ENHANCED DISEASE SURVEILLANCE AND ENVIRONMENTAL MONITORING IN FLINT, MICHIGAN

FACHEP

Flint Area Community Health & Environment Partnership

water + health

PHASE II PROJECT REPORT

AUGUST 8, 2016

WAYNE STATE

Project Summary

In the United States, cases of Legionellosis (Legionnaire's disease) have increased for several years. In Genesee County, as in other areas of Michigan, Legionellosis has been identified as a cause of epidemic disease affecting not only high-risk individuals but also those with no known risk factors. In the city of Flint and in Genesee County, a higher-than-expected number of Legionellosis cases have been reported and attributed, by many, to the changes in the Flint water distribution system. Legionellosis can be a dangerous disease. Despite the availability of *Legionella* testing and effective treatment, disease onset can be insidious, leading to missed diagnoses, rapid disease progression, and death among an estimated 10% of patients with Legionellosis.

Over the next two years, FACHEP will actively seek to reduce the threat of Legionellosis among residents of the city of Flint and Genesee County by implementing a series of coordinated, collaborative, and multidisciplinary interventions with several community-based partners and stakeholders in Flint and Genesee County. These new interventions include:

- A coordinated, transparent, and timely communications strategy that provides the public with critical information to help reduce their risk of Legionellosis.
- Clinical guidelines for educating healthcare providers and lay persons to enhance their ability to recognize and prevent Legionellosis.
- Household water and environmental monitoring of *Legionella* for residents whose water is supplied by the Flint water distribution system and in comparison populations that get water from other sources.
- Providing technical support for healthcare institutions to facilitate implementation of water treatment procedures that mitigate growth of *Legionella*.
- A Legionellosis community engagement and outreach system for Flint and Genesee County residents that identifies high-risk residents and ensures their access to community resources, social services, and health care that together support Legionellosis prevention.
- Development of resources, tools, methods, protocols, and lessons learned for managing other outbreaks in Michigan and around the country.

For the first time since the Legionellosis outbreaks were identified in Genesee County in 2014 and 2015, a comprehensive plan to reduce community risk for this potentially deadly disease has been developed. This plan, developed by FACHEP, provides critical tools and resources assembled by the FACHEP team in coordination with many community, government, and healthcare partners.

Since FACHEP began planning in early February, new conduits and bridges for communication and collaboration have been established with key community stakeholders, and strategies for meeting future challenges related to a Legionellosis epidemic have taken shape. However, this is only a beginning. Over the next two years, experts in infectious diseases, epidemiology, microbiology, communication, social work, and environmental engineering will assist the residents of Flint to implement strategies that help reduce the impact of Legionellosis among Flint residents. Reportable disease surveillance information from 2008—2012 shows that Legionellosis has already affected 37 out of 83 (45%) counties in Michigan. In 2006, at least 25 counties in Michigan experienced Legionellosis incidence greater than the national average of 0.91 cases per 100,000 people. In 2008 to 2012, at least 24 counties in Michigan experienced Legionellosis incidence greater than the national average of 1.08 cases per 100,000 people. For that reason, it is critical to recognize that the tools developed for Flint by FACHEP technical experts and partners will be useful to public health institutions, community organizations, healthcare providers and the public in the entire State of Michigan and across the country.

In May, the FACHEP team and its partners have prioritized a number of activities aimed at helping the residents of Flint to identify sources of Legionella bacteria and reduce their risk of Legionellosis. FACHEP technical staff and partners will support the following activities:

a) Environmental sampling, testing, and monitoring in Flint households. Household sampling among Flint residents will be performed to ascertain the prevalence of Legionella bacteria and identify characteristics of facilities whose residents may be at higher risk for exposure to *Legionella* based on water distribution system characteristics and chemical analysis of water samples.

b) Enhanced clinical-epidemiologic surveillance for Legionellosis. Healthcare providers will be engaged to help ensure that clinicians have clinical guidelines and education to support early identification and reporting of Legionellosis. Clinicians serving high-risk residents, such as those

who are elderly, have a history of smoking, and those who suffer from diabetes, lung disease, cancer, a compromised immune system, or end-stage kidney or liver disease will play a particularly important role in helping to diagnose and refer patients with suspected Legionellosis to tertiary care hospitals and centers. FACHEP will also provide support for ongoing evaluation of the disease surveillance system to enhance case detection and provide technical support for rapid investigation of Legionellosis outbreaks.

c) Communications, community engagement, and social-behavioral health support. Through neighborhood and community group engagement and education, the FACHEP team will work with partner organizations to develop and disseminate accurate Legionellosis information as well as soliciting input from Flint residents to ensure that they are receiving and understanding accurate information and having their questions and concerns answered in a timely fashion. In addition, "warm transfers" (i.e., directly connecting residents with appropriate service providers) will enable Flint residents to have access to local resources to meet their social and health-related needs.

What can we expect from FACHEP activities?

From June 2016 through May 2018, activities in this project will generate the following results:

a) water sampling and analysis that provides definitive evidence of the presence or absence of *Legionella* species and environmental conditions that support and/or promote the growth of *Legionella* species in the Flint water distribution system;

b) laboratory, clinical, and epidemiologic evidence demonstrating that the number of cases and rates of Legionellosis or *Legionella*-associated illness among Flint and Genesee County residents have been reduced to pre-crisis levels;

c) a communications strategy and outreach program that is relevant to the community and sustains broad stakeholder engagement with active healthcare provider and resident participation in executing activities that improve community health and welfare that ultimately leads to reduction of Legionellosis risk.

How do we know when FACHEP strategies meet their benchmarks?

1) Nationally recognized standardized measurements (in both at-risk and control communities) will be used to evaluate the quantitative water sampling and analysis (using both internal and external

controls) that is to be initiated immediately and conducted for two years with a focus on the anticipated period of highest exposure to *Legionella* (June through September).

2) A coordinated program to educate residents and healthcare providers in early recognition, reporting, and evaluation of suspected Legionellosis cases, with special emphasis placed on illness among high-risk residents. Rapid laboratory specimen testing followed by expedited reporting of results will be provided to patients, healthcare providers, and public health authorities. Standardized tools (both quantitative and qualitative) will be used to measure the quality of public health surveillance and disease reporting in Flint and Genesee County. Uptake of Legionellosis knowledge using pre-post surveys among residents and health-care professionals will be used to evaluate impact of educational efforts.
3) Quantitative analysis of surveillance and laboratory data will be performed to describe patterns and characteristics of disease and to quantify factors (exposures that both increase and reduce disease risk) associated with Legionellosis. Analysis of data will proceed continuously, with active case finding and evaluation of the activities and characteristics that optimize the function of the surveillance system throughout the project period.
4) Individual and group-based methods will be used to develop user-centered communication materials and to ascertain changes in knowledge associated with Legionellosis and *Legionella*-associated illness among Flint and Genesee County residents, with comparative surveys in control populations. Focus-group analysis will be conducted to ascertain the needs of the community residents that will be the basis for the design and usability testing of the communication materials. Community programs will be evaluated to ascertain their effectiveness in improving resident wellness, quality of life, as well as healthcare provider engagement and partnerships that foster Legionellosis control.

What will FACHEP's lasting and sustained impact be in Michigan?

In addition to directly addressing Legionellosis in Flint, results from this work will provide important information that will be applicable to other municipalities (e.g., those with potentially contaminated water supply or with outbreaks of other infectious diseases). Lessons learned will be translated into evidence-based best practices that will specifically aid county and state public health officials in reducing the risk of Legionellosis for Michigan residents.

Examples of best practices to be generated include

- Best practices in crisis communication for high-impact epidemic diseases and environmental threats to human health
- Best practices in educating at-risk communities regarding complex diseases that mimic other common illnesses
- Best practices for environmental monitoring and management of municipal water distribution systems
- Best practices in enhanced and timely Legionellosis case recognition, reporting, and investigation in diverse and potentially hard-to-reach communities
- Best practices for engaging ethnic minorities and economically underprivileged groups, and building trusted partnerships to reach common goals for long-term health and wellness of children and adults
- Best practices in delivering critical social supports that address broader health concerns that arise directly or indirectly from the emerging epidemic disease
- Transferrable and adaptable messaging tools, message templates, training modules, sampling and surveillance protocols for municipal water systems, and management guidelines will be created.

All of the above tools will be made widely available in comprehensive "Lessons Learned" documents. All documents will be widely disseminated through a broad range of communication channels for the benefit of all in the State of Michigan.

Public Abstract (for lay community)

Legionella bacteria are known causes of severe lung disease, including pneumonia. The aim of this collaborative project is to reduce the risk of *Legionella* infection among residents of the city of Flint and Genesee County. In this project, the FACHEP team of experts will monitor water sources in the community with the goal of reducing exposure to Legionella bacteria among residents who are at increased risk of Legionellosis. The FACHEP team will use a coordinated and multidisciplinary approach in partnership with citizens and community organizations located in the city of Flint and Genesee County.

Public Health Relevance

Despite the identification of *Legionella* as a cause of serious lung infections four decades ago, the control of Legionellosis has been an increasing challenge in the United States. In Flint and in Genesee County, residents experienced epidemics of Legionellosis over a 2-year period. The goal of this project is to help citizens, health-providers, government agencies and local community organizations reduce the risk of disease caused by *Legionella*. If successful, residents in Flint and Genesee County will be less likely to experience lethal *Legionella* infections.

Abbreviations:
CAP: community-acquired pneumonia
CASPER: Community Assessment for Public Health Emergency Response
CBPR: Community-based participatory research
CD: communicable disease
CDC: US Centers for Disease Control and Prevention
MDSS: Michigan Disease Surveillance System
EPA: US Environmental Protection Agency
EQGLI: European Working Group for Legionella Infections
FACHEP: Flint Area Community Health and Environment Partnership
FBO: faith-based organizations
FLA: free living amoeba
GCHD: Genesee County Health Department
HD: Health Department
HFHS: Henry Ford Health System
ICT: immunochromatographic test
IRB: institutional review board
LRTI: lower respiratory tract illnesses
MDHHS: Michigan Department of Health & Human Services
MDSS: Michigan Disease Surveillance System
MiHAN: Michigan Health Alert Network
PCR: polymerase chain reaction
PET: polyethylene terephthalate
POC: point-of-care
PoU: point-of-use
SOPs: standard operating procedures
STs: sequence types

Contents

1. Background for Project Development

In 2014 and 2015, the city of Flint and its residents, health-care and government institutions faced an unprecedented health threat in the form of acute lung infections caused by *Legionella spp*. As Legionnaires' disease cases continued to be identified, epidemiologic surveillance and environmental monitoring were instituted to identify sources of infection and develop effective control measures. By the end of 2015, a clear source of infection had yet to be identified, and so attention turned to developing strategies for mitigating the ongoing risk of Legionnaires' disease. Compounding the anxiety caused by these 87 cases, the outbreaks coincided with the city of Flint changing both the source and treatment of its municipal water supply. Although the situation in Flint continues to be challenging, opportunities now exist to rebuild trust in communities, identify key needs around social determinants of health and establish high-quality surveillance that ensures early detection of Legionellosis cases. Because *L. pneumophila* is transmitted to humans in aerosols of contaminated water, efforts to identify and eliminate the source(s) of this infectious disease are warranted. In parallel, detailed analysis of the dynamic microbiology of *Legionella* within the Flint municipal water system can inform the rational design of surveillance, remediation and risk management strategies to keep the public water supplies in our state and nation safe.

This project will implement a multidisciplinary strategy in close coordination and partnership with local health-care providers, community organizations and government agencies to integrate environmental monitoring and water testing with clinical education and population-based epidemiologic surveillance (a general description of complementary roles is presented in Appendix 1). A key to future success in population-based active Legionnaires' disease surveillance will rest in the ability of surveillance and environmental monitoring experts to establish trust, communication and credibility with residents of Flint and Genesee County. To this end, the Flint Area Community Environmental Health Program (FACHEP) partners have initiated an active program of outreach and community engagement with a broad range of stakeholders who represent community residents and community organizations.

Nationally, *Legionella* is a leading cause of disease outbreaks associated with drinking water (Falkinham et al., 2015a). For reasons not yet understood, the incidence of Legionnaires' disease increased threefold from 2000-2011 across the USA and in all age groups (Mercante and Winchell, 2015). In Michigan from 2002 to 2015, a total of 2,533 Legionnaires' disease cases were reported (**Figure 1.1**). Moreover, the actual disease burden is likely underestimated and underreported (CDC, 2011). Clinicians typically treat community-acquired pneumonia (CAP) empirically with broad-spectrum antibiotics, often forgoing specific diagnosis. When the infectious agent is sought, the most common diagnostic tool is the Urinary Antigen Test, a rapid, low-cost test that detects only *L. pneumophila* serogroup 1. Although *L. pneumophila* serogroup 1 is the predominant pathogenic type of *Legionella*e, more than 50 species and 70 serogroups exist, 25 of which have been isolated from patients (Gobin et al., 2009).

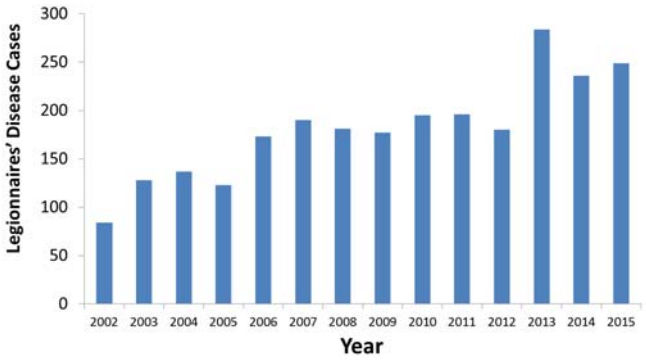

Figure 1.1. Reported Legionnaires' disease cases (N=2,533), 2002—2015, Michigan. Total annual case counts may be adjusted based on review of cases.

Exposure to aerosols containing *Legionella* is the commonly accepted exposure pathway for Legionnaires' disease. The risk of *Legionella* colonization and human exposure through the aerosol route is typically associated with large buildings where a significant portion of the water is either stagnant (Sikora et al., 2015) or vaporized via humidifiers, cooling towers, showers, and hot tubs (Falkinham et al., 2015a; Li et al., 2015; Thomas et al., 1993). Problems occur in these systems when adequate levels of chlorine cannot be maintained to restrict growth of *Legionella*. Some combination of these factors may explain the outbreaks in Flint where an unprecedented increase in Legionnaires' disease was reported for Genesee County in 2014 and again in 2015. Genesee County is among approximately half of the counties in Michigan that have experienced cases of Legionnaire's disease (**Figure 1.2**). Disease surveillance information from 2008 to 2012 shows that Legionellosis has already affected 37 out of 83 (45%) counties in Michigan. In 2006, at least 25 counties in Michigan experienced Legionellosis incidence greater than the national average of 0.91 cases per 100,000 people. In 2008 to 2012, at least 24 counties in

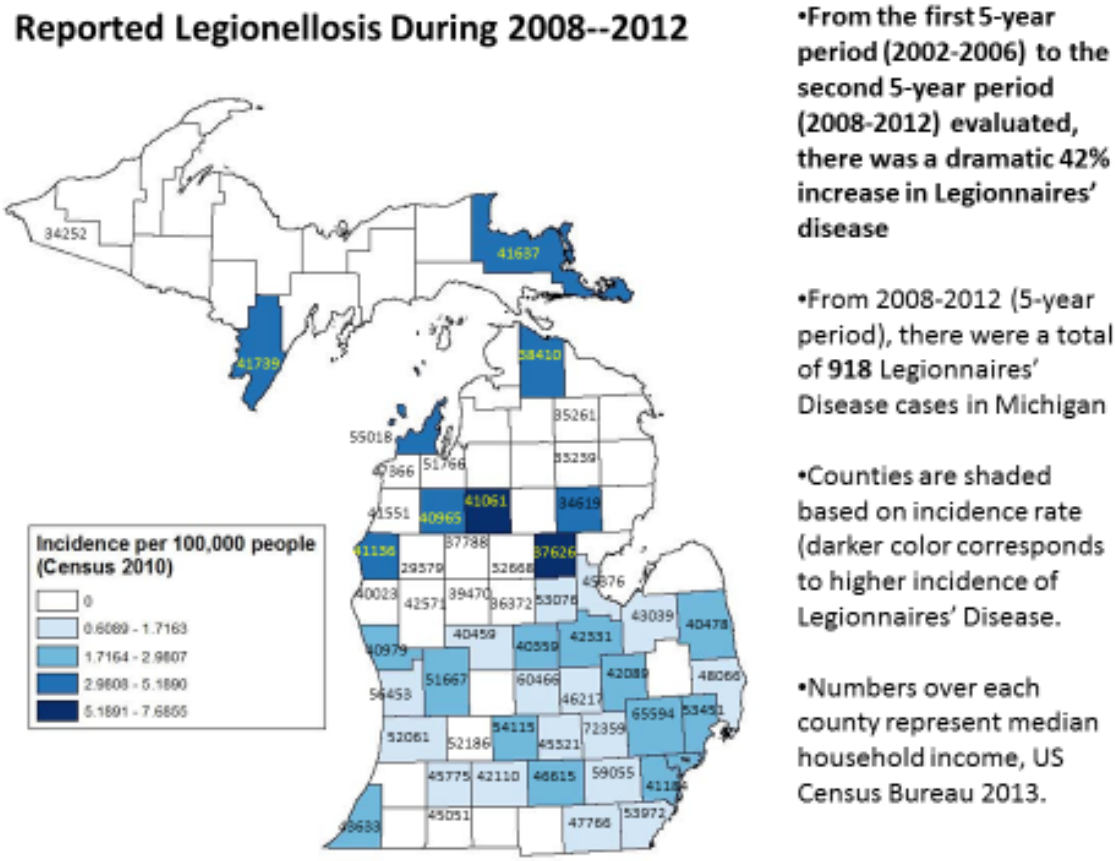

Figure 1.2. Legionellosis and median household income by county in Michigan.

Michigan experienced Legionellosis incidence greater than the national average of 1.08 cases per 100,000 people.

Despite what is known about exposure and risk in large buildings, potential exposure to *Legionella* in single family homes and low-rise housing units is poorly defined. Estimates of the number of homes that have been colonized by *Legionella*, based on limited sample sizes, range from 8% to 33% (Cooper et al., 2004; Stout and Muder, 2004). To inhibit the growth of *Legionella* and other bacteria, a chlorine residual is maintained within the water distribution system (Muraca et al., 1987b; Zhang et al., 2009). Suspended *Legionella* can be inactivated within 15 minutes by 0.4 mg/L chlorine (Yabuuchi et al., 1995). However, *Legionella* is known to reside in biofilms attached to pipe walls and to replicate within predatory free-living protozoa (Falkinham et al., 2015b), two sites that require much higher doses of chlorine to achieve the same level of disinfection. Based on multiple

sources, Lin et al. concluded that "inactivation and suppression of *L. pneumophila* requires chlorine levels of greater than 3 ppm, while the residual level in domestic water is usually less than 1.0 ppm" (Yu-sen et al., 1998). It is important to point out that chlorine residual is maintained within the water distribution system but is not guaranteed within premise plumbing. In fact, due to the elevated temperatures and long residence times within hot-water tanks, water within hot-water lines typically does not contain measurable levels of chlorine.

The impact of insufficient residual chlorine in the Flint water distribution system is particularly suspect as a potential causal factor in the recent incidents of *Legionella* in the city. As shown in **Figure 1.3**, during testing in October 2015, we found that none of the samples collected after flushing at kitchen sinks had a free chlorine concentration greater than 1.0 mg/L, which is the typical residual goal for most water utilities. More concerning was that over half of the samples had a chlorine residual of 0.2 mg/L or less. Furthermore, attempts to prevent *Legionella* growth or remediate contaminated systems with strong oxidizing disinfectants might not be sufficient. As demonstrated recently in the Bronx of New York, engineered water systems can remain colonized by *L. pneumophila* and cause recurrent disease for years and decades (Department of Health and Mental Hygiene, 2015). An analysis of 209 water samples collected at Paris hospitals that spanned a range of building sizes, ages, water temperatures, and hot-water system designs determined that use of a continuous chlorination system positively correlated with colonization by *L. pneumophila* serogroup 1 ($P < 0.01$) (Merault et al., 2011), a testament to this microbe's remarkable resistance to free chlorine and a warning to the vulnerability that drinking water distribution systems in the US face given the propensity toward use of chlorine and chloramine as residual disinfectants. Since only 4% of the disease cases reported from 2000-2009 in the US were associated with outbreaks, colonization of the built environment by *Legionella* may be more widespread and insidious than currently appreciated.

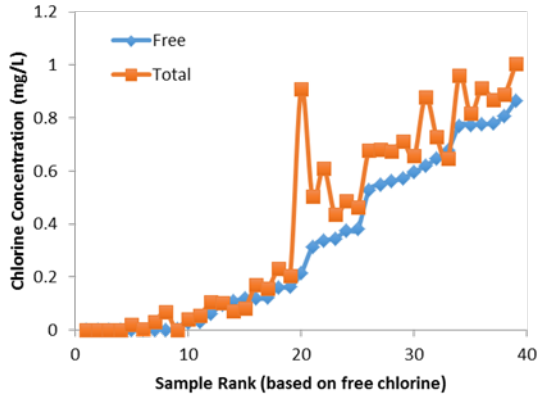

Figure 1.3. Chlorine content of water samples collected from residential taps during the switch from treated Flint River water back to water supplied by the Great Lakes Water

An additional cause for concern and major public health challenge is the resistance of *L. pneumophila* to disinfection methods, such as chlorine, other oxidants and antibiotics. One way that microbes become more resistant to antibiotics and other stresses is by acquiring mobile genetic elements. The Swanson laboratory at the University of Michigan identified one such element – the integrative conjugative element (ICE)-βox – that transmits horizontally between *L. pneumophila* strains and increases their resistance to oxidative stresses, including hydrogen peroxide, bleach and the oxidative burst of phagocytic cells—treatments that kill most microbes. In addition to acquiring new genes that increase resilience or forming protective biofilms, *L. pneumophila* naturally convert between replicating and hardy cell types. When growing within protozoa, this pathogen differentiates to a "mature intracellular form" that is more resistant to detergents and antibiotics. Swanson's laboratory recently discovered that *L. pneumophila* also becomes more resistant to detergent, heat and antibiotics within hours of simply being transferred from growth medium to tap water.

1.2. Project Objectives

1. To reduce the occurrence of Legionellosis-associated cases, hospitalizations and deaths to levels at or below those seen in years prior to 2014.

2. To define potential sources of Legionella exposure in residential households and high-risk facilities.

3. To develop evidence-based approaches for reducing exposure to *Legionella* among Flint residents.

4. To strengthen existing capacity in infrastructure, institutions and groups of individuals that enhances community resilience in addressing common threats to the health and welfare of community residents.

1.3 Legionnaires' Disease

In the United States and other countries, community-acquired pneumonia (CAP) and lower respiratory tract illnesses (LRTI) are very common, with the highest rates among the very young and older adults. Medical costs exceeded $10 billion in 2011 (Pfuntner et al., 2013). Results from a U.S. population-based study showed that the annual incidence of CAP was approximately 25 cases/10,000 adults, with highest incidence among adults aged 65–79 years (63 cases/10,000), and in those aged ≥ 80 years, the estimated incidence was 164 cases/10,000 adults (Jain et al., 2015). In addition, CAP is responsible for estimated rates of hospitalization of 1200, 2400 and 4400 cases/100,000 adults aged 65–74, 75–84 and ≥ 85 years old, respectively. In-hospital deaths as among patients aged 65 years and older ranged between 7.0% and 11.5% (Griffin et al., 2013). The majority of CAP deaths (11.5%) occur among adults aged 85 years and older (Griffin et al., 2013). Among survivors of CAP, there are notable complications and long-term disabilities, including pleural effusion, empyema, lung abscess, cardiopulmonary compromise (e.g., congestive heart failure), persistent breathing difficulties (e.g., exacerbations of chronic obstructive pulmonary disease), and pulmonary scarring or fibrosis (Corrales-Medina et al., 2014; Sowmya et al., 2016).

Leading causes of CAP and LRTI include *Streptococcus pneumoniae*, influenza viruses and several other bacterial and viral pathogens (**Table 1.1**). Clinically, differentiating the etiology of CAP and LRTI among children and adults can be extremely challenging, and, in some patients, diagnostic testing reveals mixed bacterial and viral infections occurring simultaneously.

Table 1.1. Bacterial and viral pathogens causing CAP and LRTI (Jain et al., 2015; Kilgore et al., 2016)

Bacterial and Viral Etiologic Agents	~Incidence per 10,000 persons			
	18–49 years old	50–64 years old	65–79 years old	≥ 80 years old
Human rhinovirus	0.7	1.6	4.5	13.5
Influenza A or B virus	0.5	1.8	3	11.5
S. pneumoniae	0.3	1.3	4.5	6
Human metapneumovirus	0.4	0.9	4	3
Respiratory syncytial virus	0.2	0.9	3	4
Parainfluenza virus	0.2	1.2	3	5
Coronavirus	0.1	0.8	3	6
Mycoplasma pneumoniae	0.4	0.4	1	3
L. pneumophila	0.2	0.8	1	2.5
S. aureus	0.1	0.9	2	4
Adenovirus	0.2	0.6	2	3.5
B. pertussis	0.6–8*			

*(%) in adolescents and adults

In any age group, CAP and LRTI must be considered serious diseases with progression in some cases occurring over a relatively brief period of time (hours). Although a number of recognized risk factors do exist for both CAP and LRTI, persons with illnesses may present with few or no pre-existing medical conditions or known risk factors (**Table 1.2**). In the United States, despite the availability of antibiotics and emergency health services, patients may require hospitalization, and mortality is not uncommon.

Table 1.2. Risk factors associated with CAP requiring hospitalization or outpatient visit (Jackson et al., 2004)

Risk Factors	Hospitalizations for CAP Odds Ratio (95% CI)	Outpatients visits for CAP Odds Ratio (95% CI)
Age (years)		
75—84	2.2 (1.9–2.5)	1.3 (1.1–1.4)
≥ 85	4.1 (3.5–4.9)	1.5 (1.3–1.8)
Male sex	1.34 (1.2–1.5)	1.2 (1.1–1.3)
[a]COPD	2.9 (2.5–3.3)	2.2 (2.0–2.5)
Asthma	1.6 (1.2–2.1)	1.8 (1.5–2.1)
[b]CHF	1.9 (1.6–2.2)	1.3 (1.1–1.4)
[c]CKD on prednisone	2.3 (2.0–2.8)	1.3 (1.1–1.6)
Current smoker	1.7 (1.4–2.0)	1.3 (1.2–1.5)
Diabetes	1.5 (1.3–1.8)	1.1 (1.0–1.3)
Lung cancer	1.5 (1.0–2.2)	1.4 (1.0–2.0)
Non-lung metastatic cancer	1.7 (1.4–2.20	1.6 (1.3–2.1)
Stroke	1.1 (0.9–1.3)	1.3 (1.1–1.5)
Dementia	1.6 (1.3–2.0)	1.2 (0.9–1.5)
Home oxygen therapy	1.4 (1.1–1.8)	1.23 (0.9–1.6)
Receipt of home health care	1.3 (1.1–1.5)	1.0 (0.9–1.2)

[a]chronic obstructive pulmonary disease; [b]congestive heart failure; [c]chronic kidney disease

Over the past four decades, a number of vaccines to prevent respiratory diseases have been developed and introduced in the United States. Currently, safe and effective vaccines to prevent influenza and pneumococcal pneumonia are recommended for routine use among infants, children and adults. Routine use of these recommended vaccines may help reduce the risk of severe secondary bacterial infections due to respiratory pathogens including *Legionella spp*.

Concurrently, diagnostic methods and tests have improved and become more widely available in the United States, with some infections detectable with CLIA-waived point-of-care (POC) tests that are easy to perform in the outpatient setting (**Table 1.3**). A wide array of sensitive and specific tests for both bacterial and viral pathogens are now available in hospital settings and clinical laboratories.

Table 1.3. Point-of-care tests for diagnosis of bacterial and viral pathogens.

Etiologic Agent	Type of Test	Sensitivity, (%) (95% CI)	Specificity, (%) (95% CI)
Influenza	QuickVue Influenza A+B (Quidel) (Uyeki et al., 2009)	27 (19–32)	97 (96–99.6)
	QuickVue Influenza A+B (Quidel) (Vasoo et al., 2009)	53 (41–65)	100 (86–100)
	BD Directigen EZ Flu A+B test (Becton Dickinson) (Vasoo et al., 2009)	47 (35–59)	100 (86–100)
	BinaxNOW Influenza A&B (Inverness Medical) (Vasoo et al., 2009)	38 (27–51)	100 (86–100)
	BinaxNOW		
Meta-analysis (Chartrand et al., 2012)	Directigen Flu A	57 (46–68)	99 (97–99)
	Directigen Flu A and B	77 (64–86)	97 (93–99)
	QuickVue Influenza	57 (49–65)	99 (99–100)
	QuickVue Influenza A and B	69 (58–78)	96 (91–98)
		49 (39–59)	98 (97–99)
RSV (Leonardi et al., 2015)	Sofia (Quidel., San Diego, USA)	85 (64–92)	96 (86–99)
	Quickvue (Quidel., San Diego, USA)	58 (37–69)	99.5 (92–99)
	Veritor (Becton Dickinson, Sparks, USA)	73 (55–85)	97 (93–99)
	Directgen EZ RSV (Becton Dickinson, Sparks, USA)	70 (55–85)	99.5 (97–100)
S. pneumoniae (Sorde et al., 2011)	ICT*	57–78	70–96
L. pneumophila (Shimada et al., 2009)	ICT*	74 (68–81)	99 (98–100)

*Immunochromatographic test in urine samples (urine antigen detection test).

2. Community and Clinician Engagement, Education, Outreach, Surveillance Evaluation, and Outbreak Investigation Support

2.1. Legionellosis–focused clinician engagement in Flint and Genesee County

2.1.1. Tasks

2A. Establish and support collaborative educational programs to raise citizen awareness of Legionellosis and increase health-care provider application of optimal clinical approaches for the detection, diagnosis and management of case-patients with suspected, probable and confirmed Legionellosis.

2B. Provide expert technical support to health-care providers that enables early diagnosis, treatment and reporting of all residents in Flint and Genesee County who are suspected of being infected with *Legionella* based on state-of-the-art clinical and laboratory practices

2.1.2. Approach

A. In partnership with Genesee County Health Department (GCHD), Genesee County Medical Society (GCMS) and/or other community organizations, the FACHEP team will deploy Legionellosis outreach and educational programs for community organizations, health-care providers, and hospitals serving Flint and Genesee County.

B. In partnership with GCHD, GCMS and/or other community organizations, the FACHEP team will disseminate community-based educational information (including information based on standard Legionellosis FAQs, **Appendix 2**) that helps residents understand warning signs of *Legionella* infection and encourages health-care seeking behavior in the event of suspected *Legionella*-associated illness. For lay person audiences, community-based presentations on Legionellosis will be based directly on Legionellosis FAQs and state-of-the-art scientific information from MDHHS, US CDC and peer-reviewed scientific publications. For health-care provider audiences, presentations on Legionellosis will be based on updated the clinical guidelines for Legionellosis produced jointly by MDHHS, GCHD, HFHS and the FACHEP team.

C. During clinical education outreach activities, the FACHEP team will encourage and facilitate clinical service providers to access and use the electronic Michigan Health Alert Network (MiHAN; www.michiganhan.org) to enhance early Legionellosis case reporting and outbreak recognition in the Flint and Genesee county population.

D. The FACHEP team will strongly support and encourage health-care provider use of MDHHS and GCHD resources and including health alert information related to Legionellosis cases occurring in Flint and Genesee County. Wherever possible, FACHEP will reach out and communicate with health-care providers in order to improve clinical and public health awareness of Legionellosis in Flint and Genesee County. For cases of suspected or confirmed Legionellosis that are reported to the MDSS, FACHEP staff will provide support and education that focuses on improving case report data quality, data completeness and timeliness of case data reporting.

E. The FACHEP team will work with Genesee county health-care providers (**Appendix 3.** Provisional Listing of Health-Care Facilities and Providers) to support application of clinical and diagnostic tools (e.g., enhanced Legionellosis case/proxy interview forms) that enhance early recognition and confirmation of all case-patients with suspected *Legionella* infection. The target health-care provider community for this project will be providers who may refer or provide direct clinical care for patients with suspected or confirmed Legionellosis.

F. The FACHEP team will provide technical support, education and guidance to help implement standardized algorithms for Legionellosis diagnosis and reporting across a variety of clinical practices serving a very racial/ethnically and socioeconomically diverse Flint and Genesee county population. To optimize Legionellosis surveillance, it is important to define the target health-care provider community and document the extent to which hospitals are obtaining specimens. For this project, we define our target population of clinicians as health-care providers whose facility is physically located in Flint and Genesee County.

   The FACHEP team will provide support and a cooperative partnership environment to the GCHD, MDHHS, and GCMS in order to conduct complete Legionellosis case data collection accompanied by appropriate clinical-epidemiologic statistical analyses. This support includes assistance completing the Legionellosis Case Information form (**Appendix 4.** Enhanced Legionellosis Case Information Form) and communicating observations based on use of this form with the intent to assist in improving completeness, accuracy and timeliness of Legionellosis case information reported from providers to the MDSS. The form shown in the Appendix 4 was created by Genesee County. A nearly identical form was created independently by the FACHEP team based on the US CDC Enhanced Legionellosis Case Investigation Form. For this project, we suggest using the Genesee County Form.

G. The FACHEP team will utilize data on Legionellosis collected routinely through the MDSS (See **Appendix 5**. Data Use Agreement). In addition, data will be collected in partnership with GCHD and GCMS using standardized enhanced case interview forms that captures detailed information on potential clinical risk factors as well as environmental exposures that may affect risk of Legionellosis. Data elements from the MDSS case intake section and Legionellosis case information section (**Appendix 6.** MDSS Legionellosis data elements).

H. FACHEP staff will prepare and disseminate reports of data analysis to GCHD, MDHHS, GCMS and key stakeholders, including health-care providers, community organizations, community leaders and local government agencies serving Flint and Genesee county. Standardized data tables (See **Appendix 7.** Table Shells for Data) will be generated for descriptive data analysis. Where appropriate, multivariate analysis will be tabulated and accompanied by written textual information.

2.1.3. Measurement

A. Qualitative measures

After presentations conducted in Flint neighborhoods and communities, the FACHEP team will conduct qualitative surveys to gain information on residents' and health-care professionals' views, perceptions and attitudes regarding the presentation and program content, delivery and audience engagement (**Appendix 8,** Community Legionellosis Education Presentation). FACHEP's knowledge surveys (**Appendix 9.** Pre-Post Community Presentation Survey) will be administered using a paper-based survey instruments. All surveys will be collected without personal identifiers to maintain participant anonymity.

B. Quantitative measures

Quantitative data collection will be performed to ascertain total number of residents and health-care providers who participate in clinical and community Legionellosis education programs as well as

demographic characteristics of participants, including location of residence or address of clinical practice, age, gender, and educational background as well as clinical specialty (for health-care providers only).

Additional quantitative data will be collected to determine the distribution of health-care providers who are participating in the MiHAN system operated by the MDHHS. Secular patterns in MiHAN participation will also be measured relative to health-care providers who receive *Legionella* educational materials and who are contacted by the FACHEP staff.

In conjunction with educational programs to residents and clinicians and based on distributed Legionellosis clinical guidelines, health-care providers will be provided with rapid urinary *Legionella* urine antigen-detection tests (LUAT) for use in outpatient settings for a period of enhanced surveillance. Patients with suspected pneumonia (including those with clinical signs/symptoms of pneumonia will be screened by clinicians to identify patients for testing using the LUAT. Patients with risk factors for pneumonia (e.g., underlying medical conditions as written in the **Appendix 10.** Legionellosis Clinical Guidelines).

The FACHEP team will follow-up with individual health-care providers through direct clinic visits to track number of diagnostic kits distributed as well as subsequent usage and results of testing. Clinic test utilization will be tracked and charted for communication with local provider organizations and health authorities, including the GCMS, GCHD and MDHHS.

Clinic staff and health-care providers will be surveyed to ascertain interest in receiving refresher educational updates in person, via Internet WebEx or through live-streaming services originating from Wayne State University or facilities located in Flint, Michigan. An ongoing *Legionella* Educational Registry will be maintained to ensure that all community organizations, physicians and other health-care providers have up-to-date information on Legionellosis, including approaches to recognizing, diagnosing, treating and following up case-patients.

2.1.4. Evaluation

Rigorous evaluation of educational programs (**Appendix 11.** Health-care Provider Legionellosis Education Presentation Example) will include pre- and post-presentation questionnaires to ascertain changes in *Legionella* and Legionellosis knowledge (**Appendix 12.** Pre/Post-Provider Knowledge Survey). Quantitative paper-based surveys will contain multiple-choice items. All surveys will be designed by the FACHEP team and administered at each community-based and health-care provider/health facility educational program to identify a) appropriateness of content, b) quality of presentation delivery, c) perceived accuracy of program content, d) perceived added value that the presentation brought to other available resources for Legionellosis education, e) understandability of the information presented in the program, f) cultural appropriateness of informational content, and g) future interest in receiving other educational programs focused on Legionellosis.

Additional evaluation will be conducted to ascertain the value and effectiveness of clinic-based testing using the LUAT. Clinics and health-care providers will be selected at random to participate in a brief survey regarding their usage of the LUAT. Survey items will collect information on perceived utility of the test, ease of use in the outpatient clinic setting, management of test results, including feedback to patient and follow-up of patients who test positive in order to conduct additional *Legionella* testing (e.g., bacterial culture). Survey results will be analyzed to identify opportunities for improved community and health-care provider education as well as to identify strategies for optimizing outpatient diagnostic testing for detecting patients with *Legionella* infection.

2.1.5. Reporting

A. Monthly written reports will contain a) presentations (titles) given; b) content of presentations; c) digital audio recordings of each presentation, including audience question and answer sessions; d) written notes regarding key items discussed; e) concerns voiced by the audience; f) action items for subsequent follow up and g) lists of presenters and presentation attendees. Reports will also contain summary information on institutional and neighborhood visits as well as meetings attended.

B. Quarterly written reports that detail ongoing weekly and monthly activities, including institutions visited, residents contacted, presentations given and meetings attended, will be submitted to MDHHS and shared with GCHD and other community partners. Annual written reports will also be provided to MDHHS staff and leadership detailing all monthly and quarterly activities as well as summary of key findings, data analysis, trends and results, lessons learned and future project work plans.

2.2. Community-based household survey of Legionella integrated with household water sample testing and social-behavioral evaluation to support Legionnaires' disease prevention and control in Flint.

2.2.1. Tasks

2C. To deploy trained, multi-disciplinary sample and interview teams with community navigators to conduct standardized household survey.

2D. To identify residents' needs and share information regarding resources available to Flint residents that help improve their health and well-being.

2.2.2. Approach

A. A random sample of 284 households in Flint neighborhoods will be recruited to participate in the household sampling and residents survey.

B. Health survey staff will be provided with standardized training to administer a house health survey. The health survey staff will be deployed with teams made up of community navigators, environmental sampling staff as well as health and socio-behavioral interviews.

C. Community navigators will contact each resident to identify their interest in participating in the survey. If residents agree, the IRB approved informed consent procedure will be completed prior to each household visit (**Appendix 13.** Informed Consent Forms). Community navigators will then confirm the date and time for the water sampling and survey team visit.

D. At the appointed time and day, the water sampling and survey team will visit the household and give an introduction of the team to each household resident. The water sampling and survey team will then initiate data collection. While the water sampling team collects specimens, the health and socio-behavioral survey team will conduct face-to-face interviews with an adult resident.

E. At the conclusion of the household water sampling and interviews, the resident will be provided with Legionellosis FAQ (**Appendix 2**) and an updated listing of community resources (*listing in development and revision*).

2.2.3. Measurement

A. Interview data collected using the standardized interview form (**Appendix 14.** Household Survey Form) to gather information on demographic characteristics of household members, physical characteristics of the household, existing health conditions of each family member, risk factors for Legionellosis and relevant exposures for acquisition of Legionellosis. (*Please see Community Engagement and Communications section for detailed information on socio-behavioral survey items*).

B. All collected data will be returned by household water sampling and interview teams to the FACHEP office located in the Broome Center (Saginaw St, Flint, MI). Samples and survey will be logged in by noting time and date received in the FACHEP offices.

C. Interview forms will be reviewed for completeness, consistency and accuracy of recorded data. Interview data will be transferred/transcribed into a standardized electronic data entry system prior to analysis.

2.2.4. Evaluation

A. Electronic household health survey data will be analyzed to describe household and resident characteristics in aggregate. Data will be presented in both tabular and figure formats and, where appropriate, statistical comparisons among demographic subgroups will be performed.

2.2.5. Reporting

A. Integrated results of the household water sampling, health and socio-behavioral interviews will be provided in tabular and graphic formats. Interim and final reports of the household survey will be provided to MDHHS staff, community partners and other interested groups.

B. Individual residents will be provided with household water sample testing results and a listing of their responses to the health and socio-behavioral survey within 2 months of sample and survey data collection.

2.3. Evaluation of Existing Data and Legionnaire's Disease Surveillance System

2.3.1. Tasks

2E. To apply standard US CDC methodologies to describe the Legionellosis surveillance system in Flint, Genesee County and comparison areas of Oakland and Wayne Counties. Our hypothesis during these evaluations is that the MDSS and county level surveillance systems adequately capture cases to rapidly detect outbreaks in Legionellosis.

2F. Evaluate if the incidence of Legionellosis is associated with changes in water quality. This line of investigation will be guided by the general hypothesis that residents using Flint water during 2014-2015 were more likely to acquire Legionellosis than in other comparison areas.

2G. To identify practical opportunities for improving Legionnaires' disease surveillance in the city of Flint and elsewhere that support sustainable and high-quality case-patient reporting from health-care providers and facilities to the MDSS.

2.3.2. Approach

A. *Quality assurance and quality control of epidemiologic data.* Retrospective Legionellosis surveillance data from 2011 through 2015 will also be reviewed and examined using standard methods for surveillance system

evaluations as issued by the US Centers for Disease Control and Prevention (US CDC). In addition, several key surveillance indicators that describe the collection of high-quality epidemiologic data will be measured in 2016 and 2017. Data elements will be collected from MDSS Legionellosis case information and other available information (**Appendix 6.** Data Elements from MDSS).

The timeliness of patient referrals (defined as the time [in days] from initial patient screening to the time of completed patient evaluation) and the timeliness of submission of surveillance data (defined as the time [in days] from first evaluation of enrolled patients to the time of data entry into the MDSS) will also be evaluated during surveillance (**Appendix 15.** Basic Legionellosis Case Information Checklist).

B. *Evaluation of the surveillance system, including major hospitals serving Genesee County* (**Table 2.2**). To conduct routine, standardized evaluations of the Legionellosis surveillance system, we will use established US CDC guidelines (https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5013a1.htm) that will describe the system's simplicity, flexibility, acceptability, sensitivity, predictive value positive, representativeness and timeliness.

Data inputs for the Legionellosis surveillance system analysis will arise from sources including Genesee County hospital staff, GCHD staff, GCMS and community organizations.
Data (including time stamps) for specific data elements will be collected using a standardized Legionellosis case information form (**Appendix 4.** Enhanced Legionellosis Case Information Form).

The Legionellosis Surveillance System evaluation will be conducted bi-annually with the results of the evaluation included in project reports. A final evaluation of the surveillance system will coincide with a final analysis of surveillance data, and such information will be included in the final project report.

Table 2.2. Major hospitals serving residents of Flint, Michigan.

Name	*Location*	*Bed Capacity Estimate*	*Type*	*Target Area and Population*
McLaren Flint	Flint	404	Non profit	Genesee County (including Flint)
Hurley Medical Center	Flint	443	Public teaching hospital	Genesee County (including Flint)
Genesys Health System	Grand Blanc	410	Non-profit (part of Ascension)	Genesee County (including Flint)

C. *Evaluation of possible associations with environmental parameters.* Given the initial mandate charged to FACHEP by the State of Michigan's Governor's Office, FACHEP will attempt to evaluate if the incidence of Legionellosis is associated with changes in water quality in Flint during 2014-2015. We will attempt to identify spatial and temporal trends between existing and predicted/modeled water quality parameters. Some of these parameters will be developed as part of Section 3 below. Potential hypotheses to be tested include, but are not limited to, 1) there is some increased probability residents would contract Legionellosis served by water in areas with higher water age, 2) as vacancy rates increase, there is an increased probability resident may contract Legionellosis, etc.

D. *Potential limitations in the Legionellosis surveillance system that may impact case-patient detection.* The primary causes of bias in population-based surveillance systems reside in case ascertainment, access to health-care facilities and underlying health-care usage patterns for both prevention and treatment in the target population. The following surveillance system characteristics and inputs will be considered in the evaluation:

1) identification of important health-care facilities in the surveillance area; 2) use of screening criteria by a large number of health-care providers in Genesee County and comparison areas; 3) collection of clinical and historical information by health-care providers; 4) ordering and collection of laboratory specimens by health-care providers; 5) variations in infrastructure for health-care facilities located in Genesee County; 6) changing population characteristics (including in- and out-migration) within Genesee County and comparison areas; 7) changes in the health-care delivery system for the population in Genesee County and comparison areas; 8) changes in costs of health-care delivery, including laboratory evaluations; 9) other major causes of serious pneumonia in adults; 10) other diseases in the population that may mimic the signs and symptoms of Legionellosis; 11) differential rates of patient referral; 12) differential rates of patient specimen transport; 13) differential rates of antibiotic usage; 14) varying quality of microbiologic culture techniques used at each hospital; 15) varying rates of patient referral from hospital emergency departments and outpatient departments; 16) changes in project or health-care institution staff; 17) turnover in hospital clinical staff and 18) turnover in hospital microbiology laboratory staff.

Variables that could affect surveillance system performance will be measured at periodic intervals to maintain up-to-date databases and to minimize the impact of such factors on later outcomes analysis. Clinical, epidemiologic and laboratory quality assurance and quality control procedures that are conducted on a regular basis will minimize the impact of biases related to patient evaluations, data collection, data entry and specimen analysis in hospital laboratories. Multi-agency participation in the surveillance area, which includes health directors of each county (Genesee, Oakland and Wayne), will allow inclusion of key personnel who will provide information critical to maximizing our understanding of additional factors, such as any planned introduction of new vaccines in or near the surveillance population.

2.3.3. Measurement

A. Qualitative and quantitative surveillance system characteristics. These characteristics will be measured by engaging stakeholders (e.g., GCHD staff patient interviewers, physicians, infection control personnel) who are involved in case-patient reporting and data collection, conducting objective assessment of the purpose, operational characteristics and resources used to operate the system, and collection of variables that describe the surveillance system attributes as noted below.

2.3.4. Evaluation

A. Evaluation of Legionnaires' disease surveillance. Evaluation of surveillance system functions and activities is critical to understanding a system's ability to detect the target disease and to understand the quality of data collected through the surveillance system. In the case of Legionnaires' disease (a reportable disease in Michigan), the detection of cases relies on active case identification, testing and reporting to local health authorities, such as the Genesee County Health Department. The following steps will be taken to evaluate the Genesee County infectious disease surveillance system and MDSS for detection of Legionnaires' disease:
    1. Engage stakeholders in the evaluation.
    2. Describe the surveillance system to be evaluated.
    3. Describe the public health importance of the health-related event under surveillance.
    4. Describe the purpose and operation of the surveillance system.
    5. Describe the resources used to operate the surveillance system.
    6. Focus the evaluation design.
    7. Gather credible evidence regarding performance of the surveillance system.
    8. Indicate the level of usefulness of the public health surveillance system.
    9. Describe the following system attributes:

a. Simplicity
b. Flexibility
c. Data quality
d. Acceptability
e. Sensitivity
f. Predictive value positive
g. Representativeness
h. Timeliness
i. Stability

10. Justify and state conclusions and make recommendations.
11. Ensure use of evaluation findings and share lessons learned.

B. Given the relatively low frequency of Legionellosis in Flint, the spatial temporal behavior of the disease will be analyzed using a zero-inflated negative binomial (ZINB) regression strategy. The ZINB model assumes that cases of Legionellosis arise from combination of two data generation processes. One process is binary, in this case determining whether or not a block in a given month will have any cases of Legionellosis. The second process determines how many cases will appear (for spatial units likely to have at least one case of Legionellosis). Thus, ZINB regression estimates two separate models simultaneously. The first is a logistic model (also called the inflated model) to derive a conditional expectation of the probability that a spatial unit in a given month will present with zero cases. The second is a negative binomial model (also called the count model) to derive a conditional expectation that a spatial unit in a given month will present with at least 1 case of Legionellosis.

2.3.5. Reporting

A. Quarterly written reports that describe ongoing results of statistical data analysis, presentations of data analyses given and meetings attended in gathering of data to evaluate the Legionnaires' disease surveillance system will be submitted to MDHHS. Surveillance quality indicators will be routinely generated and included in each monthly surveillance report. The preliminary analysis will be used to create the monthly surveillance reports for collaborating physicians and laboratories and to monitor performance of the surveillance system.

B. An evaluation of the Legionnaire's disease surveillance system in Genesee County will be performed bi-annually during the project period. Interim reports on the progress of the surveillance system evaluation will be conducted and will be provided as monthly electronic reports containing data tables and figures, characteristics and attributes of the surveillance system as well as a list of completed, ongoing and future activities required to accurately assess the surveillance system.

C. The results of the ZINB analysis of evaluating possible connections between spatial and environmental conditions and the incidence of Legionellosis will be published in peer-reviewed journals and communicated to residents and government officials through a careful communication strategy developed with project partners, including MDHHS and GCHD.

D. Guidance documents and reports will also be prepared to articulate best practices for Legionellosis surveillance. This document will be provided to state and county level decision-makers in order to support future Legionellosis surveillance activities at the local level.

2.4. Legionellosis case-patient, cluster and case-control outbreak investigation in Flint/Genesee County

2.4.1. Investigation of Legionellosis case-patients and case clusters

2.4.1.1. Tasks

2G. To provide hospital- and community-based technical support and backup to hospitals, GCHD and other organizations and health-care providers when requested for rapid, efficient and complete case-patient and proxy interview, data collection and preliminary analysis of exposures relevant to assess risk of Legionnaires' disease among Flint residents.

2H. To provide technical support and coordination of household and facility environmental investigations to facilitate efficient and accurate water sample collection for *Legionella pneumophila* testing.

2.4.1.2. Approach

A. The FACHEP team will work in partnership with the GCHD, GCMS and/or other community stakeholders/partnership with community organizations and local government agencies leading epidemiologic investigation. This activity is essential to build trust, identify key sources of information, support resident-initiated case reporting and encourage health-care seeking behavior when signs and symptoms of Legionnaires' disease are suspected in household members, families or neighbors.

B. Dissemination of educational information to health-care providers and residents regarding the value of this investigation. This ongoing and active engagement of health-care providers is critical to maintaining sustained vigilance for suspected Legionnaires' disease case-patients.

C. Outreach to residents and health-care facilities to ensure active and rapid case detection. Education and outreach to provide information about Legionnaires' disease in lay terms is the foundation for building resident capacity to identify and report household and family members who experience signs and symptoms of the disease. Similarly, outreach to busy health-care providers and non-infectious disease clinicians (particularly providers who care for older adults, patients with disabilities, or those who care for patients with severe end-organ disease, pulmonary disease or those who have undergone organ transplant or who have immunocompromising conditions) is critical to heighten the index of clinical suspicion for Legionnaires' disease among practicing clinicians including physicians, nurse practitioners and physician assistants.

D. Standardized outbreak and epidemiologic case investigation methods. The FACHEP team and partners will provide technical support for implementation of Legionellosis outbreak-investigation methods. Implementation of outbreak investigation procedures will be conducted at the request of the GCHD and/or MDHHS. Such methods are expected to be employed early, i.e., upon the first notification of Legionnaires' disease cases.

E. Application of enhanced clinical-epidemiologic investigation algorithms and investigation methods that maximize data quality and utility for subsequent analysis, including active, timely and complete case-patient investigations, are necessary not only for effective epidemiologic analysis but also for outbreak control. The following steps are suggested:

1. Complete interview of case-patient (and/or family caregivers [case proxies]) to gather standardized information regarding signs and symptoms of disease.
2. Complete collection of physical examination data and appropriate laboratory specimens for testing.
3. Appropriate bacterial and/or viral pathogen testing based on case-patient signs, symptoms and differential diagnosis.
4. Review of laboratory test results by FACHEP experts, hospital laboratory microbiologists, MDHHS infectious disease experts and GCHD epidemiologists including biochemical, hematologic, inflammatory markers as well as microbiological test results.
5. Call or face-to-face discussion with case-patient and family members (caregivers) to schedule detailed interview with home visit will be performed with GCHD staff and FACHEP team members using the Genesee County Legionellosis investigation form (**Appendix 4**. Enhanced Legionellosis Case Information Form).
6. Request patient follow-up as appropriate to patient's clinical condition.
7. Develop, share and support use best practices for timely completion and recording of pneumonia case information in hospital and/or clinic patient electronic health records.
8. Complete entry of case-patient information into the Michigan Disease Surveillance System (MDSS) web-based portal.
9. Review of case-patient information with technical experts, including medical epidemiologists and clinical infectious disease experts.
10. Feedback of case-patient results in surveillance to local and state health authorities.
11. Follow-up on laboratory testing to ensure complete pathogen identification and entry of results into patient electronic health record and the MDSS database.
12. Initiation of case-control investigational methods (sample size estimates, see **Table 2.1**) with timely identification, recruitment and interview of matched control subjects.
13. Hospital-based control subjects will be identified from hospitals (three in Genesee County) and residential areas in Genesee County including Flint.
14. Residential controls will be identified through an existing list of enrolled study participants in Genesee county (reference IRB #: 067216B3E; Title: FACHEP Phase 2: Environmental Monitoring and Resident Survey).

Table 2.1. Sample size estimation in an outbreak, case-control investigation

Alpha (Confidence)	Power *(1 – β)*	Detectable OR	% Exposed Cases	% Exposed Controls	Ratio, Controls: Cases	Cases	Controls	Sample Size Total
0.05	0.80	2.0	33.3	20	2:1	137	274	411
0.05	0.80	2.5	38.46	20	2:1	77	153	230
0.05	0.80	2.0	33.3	20	3:1	120	360	480
0.05	0.80	2.5	38.46	20	3:1	67	201	268
0.05	0.80	2.0	33.3	20	4:1	112	446	558
0.05	0.80	3.0	42.86	20	4:1	43	170	213

Kelsey et al., *Methods in Observational Epidemiology*, 2nd Edition, Table 12-15
Fleiss, *Statistical Methods for Rates and Proportions*, formulas 3.18 &3.19

2.4.1.3. Measurement

A. Prospective and recurring stakeholder mapping to ensure that no residents are left behind. Standardized stakeholder mapping algorithms will be applied to ensure that no residents or community organizations are inadvertently excluded from clinician and community organization educational outreach programs.

B. Enumeration of educational programs and health-care providers reached during investigation. An updated line listing of programs and their participants will be maintained to identify areas where there may be a need for more intensive outreach and education within the city of Flint and Genesee County to ensure a high degree of knowledge about Legionnaires' disease.

C. Assist, when requested, local and state public health authorities in collecting case-patient information. When desired, the FACHEP team will stand ready and prepared to offer immediate assistance (24/7) in order to maximize the quality of case-patient reporting, data collection and investigation. The FACHEP team will work alongside local health authorities, health-care providers, community organizations and residents to ensure that information is shared and that open lines of communication among organizations and health-care providers are maintained throughout.

D. Support for rapid analysis of Legionellosis case-patient and control subject exposure information and measures of association. The FACHEP team has developed database management and analytic study tools that are ready for direct application to the analysis of Legionnaires' disease case-patient information as well as to evaluate potential exposure risks identified among case-patients or their proxies. These tools will be used in cooperation with local health authorities and health-care providers to ensure high-quality case-patient data collection and timely completion of data analysis.

E. Timely access to Legionellosis case investigation. To help ensure transparency and timeliness of case-patient demographic, clinical and laboratory data collection, the FACHEP team must execute Data Use/Sharing Agreements with the MDHHS that will permit access to case information. Access and use of these data will be used to understand completeness of case-patient information to facilitate collaborative partnership in case investigations.

2.4.1.4. Evaluation

A. Timeliness and completeness of case-patient, case proxy and control subject interviews and data collection using standardized data collection instruments will be determined based on date and time stamps for individual case-patients, proxies and control subject interviews.

B. Educational programs delivered during Legionellosis outbreaks will be monitored to ascertain the number of audience members attending each session, and feedback following attendance by audience members will be tabulated (including surveys of laypersons and professionals).

C. Timeliness in creating and editing the epidemiologic investigation database containing case-patient demographic, clinical, laboratory and exposure variables will be measured to ascertain efficiency of epidemiologic outbreak investigation. Completeness, consistency and accuracy of collected data will be ascertained on an ongoing basis to identify opportunities to improve processes and methods for case-patient data capture in the MDSS database as well as case-patient or proxy follow-up, to ensure that up-to-date epidemiologic data are maintained at all times.

2.4.1.5. Reporting

A. Monthly written internal project reports will contain a) summary tables and line listing of suspected and confirmed Legionnaires' disease case-patient information. Additional information will be reported to communicate ongoing or new challenges and opportunities for improving the quality, completeness and accuracy of case-patient and proxy information. Internal reports will also contain summary information on institutional and neighborhood visits as well as meetings attended.

B. Quarterly written reports will be submitted to MDHHS that describe ongoing weekly and monthly activities, including community and health-care institutions visited, residents contacted, presentations given, meetings attended. Annual written reports will also be provided to MDHHS staff and leadership detailing all monthly and quarterly activities as well as a description of key epidemiologic findings, data analysis, trends and results, lessons learned and future project work plans.

2.4.2. Control subjects' and population data collection in case-control investigation

2.4.2.1. Tasks

2E. The FACHEP team will work with GCHD, GCMS, hospitals and community partners to conduct a matched case-control investigation when a Legionellosis case cluster or outbreak is identified in Genesee County. As part of this investigation, the FACHEP team will assess the relative risk (odds of disease) for Legionnaires' disease among Flint and Genesee county residents compared with residents living in control populations in order to provide insight to residents and health-care providers on strategies for disease prevention.

2F. Ascertain population-adjusted rates of Legionellosis in order to compare Legionellosis incidence rates in the city of Flint, Genesee County outside of Flint and the control populations in Oakland County.

2.4.2.2. Approach

A. In conjunction with hospital infection control staff of hospitals, FACHEP staff will partner to conduct hospital control subject visits with interviews of age group matched control subjects in Genesee County hospitals (**Appendix 16.** Legionellosis Control Subject Interview Form).

B. FACHEP will assemble and maintain an updated list of households and resident contacts with demographic information. If needed, this list will be used to randomly select age-matched controls for interview.

C. In conjunction with community partners, FACHEP staff will conduct household visits to interview community age-matched controls in Genesee County, along with environmental monitoring and sampling by FACHEP team members supervised by Dr. Shawn McElmurry.

D. Administer standardized, pretested in-person surveys to age- and sex-matched control subjects residing in population areas outside the city of Flint. Collect and enter survey data into standardized electronic database formats for subsequent data analysis using SAS statistical software (Cary, NC).

E. Case and control individual identifying information will be de-identified (delinked) from information collected during case and control interviews immediately following completion of interviews. Identifying information with case identification number will be maintained in secure locked cabinets and password-protected computers.

F. Gather electronic Census bureau databases from control populations that are demographically stable and socioeconomically similar to Flint but geographically distinct from the city of Flint. Candidate control populations will be selected from a short list of candidate areas including the City of Pontiac, cities in Wayne County (e.g., Romulus) and the city of Saginaw, Michigan.

2.4.2.3. Measurement

A. Standard epidemiologic analytic methods will be applied to provide univariate and multivariate statistical comparisons of health outcomes across the populations residing in the city of Flint, other areas within Genesee County and the control area populations.

B. Data on health outcomes will be tabulated to compare outcomes among the city of Flint, Genesee County (excluding Flint) and control area populations. Provisional table shells have been created to illustrate the depiction of data as well as the results of statistical data analysis (**Appendix 7**).

C. Conduct comparisons of total health outcomes (e.g., clinical pneumonia, laboratory-confirmed pneumonia, reported Legionnaires' disease and laboratory-confirmed Legionnaires' disease) in order to identify quality of case-patient referral and enrollment in the MDSS reportable disease system.

2.4.2.4. Evaluation

A. Legionellosis incidence rates will be calculated for Genesee County and City of Flint (with 95% confidence intervals). Population-adjusted rates of Legionellosis will also be determined (with 95% confidence intervals) for populations in comparison populations of Oakland and Wayne Counties.

B. Case-control study analytics will be performed to identify factors that may influence the risk for Legionellosis. Unadjusted and adjusted odds ratios (or relative risks) will be computed. A matched case-control investigation will be performed.

2.4.2.5. Reporting

A. Monthly electronic internal project reports (using MS Word) will contain a) summary data tables and figures describing patients with pneumonia, laboratory-confirmed pneumonia, and Legionnaires' disease in control populations from Genesee County and other control populations. Sources of de-identified data will be provided to authenticate the veracity of data subjected to rigorous statistical analysis. Interpretation of data analysis as well as limitations encountered in any data analysis will be reported.

B. Quarterly project reports will be submitted to MDHHS to provide qualitative and quantitative description of project activities and Legionellosis cases. Annual written reports will be provided to MDHHS staff and leadership detailing monthly and quarterly activities as well as a descriptive, bivariate and multivariate data analysis, epidemiologic disease trends, lessons learned, recommended best practices and future project work plans. In the event of a Legionellosis outbreak investigation, the FACHEP team will provide specific and focused recommendations for control of Legionellosis in affected populations and health-care facilities.

3. LEGIONELLA ENVIRONMENTAL SAMPLING & MONITORING

3.1. Objectives

Due to the increased number of Legionnaires' disease cases observed in Genesee County since 2014 and the apparent association with changes to the Flint drinking water, questions regarding the risk of exposure to *Legionella spp.* via the municipal drinking water system have been raised. Critical questions include:

1. What is the prevalence of *Legionella spp.* within Flint's municipal water distribution system?
2. Is the prevalence of *Legionella spp.* within Flint's municipal water distribution system greater than other comparable cities?
3. What is the genetic similarity between *Legionella spp.* observed in environmental and clinical isolate samples?

The identification of these critical questions are the result of numerous meetings with state and local leaders, residents of Genesee County and Flint, and subject matter experts. The answers to these questions are important to understanding the relationship between exposure to *Legionella spp.* in municipal drinking water and the elevated number of Legionnaires' disease cases observed in Genesee County. However, other important research questions remain regarding how to mitigate risk potentially associated with distributed drinking water in Flint. To answer the above questions, the following research questions must also be answered:

1. How does the prevalence of *Legionella spp.* in Flint compare to that in Genesee County and to other comparable community water systems?
2. What is the relationship between the prevalence of *Legionella spp.* in these water systems and chlorine residual, organic carbon content, nutrients, and other water quality parameters?
3. Does solution chemistry (e.g. presence of metals) correlate to the prevalence, resilience and virulence of *L. pneumophila*?

Addressing these questions will not only help account for the increased number of Legionnaires' Disease cases observed in Genesee County and Flint but also help inform strategies to mitigate the risk of exposure to pathogenic *Legionella* and development of protocols to respond to such outbreaks should they occur. Through a multidisciplinary, multi-institutional collaboration, the Flint Area Community Health and Environment Partnership (FACHEP) team has the expertise and capacity to address these critical questions.

3.2. Determine the prevalence of *Legionella* within Flint

3.2.1. Tasks

3A. Engage residents and other key stakeholders to assist with and participate in water sampling

3B. Develop listing and schedule for water sample collection

3C. Evaluate and finalize sampling and analysis standard operating procedures (SOPs)

3D. Measure the prevalence of *L. pneumophila* in high-risk facilities

3E. Measure the prevalence of *L. pneumophila* in Flint homes

3F. Measure the prevalence of *Legionella spp.* in the US EPA monitoring locations

3G. Correlate physical and chemical water quality characteristics with prevalence of *L. pneumophila*

3.2.2. Sampling approach

Prior to sampling, the project team will engage with residents and other key stakeholders (Task 3A), define sampling locations (Task 3B), and finalize analytical procedures (Task 3C). Community engagement with residents and other key stakeholders (Task 3A) will be led by Dr. Laura Sullivan and Dr. Ben Pauli. This effort (Section 5) will utilize the community navigators recruited from the city of Flint to facilitate comfortable access into residents' homes. Prior to entering the field to collect samples, all participants will undergo cultural competency training at the University of Michigan.

Through Task 3B, we will define the list of potential sampling locations from registries of facilities that are considered high risk or frequented by at-risk populations (described below) as well as residential households. The selection of these locations is described in detail later in this section. Data used to identify sampling locations will be collected and analyzed by Sadler (MSU) and Zahran (CSU).

To ensure the highest level of data quality, standard operating procedures (SOPs) will be documented prior to sample collection and analysis (Tasks 3C through 3G). For example SOP, see **Appendix 17**. *FACHEP SOP: In-Field Environmental Sampling*. SOPs for all analytical and sampling procedures will be submitted by project team members to project PIs for review and approval. All SOPs will be reviewed by the Analytical Quality Assurance Team (AQAT) for adequacy, appropriateness, and consistency across the multi-university teams.

To characterize the prevalence in *Legionella spp.* within the Flint water distribution system, water and biofilm samples will be collected from (i) high-risk facilities, (ii) residential homes, and (iii) selected points within the water distribution system. Based on discussions with *Legionella* experts, particularly Dr. Janet Stout (personal communication), multiple samples within each facility are needed to adequately characterize potential exposure to *Legionella spp.* Details describing the samples that will be collected and analytical methods to be used are provided Section 3.7.

High-rise buildings, buildings frequented by at-risk populations (e.g., immunocompromised individuals), and adult care and medical facilities are considered high-risk locations (Barna et al., 2015; Colmenar-Santos et al., 2014). Genesee County has 281 adult care facilities (family homes, group homes and homes for the aged), of which ~80 are located within the Flint water distribution system. Additionally, the city of Flint has about 75 medical facilities. Importantly, several of these properties are located in areas where low chlorine residuals have been observed (**Figure 3.1**). In coordination with the Genesee County Health Department (GCHD), FACHEP proposes to sample for *Legionella spp.* from all high-risk facilities at least once during the first year of this project (Task 3D).

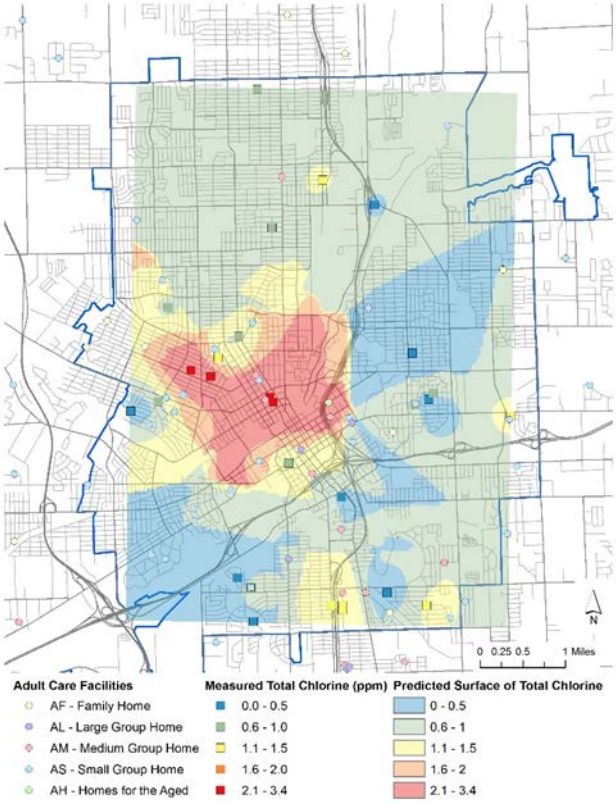

Figure 3.1. Location of adult care facilities and predicted chlorine levels (ppm) based on data collected January 28, 2016.

In addition to monitoring for *Legionella spp.* in facilities categorized as high risk, we will characterize the prevalence of *Legionella spp.* in residential homes (Task 3E). The monitoring of residential homes is

warranted given (1) two consecutive years of elevated Legionnaires' disease cases with undocumented sources and (2) the unprecedented and persistent problems with maintaining adequate levels of chlorine in the Flint municipal water system. Homes will be identified based on a stratified random sampling approach. Approximately 50 percent of samples will be collected from homes in areas of the city where chlorine residual levels are anticipated to be less than 0.5 mg/L (regions in blue, **Figure 3.1**) or with high vacancy rates. The remaining 50 percent of homes sampled will be selected at random to provide adequate geographic coverage. This sampling will be performed during the 2016 summer (July-September), the period when the number of cases of Legionnaires' disease are typically greatest.

In collaboration with GCHD and their project partners (Joan Rose, Janet Stout, etc.), the prevalence of *Legionella spp.* will be measured in water samples collected at the 34 routine monitoring locations within the water distribution system identified by the US EPA (Task 3F). Samples will be collected in August 2016. Samples collected from these monitoring locations will be flushed for 5 min prior to sampling in an attempt to determine the amount of *Legionella spp.* delivered to homes by the distribution system. This measurement represents the potential load to all points within the water distribution system, including residential houses, and may serve to seed biofilms with *Legionella spp.* Additionally, sampling will be coordinated with surface and ground water sampling in and near Flint by scientist from the US Geological Survey (USGS) Water Science Center. The USGS team will characterize, chemically and biologically, the composition of source water entering the Flint water distribution system as well as residents' private wells that may be in the comparision sites described later (Section 3.3)

3.2.3. Number of Samples

The number of homes that must be sampled to accurately characterize the prevalence depends on the number of homes that will test positive and the desired margin of error (**Appendix 18**. Environmental Sample Size). Logistics and cost are two other primary considerations. Based on numerous discussions with *Legionella* experts and a review of past literature (Al-Matawah et al., 2012; Arnow et al., 1985; Azuma et al., 2013; Bates et al., 2000; Bauer et al., 2008; Borella et al., 2005; Borella et al., 2004; Chen et al., 2002; Codony et al., 2002; Dewailly and Joly, 1991; Lee et al., 1988; Lévesque et al., 2004; Mathys et al., 2008; Muraca et al., 1987a; Pedro-Botet et al., 2002; Stanwick, 1986; Stout and Muder, 2004; Stout et al., 1987; Stout et al., 1992; Tiefenbrunner et al., 1993), the number of homes in Flint testing positive for *Legionella spp.* is anticipated to be between 5 and 30%. With a 5% margin of error, a level commonly considered acceptable for environmental monitoring, at least 246 households must be sampled to characterize 20% prevalence (Appendix 18). A summary of samples collected for water quality analysis is provided in **Table 3.1**.

Table 3.1 Summary of water quality analyses performed in addition to the measurement of *Legionella spp.*

Parameter(s)	Reference	Laboratory responsible for analyses
Anions (Cl^-, SO_4^{2-}, F^-, NO_3^-)	Standard Method 4110B (APHA, 2012)	Masten, MSU
Organic carbon, inorganic carbon	Standard Method 5310B (APHA, 2012)	Masten, MSU
Assimilable organic carbon	Standard Method 9217B (APHA, 2012)	Masten, MSU
Total nitrogen, ammonia, nitrite, nitrate	Standard Methods 4500 NC; 4500-NH_3 F; 4500 –NO_2^- B; 4500-NO_3^- E (APHA, 2012)	Love, UM
Cations (Na, K, Ca, Mg, Fe)	Standard Methods 3125 (APHA, 2012)	McElmurry, WSU

Total and dissolved phosphorus	US EPA Method 365.1, Rev. 2.0 (EPA 1993)	McElmurry, WSU
Free and total chlorine	Chlorine Vacu-vial Kits, based on Standard Methods, 4500-CI (APHA, 2012) and US EPA Method 330.5 (EPA 1983)	McElmurry, WSU
Intact cell counts (ICC, surrogate for heterotrophic plate count)	Flow cytometry with dual fluorescent stains	Zhang, WSU

3.2.4 Evaluation

The prevalence of *Legionella spp.* in residential dwellings, health-care facilities, and associated water distribution systems will be quantified. As exposure is believed to be most likely from aerosols, emphasis will be placed on bathroom showers. Sampling the hot water is critical to assessing exposure as disinfectants are degraded by the high temperature (Brazeau and Edwards, 2013) and *L. pneumophila* is capable of thriving at temperatures commonly found in home hot systems (Bates et al., 2000; Rogers et al., 1994). The prevalence of *L. pneumophila* will be compared in (1) hot water samples from showers, (2) hot water samples from the hot water tanks, (3) the biofilm obtained from the neck of the shower following removal of the showerhead, (4) the cold water kitchen tap after 5 minutes of flushing in order to obtain water from the service lines, and (5) the PoU filter on the kitchen sink will be sampled as it will give some insight into the loading of *Legionella spp*. into the house from the cold water line over time. To sample the PoU filter, the existing cartridge will be removed from the faucet and taken back to Nancy Love's laboratory at the University of Michigan where it will be carefully disassembled and DNA will be extracted from the upstream side of the filter. Cold water samples collected from the kitchen tap will be analyzed for *L. pneumophila* and water quality parameters. The water quality parameters to be quantified are in accordance with **Table 3.1**: chlorine residual, assimilable organic carbon, soluble metals, nutrients (phosphate, total nitrogen, ammonia, nitrite), anions, total organic carbon, inorganic carbon, cations and intact cell counts (ICC). The premise plumbing material will be identified at the time of first sampling. If possible, the service line material will also be identified.

The relationship between chemical factors and the prevalence of *L. pneumophila* will be identified with specific attention paid to chlorine residual and organic carbon as these factors are believed to control *L. pneumophila* prevalence (Kim et al., 2002; Lau and Ashbolt, 2009; Muraca et al., 1987a).

Organic compounds in water provide energy and carbon sources for heterotrophic bacteria such as *Legionella*. Previous studies have shown that often the concentration of biodegradable organic matter in drinking water is the critical factor which determines the rate of growth of heterotrophic bacteria in water distribution systems (Lechevallier et al., 1991; Servais et al., 2004). LeChevallier et al. (1991) suggest that, in chlorinated water, if the concentration of assimilable organic organic water is less than 50 µg/L, then the water is biostable. If chlorine is not present, then van der Koogi suggests that to control biofilm growth the AOC should be less than 10 µg/L (Vanderkooij, 1992). However, in a model hot water system (37ºC), operated using a water with low AOC concentration (< 10 µg/L), a biofilm formed that was sufficient to support the growth of *Legionella* (van der Kooij et al., 2005). Water monitoring and analysis will be combined with watchful monitoring for disease that may be due to infection with *Legionella* bacteria. A coordinated strategy of public communication, education, citizen and organization engagement and social-behavioral interventions will be provided to help citizens reduce their risk of infection with *Legionella*. The results of ongoing water testing and human disease surveillance will be shared on a monthly basis with citizens, government agencies, healthcare providers and community organizations to identify additional opportunities to reduce the risk of *Legionella* infection and maximize the health and well-being of all residents in Flint and in Genesee County.

Williams et al. (2015) studied a simulated hot water heater in water containing ozonated fulvic acid. For *Mycobacterium avium* there was a strong correlation between added TOC and bacterial numbers. However, there was no correlation between TOC and *L. pneumophilia* numbers in the water. At all TOC levels, a drop of several orders of magnitude in the numbers of *L. pneumophilia* was seen, so while this project illustrates the complexity of the microbial ecology in the system, the results do not contradict the previous conclusion that, if the concentration of biodegradable organic carbon in the water is very low, then limited bacterial growth can be expected.

Assimilable Organic Carbon (AOC) and Biodegradable Dissolved Organic Carbon (BDOC) are widely used indicators of bacterial regrowth potential in drinking water (Escobar and Randall, 2001). AOC is a standardized test to measure the growth of *Pseudomonas fluorescens* strain P-17 and the *Spirillum* strain NOX. BDOC measures the fraction of the DOC that is assimilated or mineralized by a heterotrophic flora. AOC gives the most direct estimate of regrowth potential (Escobar and Randall, 2001). For our monitoring program in Flint, only AOC will be measured routinely to maintain a reasonable workload. However, BDOC will be determined on selected samples to yield information about the pool of carbon that could potentially be hydrolyzed to form AOC.

3.2.6. Reporting

A. A graphic and narrative stakeholder map of Flint and Genesee County will be provided to project partners (e.g., DHHS, GCHD, city of Flint).
B. Detailed SOPs will be posted on the project website.
C. Regular descriptions of the prevalence of *L. pneumophila* will be reported to the public, local, state and federal partners as data are validated and become available, at least quarterly. Individuals occupying homes where samples were collected will receive a written notice describing the results within 2 months, more likely 1 month, At the end of each sampling year, a detailed report containing the following information will be released using de-identified information:
    a. prevalence of *L. pneumophila* in high-risk facilities,
    b. prevalence of *L. pneumophila* detected within Flint homes,
    c. estimated load of *L. pneumophila* in water being delivered from the distribution system,
    d. relationship between water quality parameters and the prevalence of *L. pneumophila.*

3.3. Comparing the prevalence of *Legionella spp.* observed in homes on Flint municipal water with comparison populations

3.3.1 Tasks

3H. Measure the prevalence of *L. pneumophila* in homes within comparison area A – homes in Genesee County but outside Flint.

3I. Measure the prevalence of *L. pneumophila* in homes within comparison area B – homes in a city with similar demographics and environmental conditions.

3.3.2. Approach

The prevalence of *Legionella spp.* in Flint homes will be compared to two other areas: comparison A - residential households within Genesee County, outside of Flint's water distribution system; and comparison B - homes in a city outside of Genesee County that has comparable demographics. This approach leverages monitoring performed as part of Task 3E and generally employs a regression discontinuity design approach for evaluating causal effects. Spatial continuity stipulates that residents living next to one another are more likely to share similar demographic risk factors than those that live far apart. By selectively sampling residents within Flint and those adjacent to the system but within the same county (comparison A, Task 3H, this approach will minimize confounding variables likely to interfere with our analysis. For comparison B we will evaluate the prevalence of

Legionella spp. in a city with similar demographics and environmental conditions (Task 3I). Likely candidate comparision cities include Saginaw, Pontiac and Detroit. Pontiac appears to be ideal as it has very similar demographics, and the Great Lake Water Authority (formerly DWSD) has supplied water to the city continuously over the course of the current Legionellosis outbreak. Similar to Task 3E, this intensive monitoring will occur during summer when the likelihood of detecting *Legionella spp.* is greatest.

3.3.3. Number of Samples

Assuming a baseline prevalence of *Legionella spp.* of 10% in residential units and in the comparison locations (Appendix 18), to identify a doubling of the number of residents with Legionellosis in Flint (odds ratio = 2), 284 homes will have to be sampled (alpha = 80%). By collecting samples from a total of 284 homes in Flint, this satisfies the number (246 homes) required in Section 3.2.3 to characterize the prevalence of *Legionella spp.* within Flint. The same number of homes (284) is also required to be sample in each of the comparison cities for statistically meaningful comparisons (Task 3H and Task 3I).

3.3.4. Evaluation

A. The prevalence of *Legionella spp.* in residential dwellings will be compared between Flint and the control areas.
B. The prevalence of *L. pneumophila* will be compared between different sources within Flint and the comparison areas. For the same reasons mentioned above, sample sources include: (1) hot water samples from shower, (2) hot water from the hot water tank, (3) biofilm from the neck of the shower following removal of the showerhead, (4) cold water at the kitchen tap, after 5 minutes of flushing, and (5) biofilm from PoU water filters at the kitchen sink.
C. The relationship between chemical factors and the prevalence of *L. pneumophila* will be identified with specific attention paid to chlorine residual and assimilable organic carbon in the distribution systems for Tasks 3H and 3I. Other water quality parameters are: soluble metals, nutrients (phosphate, total nitrogen, ammonia, nitrite), anions, total organic carbon, inorganic carbon, cations and ICC. The premise plumbing material will be identified at the time of first sampling. If possible, the service line material will be identified at that same time. Water quality assessment will be focused on the cold water from the distribution line. If time and funds allow, water quality will also be assessed from the shower head to determine changes in water quality within the premise plumbing.

3.3.5. Reporting

A. The comparison between samples collected in Flint and other comparison areas will be reported at the end of each year using de-identified information.
B. Regular descriptions of the prevalence of *L. pneumophila* will be reported to the public, local, state and federal partners as data are validated and become available, at least quarterly. Individuals occupying homes where samples were collected will receive a written notice describing the results within 2 months, more likely 1 month.

3.4. Determination of *L. pneumophila* diversity among environmental and clinical isolates

3.4.1. Tasks

3J. Collect environmental samples in support of the Legionellosis outbreak investigation.

3K. Determine *L. pneumophila* diversity among environmental and clinical isolates.

3.4.2. Approach

The remarkable versatility of *L. pneumophila* is reflected in the species genome, where a core of ~2000 genes is supplemented by ~1000 additional genes that are present in some strains but not others. The 2014 – 2015 seasonal Flint outbreaks may have been caused by a limited number of *L. pneumophila* genetic variants that are especially proficient at colonizing the municipal water supply, surviving within aerosols, and/or infecting the human lung. Alternatively, genetically distinct strains may have become more resilient and virulent due to acquisition of ICE-ßox, a mobile element that protects *L. pneumophila* from killing after being ingested by aquatic protozoa or white blood cells known as macrophages. Since ICE-ßox also confers resistance of this pathogen to ß-lactam antibiotics and other oxidative stresses, including bleach and hydrogen peroxide, use of strong oxidants as biocides in municipal water systems may inadvertently increase colonization by more virulent strains of *L. pneumophila* (Flynn and Swanson, 2014). A third possibility is that during 2014-2105 the chemical composition of the Flint water distribution system may have become especially favorable for growth of a wide range of pathogenic *Legionella spp.* due to the increased concentration of organic matter in the treated Flint River water compared to that in treated Lake Huron water. The latter two models are consistent with restriction fragment length polymorphism (RFLP) analysis of the 2015 clinical isolates, which indicated that 6 of the 8 strains are genetically distinct. To distinguish between these three models, the genetic profiles of *L. pneumophila* isolated from the Flint water distribution system will be analyzed. Knowledge of the genetic diversity of *L. pneumophila* in the Flint water system is critical to designing strategies to identify the source(s) of exposure and to developing testable hypotheses to understand why the Flint community experienced increased risk of Legionnaires' disease.

In support of surveillance performed by Genesee County Health Department (GCHD), two response teams will be prepared to respond to Legionellosis case investigations (Task 2D and 3K). Each team will consist of at least three individuals: (1) a licensed master social worker, (2) an epidemiologist, and (3) an environmental engineer/scientist. Environmental assessments for 100 case investigations over the full project period are budgeted. Samples collected will include: (1) hot water samples from shower, (2) hot water from the hot water tank, (3) biofilm from the neck of the shower following removal of the showerhead, and (4) biofilm from PoU water filters at the kitchen sink. Other potential likely sources of exposure to *L. pneumophila* will also be sampled (e.g. humidifiers, nebulizers).

As one approach to determine the source of the *L. pneumophila* that caused the outbreaks in Flint, we will determine the genetic "fingerprint" of *Legionella* strains isolated from patients or the natural or built environment. For this purpose, the international *Legionella* community applies a standardized DNA sequence-based typing (SBT) method. A single SBT reaction distinguishes not only *L. pneumophila* serogroup 1 strains, but also five of the most prevalent non-pneumonia species associated with disease, plus four other minor species. A second SBT test can discriminate among >2000 different sequence types (STs) of *L. pneumophila* serogroup 1 strains present worldwide, significantly increasing the power of outbreak investigations. An alternative and more comprehensive state-of-the-art fingerprinting approach is whole genome sequencing, which can be used to generate a reference genome database.

A reference genome database will be developed by determining the complete genome sequences for the predominant ST(s) identified during the 2015 Flint outbreak and during environmental and clinical surveillance in the FACHEP Phase II project period. Specialists in the University of Michigan Medical School (UMMS) Human Microbiome Initiative Core will analyze genomic DNA using the PacBio platform, and genome sequences will then be assembled and analyzed in collaboration with experts in the UMMS Bioinformatics Core. The *in silico* analysis will verify the ST of each strain and also determine whether or not each strain encodes ICE-ßox. In addition, the reference database will be a valuable resource for future hypothesis-driven research to understand the mechanisms that equip *L. pneumophila* to persist in municipal water systems and to infect human lungs.

As additional strains of *Legionellae spp.* are isolated from the environment or patients during the 2016 and 2017 surveillance campaigns, the genome sequences of as many as 100 strains can be determined using the high-throughput Illumina Platform. The complete genomes could then be assembled from the shorter sequence reads with additional computational effort, but the raw data would be sufficient to identify the ST *in silico* and to determine whether or not the strains encoded ICE-ßox. Alternatively, if a large number of *L. pneumophila* strains are isolated in 2016 – 2017, standard SBT and PCR analysis to detect ICE-ßox can be performed more quickly and at lower cost than whole genome sequencing. The *Legionella* strains from the 2015 Flint outbreak will be compared to: 2010-2013 Flint endemic isolates obtained from the State of Michigan Bureau of Laboratories through data and material sharing agreement; any outbreaks that occur in Flint during the course of this project; and reference strains obtained from the Swanson laboratory collection.

Knowledge of the whole genome sequences and the STs of the *L. pneumophila* isolated from the 2015 outbreak cases and prior endemic disease cases in the Flint region will provide a baseline for ongoing surveillance and risk-management analysis. Finding that a diverse panel of STs caused disease in the region since 2010 will favor a model whereby multiple built environment sites are colonized with a variety of *L. pneumophila* strains, each capable of causing human disease. Alternatively, finding a specific subset of STs linked to clinical cases will favor models in which particular genetic variants that are more resilient and/or virulent have become dominant in the region. If so, environmental surveillance protocols can be modified to screen for these more resilient or virulent STs of *L. pneumophila.* Likewise, if the presence of ICE-ßox is found to correlate with increased disease incidence, this molecular marker of risk can be incorporated into environmental surveillance methods. Whether a subset of these STs correlate with particular water composition profiles can also be determined by comparing data obtained by other members of the FACHEP team. Additional genetic determinants of resilience and/or persistent can be identified in future efforts by a combination of molecular and classical genetic methods, including comparative analysis of their whole genome sequences and transposon mutagenesis.

3.4.3. Measurement

The diversity of clinical and environmental isolates will be determined by identifying the STs of the 8 clinical isolates from 2015 Flint outbreak, as well *as L. pneumophila* strains isolated during the environmental and clinical surveillance during the FACHEP Phase II project period. . The strains will be classified by ST *in silico* using the platform developed by the European Working Group for Legionella Infections (EWGLI; http://www.hpa-bioinformatics.org.uk/legionella/legionella_sbt/php/sbt_homepage.php). To ensure quality control, with each assay run, a sample that lacks genomic DNA (negative control) and one that includes a known quantity of *L. pneumophila* DNA (positive control) will be analyzed. To avoid cross-contamination, samples will be handled in the following order: negative control, test samples, positive control. Relatedness will be determined by generating an eBURST map (Kozak-Muiznieks et al., 2014).

Strains will be also classified for the presence or absence of ICE-ßox *in silico* (Flynn and Swanson, 2014). Reference strains know to encode or lack ICE-ßox will be analyzed to ensure quality of the results. To avoid cross-contamination, samples will be handled in the following order: negative control, test samples, positive control.

We will perform standard SBT of the 8 clinical strains isolated in 2015 using the EWGLI protocol to verify sequence data and as a training tool in preparation for 2016 surveillance. First we will classify strains according to Centers for Disease Control and Prevention (CDC) ST analysis of ~750 strains (Kozak-Muiznieks et al., 2014) as an indicator of risk of persistence or disease. Next we will correlate the STs with the 2015 Flint epidemiological report to determine whether certain STs correspond to particular risk factors, geographic locations, and /or residential water sources.

As additional strains are isolated from 2016 and 2017 environmental and clinical surveillance, we will determine their ST using the EWGLI protocol. In addition, we will screen by PCR for the presence of ICE-ßox (Flynn and Swanson, 2014). To seek genetic markers of risk, we will compare ST and ICE-ßox prevalence between the Flint region isolates before 2014 *versus* after 2014 as well as compare clinical isolates *versus* environmental isolates.

3.4.4. Reporting

A. Potential associations between environmental and clinical isolates will be published as needed, at least yearly, using only de-identified strain names. Reports including protected health and identifiable information will be provided to appropriate public health agencies as described in institutional review board (IRB) approved protocol.
B. At end of each year, reports describing genetic composition of isolates will be reported to public health agencies.

3.5. Determine whether water chemistry affects *L. pneumophila* resilience

3.5.1. Tasks

L. pneumophila is a versatile bacterium. This opportunistic pathogen can thrive in natural and engineered water supplies, replicate in a wide variety of amoebae and protozoa, survive within aerosols, and evade killing by white blood cells in the human lung. To do so, *L. pneumophila* alternates between distinct cell types in response to local cues. Currently, it is not possible to predict whether particular chemical profiles of water systems will inadvertently increase resilience or virulence of *L. pneumophila*. Therefore, we will investigate the impact of Flint River water treatments on the viability, resilience and virulence of *L. pneumophila.* To do so, we will apply variables relevant to the Flint municipal water system and laboratory assays that are standard in the Swanson lab (Molofsky and Swanson 2004, Flynn and Swanson 2014**)**. This work will be informed by our collaboration with scientist from the US Geological Survey who will conduct coordinated sampling of surface and ground waters in and near Flint.

3.5.2. Approach

Prior research has demonstrated that *L. pneumophila* thrives in conditions that promote biofilm growth. When starved microorganisms contact materials that release nutrients, they settle, form biofilms, and proliferate (Flemming et al, 2014). The presence of organic matter, either naturally occurring or released by distribution system materials, along with nitrate and phosphate, can also promote biofilm formation by *Legionella* and other microbes (Flemming et al., 2014). Knowledge of the impact of water quality and treatment protocols on *L. pneumophila* viability, resilience, and virulence will inform critical decisions regarding remediation of distribution systems/premise plumbing that contain biofilms harboring *L. pneumophila* and/or treatment technologies for the Flint Water Plant once the KWA pipeline comes online.

Clinical, environmental, and laboratory *L. pneumophila* strains treated or not with water of different compositions will be compared using a panel of laboratory assays of viability, resilience and virulence established previously in the Swanson lab. This laboratory analysis will focus on the predominant ST(s) identified during the FACHEP Phase II clinical and environmental surveillance program. Specific microbiological assays will include: measuring viability by plating for colony forming units; measuring resilience by determining viability after exposure to detergents, antibiotics, strong oxidants, and amoebae; measuring biofilm formation by microscopic and Crystal Violet and Congo Red binding assays; evaluating virulence by quantifying survival and replication within white blood cells by microscopic and viable plate count assays.

To investigate the impact of water quality parameters on the viability, resilience, and virulence of *L. pneumophila*, we will analyze *L. pneumophila* after exposure to water of different compositions. These will include: Ann Arbor tap water as a baseline reference; defined freshwater medium (Trigui et al. 2015); defined freshwater medium

supplemented with constituents known to be present in the water system during the outbreak period (see below); Flint River water before, during, and after the 2014-2015 disease outbreaks; Great Lakes Water Authority water prior to and after entering the Flint water distribution system; and water from other potential sources being considered as new water supplies during the project (e.g. Lake Huron water being delivered from the Karegnondi Water Authority).

As quality controls, laboratory reference strains will be analyzed in parallel with clinical and environmental isolates. For each water sample analyzed, a minimum of 3 independent samples from each source will be analyzed to gauge reproducibility. Statistical analysis will determine whether any differences observed are significant. All clinical and environmental bacterial isolates will be coded by HFHS and analyzed "blind" by investigators at the University of Michigan Medical School, who will return coded data to WSU collaborators for decoding. Likewise, all water samples will be obtained and coded at WSU before transfer to University of Michigan for "blind" analysis.

Knowledge of the impact of water composition on the capacity of *L. pneumophila* to persist within water systems and to survive and replicate within protozoa in water and white blood cells in the human lung will inform rationale design of water treatment protocols that reduce the risk of Legionnaires' disease.

3.5.3. Reporting

A. Potential associations between water chemistry and *L. pneumophila* resilience or virulence will be published as needed, at least yearly, using only de-identified strain names. Reports including protected health and identifiable information will be provided to appropriate public health agencies as described in institutional review board (IRB) approved protocol.
B. At the end of each year, reports describing the impact of water chemistry on resilience or virulence of isolates will be reported to public health agencies.

3.6. Methodologies and Summary of Field Samples

Up to 100 facilities will be sampled as part of Task 3D. To quantify the prevalence of *L. pneumophila* in Flint homes (Task 3E) and evaluate if there is a difference in the prevalence of *Legionella spp.* present in Flint homes relative to the two comparison areas (Tasks 3G and 3H), 284 samples must be collected in each area. Water samples will also be collected at the 34 routine monitoring locations within the water distribution system identified by the US EPA (Task 3F).

3.6.1. Sample collection

Samples will be collected from potential points of exposure in single-family residential homes and commercial facilities. When surveying residential households, the project team will collect the following samples: (1) hot water from shower, (2) hot water from hot water tanks, (3) biofilm from the neck of the shower following removal of the showerhead, and (4) biofilm from PoU water filters at the kitchen sink. A draft SOP for sample collection is described in Appendix 17. Other potential point sources to sample include humidifiers, nebulizers, etc. that represent potential sources of *L. pneumophila* exposure. PoU filters will serve as a "composite sample", collecting where any biomass enters homes and buildings over time.

All samples will be transported to WSU where they will be recoded (Chain of Custody will be created) and split for further analysis. Deidentified samples with unique identifier (Sample ID) will be provided to laboratories for analysis as an additional level of security and confidentiality as well as to avoid bias. Samples will then be delivered to the following locations for further analysis:

- *Legionella* samples (water samples and swabs): Henry Ford Health Systems

- TN, nitrate, nitrite, ammonia, PoU filters: University of Michigan
- TP, anions/cations, cell counts: Wayne State University
- TOC, TIC, AOC : Michigan State University

All analyses will be performed using SOPs approved by the AQAT. For example, the protocol for Legionella analysis, based on recommendations by the CDC, is provided in the **Appendix 19** – *Legionella Laboratory Testing Procedures*, and Legionella sample processing flow is shown in **Figure 3.2.**

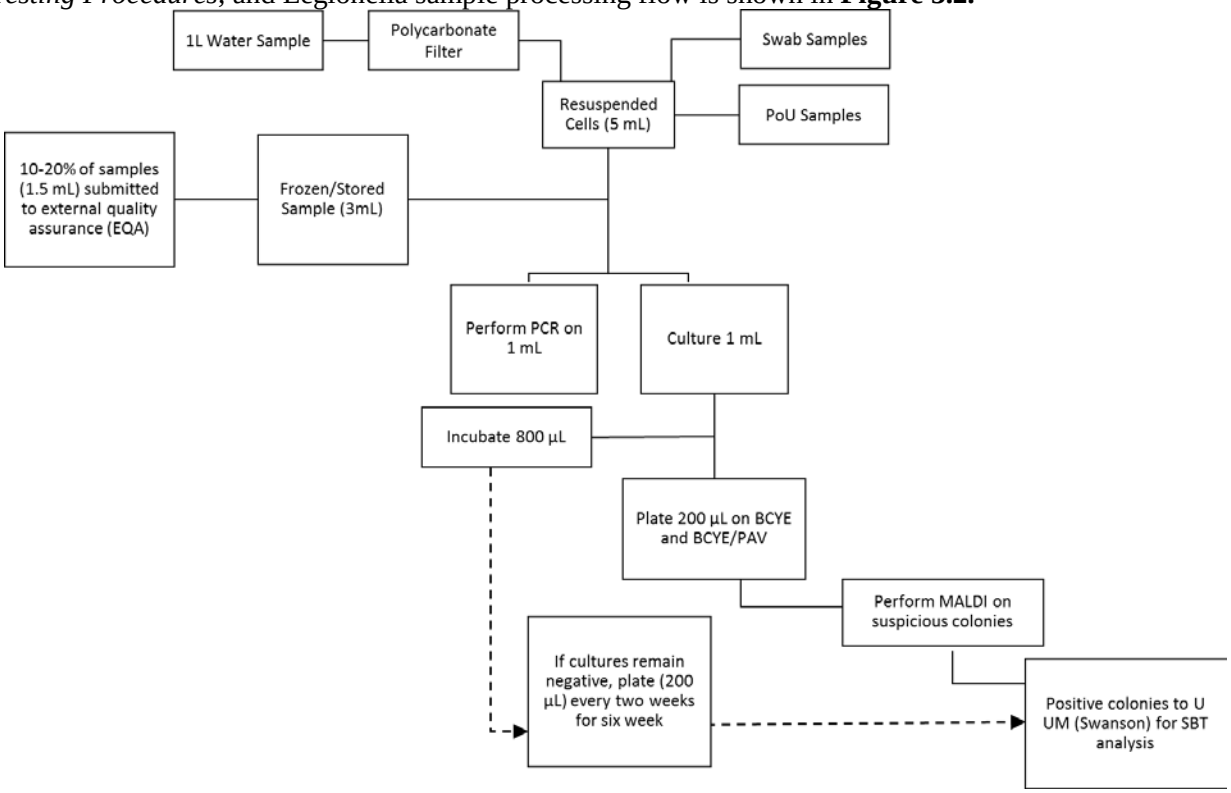

Figure 3.2. Microbiological analysis sample handling.

3.6.2. Water Sample Collection and Analysis

Water samples will be collected for microbial analyses according to CDC recommendations. In the field, at least 1 L of water will be collected aseptically in sterilized 1 L polyethylene terephthalate (PET) bottles (Dnase-, Rnase-, and human DNA-free; nonpyrogenic and noncytotoxic). Sodium thiosulfate (0.5 mL of 0.1N) will be added to deactivate residual chlorine. On the same day, water and biofilm samples will be stored in coolers for transport to HFHS laboratories where they will be filtered. Immediately after sample collection, temperature, dissolved oxygen (%, mg/L), specific conductivity (µs/cm), pH, and oxidation/reduction potential (ORP, mV) will be recorded in the field using a YSI Pro Plus multi-parameter water quality meter (Yellow Springs, OH). Water quality meters will be calibrated daily.

Once aqueous samples arrive at HFHS, they will be filtered through 0.2 µm 47-mm polycarbonate filters using a multi-filter assembly manifold system; next, filters will be put into sterile test tubes, suspended in 5 mL suspension media and vortexed to suspend bacteria (within 24 hrs of sample collection). Two 1 mL aliquots from resuspended cell suspensions will be taken. One 1 mL aliquot will be used to extract DNA for analysis of *Legionella* (HFHS) using polymerase chain reaction (PCR). The *Legionella* PCR protocol was optimized during Phase 1 and will be run with 2 positive controls. The other 1 mL aliquot will be reserved for culturing.

Specifically, 100 µL of suspension will be placed on each of two plates: buffered charcoal yeast extract (BCYE) and BCYE w/ PAV (polymyxin B, anisomycin, and vancomycin). The remaining 3 mL of samples will be stored in a -80ºC freezer for future analysis and to serve as backup in case additional analyses are needed. For external quality assurance (EQA), 20% of stored samples will be submitted by HFHS to external lab with experience culturing Legionella (i.e., ELITE certified laboratories such as PathCon) or CDC laboratories (Atlanta, GA).

Samples will be collected and stored for analysis of key water quality chemical parameters according to Standard Methods (APHA, 2012) and highlighted in Table 3.1. These parameters include chloride, free and total chlorine, total organic carbon (TOC), total inorganic carbon (TIC), total iron, assimilable organic carbon (AOC), orthophosphate, total phosphorus, nitrate, nitrite, ammonia, total nitrogen, cations, and anions. In samples where free chlorine levels are below 0.5 mg/L, a 250 mL sample will be collected for *E. coli* testing via the IDEXX Colilert® test, which in an approved US EPA method and is included in Standard Methods (APHA, 2012).

It is important to estimate the total microbial growth in the distribution system over time as a normalizing basis for *Legionella spp.* counts and to quickly assess when microbial counts increase in various parts of the distribution system that is vulnerable to large variations in disinfection residual. To do so, we will use flow cytometry coupled with SYBR Green I and propidium iodide fluorescence staining to measure intact cell counts (ICC) as a surrogate for the traditional heterotrophic plate count (HPC) method. HPC notoriously underestimates total cell counts due to culturability problems with highly oligotrophic cells such as those found in drinking water (Gillespie et al., 2014). Flow cytometry-based HPC has been well-established in drinking water (Berney et al., 2008; Hammes et al., 2008) and has become a standard in some European countries. Because our project is focused on assessing the presence, infectivity and management of *Legionella spp.* in the Flint water distribution system, it is important to see if other correlating factors can be found as well. While we do not expect ICC measurements to necessarily predict the presence of *Legionella spp.*, flow cytometry is rather sensitive to changes in cell counts and, therefore, community structure (Lautenschlager et al., 2013). Flow cytometery protocols will be developed in the first month of the project. A 10 mL sample will be collected for flow cytometry. Results of these measurements will be compared to assimilable organic carbon data, which determines the potential of water to support heterotrophic bacterial growth. *Pseudomonas fluorescens* P17 and *Spirillum* sp. NOX are used to determine AOC, whereas the flow cytometry method uses the native organisms in the water.

3.6.3. Biofilm Samples from Point-of-Use Filters

Home PoU filters provide a unique opportunity to capture time-averaged microbial samples for water passing into residents' homes from the distribution system as well as growth of those organisms once on the filters. Therefore, a component of our household sampling campaign will be to collect used PoU water filters from resident's homes and replace them with the same or better (e.g. NSF certified for lead and TTHM removal) filters. Prior work by Dr. Love and colleagues with the same model of PoU filters being widely used in Flint has shown that the fabric wrap around the core filter media captures and supports significant growth of bacteria from distribution systems (Wu et al., In preparation). Filters collected from Flint homes are also expected to have detectable growth on the fabric wrap located on the upstream side of the block activated carbon filter, even for filters collected after two weeks of use. After filter samples are cataloged at HFHS, they will be transported to the University of Michigan Ann Arbor campus for disassembly using methods previously developed there. Some components of a subset of filters will be analyzed further for microbial composition as part of a separately funded National Science Foundation RAPID grant. The fabric wrap will be removed, cut into equal-sized pieces using a sterile Exacto knife, and pieces will be placed into sterile tubes. Samples will be transported to HFMS for *Legionella spp.* analysis according to Figure 3.3. Previous work used a different and more rigorous extraction protocol that may need to be adapted for this project if the vortexing protocol used by HFHS does not recover enough DNA.

3.6.4. Biofilm Samples from Premise Plumbing

Samples from shower heads and selected locations within homes and premise plumbing will be collected using sterile long-stem swabs with polyester tips, in accordance with CDC (2005) protocols. These swabs will be stored with either (a) water from the sample source or in (b) phosphate buffer solution (PBS) for samples from sources without a water outlet (e.g., hot water tanks). Swab samples will be processed for *Legionella* as will be done for the polycarbonate filters used to concentrate cells in water samples, as noted in section 3.7.2.

3.6.5. Quality Assurance and Control

A detailed quality assurance/quality control (QA/QC) document is under development and will be completed by the Analytical Quality Assurance Team (AQAT, at least one representative each from WSU, MSU, HFHS and UM) in June 2016 for this project. The document will contain a compilation of ***Standard Operating Protocols (SOPs)*** that will be developed for all analytical methods used in this project and for each location where the method is practiced. All SOPs will include: (i) change record outlining when and who made changes to the protocol; (ii) a detailed description of the theory behind the method; (iii) the procedure in very detailed, step-by-step format; (iv) known interferences; (v) sample preservation; (vi) data collection, logging method, and retention; (vii) a schedule showing approximate times required for all major steps in the protocol, and (viii) safety details associated with chemicals used in the procedure and waste handling. In addition, a ***Standard Handling Procedure (SHP)*** for managing chemical storage, hazard awareness, waste management, personal protective equipment required, and accidental spill management plan is required in each lab (for example, see http://www.oseh.umich.edu/pdf/sop.pdf for a template). All SOPs and SHPs will be reviewed by the AQAT. All SOPs and SHPs will be stored centrally in the shared cloud folder for the project, and in the permanent backup storage location.

Each analysis will be based on calibration curves and will be evaluated for method detection limits. Method blanks and replicates will be conducted with each sample set. In-matrix spiked samples will be conducted to affirm methods during protocol development, and will be conducted randomly with at least 5% of samples (minimum of 2) per batch of samples analyzed. Each laboratory will maintain their respective records on data quality and the PI from each partner institution is responsible for ensuring the records are being kept and reviewed. The records will also be reviewed by the AQAT quarterly. All records will include the date, name of the analyst, and all results from the controls, blanks and spiked additions performed.

With regard to water quality analyses:

- For analyses that involve use of calibration curves, at least 4 (and, preferably, 5) points over the range of concentrations of anticipated interest for the project will be used to create the curve. We anticipate that calibration curves will be linear and have $r^2 \geq 0.95$.
- One duplicate will be analyzed per 10 samples, at least. For some protocols, duplicate measurements will be taken for all samples. Acceptance criteria for duplicate analyses will be set at 20% of the average (duplicates) or standard deviation.
- Recoveries from spiked samples should be greater than 75%.
- The method detection limit (MDL) will be established for each type of sample matrix (based upon the standard deviation of 7 replicate standards whose concentration is roughly 3 times larger than the anticipated MDL).

With regard to biomolecular analyses:

- Standards or standard curves (as appropriate) will be run with every test sample.
- PCR and qPCR amplification efficiencies will be calculated using a ten-fold dilution series. Efficiencies > 90% are expected for all primers that amplify < 300 base pair product; more leniency may be needed for larger base pair products.

- Negative extraction controls will be conducted with each DNA and RNA extraction batch. The negative controls will consist of buffer at the same volume as the samples.
- The quantity (fluorescent) and quality (UV) of extracted nucleic acids will be quantified using spectrophotometric methods for each extraction.
- Each sample will be run in triplicate
- No template controls (NTCs) will be included for every PCR or qPCR plate or set. If NTCs ever give a positive result, the false positive must be investigate, mitigated and reported to AQAT.
- Means and standard deviations will be determined for replicates (at least triplicates for qPCR, at three different dilutions). Non-detects will be included in the calculated means.

3.6.6. Data Management

The PI (McElmurry) and the project manager (TBD) will lead the development of a coordinated data storage, access and dissemination plan for all project participants. All electronic research data files generated as part of the project will be stored using a Dropbox Business cloud services account (or other comparable services) acquired just for this project. This service has unlimited file recovery, unlimited space, remote wipe to secure data in case of a lost device, and other administrative features (individual password protection for secure storage, etc.). The primary tier of folder architecture will be created by the PI and managed by a core team of co-PIs. Each analyst will upload all data files to their designated folder daily or through automated syncing. Meeting minute notes will also be maintained in this shared file storage system. Non-digital laboratory notebooks and any data or information collected manually will be scanned (e.g., via Tinyscan, a smart phone-based app that can be used directly in the lab to scan documents) and uploaded into Dropbox folders. Any staff involved with collecting data for this project will undergo Responsible Conduct of Research Training, which will include: how to maintain a laboratory notebook; how to manage data; and how to use Dropbox, and others.

3.7. Outcome of Environmental Sampling and Monitoring

Conclusions from these investigations will indicate if *Legionella* serotypes found in drinking water are the same (or not) as detected in Legionellosis patients, and provide practical insight that, with additional work supported elsewhere, will lead to the development of remediation strategies and other management decisions (e.g., maintaining adequate chlorine levels, determine the impact of increased co-habitation of *L. pneumophila* and protozoan hosts on remediation strategy) that reduce the risk of exposure to *L. pneumophila* within municipal water systems.

4. Communications, Engagement and Social Behavioral Health

4.1 Overview

Many residents of Flint are overwhelmed, confused and lack trust in local and state officials. Messages about the water crisis are disseminated frequently through various channels, legacy and social media, institutional reports, organized forums and informal conversations. Many of these messages are incomplete and contradictory. Some are inaccurate. Residents must sort through the contradictory information to learn ways to protect their families and access resources. Adding to this are feelings of alarm, frustration, anger and a sense of betrayal, which many residents are expressing in response to what they perceive to be inadequate government response.

Under the current conditions, any research or intervention—no matter how well-intentioned—may be viewed with caution at best or outright hostility at worst. Moreover, the pressures of bureaucracy, the limitations of resources and the push to find answers might work against attempts to engage residents in a supportive research process that addresses their interests and needs. The FACHEP addresses these concerns by taking into account the need to enact ways of conducting community-based work on Legionellosis that protects or enhances the dignity and well-being of all residents. A coordinated strategy of public communication, education, citizen and organization engagement and social-behavioral interventions will be provided to help residents reduce their risk of infection with *Legionella spp.*

4.1.1 Communications

Communication is critical to managing risks and crisis (Ulmer et al., 2015). Risk and crisis communication as areas of research and practice are robust, multidisciplinary fields. In 1996, the National Research Council defined risk communication as "*an interactive process of exchange of information and opinion among individuals, groups, and institutions. It often involves multiple messages about the nature of risk or expressing concerns, opinions, or reactions to risk messages, or to legal and institutional arrangements for management*." Risk and crisis communication is a central process for reducing and mitigating harm during extreme events (CDC, 2015). Such events include situations where contaminated water poses a risk to population health.

High profile water-related emergencies include the 1993 *Cryptosporidium* contamination of the Milwaukee, Wisconsin water supply. During this outbreak, over 400,000 people became ill with diarrhea from a water-borne parasite. The contamination was linked to run-off from agricultural operations that contaminated the municipal drinking water supply. In another case, Walkerton, Ontario experienced contamination of its municipal water supply in 2000 with *E. coli* bacteria. In that outbreak, several thousand residents suffered from bloody diarrhea and seven persons died. For several days after the initial report, the operators of the municipal water supply continued to claim that the water was safe, thus exposing more residents to the contamination. In 2014, 7,500 gallons of crude 4-methylcyclohexanemethanol, a chemical used in coal cleaning, contaminated West Virginia American Water's drinking water intake, treatment and distribution center. Residents of the nine affected counties were advised not to drink, cook with, bath, or wash with the water. A total of 300,000 people were affected by the spill, with 14 people hospitalized after showing symptoms including nausea, vomiting and rashes. In cases such as these, effective and timely communication is critical to reducing and containing harm. The Wisconsin outbreak

was complicated by delayed recognition of the outbreak and lack of timely public warnings. In the Walkerton case, information was withheld and warning messages were not distributed in a timely manner leading to further exposure of residents to pathogenic organisms. The Elk River case involved an expanding crisis where messages could not keep up with the scope of the crisis.

Methods for responding to water contamination depend on the specific agent(s) involved, their concentration, the location of the contamination and the communities affected. Regardless of those variables, however, effective communication with the public regarding how to respond to water contamination is necessary to forestall further harm and illness. Warning messages, such as boil water, don't drink the water, and avoid all contact with the water, can be complex and not easily understood. Because water is a necessary commodity, and access to potable water is a basic human need, methods of response can be difficult to implement. These challenges are be increased further when trust has been disrupted and when various sources are addressing the risks from multiple standpoints (CDC, 2015).

Several efforts have tried to describe the challenges of crisis communication and to identify ways to effectively communicate during the challenges of a crisis. These efforts include the CDC's Crisis and Emergency Risk Communication framework and a set of best practices for crisis communication. Crisis and Emergency Risk Communication was developed to provide public health officials with tools for communicating during crisis. The framework includes a number of principles for facilitating strategic communication planning, matching communication strategies to the dynamics of the crisis, addressing audience needs and building trust with stakeholders. The best practices approach to crisis communication includes a set of principles for improving the overall effectiveness. These principles include creating consistent messages, providing messages of self-efficacy and addressing the needs of the public, among others.

4.1.2 Engagement

Community engagement builds directly from the community's knowledge that a problem exists and fosters direct input from individual residents and organizations. Achieving consensus among community stakeholders also encourages buy-in from diverse partners and accountability among organizations and agencies with direct responsibility for city residents and vulnerable groups. In this way, community engagement identifies urgent and long-term needs among those most affected, and is good politics. Thus, community engagement provides the opportunity for local, state and national leaders to directly visualize programmatic success and relevancy of investments in public infrastructure. Community engagement is about (1) decision-making, (2) relationship development, and (3) capacity-building and is an active method of implementing change. Community engagement requires democratic processes and provides representative voice of the community. Assumptions must be checked as there is the danger of newly minted well-intentioned groups to move to action prematurely relative to method and/or strategy. Efficacious techniques for community engagement bring residents and stakeholders together to discuss solutions to a common challenge or crisis. To build trust, buy in, and gain valuable feedback, engagement should be an interactive bidirectional process with the exchange of vital information relative to Legionellosis, detection and the valuable role of surveillance and monitoring, the role of community leaders, community networks, and cultural agents will play a central role in acquiring, processing, disseminating and interpreting information.

4.1.3 Social and Behavioral Support

State and federal agencies, university researchers, philanthropic organizations and other organizations with interests in the Flint water crisis and its remedies have descended upon Flint, creating a complex network of investigation, support and resources. In addition, concern regarding the quality of Flint city water has a direct

relationship to perceptions and behaviors related to the risk of Legionellosis. To develop an effective Community Engagement Program for Legionellosis Control that addresses the health and welfare concerns of all Flint residents, communication (including Legionellosis educational outreach) as well as the steps taken and the services and support provided by the various public and private organizations and agencies is essential. The seat of local government is central to a coordinated response, but the size and scope of water crisis accompanied by an extensive number of interactions with agencies and constituents has taxed existing resources available to the City of Flint government. Although resources have been deployed by the U.S. Public Health Service and the U.S. CDC to assist the City of Flint, there are many tasks and coordinating activities of the local government that need to be supported.

A key role of the FACHEP Communications, Engagement and Social-Behavioral Health Team is to identify evolving community concerns and reactions to perceived environmental hazards. This community participatory work is critical to ensuring that the community does not inadvertently take actions that actually <u>increase</u> their risk of Legionellosis.

At this phase in the Flint water crisis, many groups are seeking to mitigate environmental factors related to contaminated water exposure in an effort to reduce their risk of exposure to other reported or unknown hazards.
In this work, FACHEP will identify and work with partners to addressing residents' feelings of stress, anxiety and anger that is often accompanied by a heightened sense of distrust and hopelessness. Active community interventions that support reductions in risk of Legionellosis are of vital importance too, as the psychological toll of dealing with the water crisis is routinely exposing social vulnerabilities that may be exacerbated by chronic psychological trauma experienced during the crisis. A social-behavioral intervention to minimize risks associated with Legionellosis begins with people's experiences in order to provide a more accurate representation of their daily reality. This perspective brings value and respect with an ethic of caring (Collins, 1991).

Known high-risk groups for Legionellosis exist and represent a large proportion of community residents in Flint. Those at higher risk for Legionellosis include

- **older adults (≥ 50 years of age),**
- **former or current smokers,**
- **persons suffering from chronic medical conditions (heart and lung disease),**
- **metabolic diseases such as diabetes, kidney and liver dysfunction or failure,**
- **persons with immune compromised conditions (e.g., those using immunosuppressive drugs, or**
- **those suffering from HIV/AIDS).**

In addition to the psychological toll, older adults are particularly vulnerable and, even under normal circumstances they require monitoring relative to access to nutrition, health and behavioral health services. Across the life course, exposure to drinking water contaminants can differently impact physical, mental, and social well-being. Challenges that older adults may face, such as social isolation, frailty and high rates of co-morbidities (e.g., mobility impairments, chronic obstructive pulmonary disease, dementia/Alzheimer's disease), can exacerbate the harmful effects of *Legionella* exposure in late life (Needleman, 2004). Moreover, due to a range of health and social disparities experienced by some individuals across the life course, *Legionella* exposure in late life is one among many environmental and social harms that cumulatively affect vulnerable older adults in Flint.

4.2. Objectives

1. To foster a multidisciplinary, professional and proactive Legionellosis communication strategy that links and coordinates government agencies, media, community organizations and citizens and provides timely, meaningful and clear messaging that fosters prevention of Legionellosis.

2. To fully engage individuals, health-care providers and institutions so that the needs and desires of the community are heard in such a way that will improve their access to care and proactively engage residents and communities in health-promoting self-care.

3. To offer complementary social behavioral resources and expertise to Flint families and households to ensure that key social needs are met and that adaptive behaviors are reinforced in order to guide resource-limited individuals and families toward sustained patterns of healthy living.

4. To engage local opinion leaders, cultural agents and networks as resources for understanding community concerns and disseminating accurate and timely information.

4.3. Enhance the effectiveness of Flint water risk and crisis communication

4.3.1. Tasks

4A. Create structures and systems for coordinating Legionellosis messages among community, county, state and federal public health partners.

4B. Cooperatively develop and implement a proactive Legionellosis communication plan and strategy that identifies audience needs, including the community, agencies (Genesee Country Public Health, Michigan Department of Health and Human Services) and organizations.

4C. Develop sustainable channels of communication to address audience needs that maximizes community participation in prevention and control of Legionellosis.

4D. Enhance Flint residents' understanding, cooperation and trust to empower them in reducing risk of Legionellosis.

4E. Enhance communication resources and skills through training that strengthens community response and support for Legionellosis prevention and control.

4F. Foster integration of constructive communication with Subject Matter Experts (SMEs) community that provides residents with increased expertise and confidence to deal with Legionellosis in their community.

4.3.2 Approach

The project approaches crisis and emergency risk communication from two broad perspectives: the agency and community. FACHEP will work with those agencies already involved in providing risk and crisis information to the public to develop a larger communication and engagement strategy, identify what is already being done and where gaps may exist. Given that coordination is a common problem in crisis communication and that trust is low, facilitating a high degree of consensus about strategy and activities is a critical first step. This will include national, state and local agencies and will involve regular and ongoing meetings with the designated

communicators for the agencies. This strategy will involve the identification of existing channels for risk communication and expanding channels where appropriate, developing coordinated content, and capacity building through training and development and by placing key personnel in agencies.

Our second approach will actively engage communities around Legionellosis communications to ensure ongoing or new concerns will involve an ongoing assessment of Flint residents and community needs to ensure timely response to concerns among citizens. To achieve this, we will work with residents of Flint through community groups and organizations to identify their informational needs, concerns, and preferred methods for receiving ongoing Legionellosis-related information. This assessment will occur both systematically at regular intervals, through survey data collection and by monitoring other community meetings, social media and other sources. Additional segmenting of the public audiences will occur to assess how needs vary among various groups (e.g., elders, parents with young children, etc.) These two approaches will allow for the identification of key target audiences and their associated informational needs.

In addition to coordinating and facilitating communication, FACHEP will build on its existing communications systems to address key audiences using the following tools:

Table 4.1. Key target audiences for risk communications include the following groups.	
Media	News value messages (i.e., findings)
Flint residents	-Messages about FACHEP -Messages about self-efficacy, self-protection -FAQs about Legionnaire's disease
Sampling partners	-Information about community developments and resources -Information about interpreting results
Community groups	Information about FACHEP, Legionnaire's disease, and self-efficacy
Public health partners	Updates on activities Information for purposes of coordination

The communication plan for FACHEP will include the following:

Table 4.2. Channels for risk communication and dissemination of information	
FAQs	General messaging, Promoting individual and community self-efficacy
Web Page	General Updates, Links, Team member Bios and opportunities for community members to ask questions
Newsletter	Web-based News Aggregator, Bi-Weekly Updates, and Community News
Presentations	Subject Matter Content to Churches, Community Groups, Resident Groups
Brochures	Technical content and community resources to address residents' needs
Letters	Sampling Partners, Community Health Partners
Conference Calls	Coordinating with Public Health Partners
Training	Risk and Crisis Communication training will be delivered to agency partners, and community leaders.

The following personnel will also support active communication strategies: Webmaster, Newsletter Editor and Outreach Support.

4.4. Community Engagement and Education

4.4.1 Tasks

4G. Increase awareness about behavioral and environmental exposures that increase risk of Legionellosis in the community.

4H. Identify locally developed and culturally competent strategies to reduce the risk of Legionellosis.

4I. Systematically identify concerns of the public regarding their risk of Legionellosis by capturing comments, monitoring social media, and assessing public inquiries through systems such as 211.

4.4.2 Approach

In engaging communities of Flint and Genesee County, the FACHEP team will build on the existing networks for community collaboration and promote new outreach strategies that can be integrated for in-depth engagement with residents and organizations to identify and reduce risk of Legionellosis. The number of networks that have been developed in Flint and Genesee offer multiple points of entry including the faith community, governmental agencies and institutions, local community organizations, and resident groups. Selected public faces of the issue who have community trust (e.g., Mona Hanna-Attisha) also provide for important interactions.

Engaging with these community networks is necessary for effective communication and trust building. Such engagement includes providing resources and accurate and timely information. Community members expect subject matter experts to be independent of particular agendas, to address their questions and concerns in respectful, responsive and accessible ways and for messages to be consistent.

Working through and with members of the community to leverage trust and credibility is essential. Successful approaches for engagement in communications will ensure that: a) all voices are heard; b) messages are communicated with maximum clarity to key target audiences, and c) residents from all walks of life, cultural backgrounds and languages will understand and be motivated to act on the *Legionella* messages around early detection, diagnosis, health-care seeking behavior and prevention. In community engagement, Dr. Laura Sullivan and Dr. Ben Pauli, FACHEP team members, have undertaken a sustained and extensive outreach and early engagement to understand key local organizations, power structures and influencers in the community as well as opportunities for new partnerships based on highly active and engaged individuals (See **Appendix 20** for summary of groups and meetings).

4.4.2.1 Entry points into Flint community

Community engagement into the Flint community will be facilitated by working with city, state and local entry points.

1- City –Twice weekly meetings are held with city administrators and public health advisors to communicate regular updates on community concerns, health issues, infrastructure status, staffing, and mapping of lead service lines. Information will be exchanged with members of city council and other city leaders to stay updated on funding health and infrastructure and collaboration on relief efforts.

2- State- Weekly meetings with Flint Water Interagency Coordinating Council (FWICC) and subcommittees to stay apprised of policy, infrastructure, water quality, service coordination and to provide perspective regarding Flint residents' perceptions and trust.

3- Local – Weekly meetings with groups including Flint Democracy Defense League, Michigan Faith in Action, Flint Rising, Flint Moms' Power, and Crossing Water that provide two-way interaction to present updates on FWICC meetings, mayor's office activities and to stay apprised of canvassing activities, demonstrations, protests and to facilitate cooperation and collaboration of residents.

As the FACHEP team moves forward in planning and implementing its objectives to evaluate and reduce the risk of Legionellosis, the team will work through the City of Flint Mayor's office and/or Senator Ananich to identify "co-sponsors" for support including: Leaders (based on position AND reputation) Flint Pastors/Priests, CEO/ED of United Way, Greater Flint Health Council, Genesee County Medical Society, Flint Community Schools, Community Foundation of Greater Flint, Community Action Resource Department, Catholic Charities of Genesee County, Hurley Medical Center, McLaren RMC, Genesys RMC, city of Flint Chief Public Health Advisor, others as advised by Mayor Weaver/Sen Ananich and Flint residents – representative sample for diversity, socioeconomic background, and neighborhood.

One of the critical points of contact within the community will be the Chief Public Health Advisor. This proposed position is vital to coordinating FACHEP activities with Flint residents and other county, state and federal partners. Currently this role is temporarily being filled by US Public Health Service Rear Admiral Michelle Dunwoody. To best facilitate engagement, a dozen community representatives have been identified to assist in leading discussions, education and outreach. A list of these community partners is presented in Appendix 1.

The FACHEP team has held meetings with several community organizations to survey and assess community engagement activities in order to ensure that FACHEP resources do not duplicate any existing or planned activities. This approach is critical to ensuring smooth lines of communication among local organizations and to avoid duplication of activities and ensure careful allocation of resources to support Phase II activities.

4.4.2.2 Identifying Concerns and Community Engagement Activities

Step 1: Organize meetings to identify community perspectives, needs and concerns.

Meet with representative group of Flint residents to explore concerns and possibilities for collaboration – introduce FACHEP goals and objectives, provide Frequently Asked Questions about Legionnaires' Disease for Flint residents, review findings from other assessments such as the Health Vulnerability Assessment (ATSDR, 2016) or CASPER Assessment (Center for Disease Control, 2012 report and the upcoming CASPER assessment to be conducted in May 2016 by the Genesee Health System, US CDC and other partners) or others, and gather perspectives about Legionnaire's disease, perceived risk and extent of and suggestions for community involvement. From these initial meetings, the community engagement team will assemble a mix of co-sponsors and residents to constitute a community-driven steering committee focused on Legionellosis prevention and control.

Step 2: Design community-informed and engaged processes to support active surveillance, case identification, and culturing alongside addressing community identified problems.

FACHEP will work though an ad hoc coalition to determine best methodologies for creating an exchange of information that supports resident and other stakeholder input into the FACHEP objectives and tasks. The ad hoc coalition will create an annual strategic plan for engagement activities that considers ongoing Flint local, state and organizational activities for integration in order to avoid redundancy of effort and reduce resident fatigue. In

addition, the coalition will develop a feedback loop with all stakeholders for input on strategies, campaigns and other activities for successful engagement on Legionellosis monitoring and surveillance.

Step 3: Conduct community engagement and follow-up activities to ensure that community-identified problems are addressed/rectified.

There are a variety of methods we will utilize to collect this information. Community engagement methods will be selected depending on the purpose of the method, how the information will be used and the phase of the project. Three strategies are recommended for small and large group gatherings.

Focus Groups is a method of group interviewing where the interaction between the moderator and the group, as well as the interaction between group members, serves to elicit information and insights in response to carefully designed questions to generate a rich source of information. The dynamic nature of the questions asked by the moderator via the group process, facilitates integrated stories, promotes vibrant dialogue, and produces a level of insight that is rarely derived from 'unidirectional' information collection such as surveys and less interactive interview techniques. Focus groups will also provide important insights into how individuals interact with information (e.g., what they need to know, the media they use, their personal and cultural contexts) so that communication materials can be designed to facilitate interaction with the FACHEP team.

World Café is a simple yet powerful method for large and small groups of people to foster collaborative dialogue, share and create new knowledge, build community, and inspire collective action. World Café techniques assume that outcomes are better when they are informed by: a diversity of perspectives, cross pollination of ideas, attention to meta-level themes and patterns, and focus on the questions that matter most to the target population.

Open Space Technology (OST) is a method of facilitating group dialogue by bringing people together to discuss a common theme or issue of mutual concern. OST is an interactive process involving simultaneous mini-group discussion around a central theme (e.g., Legionellosis). The goal is to engage and gain valuable feedback from established stakeholders and newcomers alike. According to Michael Herman, Open Space meetings provide participants with the opportunity to come together to create and manage their own agenda of parallel working sessions around a central theme of strategic importance. Open Space "…works best when the work to be done is complex, the people and ideas involved are diverse, the passion for resolution (and potential for conflict) are high, and the time to get it done was yesterday. It's been called passion bounded by responsibility" (http://www.swaraj.org/shikshantar/expressions_herman.pdf).

Through primary community engagement methods and analysis of existing data, causal factors (e.g., pre-disposing, reinforcing and enabling) that influence given behaviors and/or environmental factors will be pinpointed. Based on the ongoing analysis of information and data gathered, a community education campaign will be conducted to translate Legionnaire's data in meaningful ways. This will be coordinated with the communication strategy outlined in 4.1 above. We also recognize that community engagement activities and the education campaign will need to be nimble to respond to current events, adaptations to FACHEP project methods and expanded as needed to support the project goals.

Step 4: Analysis and reporting on best practices for community engagement.

The FACHEP community engagement team will analyze and report-out all findings (i.e. community-identified priorities/problems; surveillance data for Legionnaire's; other uncovered issues/resources) through existing channels and mechanisms of communication including reports to Flint residents, state and local leaders, community and faith-based organizations.

4.5. Community Support and Coordinating Access to Resources

4.5.1. Tasks

4J. Provide support to Flint residents (e.g., older adults) in order to maximize access to resources that help reduces the individual risk of Legionellosis.

4K. Enhance local government's workforce in supporting Legionellosis surveillance and monitoring.

4.5.2. Approach

4.5.2.1. Support to Flint Residents

The FACHEP project team proposes to use an interdisciplinary approach due to the complex health issues and conditions that will be assessed in each home. Interdisciplinary projects integrate information, data, techniques, tools, perspectives, concepts and or theories from two or more disciplines of specialized knowledge to advance fundamental understanding to solve problems whose solutions are beyond the scope of a single discipline or area of research practice (National Academy of Science, 2004). Along with the epidemiologists and engineers, a professional social worker will accompany the surveillance team to provide immediate support and to engage residents to explore their response to the crisis.

Engaging with the resident through introductory questions and rapport building techniques will be the first step (e.g., how did you first learn about the water crisis with a reflective response that acknowledges residents' feelings). By engaging with the resident, the social worker seeks to build trust in the relationship, which is essential in the helping process. The second step is to conduct a brief needs assessment related to the water crisis and other health related issues. The social worker will be trained on the resources that are available in the community and county. FACHEP will hire Flint residents for these positions and a licensed social worker (LMSW) will supervise the social workers and work with the community navigators to connect residents to community resources that aid in prevention and control of Legionellosis.

For those residents who appear in crisis situations for basic needs services, the social worker will contact the Genesee County Community Action Resource Department or other appropriate agency and make a warm transfer. "Warm transfer" is the polite and personal referral of a resident to an agency for the purpose of providing access to appropriate services necessary for successful goal achievement, and relationship and trust building (Minkoff and Cline, 2004; Richter et al., 2012). Warm transfers demonstrate to residents that the community cares and views their needs as a priority. In addition to the tangible benefit to the resident, warm transfers help to develop the type of trust needed for residents to continue to participate in Legionellosis surveillance over time. Social workers will document their activities, transfers, and resident outcomes related to their activities.

In household visits with the environmental sampling and surveillance team, the social worker will use techniques that focus on empowerment and resident strengths (Blundo and Saleebey, 2009; Rappaport, 1990; Saleebey, 2012). Residents will be provided access healthcare services and empowered to reduce their risk of severe Legionellosis especially among high-risk individuals. Despite the struggles that many Flint residents may experience, all persons possess strengths that can be respected. Residents' motivation can be increased by a consistent emphasis on strengths as defined by the resident. It's a process of cooperative exploration toward discovering how the residents have persevered in the most difficult of situations.

During household visits, the social worker will seek permission from the homeowner to participate in a project related to understanding their experience with the Flint water crisis. The social worker will interview the

respondent about the ways that they have dealt with the water crisis. While Flint residents are likely to be overwhelmed they may also have found the power and resources to respond that has helped their family or neighbors. An interview protocol will be used to assess resident's coping, resilience, and service utilization.

In addition, the social worker will inform the residents about the opportunity for a follow-up project specifically addressing older adults representing a high-risk group for Legionellosis. This project seeks to understand how older adults experience and perceive the current water crisis, in addition to their perspectives on how the crisis might or might not affect their aging processes. Through extended in –depth engagement with older adults, this project to offers a life-stage perspective on the Flint water crisis. Investigators will also engage with community stakeholders to conduct a health fair. The social worker will offer an information sheet that informs the resident about the older adult project and who they can contact for further information.

4.5.2.2. Local government support

Wayne State University School of Social Work proposes to support the city of Flint by providing a trained LMSW community practitioner who can serve the offices of the city in ways that will supplement a coordinated response in addressing the aftermath of this crisis. Community practitioners are skilled in inter-organizational relations, community organizing, communication and coordination, policy analysis and data management. Having an LMSW on staff will also provide leverage for obtaining and extending other resources. Specifically, we plan to recruit and place two MSW student interns from our Innovation, Community, Policy and Leadership concentration at the city of Flint offices. These students are required to complete 240 hours of field placement work per semester as a degree requirement. Since the crisis, many of our students have already been volunteering through weekly Friday trips to Flint and have raised funds for various charities working in the community. Our students are committed to learning and applying their social work and leadership skills, and completing a Flint internship within the scope of this proposal will provide an opportunity to do so within an environment of emerging social change. Every year we place students in government offices in the City of Detroit; providing this resource to Flint will demonstrate one of the many ways that universities expand and deploy resources to meet their urban missions.

The Social Work faculty members and staff will be available to guide the community practice assignments and student project activities to ensure alignment with the goals of the Mayor's office. Initial meetings over the summer between faculty and Flint staff will be conducted to understand the current social, community and organizational environment. Depending on the needs of the city offices, there are a number of strategies that may be undertaken through this project that will enable Flint staff to identify and assess unmet needs, and find effective solutions to the meeting the challenges they confront every day. Social action research, systems planning and analytical methods are likely approaches to answer the project questions and will involve different data collection methods and recruitment. Analysis of service system and collaboration activities may involve interviews with key informants and secondary data collection while needs assessment may require community engagement and survey research. All activities will be vetted by the city of Flint and approved through the WSU IRB as appropriate.

4.6. Measurement

4.6.1. Communications and Engagement

The city of Flint is experiencing a slow moving, long term crisis that impacts the public health. The dynamics of the crisis have created significant levels of distrust among the public. This has been compounded by inexperienced coordination of this magnitude among agencies, diffusion of responsibility, and lack of consistent messages. In addition, the way in which the crisis developed allowed a number of unofficial sources to emerge

and fill the information vacuum. The result is an especially complex and challenging crisis and risk communication context. The result will also greatly affect the design and testing of communication materials (Mackenzie-Taylor, 1997; Sless, 2008) In this context, some key questions that will be addressed through a coordinated communications and engagement strategy include:

1. What are the current and ongoing needs of Flint residents?
2. What is the level of awareness about Legionnaires disease in the community?
3. What agencies and other support organizations are involved in assisting Flint residents?
4. What new and existing services are available but underutilized?
5. What are perceived levels of collaboration among organizations and agencies working on addressing the Flint water crisis?
6. What are the best practices and challenges to collaborating among agencies and organizations?
7. To what extent and in what manner are Flint residents involved in efforts to engage in and respond to the water crisis and other health related conditions?

In addition, specific measures will seek to:

1. Identify pre-disposing factors (e.g., knowledge, skills, beliefs, attitudes, values, & perceptions that facilitate/hinder motivation; self-efficacy; outcome expectations; behavioral capability)
2. Identify reinforcing factors (e.g., rewards/feedback for behaving in a specific/desired way; attitudes of friends, family, employers, etc.)
3. Identify enabling factors (e.g., skills, resources, barriers that help/hinder behavioral change; availability of resources, accessibility, referrals, rules/laws, skills, engineering)
4. Identify tasks (e.g., what specifically are individuals being asked to do in terms of awareness and action about Legionnaires disease through the communication materials?)

4.6.2. Social Behavioral

During the initial visit, the FACHEP team led by the social worker will seek permission from the homeowner to gather information related to their experience with the Flint water crisis. The social worker will interview the respondent about the ways that they have dealt with the water crisis. While Flint residents are likely to be overwhelmed they may also have found the power and resources to respond that has helped their family or neighbors. An interview protocol will be used to assess resident's needs (Moos and Moos, 1994; Schinka, 1984); past and present help-seeking behavior (Moos, 1993; Wilson et al., 2005), resilience (Burns and Anstey, 2010), and service utilization. This interview will serve a dual purpose of assessing resident needs, while simultaneously providing evaluation data. The survey is expected to take no more than 30 minutes to complete.

The following hypotheses will be examined to evaluate the effectiveness of the program:

1) Following the initial visit, residents will show increased help-seeking behavior, including awareness of appropriate resources and behavior to engage with needed services, and improved coping strategies.
2) Across the duration of the project, residents will report a wide variety of needs related to health, financial, and social issues. By the end of the project, residents are anticipated to report fewer unmet needs due to increased ability to access resources.
3) By the end of the project, residents will report decreased anxiety and depression, and increased hopefulness and empowerment.

In the qualitative investigation with older adults, investigators seek to understand how older adults experience and perceive the current water crisis, in addition to their perspectives on how the crisis might or might not affect their aging processes. Through extended in-depth engagement with older adults, this project complements similar studies on exposure to drinking water contaminants and offers a life-stage perspective on the Flint water crisis.

FACHEP team members (including specialists in gerontology and anthropology) will draw on their expertise on older adults in urban environments and qualitative community-based participatory research methodology. Research participants will be recruited from the homes visited by the surveillance team, from local agencies serving older adults, and by snowball sampling from referring participants. Criteria for inclusion will be: 1) ≥50 years of age; and 2) current or previous residence in a home in Flint, Michigan, or repeated visits to such a home. Across active data collection phases methods will include: 1) standardized sociodemographic questionnaire; 2) open-ended semi-structured interviews; 3) ethnographic descriptions and observations of domestic living spaces and community surroundings; and 4) photographic documentation of domestic and community spaces.

Older adult questions include:
1) What are the perceived individual, social, and political effects (including harms) of the water crisis on older adults, in both the short- and long-term? This will include investigations into access to resources, caregiving and kin relationships, and comorbidities commonly experienced in older adulthood.
2) How does the water crisis shape a) how older adults navigate everyday activities and larger life changes/decisions (e.g., relocating within or out of the area) and b) how older adults imagine a future for themselves and their families?

4.7. Evaluation

4.7.1. Communications

The evaluation of the communication materials and programs will assess effectiveness on three measures.

Frequency of Messages: How many messages are produced in what form targeting what audiences.

Number of Information Receivers: Records will be kept of how many people receive the messages through participation in community meetings, training, and media. A log will be kept of media coverage.

Survey of Public Health Partners: Two surveys will be conducted of public health partners to assess the effectiveness of FACHEP communication activities.

4.7.2. Community Engagement

Qualitative and quantitative metrics will be utilized to ascertain levels of engagement, frequency of engagement and avenues for engagement will be critical to ensuring trust among community organizations, local government agencies and residents. Paper- and electronic-based survey tools will be utilized where possible to disseminate survey tools. Survey items will be allocated to assess knowledge, attitudes, perceptions, behaviors and trust among individuals and organizations going forward. An electronic record keeping system will be used to document the community engagement meetings attended and organized (date, frequency, name of groups, purpose, etc).

4.7.3. Social Behavioral

The warm transfers and referrals to social work service will be documented through a service completion form. Workers will record: demographics of individual engaged in the home, length of visit, needs of the engaged resident, type of service referral provided at the time of the visit, and follow-up contact with resident documenting success or barriers with referrals and the identification of any new needs that may have occurred since the last visit.

The FACHEP team will report on the meetings attended, including purpose, frequency, scope of participation by other agencies and outcomes in terms of actions taken or knowledge gained as a result of participation. The frequency and amount of supervision will also be documented.

Social Work faculty and students will meet regularly to plan and monitor their Legionellosis related activities by completing weekly electronic logs documenting the nature and frequency of their activities undertaken. Because these activities will be developed in real time, measurements are instrument dependent dictated by work assignments and will include qualitative and/or quantitative data.

The older adult investigators will meet regularly during all phases. Preliminary data analysis (collaborative memo-writing, identifying common themes) will begin during active data collection phases. Ongoing data analysis allows for on-the-ground refinement of methods and research questions that are central to the ethnographic process. The data analysis phase will focus on identifying patterns and changes over time in experiences and understandings of the water crisis.

4.8. Reporting

4.8.1. Communications

Communications functions will be reported regularly through the project website as well as during end of year reports. Two assessment documents will also be completed: (1) community information needs, and (2) barriers identified to uptake of *Legionella* education information among Flint and Genesee County residents. These documents will provide key information on best practices in communication for Legionellosis across the State of Michigan.

4.8.2. Community Engagement

Early, frequent and sustained engagement and partnership between FACHEP and organizations at all levels in Flint will be critical to the improvement of health status and reduced risk of Legionnaires' disease among Flint residents. Borrowing lessons from Community Health Needs Assessments conducted by hospitals serving the Flint community and from an examination of recent events as well as locally available social service resources, the FACHEP team has established a Strategic Framework for stepwise, proactive, concrete and measurable community engagement activity that addresses generational needs relative to the control and prevention of Legionnaires' disease.

4.8.3. Social Behavioral

Rapid assessment reports will be developed (at least monthly) for the project principals highlighting accomplishments, barriers and solutions taken to address implementation challenges. Monthly reports will provide aggregate and cumulative data on social work activities as part of the Legionellosis team. Midterm and annual reports will be written and modified for power point presentations to various stakeholders

5. Timeline of activities

Table 5.1. General timeline of FACHEP activities

	2016							2017										
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
LEGIONELLA CLINICAL-EPI EDUCATION, CASE IDENTIFICATION																			
Identification and outreach to health-care providers and clinical facilities to implement Legionella educational activities and programs	■	■	■	■	■	■	■												
Health-care provider engagement for education and participation in MDSS, MiHAN and other surveillance/public health activities	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Dissemination & implementation of clinical guidelines for Legionellosis; regular re-evaluation of clinical guidelines to ensure they are consistent with changing knowledge of Legionella in the community	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Technical guidance for case-patient and proxy interviews identification to promote timely case reporting to public health authorities	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Collaboration (as requested by local or state health authorities) to support conduct of special case-control epidemiologic investigation in the event of a Legionellosis outbreak	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Implementation of coordinated household sampling and interviews among control population residents outside Flint and in comparable communities	■	■	■	■	■														
Fast track preparation and dissemination of recommendations for control of Legionellosis outbreak	■	■	■	■	■														
Interim and final analysis, development of best practices, report writing & results feedback to citizens, health-care providers and community organizations	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
LEGIONELLA ENVIRONMENTAL SAMPLING & MONITORING																			
Community engagement with residents & other key stakeholders for water sampling	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Develop listing and schedule for water sample collection	■	■	■	■				■	■										
Evaluate and finalize sampling and analysis standard operating procedures (SOPs)	■	■																	
Evaluate prevalence of *L. pneumophila* in high-risk facilities	■	■	■	■	■	■	■												
Characterize the prevalence of *L. pneumophila* in Flint homes		■	■	■	■				■	■									
Characterize the loading of *L. pneumophila* in Flint water distribution system				■															
Characterize the prevalence of *L. pneumophila* in homes within comparision area A		■	■	■	■														
Characterize the prevalence of *L. pneumophila* in homes within comparision area B		■	■	■	■														
Collection of environmental samples in support of Legionellosis outbreak investigation	■	■	■	■	■	■	■												
Determination of *L. pneumophila* diversity among environmental and clinical isolates	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Reference laboratory testing of environmental samples to identify presence of *Legionella spp*.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Development of best practices, reports preparation, results feedback to residents & other key stakeholders								■	■	■	■	■	■	■	■	■	■	■	■
LEGIONELLA COMMUNICATIONS, COMMUNITY ENGAGEMENT & SOCIAL-BEHAVIORAL HEALTH																			
Developing, editing & revising of Legionellosis messages, FAQ's, Guidances, Press statements and releases	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Create structures and systems for coordinating messages among community, county, state, and federal public health partners.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Development of Crisis and Risk Communication plan for Legionellosis	■	■	■	■															
Dissemination, outreach and education for ASHRAE guidelines	■	■	■	■	■	■	■	■	■	■	■								
Assess community informational needs and Identification of barriers to uptake of Legionella education information among Flint and Genesee county citizens		■	■	■	■	■	■	■	■	■	■	■	■						
Provide crisis and risk communication training to public health partners	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Provide a minimum of 10 interactive SME communication presentations to community groups	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Coordination of Legionella information dissemination that enables timely, accurate, efficient and clear communication to citizens in the event of a Legionellosis outbreak	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Coordination of social work team activities to correspond with Legionellosis surveillance to include assessing needs and facilitating warm transfers to appropriate providers and resources.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Planning and coordinating capacity building activities as requested by Mayoral staff, Genesee County Public Health,	■	■	■	■	■	■	■	■	■	■	■								

6. Expected Outcomes

1. High sensitivity for detection of Legionnaires' Disease case-patients with high degree of complete patient or patient proxy interviews that provide guidance on sources of infection and inform rational strategies for disease prevention.

2. Define distribution of *Legionella spp.* in potable water as well as water distribution systems in and around Flint

3. Characterize prevalence of *Legionella spp.* related to of seasonal influences

4. Describe relationship between chlorine residue and presence of *Legionella spp.* in public water systems

5. Facilitate community participation in improving public health and well-being

6. Educated community residents and forward-looking health programs in which residents have clear sense of ownership;

7. Reduced numbers of cases and deaths associated with Legionnaires' disease at or below rates found over previous 10 years.

8. Enhanced coordination among official sources

9. Greater communication capacity

10. Higher levels of self – efficacy among the public

11. Improved health knowledge, lower levels of misunderstanding

12. Enhanced trust

13. Participation of residents in gathering, analyzing and interpreting health information

14. Individual-, household- and community-level interventions that foster sustained development of adaptive behaviors that favor healthy living in Flint, including reducing the risk of developing Legionnaires Disease.

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8. Appendices

Appendix 1. Collaboration with Project Partners

Appendix 2. Legionellosis FAQs

Appendix 3. Provisional Listing of Health-Care Facilities and Providers

Appendix 4. Enhanced Legionellosis Case Information Form

Appendix 5. MDHHS Data Use Agreement

Appendix 6. MDSS Legionellosis data elements

Appendix 7. Table Shells for Data

Appendix 8. Example Community Legionellosis Education Presentation

Appendix 9. Pre-Post Community Presentation Survey

Appendix 10. Legionellosis Clinical Guidelines

Appendix 11. Health-care Provider Legionellosis Education Presentation Example

Appendix 12. Pre/Post-Provider Knowledge Survey

Appendix 13. Informed Consent Forms

Appendix 14. Household Survey Form

Appendix 15. Basic Legionellosis Case Information Checklist

Appendix 16. Legionellosis Control Subject Interview Form

Appendix 17. *DRAFT* FACHEP SOP for In-Field Environmental Sampling

Appendix 18. Environmental Sample Size

Appendix 19. *DRAFT* Legionella Laboratory Testing Procedures

Appendix 20. Summary of Groups and Meetings

Appendix 21. Biosketches of Senior Personnel