proxy, preferably one who was a case-patient reported to MDSS.

If talking to the index case-patient: “Now I’m going to ask you some questions related to water.”

If not talking to the index case-patient: “Now I’m going to ask you some questions related to water. Do your best to answer them on behalf of the first person who got sick in your household.”

1. In the week before you got sick, did you/they swim, wade or play in water?
 No Yes Don’t know Refused

IF NO: Skip to 2.

IF YES: Read the following options and choose all that apply:

- Ocean Beach
- Lake, pond, river, or stream
- Hot tub/spa, whirlpool, Jacuzzi
- Recreational water park
- Natural hot spring
- Swimming Pool

“As you know, the outbreak of diarrhea caused by the *Shigella* germ has affected Genesee and Saginaw Counties. Similarly, we recognize that the Flint Water Crisis has had an impact beyond Flint and Genesee County. Since residents of this area have told us that they’ve changed the way they use water, I’d like to ask whether you’ve made any changes to the way you use water.”

2. Which one of the following is the source of tap water in your home?

(Choose ONE answer – READ OPTIONS)

- Municipal, city, or county water (Specify name of water utility, if known: _____)
- Private well water
- No tap water available
- Refused
- Other: _____

“Now I’d like to ask how members of your household used water in the week before you became sick. I’ll start off by listing the different types of water you might use, then I’ll list the things you might use water for.”

Read types of water (e.g., unfiltered tap water, filtered tap water, etc.), then read water uses (e.g., drinking, mixing cold drinks, etc.).

“As an example, members of your household might use both bottled water and unfiltered tap water for preparing hot food. Let’s get started. In the week before you got sick, what type of water did members of your household use for...”

Begin reading uses of water, starting with ‘drinking’. Place a checkmark in boxes that correspond to the interviewee’s answers. If different household members use different types of water for any single activity, place a check in each appropriate box.

	Unfiltered tap water	Filtered tap water	Bottled water	Boiled water	Other (write)	Don’t know
Drinking						
Mixing cold drinks (like iced tea, lemonade, cool-aid)						
Hot drinks (like coffee or tea)						
Making ice						
Cooking hot food						
Mixing infant formula						
Brushing teeth						

“Now I’ll ask you how you and members of your household cleaned, cooked, and bathed during the week before you/they got sick. In addition to the types of water we already listed, let me know if you used hand sanitizer or cleansing wipes for any of these tasks.”

Begin reading down the first column, starting with ‘rinsing fruits, etc’. Place a checkmark in boxes that correspond to the interviewees answers.

	Unfiltered tap water	Filtered tap water	Bottled water	Boiled water	Hand sanitizer	Cleansing wipes	Other (write)	Don't know
Rinsing fruits, vegetables, other foods								
Washing dishes by hand								
Cleaning kitchen or bathroom counters								
Washing hands								
Bathing/showering								
Bathing someone (like a baby or elder)								
Cleaning diaper-changing station								

3. Since the Flint water crisis, have you changed your bathing and/or showering habits?

- No Yes Refused

IF NO: Skip to 4.

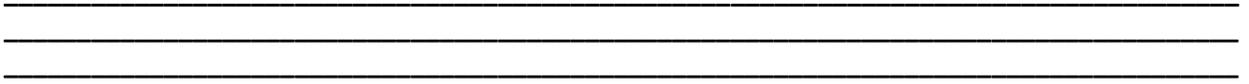
IF YES: Can you tell me more about what changes you've made to bathing and/or showering habits? Here are examples of prompts you can give the participant if need be: method (e.g., cleansing wipes, sponge bathes, bottled water), location (office, someone else's house, etc), frequency (more/less), duration (longer/shorter)

4. Since the Flint water crisis, have you changed your handwashing habits?

- No Yes Refused

IF NO: Skip to script below.

IF YES: Can you tell me more about what changes you've made to handwashing? Here are examples of prompts you can give the participant if need be: method (e.g., hand sanitizer, cleansing wipes, soap without water, soap with water), location (office, someone else's house), when (after using the bathroom, after changing diapers, before eating, before preparing food), frequency (more/less), duration (longer/shorter)



“That’s the end of the interview. Thanks for taking the time to answer these questions today. Is there anything else you’d like to share with us or any questions we can answer for you?”

Refer to FAQ; if the answer is not listed, record the question below and inform the interviewee that an expert from the health department will call them within 24 hours.

“Would you like us to send you information about *Shigella*, the germ that caused you to get sick?”

- No Yes

“Thanks again for helping us today. We’ll share updates on the progress of our investigation along the way, and we plan to share our results at a community meeting. The results will also be available from your local health department. Thanks again and have a great day.”

-- END OF INTERVIEW --

Table 1

Person #	1	2	3	4	5
MDSS ID <i>(if applicable)</i>					
Onset Date MM/DD/YY	___ / ___ (MM/DD)				
Index Case <i>(select 1 only)</i>	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No
Age	_____ yrs / mo				
Sex	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other
Race	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.
Ethnicity	<input type="checkbox"/> Hispanic/Latino <input type="checkbox"/> Arab/Chaldean <input type="checkbox"/> Neither				
Was this person ill?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Symptoms	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement
Duration of illness (days)					
Medical care	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None
Antibiotics	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Chronic medical conditions	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Immuno-compromised	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Wore diapers	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know

TABLE 1 (Continued)

Person #	6	7	8	9	10
MDSS ID <i>(if applicable)</i>					
Onset Date MM/DD/YY	___/___ (MM/DD)				
Index Case <i>(select 1 only)</i>	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No	First person ill? <input type="checkbox"/> Yes <input type="checkbox"/> No
Age	_____ yrs / mo				
Sex	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> Other
Race	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.	<input type="checkbox"/> Black/African Am. <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> American Indian <input type="checkbox"/> Hawaian/Pacific Isl.
Ethnicity	<input type="checkbox"/> Hispanic/Latino <input type="checkbox"/> Arab/Chaldean <input type="checkbox"/> Neither				
Was this person ill?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Symptoms	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement	<input type="checkbox"/> Fever >100F <input type="checkbox"/> Stomach ache <input type="checkbox"/> Diarrhea <input type="checkbox"/> Bloody stools <input type="checkbox"/> Nausea <input type="checkbox"/> Vomiting <input type="checkbox"/> Urgency to have a bowel movement
Duration of illness (days)					
Medical care	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None	<input type="checkbox"/> Doctor office <input type="checkbox"/> Urgent care <input type="checkbox"/> Pharmacy <input type="checkbox"/> Natural healer <input type="checkbox"/> Emergency dept <input type="checkbox"/> Hospitalized (admitted >36 hrs) <input type="checkbox"/> None
Antibiotics	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Chronic medical conditions	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Immuno-compromised	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Wore diapers	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know