IMPLEMENTING WATER SAFETY PLANS IN NORTH CAROLINA: BRIDGES, BARRIERS, AND POTENTIAL BENEFITS

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ABSTRACT

Rachel Baum: Implementing water safety plans in North Carolina: Bridges, barriers, and potential benefits
(Under the direction of Jamie Bartram)

While developed countries are often thought to have assured safe drinking water, periodic contamination events and outbreaks still occur. Many countries have implemented water safety plans (WSPs), a preventive risk management approach, to improve drinking water quality, with documented benefits. However, WSPs are not widespread in the US. This study examines the enabling environment promoting the adoption of WSPs, the added value of preventive risk management, and the willingness and ability of water utilities to implement WSPs in North Carolina (NC). Results show that guidelines, regulations, contextual evidence, and public health focus create the enabling environment. US regulations and WSP steps align in most areas, but gaps exist in a few. In NC, implementation of WSPs would require: time and resources, perceived benefits, and strong leadership. This study contributes to understanding the barriers to WSP adoption and implementation in the US and the extent to which implementing WSPs could benefit water systems to improve drinking water safety and human health.
ACKNOWLEDGEMENTS

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<tbody>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>AWOP</td>
<td>Area Wide Optimization Program</td>
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<td>AWWA</td>
<td>American Water Works Association</td>
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<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
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<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
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<td>DWD</td>
<td>Drinking Water Directive</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>HACCP</td>
<td>Hazard Analysis and Critical Control Point</td>
</tr>
<tr>
<td>IWA</td>
<td>International Water Association</td>
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<tr>
<td>MCL</td>
<td>Maximum Contaminant Level</td>
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<tr>
<td>NC</td>
<td>North Carolina</td>
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<tr>
<td>ORC</td>
<td>Operator in Responsible Charge</td>
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<tr>
<td>PRISMA</td>
<td>Preferred Reporting Items for Systematic Reviews and Meta-Analyses</td>
</tr>
<tr>
<td>RAMCAP</td>
<td>Risk Analysis and Management for Critical Asset Protection</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SDWA</td>
<td>Safe Drinking Water Act</td>
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<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
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<tr>
<td>US</td>
<td>United States</td>
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<tr>
<td>VSAT</td>
<td>Vulnerability Self Assessment</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>WSP</td>
<td>Water Safety Plan</td>
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INTRODUCTION

The consistent delivery of safe drinking water is a primary goal for all water systems. In order to attain this goal, effective risk management practices are critical. In the United States, these risk management practices are guided by regulations demanding specific water quality standards, treatment processes, system management, and external communication. Despite these regulations, water contamination events still occur, contributing to waterborne disease that affects an estimated 19.5 million people per year (Reynolds et al., 2008).

In order to reduce the incidence of waterborne disease from community water systems (public water systems supplying water to the same population year-round) in the US, steps must be taken to improve the safety of drinking water by preventing contamination events. This can be accomplished by adopting risk management practices that reach beyond current regulations.

Water safety plans (WSPs) offer a potential path for improvement, through their systematic risk management approach that has documented benefits in improving microbiological water quality and decreasing the incidence of clinical cases of diarrhea in other developed countries, such as Iceland and Australia (Gunnarsdottir et al., 2012a; Martel et al., 2006; Rizak et al., 2003; Brauer et al., 2014). Successful implementation of WSPs, or similar risk management practices (such as Hazard Analysis and Critical Control Points (HACCP)), has been seen in many developed countries, such as Australia, Austria, Belgium, Canada, France, Germany, Hungary, Iceland, Japan, Portugal, The Netherlands, New Zealand, Slovenia, Spain, Switzerland, and the United Kingdom (Brauer et al., 2014; Gunnarsdottir et al., 2012a; Japan Ministry of Health, Labour, and Welfare, 2008; Malzer et al., 2010, Davidovits, 2014; Martel et al., 2008). However, WSPs have had limited application in the US.
In order to attain the benefits of WSPs in the US, an enabling environment is needed that includes formal rules (regulations and policies) and conditions (norms, culture) that promote the scaling up and sustainability of WSPs (Amjad et al., 2015; Ojomo et al., 2016). An enabling environment for enhanced drinking water safety should not only incorporate policies and institutional behaviors that promote WSPs but should also offer resources to achieve positive, clearly defined outcomes (Amjad et al., 2015).

The purpose of this research was to determine whether, and to what extent, WSPs could benefit US water systems and what barriers and bridges exist to implementing WSPs. Since other developed countries have successfully implemented WSPs, the first objective of this research was to conduct a systematic literature review to determine the rules and conditions of the enabling environment in other countries that led to the adoption and implementation of WSPs. This information can help to highlight the support and conditions that could help promote adoption of WSPs in the US. These other developed countries have not only implemented WSPs, but have also realized improvements in drinking water safety from the implementation of WSPs. Therefore, the second objective of this research was to compare current US drinking water regulations to WSPs to determine whether there are differences between them and then assess whether there might be added value from WSPs to assist in improving drinking water quality. Through this comparative analysis, I first assessed the potential benefits of implementing WSPs and then determined the extent to which WSPs could help to reduce future waterborne disease in the US. For the third objective, I examined the willingness and ability of water utilities to implement WSPs in the state of North Carolina (NC) through qualitative interviews, determining what barriers and bridges exist in adopting and implementing WSPs. These interviews helped to determine the changes to the enabling environment needed to promote adoption and
implementation of an improved risk management system, like WSPs, for water systems in the US.

This work is composed of three journal articles. The first is a systematic literature review of other developed countries’ experiences with WSPs, which will be submitted to the Journal of Water and Health. The second is a comparative analysis of US drinking water regulations and WSP steps that highlights the differences between the two, followed by a discussion on the potential of addressing these differences to improve the safety of US drinking water systems. This article was published in the International Journal of Hygiene and Environmental Health in 2015. Finally, the third article is a qualitative analysis of water utilities in North Carolina to identify the institutional bridges and barriers that exist to implementing WSPs. This article has been reviewed and re-submitted with revisions to the Journal of Water and Health.
CHAPTER 1: A SYSTEMATIC LITERATURE REVIEW OF THE ENABLING ENVIRONMENT TO PROMOTE IMPLEMENTATION OF WATER SAFETY PLANS IN DEVELOPED COUNTRIES

1.1 INTRODUCTION

Safe drinking water is consistently expected in developed countries. However, waterborne disease and outbreaks still occur (Hrudey & Hrudey 2004). In order to reduce the incidence of waterborne disease and outbreaks, enhanced risk management practices, such as water safety plans (WSPs) can be implemented. WSPs are a preventive risk management strategy to ensure safe drinking water from catchment to tap (Davison et al. 2005; Bartram et al. 2009). WSPs have been implemented in Australia, Austria, Belgium, Canada, France, Germany, Hungary, Iceland, Japan, Portugal, The Netherlands, New Zealand, Slovenia, Spain, Switzerland, and the United Kingdom (Brauer et al. 2014; Gunnarsdottir et al. 2012b; Japan Ministry of Health, Labour, and Welfare 2008; Malzer et al. 2010, Davidovits 2014; Martel et al. 2008; Davison et al. 2005). WSPs have shown benefits in improving regulatory compliance, water quality, communication, asset management, and public health outcomes (Gunnarsdottir et al., 2012a). While WSPs have evolved from individual water system practices to national guidelines to regulatory requirements in some of these developed countries, the United States (US) has limited experience with WSPs (Martel et al., 2006; Hamilton et al., 2006).

Although the US has high drinking water quality standards and requires specific treatment processes and system management practices, water contamination events still occur, contributing to waterborne diseases that affect 19.5 million people per year (Reynolds et al.
The Environmental Protection Agency (EPA) is the national government agency of the US charged with protecting public health and the environment. In this role, EPA officials create regulations to ensure safe drinking water to protect public health (Summerill et al., 2010; Vierira, 2011; Hrudey et al., 2006). Many drinking water regulations overlap with components of a WSP, however gaps exist between them (Baum et al. 2015). Given these gaps between US drinking water regulations and WSPs, there are benefits to be realized in improving the risk management practices of drinking water systems in the US.

While formal rules (regulations or policies), can promote the uptake of risk management practices such as WSPs, other conditions, such as cultures and norms, or the physical environment, can also influence risk management practices. Together, these formal rules, conditions, and physical environment that affect the achievement of objectives are considered the enabling environment (Amjad et al., 2015; Ojomo et al., 2016). To improve drinking water safety, an enabling environment can be created that supports that goal.

The objective of this systematic literature review was to assess the enabling environment through regulations, guidelines, conditions, and experiences that promoted the adoption and implementation of WSPs in drinking water systems in developed countries (defined as high-income Organization for Economic Cooperation and Development (OECD) member states as classified by the World Bank\(^1\)).

1.2 METHODS

\(^1\)High-income OECD countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Rep. of Korea, Luxembourg,
To conduct the systematic literature review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used (Moher et al., 2009). Study articles were identified from: Web of Science, ScienceDirect, Water Safety Portal, and the drinking water quality agency website of each high-income OECD member country. Bibliographies from these articles were searched to identify other relevant studies or grey literature that were not found directly through the search. This search was conducted between March 1, 2016 and April 6, 2016.

Search terms were chosen so as to include articles that discussed any experiences related to water safety plans or other risk management plans for water systems in high-income OECD countries. Only articles in English were included. Since many water systems used HACCP as a risk management practice comparable to WSPs, HACCP was used as a synonym for WSP when searching. The search terms used were: “drinking water ” AND regulat*2 OR legislat* OR adopt* OR implement* OR experience* (included in the article) AND “water safety plan*” OR “HACCP” OR “risk management” OR “safety plan*” AND water (included in the title).

1.3 RESULTS

Search Results

The literature search yielded 142 unique results (Figure 1). These 142 articles were screened by title and abstract to determine which were eligible for inclusion. Inclusion criteria were that the articles must be: about high income OECD countries, related to community water systems, and about implementation or experiences with WSP or HACCP strategies. Articles about evaluation frameworks for risk management strategies, specific technologies to aid in risk management, or articles on developing countries were excluded. This screening process led to

*indicates that any form of the word was searched
the inclusion of 72 articles that discussed the enabling environment through regulations, institutional arrangements, or experiences of a water system or set of water systems that led to the adoption of a WSP or similar risk management practice in a high-income OECD country. Two articles were excluded based upon full text review, in which it was revealed that the content was unrelated to the implementation or experience of a WSP or HACCP. A total of 70 articles were included in the synthesis of the literature review.

Figure 1.1 PRISMA systematic literature review articles on the enabling environment for drinking water risk management experiences

Qualitative Synthesis

The literature review revealed many individual case studies of WSP experiences. However, there were few articles that compared different drinking water safety experiences. This literature review synthesizes the regulations, institutions, and conditions of the enabling
environment across all WSP experiences at international, national, and local levels that led to the adoption and implementation of WSPs.

*International-scale promotion and adoption of WSPs*

On an international level, many systematic risk management practices for water systems in developed countries began as HACCP practices that were first used in the food industry to assure food safety (Havelaar, 1994). HACCP practices for the food industry began in the 1970s in the US and by the 1990s were practiced globally (Mortimore and Wallace, 2013). Havelaar first noted the potential application of HACCP practices to drinking water systems in 1994 (Havelaar, 1994). Since then, some countries, such as Switzerland, Iceland, Australia, France, and Slovenia have held water systems to the same standards as food processing centers, requiring water systems to institute HACCPs (Beir et al., L., 2003; Bosshart, U., 2003; Cunliffe, D., 2003).

While HACCP was a strong initial driver for improved risk management of drinking water systems, given its global application in the food industry, widespread application of HACCP for drinking water safety did not exist. From 1994 through 2004, the World Health Organization (WHO) worked towards developing formal rules (international guidelines) for an enhanced systematic risk management plan for drinking water systems through an extensive design and consultation process. The WHO contributed to the conditions for an enabling environment that created a culture of improving drinking water safety through widely publicizing and promoting the use of what became known as WSPs through conferences, engagements, and discussions that ultimately led to the formal inclusion of WSPs in the 2004 WHO Guidelines for Drinking Water Quality 3rd Edition (WHO Guidelines) and IWA’s 2004 Bonn Charter for Safe Drinking Water (Bonn Charter). The WHO Guidelines added to the formal rules of the enabling
environment that promoted the adoption of similarly aligned national guidelines and ultimately regulations requiring systematic risk management practices (Hamilton, 2006; Martel et al. 2006). The WHO Guidelines and the Bonn Charter suggested that not only are hazard analysis and controls needed (like HACCP practices), but also risk assessments of the entire water system are necessary to ensure the safety of drinking water (WHO, 2004; IWA, 2004).

National-scale promotion and adoption of WSPs

While HACCP was common practice in the food industry internationally, the consideration of water as a food and the subsequent introduction of HACCPs to water systems was often driven on a national level by the country’s public health agency, as they were charged with creating national regulations to improve public health (Hamilton, 2006; Jayaratne, 2008). These national public health agencies were influenced by international discussion and guidelines that recognized that end-point testing was insufficient to guarantee safe drinking water (Hamilton, 2006; Martel et al., 2006; Jayaratne, 2008; Brauer, 2014). In some instances, HACCP practices were initiated out of concern for public health following waterborne disease outbreaks from drinking water (Hamilton, 2006; Jayaratne, 2008). For example, in Australia, Sydney endured a Cryptosporidium scare in 1998 that led to the discussion of HACCP practices being needed and ultimately being required (Hamilton, 2006). Water systems began to implement HACCP risk management practices in Switzerland (1995), Iceland (1997), Australia (1999), France (2001), and Slovenia (2004). In these countries, regulatory requirements for HACCPs for all water systems were influenced by international discussions and promotions before formal international guidelines endorsed the adoption of WSPs (Brauer et al., 2014).
Following the publication of the WHO Guidelines and the Bonn Charter, many countries responded to this formal rule and amended their drinking water quality regulations to include specific risk assessment components of WSPs in addition to hazard analysis (Martel et al., 2006; Brauer et al., 2014). In many countries, national agencies first introduced WSPs as pilot projects in a few individual utilities before creating national guidelines and regulations that led to large-scale implementation of WSPs or similar risk management practices (Table 1). In other cases, such as Australia, individual water utilities led their own initiatives to implement WSPs before national agencies introduced WSP pilot projects, guidelines, or regulations (Jayaratne, 2008; Mullenger et al. 2002). While national guidelines are not legally enforceable, like regulations are, they provide the standards for due diligence and help to create the conditions of an enabling environment that supports the scale up of WSPs.

<table>
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<tr>
<th>COUNTRY</th>
<th>REGULATIONS</th>
<th>GUIDELINES</th>
<th>SOURCES</th>
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<tr>
<td>Canada</td>
<td>By province: Drinking water safety plans (Alberta, 2011) requiring WSPs</td>
<td>Health Canada (2010) – Drinking water guidelines promoting multi-barrier approach</td>
<td>Martel et al. (2006); Perrier et al. (2014); Health Canada (2010); Reid et al. (2014)</td>
</tr>
<tr>
<td>Chile</td>
<td>Ministry of the Environment – no guidelines on risk management procedures</td>
<td></td>
<td>Chile Ministry of the Environment, Ch. 5 (2012)</td>
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<tr>
<td>Iceland</td>
<td>HACCP – regulated as food (1997)</td>
<td>Gunnarsdottir (2008); Gunnarsdottir (2012b); Brauer et al. (2014)</td>
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</tr>
<tr>
<td>Israel</td>
<td>Ministry of Health – annual sanitary surveys but no systematic risk management plan</td>
<td>Israel Ministry of Health Public Health Regulations (2013); (Winston et al., 2003)</td>
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International and national rules and conditions together helped in forming the enabling environment that led to an increased uptake of HACCPs or WSPs for drinking water systems.

Australia, Iceland, and Switzerland all instituted regulatory requirements for HACCPs for water

$^3$High-income OECD European Union countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom
systems, adding formal rules to their enabling environments (Table 1.1) (Brauer et al., 2014; Martel et al., 2006; Hygiene Ordinance 817.051, 1995; Gunnarsdottir 2008; Gunnarsdottir 2012b; Martel et al., 2006; Jayaratne, 2008). The WHO’s promotion of WSPs over this period also contributed to establishing an enabling environment that increased adoption of WSPs. Several countries that are now part of the European Union (France, Portugal, Slovenia, England and Wales, Hungary) were enabled to implement WSPs by national regulations and international guidelines prior to the European Union’s (EU) Drinking Water Directive (DWD) 2015/1787 requiring WSPs for water systems (Brauer et al., 2014; Vierira, 2007; Beir et al., 2003; Metge et al., 2003; May, 2010; England and Wales Statutory Instruments No. 2734, 2007; Hungary Regulation 65/2009, 2009).

The EU established the DWD in 1998, which provides the minimum requirements for each country’s national legislation. In 2015, the DWD passed Commission Directive 2015/1787, which made systematic risk management plans compulsory for all water systems (EU 2015/1787, 2015). This supranational directive further enhances the enabling environment to help increase the spread of adoption of WSPs. Each country has until 2017 to ensure that its regulations comply with the DWD legislation.

In Norway, national regulations crafted the enabling environment that led to the scale up of WSPs. Drinking Water Regulations No. 1372, Sec. 10 requires water systems to submit recommendations for water sampling and analysis based upon a risk assessment of the water system. While a WSP is not specifically required, hazard analysis, risk assessment, and continual development are.

In New Zealand, the Ministry of Health implemented formal rules requiring all water systems to have a WSP (previously known as Public Health Risk Management Plans) (Health
Amendment Act, 2007; Martel et al., 2006; NZ Ministry of Health, 2014). New Zealand’s Ministry of Health has published various documents to help both large and small water systems adopt WSPs (NZ Ministry of Health, 2014).

In both Australia and Canada, the National Health departments created guidelines for drinking water promoting the adoption of WSPs, however it is each state/province’s responsibility to create state regulations if they want to require WSPs (Martel et al., 2006; Perrier et al., 2014; Health Canada, 2010; SDWA, 2003). These National Health departments created the conditions for an enabling environment that promotes the adoption of formal regulations in each state/province. In Australia, both Victoria and Queensland require drinking water risk management plans and in Canada, Alberta requires WSPs by law. In both of these countries, pilot WSPs were tested in water systems to determine their applicability, feasibility, and benefits prior to implementing regulations requiring WSPs (Jayaratne, 2008; Reid et al., 2014; Perrier et al., 2014).

In Korea, the state-owned drinking water utility introduced WSPs into the risk management plans of water systems in order to comply with the Water Supply and Waterworks Installation Act. This Act, part of the formal rules of the enabling environment, requires the practice of many risk management components similar to WSPs, so WSPs were implemented to determine their specific benefits to water systems in Korea (Water Supply and Waterworks Installation Act, 2008; WSPortal, 2015).

In Israel, Japan, and Chile, the Ministry of Health creates both conditions (guidelines) and formal rules (regulations) for enhanced water system risk management (Israel Ministry of Health Public Health Regulations, 2013; Japan Ministry of Health, Labour, and Welfare, 2008; Chile Ministry of the Environment, 2012). In Israel, preventive sanitary surveys are required
annually at each water system, however these surveys are not part of the daily culture of the risk management of the water system, like WSPs are (Israel Ministry of Health Public Health Regulations, 2013). They are used to identify hazards and risks throughout the drinking water system, but a team of water utility personnel to continually assess and manage these risks is not required. In Japan, specific water quality standards and treatments are regulated by the Waterworks Act, however only guidelines for WSPs exist from the Ministry of Health (Japan Ministry of Health, Labour, and Welfare, 2008). In Chile, the Ministry of Health creates water quality regulations, however there are no regulations or guidelines for risk management plans for water systems (Chile Ministry of the Environment, 2012).

Local-scale promotion and adoption of WSPs

Prior to the creation of national legislation, some countries, such as Australia and Portugal, chose to pilot WSPs before any nationally led initiatives (Jayaratne, 2008; Vierira, 2007). In 1998, at Yarra Valley Water in Australia, water utility managers realized that its focus on end-point testing was insufficient to protect water safety (Jayaratne, 2008). In other countries, such as Germany and Greece, national institutions chose water systems in which to pilot WSPs in order determine their feasibility and added benefit before implementing specific national regulations requiring WSPs (Schmoll et al., 2011; Damikouka et al., 2007). In Germany, the Federal Ministry of Health, the Federal Environment Agency, and the Association for Gas and Water led the effort to carry out pilot WSP implementation in select water systems in order to assess the applicability, feasibility, and benefits of WSPs. Through this effort, German water system managers realized that at least 70% of their current practices corresponded with WSPs, so large scale changes would not be needed (Schmoll et al., 2011). Many small water system
managers in Germany saw the benefits of formal rules requiring WSPs, in order to garner resources and support from stakeholders (Schmoll et al., 2011). While Germany did not implement regulations requiring WSPs prior to EU 2015/1787, many water systems had by then recognized the potential benefits of WSPs.

1.4 DISCUSSION

In the US, similar to these other developed countries, there is substantive overlap between existing regulations and WSPs. However pilot projects of WSPs have not been implemented in the US (Martel et al., 2006). Similar to German water system operators, US water system operators would most likely also realize the similarities between their current practices and WSPs, making the adoption of WSPs less daunting. In fact, with institutional support, the tools and training to smoothly implement a WSP could make water system managers more willing and able to do so (Schmoll et al., 2011). In Alberta, Canada, the Environment and Sustainable Resource Development group developed a template with notes to assist water system managers in implementing their WSPs, which could be revised to apply to US water systems (Reid et al., 2014). Crafting the formal rules and conditions of the enabling environment to create greater institutional support could lead to greater uptake of WSPs and enhanced drinking water safety.

There are benefits for improved waterborne disease prevention in water systems in the United States and resources should be dedicated to create the formal rules and conditions of an enabling environment that supports the implementation of WSPs to improve public health (Hrudey et al., 2006). While the United States has not implemented pilot WSPs in water systems, recent drinking water crises in Toledo, Ohio and Flint, Michigan remind water system managers
and local governments of the importance of preventive risk management to reduce waterborne disease and protect the health of their communities (Jetoo et al., 2015; Bellinger, 2016). The recent state of emergency declared in Toledo, Ohio in 2014 that involved a “do not drink” water advisory due to high levels of toxic microcystin might have been prevented, had a WSP been in place (Jetoo et al., 2015).

It is important for US water system managers and lawmakers to consider the public health concerns of drinking water safety, which can be addressed through WSPs (Jetoo et al., 2015; Hamilton, 2006; Jayaratne, 2008). While many other developed countries, such as Australia, New Zealand, Iceland, Switzerland, and Canada have Ministries of Health through which water quality regulations are passed, the US has an Environmental Protection Agency that has a dual mission to protect both human health and the environment. Carrying out this mission of protecting human health is important to ensure safe drinking water practices and waterborne disease prevention.

1.5 CONCLUSION

International, national, and local rules and conditions interact to create the enabling environment for drinking water safety. International guidelines promote the creation of national regulations that depend on the support of public health agencies and local implementation and cooperation to show evidence of the benefits of WSPs in improving drinking water safety. These elements collectively lead to the scale up and impact of WSPs and promote their sustainability.

While other developed countries regulated the implementation of WSPs at different times, the elements contributing to the enabling environment that led to these regulations were
similar. A focus on the public health benefits of improved drinking water safety was key as were benefits in management, communication, and finances of water systems.

Since the implementation of regulations requiring WSPs, developed countries have begun to show more evidence of the positive results from WSP implementation in enhanced water system management and water safety. The US might also be able to realize these benefits if a similar enabling environment were created to promote the widespread implementation and support of WSPs.
CHAPTER 2: AN EXAMINATION OF THE POTENTIAL ADDED VALUE OF WATER SAFETY PLANS TO THE UNITED STATES NATIONAL DRINKING WATER LEGISLATION

2.1 INTRODUCTION

The effective management of drinking water systems is critical to ensure the delivery of safe drinking water. Water safety plans (WSPs) offer an internationally recognized systematic risk management approach to enhance water quality from source to tap that has been used in both developed and developing countries (Bartram et al., 2009 and Mahumud et al., 2007). Through the implementation of this risk management approach, water systems have seen improved water quality, regulatory compliance, communication, asset management, and public health outcomes (Gunnarsdottir et al., 2012a).

Despite the documented benefits of WSPs, they have had limited application in the United States (US). Accordingly, the purpose of our research was to compare current US drinking water regulations to WSPs. Given the regulations that exist in the US, we explored the differences between current regulations and WSPs and whether there might be added value from WSPs to assist in improving drinking water quality. This article begins with descriptions of US drinking water regulations, voluntary US drinking water enhancement programs, and WSPs. It continues with a comparative analysis between US drinking water regulations and WSP steps in

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4This chapter previously appears as an article in the International Journal of Hygiene and Environmental Health. The original citation is: Baum, R., Amjad, U., Luh, J., Bartram, J. 2015. An examination of the potential added value of water safety plans to the United States drinking water legislation. Int J Hyg Environ Health 218(8), 677-85. Individual contributions were as follows: Background research (Baum, Amjad, Luh), mapping of regulations (Baum), contributing factor analysis (Baum, Bartram), writing and revising (Baum, Amjad, Luh, Bartram).
order to identify the differences between the two, followed by a discussion on the potential of addressing these differences to improve the safety of US drinking water systems.

**History of US Drinking Water Regulations**

In 1914, the US Public Health Service set microbiological drinking water quality standards for water systems providing water to interstate transporters. By 1962, the US Public Health Service was regulating 28 contaminants in an effort to control end product water quality. Although these standards did not apply to public water systems, most states adopted these standards as guidelines (USEPA, 2013). As treated water quality testing became more frequent, more water system deficiencies were found and water contamination became increasingly recognized (USEPA, 2013). As a result of these findings, environmental concerns came to the forefront of Congress, resulting in the passage of the Water Pollution Control Act, National Environmental Policy Act, and the Safe Drinking Water Act (SDWA). The SDWA and its amendments are the main sources in the US from which drinking water regulations were created to ensure the quality of drinking water treated and delivered from public water systems (Title XIV, 2002). The Environmental Protection Agency (EPA), an agency of the federal government, is responsible for writing regulations to enforce this legislation and as a result, has established the National Primary Drinking Water Regulations, National Primary Drinking Water Regulations Implementation, and National Secondary Drinking Water Regulations (Code of Federal Regulations Title 40, Parts 141-143) (Code of Federal Regulations, 2013).

The SDWA requirements, with which approximately 150,000 public water systems in the US must comply, include water quality standards to be met, treatment levels to be applied, system management to be conducted, and external communication to be managed (Title XIV,
Primacy agencies (regulation enforcers for the states) then develop regulations based upon the SDWA, which sets the foundation on which water suppliers act, with the goal of meeting developed regulations. Public water system operators must submit reports to primacy agencies identifying violations of drinking water standards, violations in monitoring, and violations in consumer notification (Title XIV, 2002). Based upon these reports, primacy agencies issue compliance orders against the system supplier (Title XIV, 2002) (SDWA, Sec. 1414). Enforcement is prioritized by targeting water system suppliers with a history of violations and systems that most immediately and significantly compromise public health. Primacy agencies are in charge of enforcement and penalties, however the EPA will step in when needed. The goal of the EPA, in regard to water systems, is for all water systems to attain compliance levels or return to compliance levels within six months of a violation (USEPA Office of Enforcement and Compliance Assurance, 2009).

While the United States has a system of periodic testing for contamination, and responding to detected risks, outbreaks have been documented in systems that comply with SDWA regulatory requirements. From January to December 2011, it was estimated that 25% of the US water treatment systems had violated the SDWA (USEPA 305RI3002, 2013). Of these violations, 25% were of health-based standards (USEPA 305RI3002, 2013). These health-based standards violations contribute to microbial waterborne illnesses, which are estimated to affect 19.5 million Americans annually (Reynolds et al., 2008). However, these waterborne illnesses are the result of both regulated and non-regulated contaminants. For example, algal blooms in the Great Lakes recently caused the shutdown of a local drinking water treatment plant following voluntary testing of cyanotoxins (Yeager-Kozacek, 2013), an unregulated contaminant group produced by algal blooms which poses a health risk to humans (USEPA 4304T, 2013).
Cyanotoxins are currently on the Contaminant Candidate List to be considered for regulation in the next five years, however until cyanotoxin testing becomes regulated, some drinking water systems may not test for these compounds and thereby not take precautions against them.

Voluntary US Drinking Water Quality Optimization programs

Voluntary initiatives to improve drinking water quality in the US, such as the Partnership for Safe Water and the Area-Wide Optimization Program have reported success in improving drinking water quality (AWWA, 2013 and Sadkosky, 2013), suggesting that enhancement programs lead to benefits. These voluntary programs have similar goals to US regulations and WSPs (i.e., to improve drinking water quality). All of these voluntary programs aim to improve drinking water quality through additional monitoring and controls beyond current drinking water regulatory requirements in the US. The purpose of the following discussion of voluntary programs is to show how such non-required guidelines complement the regulations stemming from the SDWA. Examining this relationship between existing voluntary standards and regulations is useful in setting up the comparative analysis to follow, as WSPs are an example of voluntary guidelines that would potentially complement existing US regulations of drinking water quality.

The Partnership for Safe Water, an Enterprise Department of the American Water Works Association (AWWA), works to improve treatment and distribution performance through self-assessment programs, data analysis, and optimization programs. Since its inception in 1995, the Partnership for Safe Water has documented improved teamwork in water systems, greater customer confidence, cost effective optimization solutions, and improvements in water quality delivered to customers (AWWA, 2013). The Partnership for Safe Water focuses its data analysis
on four indicators - turbidity, disinfectant residuals, pressure, and main break frequency – and thus differs from WSPs as the number of indicators for WSPs is tailored for each system. Additionally, the Partnership for Safe Water focuses on an annual data analysis process that differs from the WSP emphasis on continually documenting changes and revising approaches. AWWA also created AWWA Standard G200-04 – Distribution Systems Operation and Management in 2004 to further improve water quality management in a water system (AWWA, 2004). This standard was very similar to a WSP, in that it called for the assessment of hazards throughout the water system and the creation of operational and maintenance plans for water system management (Kirmeyer, 2007). While pilot studies were conducted to evaluate this Standard, it was ultimately not pursued nation-wide.

The EPA developed a program similar to the Partnership for Safe Water in 1998, the Area-Wide Optimization Program (AWOP) for water systems, focused on decreasing turbidity of treated water through comprehensive performance analysis (USEPA AWOP, 2013). AWOP also provides performance-based training programs to educate suppliers on how to improve treatment processes. Most recently, the EPA has created additional programs for disinfection byproducts reduction for surface water plants and groundwater system optimization for groundwater-fed systems (USEPA AWOP, 2013). System operators that are committed to AWOP have reported improvements in water quality (Sadosky, 2013). However, water system leaders have expressed difficulty in committing to this program due to lack of time and money (Sadosky, 2013). The AWOP improves upon current regulations from the SDWA to ensure water system quality and performance by focusing on decreased water turbidity and improved treatment processes. AWOP differs from WSPs in its focus on two specific indicators while WSPs develop indicators for each utility, based upon specific needs. The processes for AWOP focus on data analysis of indicators
to see the results of optimization, while WSPs focus on improving monitoring and documentation through management processes to prevent contamination.

The American National Standards Institute (ANSI) and AWWA recently produced the J100 Risk Analysis and Management for Critical Asset Protection (RAMCAP) Standard for Risk and Resilience Management of Water and Wastewater Systems (Sadosky, 2013). The J100 RAMCAP is focused on assessment of not only water quality, but also water quantity and public confidence. The foundation of the assessment is in the RAMCAP process, which consists of: asset characterization, threat characterization, consequence analysis, vulnerability analysis, threat analysis, risk/resilience analysis, and risk/resilience management. This seven-step process aligns with the WSP identification of hazards, risks, and controls, however RAMCAP has a particular focus on risk and resilience, with less emphasis on team development, communication, and documentation. There has been limited adoption of the J100 in the US, as it was developed in 2010, and the benefits resulting from J100 adoption have not been assessed yet.

World Health Organization and Water Safety Plans

Over thirty-five countries worldwide have multiple water systems that have well documented cases of either voluntarily or mandatorily implemented WSPs, or their equivalent under other names, that served as a preventive risk management approach in an effort to ensure the safety of drinking water. These include Argentina, Australia, Austria, Bangladesh, Bhutan, Belgium, Bolivia, Brazil, Canada, China, Ecuador, France, Germany, Guyana, Honduras, Hungary, Iceland, India, Indonesia, Jamaica, Japan, Lithuania, Malaysia, Morocco, Nepal, The Netherlands, New Zealand, Peru, The Philippines, Portugal, Singapore, South Africa, Spain, Switzerland, Uganda, and The United Kingdom (USEPA HACCP, 2014, Malzer et al., 2010,
Although WSPs have been implemented in more countries, a lack of documented cases in these areas suggests more research needs to be done in order to successfully advertise the benefits of the WSP approach throughout different regions of the world. WSPs were developed by the World Health Organization (WHO) from 1994–2003 and were published in its Guidelines for Drinking-water Quality in 2003 to ensure that all hazards and risks that could adversely affect drinking water safety are managed to assure the safety of drinking water.

WSPs have three components: system assessment, operational monitoring, and management and communication, which are implemented through an 11-step process: (1) Assemble the team, (2) Describe the water supply system, (3) Identify hazards and hazardous events and assess the risks, (4) Determine and validate control measures, reassess and prioritize the risks, (5) Develop, implement and maintain an improvement/upgrade plan, (6) Define monitoring of the control measures, (7) Verify the effectiveness of the WSP, (8) Prepare management procedures, (9) Develop supporting programs, (10) Plan and carry out periodic review of the WSP, and (11) Revise the WSP following an incident.

Studies have shown that water systems which have implemented WSPs or their equivalent have seen an increase in regulatory compliance, improvements in microbiological water quality, decreases in the incidence of clinical cases of diarrhea, greater customer satisfaction, and better asset management, leading to potential financial benefits (Gunnarsdottir et al., 2012a, Howard et al., 2012, Madmud et al., 2010, Martel et al., 2006, Rizak et al., 2003). These benefits suggest that implementing WSPs in the United States could offer added value to existing regulations.
2.2 MATERIALS AND METHODS

In order to evaluate the similarities and differences between WSPs and US regulations, all US legislation and regulations on drinking water treatment and drinking water quality standards were examined. US legislation and regulations on drinking water quality were retrieved from the EPA website. The primary source from the EPA website on water quality legislation was the Safe Drinking Water Act and its amendments. The regulations from the SDWA were found in the National Primary Drinking Water Regulations, National Primary Drinking Water Regulations Implementation, and National Secondary Drinking Water Regulations (Code of Federal Regulations (CFR) Title 40 – Protection of the Environment, Parts 141-143).

The eleven steps of the WSP process served as the organizing principle for the comparative analysis. Legislation and regulations were retrieved from the SDWA and CFR 141-143 water quality standards and regulations, and each rule was categorized by the step of the WSP to which it applied, based upon its similarity with keywords found in each step of the WSP Manual, following a compare and contrast approach (Miles et al., 2014). The keywords used for matching were:

**WSP Step 1 Assemble the WSP team**: senior management, financial and resource support, expertise and size of team, training, certification and skills, team leader, roles and responsibilities, time frame to development

**WSP Step 2 Describe the water supply system**: Water quality standards, sources of water (runoff and/or recharge processes, alt. sources), conditions affecting source water quality, interconnectivity of sources, details of land use in catchment, abstraction point, storage water information, treatment of water (processes and chemicals), distribution information (network,
storage, tankers), description of materials in contact with water, users and uses of water, trained staff availability, existing procedure documentation)

WSP Step 3 Identify hazards and hazardous events and assess the risks: hazards, hazardous events (site visits and desk studies, historic information, age of pipes, specific chemicals, etc.), assessment of risk, likelihood of occurrence, monitoring and reporting requirements, severity of consequences

WSP Step 4 Determine and validate control measures, reassess and prioritize the risks: Control identification, validation of effectiveness of controls, risk reassessment, prioritization of risks

WSP Step 5 Develop, implement and maintain an improvement/upgrade plan: improvement or upgrade plan, short-, medium-, and long-term controls, implementation, recalculation of risks

WSP Step 6 Define monitoring of the control measures: what is measured, how it is measured, frequency of measurements, who monitors, who analyzes, corrective action implementation

WSP Step 7 Verify the effectiveness of the WSP: Compliance monitoring, meeting targets, internal and external auditing, ensured implementation, management oversight, effectiveness, consumer satisfaction

WSP Step 8 Prepare management procedures: Standard Operating Procedures and ‘Incident’ Procedures must be documented that address: response actions, operational monitoring, responsibilities of utility, communication protocols and strategies, emergency situation responsibilities, review and revisions plans, distribution of emergency supplies of water, staff ownership and implementation of procedures

WSP Step 9 Develop supporting programs: training, research, development, continuing education courses, equipment calibration, preventive maintenance, supporting programs

WSP Step 10 Plan and carry out periodic review of the WSP: revision, review, regular meetings
WSP Step 11 Revise the WSP following an incident: revision after incident, emergency, near miss, determining cause of incident, response adequacy, incorporation of lessons learned.

2.3 RESULTS

Comparison of US Regulations to WSP Step 1: Assemble the WSP team

The first step of the WSP involves assembling a team to develop and carry out the WSP. As seen in Table 2.1, US regulations do not specify staff to develop risk management approaches for the water systems. While regulations do require operator certification and an Operator in Responsible Charge (ORC) to have knowledge of the workings of the entire system, requirements to have a full team with senior management, outside stakeholders, and team members with clear roles and responsibilities do not exist.

Table 2.1 US water regulations parallel to WSP Step 1: Assemble the WSP Team.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify team members with appropriate training, certifications, and skills</td>
<td>40–CFR 141.70(c)</td>
<td>Operator certification required for the operator in responsible charge</td>
</tr>
<tr>
<td>Engage senior management, secure financial and resource support</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Identify required expertise and appropriate size of team</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Define roles and responsibilities of team members</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

Comparison of US Regulations to WSP Step 2: Describe the water supply system

US regulations and WSPs are similar in their requirements for describing the water supply system, as seen in Table 2.2. The difference that exists between them is that WSPs identify specific users and uses of water while US regulations do not.
<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source water quality assessment</td>
<td>40-CFR 141.401; 40-CFR 141.71;</td>
<td>Source water assessment through sanitary survey; Identification of characteristics or activities affecting source water quality;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Details of land use in catchment, interconnectivity of sources</td>
<td>40–CFR 141.713; 40–CFR 141.716;</td>
<td>Annual watershed control program status report; Identify sources of Cryptosporidium</td>
</tr>
<tr>
<td>Description of treatment, distribution, and storage</td>
<td>40-CFR 141.83; 40-CFR 141.70; 40-CFR Subpart G</td>
<td>Source water treatment requirements; Source water treatment technique requirements; Identify best technologies and treatment techniques to remain below maximum contaminant levels (MCLs) for contaminants</td>
</tr>
<tr>
<td>Drinking water quality standards</td>
<td>40-CFR 141.21-27; 40-CFR 141.701</td>
<td>MCLs for total coliforms, turbidity, inorganic chemicals, organic chemicals and radionuclides; Cryptosporidium source water monitoring requirements</td>
</tr>
<tr>
<td>Description of materials in contact with water</td>
<td>40-CFR 141.80;</td>
<td>Lead and copper source water monitoring;</td>
</tr>
<tr>
<td>Identification of users and uses of water</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Documentation of existing procedures</td>
<td>40-CFR 141.71;</td>
<td>Annual report submitted to the State identifying watershed activities affecting water quality and how they are handled;</td>
</tr>
</tbody>
</table>
Comparison of US Regulations to WSP Steps 3, 4, and 5: Identify hazards and hazardous events and assess the risks, Determine and validate control measures, reassess and prioritize the risks, Develop, implement and maintain an improvement/upgrade plan

The third, fourth, and fifth steps of the WSP are grouped together since they focus on the hazards, risks, and controls, which are assessed collectively in WSPs. US regulations require water systems to identify hazards, specifically as they relate to potential terrorist attacks. However, US regulations differ from WSPs because US regulations do not require internal assessments of risks, internal identification of controls, or prioritization of risks by the individual water systems, while WSPs do. Rather, US regulations control for risks by determining maximum contaminant levels and appropriate treatment technologies to minimize risk of contaminants, at a national level. US regulations individualize the risk assessment through requiring an external auditor from the state to conduct a sanitary survey by assessing the source water, water treatment process, distribution system, finished water storage, pumping facilities, monitoring and reporting, water system management and operations, and operator compliance with state requirements (USEPA Sanitary Survey, 2008). Once these risks are assessed, corrections must be made to improve any identified deficiency. Despite the extent of coverage in sanitary surveys, they are fundamentally different from a WSP in that sanitary surveys are conducted by an external auditor periodically (every 3 years for community water systems, 5 years for non-community water systems) whereas WSPs are embedded in the water system and carried out by a team with internal leaders who are more familiar with the water system. While sanitary survey auditors interact with water system staff, their knowledge of the system is limited to existing documentation, which may be lacking.
Table 2.3 US water regulations parallel to WSP Steps 3, 4, and 5: Identify hazards and hazardous events and assess the risks; determine and validate control measures, reassess and prioritize the risks; develop, implement and maintain an improvement/upgrade plan.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify hazards and hazardous events; Identify controls</td>
<td>40-CFR 142.16(b); 40-CFR 141.21-26; 40-CFR 141.61-66, 110-111, 135</td>
<td>Sanitary surveys identify hazards and hazardous events through external audits of water systems; Hazards are identified by MCLs; Controls are identified by EPA through best available technologies and treatment techniques</td>
</tr>
<tr>
<td>Assess risks</td>
<td>40-CFR 141.21-26</td>
<td>Risks are assessed (at a national level) through determining MCLs and treatment technologies</td>
</tr>
<tr>
<td>Validate effectiveness of controls</td>
<td>40-CFR 141.21-26, 61-66, 110-111</td>
<td>Determine if contaminant levels are below MCLs and best treatment techniques and technologies are used</td>
</tr>
<tr>
<td>Reassess and prioritize the risks</td>
<td>40-CFR 142.16(b);</td>
<td>Sanitary surveys prioritize risks, as determined by the external auditor (not done internally)</td>
</tr>
<tr>
<td>Prioritize all identified risks</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

Comparison of US Regulations to WSP Step 6: Define monitoring of the control measures

While US regulations do not require water systems to identify hazards on their own, which WSPs do require, US regulations enforce treatment, monitoring and reporting requirements for specific hazards and controls identified at a national level, as seen in Table 2.4. These requirements are consistent across all water systems for acute contaminants, regardless of which specific hazards affect each one. However, since all the system-specific hazards are not explicitly identified in WSP Step 5, it is unknown if all potential control measures are applied or monitored.
Table 2.4. US water regulations parallel to WSP Step 6: Define monitoring of the control measures.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine what will be measured and how</td>
<td>40-CFR 141.21-26</td>
<td>Monitoring and compliance requirements established for total coliforms, turbidity, inorganic chemicals, organic chemicals, radionuclide sampling, and radioactivity analytical methods;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 141.40</td>
<td>Monitoring requirements for unregulated contaminants established;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 141.50-55;</td>
<td>MCLs and treatment techniques established for organic, inorganic, microbiological, disinfection byproducts, disinfectants, and radionuclide indicators;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 141.60-66;</td>
<td>MCLs established for organic, inorganic, microbiological, disinfection byproducts, disinfectants, and radionuclide contaminants;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 620-627;</td>
<td>Stage 2 disinfection byproduct requirements and monitoring;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 141.700-723;</td>
<td>Enhanced treatment for Cryptosporidium requirements, sampling schedules, and monitoring;</td>
</tr>
<tr>
<td></td>
<td>40-CFR 143.3</td>
<td>Secondary MCLs and monitoring requirements established for contaminants</td>
</tr>
</tbody>
</table>
Comparison of US Regulations to WSP Step 7: Verify the effectiveness of the WSP

Table 2.5 shows how water systems in the US are driven by compliance and can measure their achievements in this manner through meeting EPA requirements. State institutions and the EPA ensure that targets are met and can assess progress on these targets through annual reports and a six-year review of national primary drinking water regulations. Additionally, sanitary surveys assess the risk management and operations of water systems at least every 3-5 years.

Table 2.5 US water regulations parallel to WSP Step 7: Verify the effectiveness of the WSP.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check consumer satisfaction</td>
<td>40-CFR 151-155</td>
<td>Consumer confidence reports</td>
</tr>
<tr>
<td>Internal and external auditing of operational activities</td>
<td>40-CFR 142.16(b)</td>
<td>Sanitary surveys assess risk management and operational activities (external)</td>
</tr>
<tr>
<td>Compliance monitoring to ensure meeting targets</td>
<td>EPA SDWA 1414C, 114A Annual report on violations; EPA SDWA 1412(b)(9); 40-CFR 141.31; 40-CFR 141.33; 40-CFR 141.622</td>
<td>Water systems must report monitoring results to the state; The EPA must review and revise 40-CFR 140-143 every six years; Water systems report regular and failure reports to the State; Water quality analysis records must be maintained for 5 years (microbiological) or 10 years (chemical); Monitoring plans are developed for disinfection byproducts</td>
</tr>
</tbody>
</table>
Comparison of US Regulations to WSP Step 8: Prepare management procedures

US regulations require that water systems must prepare an emergency response plan based on the vulnerability assessments to terrorist attacks, however as seen in Table 2.6, standard operating procedures and other incidence procedures are not required in legislation. For WSPs, response plans are required for all incident types.

Table 2.6 US water regulations parallel to WSP Step 8: Prepare management procedures.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOPs and ‘Incident Procedures’</td>
<td>EPA SDWA Sec 1433 (Public Health Security and Bioterrorism Preparedness and Response Act - Drinking water security and safety);</td>
<td>Emergency response plan based upon vulnerability assessment</td>
</tr>
<tr>
<td>Determine specific staff responsibilities</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

Comparison of US Regulations to WSP Step 9: Develop supporting programs

Table 2.7 shows that no specific supporting programs for each water system are required in US regulations, however training, research, and capacity development at a national level are required to ensure operators are certified, water system needs are met, and programs are created to improve water systems.
Table 2.7 US water regulations parallel to WSP Step 9: Develop supporting programs.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water system specific supporting programs are developed</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>Training, research, development and maintenance programs are developed</td>
<td>40-CFR 141.70(c); 40-CFR Part 35; EPA SDWA Sec 1420A, 119; EPA SDWA 1452A1G, 130; EPA SDWA Sec 1420C, 119</td>
<td>Operators are trained through operator certification; Drinking water state revolving fund identifies needs of water systems through research; New water systems must have technical, financial, managerial capacity to meet drinking water regulations; State capacity development – assist all systems in technical, financial, and management capacities; State capacity development, encouragement of partnerships, assistance in training.</td>
</tr>
</tbody>
</table>

Comparison of US Regulations to WSP Step 10: Plan and carry out periodic review of the WSP

As seen in Table 2.8, periodic review and updates of hazards, risks, and controls is partially covered by regulation. Individual water systems lack the authority to revise and update their own plans, which is fundamentally different from WSPs. However, in the case of US regulations, capacity development reports periodically review the management and technical procedures of the water system. Similarly, when sanitary surveys are conducted (at least every 3 years), deficiencies are identified through an external audit.
Table 2.8 US water regulations parallel to WSP Step 10: Plan and carry out periodic review of the WSP.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularly report, revise and update</td>
<td>EPA SDWA 1412(b)(9); EPA SDWA Sec 1420C3-119; 40-CFR 142.16(b); 40-CFR 141.23; 40-CFR 141.83; 40-CFR 141.621;</td>
<td>The EPA must review and revise 40-CFR 140-143 every six years; Reports to governor every 3 years on efficacy of capacity development strategy; Sanitary surveys identify hazards and hazardous events through external audits of water systems; State revises reporting frequency of inorganic contaminants based upon records; State revises optimal corrosion control programs and treatment for copper and lead when appropriate; State approves monitoring changes for Stage 2 disinfection byproducts</td>
</tr>
</tbody>
</table>

Comparison of US Regulations to WSP Step 11: Revise the WSP following an incident

Regulations establish that only in a few cases must procedures or documentation be revised following an incident, as Table 2.9 shows. Only in the case of missed sampling dates for Cryptosporidium and total coliform, must additional sampling be done. Incidents or emergencies beyond Cryptosporidium sampling are not specifically revised.
Table 2.9. US water regulations parallel to WSP Step 11: Revise the WSP following an incident.

<table>
<thead>
<tr>
<th>Water Safety Plan Feature</th>
<th>United States Regulation</th>
<th>Description of Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revise the WSP following an incident or emergency</td>
<td>40-CFR 141.702</td>
<td>Cryptosporidium monitoring must be revised if sampling schedule dates are missed</td>
</tr>
</tbody>
</table>

2.4 DISCUSSION

Our findings show that US drinking water regulations align fairly well with WSPs, however, differences exist that highlight the potential added benefits of WSPs to US water systems. US regulations focus on setting national standards for maximum contaminant levels, best treatment processes, and best available technologies for contaminant reduction, by which each utility determines the safety of their water through the detection of pathogens and toxins in treated water. By the time these contaminant levels have been detected, contaminated water may already be distributed and cause exposure. In contrast, WSPs have an additional focus of preventing contamination, resulting in the potential to prevent distribution of contaminated water. This difference in focus between US drinking water regulations and WSPs can be seen in three main areas: internal risk assessment and prioritization, management procedures and plans, and team procedures and training.

The most recent report from the Centers for Disease Control and Prevention (CDC) on waterborne disease outbreaks in the US documents the factors contributing to outbreaks, and thus provides insight into the problems in water system management that caused these outbreaks. In 2009-2010, 28 drinking-water associated outbreaks were reported in public, community-level water supplies (CDC Surveillance, 2013). However, these reported outbreaks represent a small fraction of total waterborne disease in the US, which is estimated to affect 19.5 million people per year (Reynolds et al., 2008). This waterborne disease burden cannot be examined in detail, as
data is only available for the cases associated with these 28 outbreaks. Five types of contributing factors that were under the jurisdiction of the water system, and which contributed to the outbreak, were identified for 13 of these sites (See Table 2.10) (CDC National Outbreak Reporting System, 2013). These were: backflow from cross-connection, corrosion and aging of pipes or storage tanks, distribution monitoring and maintenance failures, lack of treatment and disinfection, and source water contamination. As described below, gaps in US regulations that WSPs could address help to control these contributing factors from occurring and causing waterborne disease.

**Table 2.10** Contributing factors detected, investigated, and reported in waterborne disease outbreaks in the US, 2009-2010.

<table>
<thead>
<tr>
<th>Contributing Factor</th>
<th>Number of Outbreaks Caused (in part or whole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backflow from cross-connection</td>
<td>2</td>
</tr>
<tr>
<td>Corrosion and aging of pipes or storage tanks</td>
<td>2</td>
</tr>
<tr>
<td>Distribution monitoring and maintenance failures</td>
<td>4</td>
</tr>
<tr>
<td>Lack of treatment and disinfection</td>
<td>4</td>
</tr>
<tr>
<td>Source water contamination</td>
<td>3</td>
</tr>
</tbody>
</table>

*Risk assessment and prioritization*

Of the 13 waterborne disease outbreaks due to factors related to the drinking water system, two were caused solely by contamination from cross-connection of potable and non-potable water pipes resulting in backflow. Although the EPA has published a ‘Cross Connection Control Manual’ and most states have cross-connection and backflow control programs, this control is not required by national regulations (USEPA Cross Connection Control, 2013). In contrast, the WSP approach expects that from Step 3 (hazard identification), cross-connection
and backflow contamination would be identified, and control measures would be developed and monitored (Step 4) (Mahmud et al., 2010).

As for risk analysis and prioritization, the EPA requires operators to know the system risks, however a specific risk analysis is not conducted, nor are risks prioritized. As a result, knowledge of risks has little impact on system management. Although the Vulnerability Assessment (SDWA Sec 1433) was added as a mandatory assessment in 2002, requiring water systems to assess their vulnerability to terrorist attacks, it only looks specifically at threats from terrorist activities. Current practices do not always recognize all of the everyday hazards and risks that can directly affect the quality of drinking water. On the other hand, WSPs emphasize that all hazards and risks of the system are recognized and controlled to ensure safe drinking water. Operational plans and incident plans are both prepared in advance to respond to predictable and emergency events. Improvement plans are created, based upon the controls that need to be in place to mitigate risks.

Management procedures and plans

Four waterborne disease outbreaks were caused partially by distribution maintenance and monitoring issues in which low pressure and/or failure to regularly flush the system contributed to the outbreak. Regular flushing and sufficient pressure are not required by regulations, but could be recognized as necessary controls by a WSP. Additionally, monitoring to ensure appropriate distribution maintenance may not always happen. WSPs stress defining improved monitoring of these controls and developing specific procedures to ensure that this monitoring occurs to help prevent contamination events.
The remaining contributing factors to waterborne disease outbreaks, detailed below, are controlled through US regulations, but improved controls and monitoring are needed to prevent these outbreaks. WSPs emphasize defining monitoring of control measures rather than of system failures (Step 7), developing management procedures (Step 8), and developing supporting programs (Step 9) to enhance control measures and monitoring.

Two waterborne disease outbreaks were partially caused by corrosion and aging of pipes or storage tanks. While regulations require a ‘Corrosion Control’ program, frequent monitoring and updating may not be part of a water system’s standard operations. WSPs have been shown to lead to better management of assets, monitoring, and documentation which would help ensure that normal corrosion and pressure differentials from aging of pipes does not lead to contamination of water systems (Gunnardottir et al., 2012). Based upon the comparative mapping, WSPs require more documentation, revision, and review of reports and plans than US regulations. Expanding beyond monitoring for corrosion control programs, WSPs monitor to determine if the WSP aids the water system in meeting its targets, and internal and external auditing of system operations ensures effective implementation of risk reduction plans.

Lack of treatment and failure of disinfection contributed in part to four outbreaks. While the SDWA and the regulations developed under SDWA have specific treatment and disinfection requirements, improved documentation and monitoring of these procedures may have helped to prevent the outbreaks. With emphasis on documentation and monitoring, WSPs potentially offer an approach that might help to improve these controls.

WSPs require Standard Operating Procedures (SOPs) that cover response actions, operational monitoring, responsibilities of the water system, communication protocols and strategies, emergency situation responsibilities, and review and revision of plans. SOPs contain
details of staff activities, fostering ownership and implementation of procedures. While the SDWA requires that water systems must have certified operators, there is no requirement for SOPs, which might provide greater clarity, institutional memory, and sense of ownership. In order to ensure that everyone knows their role and how to operate the system, studies have shown that SOPs improve the understanding of potential incidents, thereby reducing errors and mitigating potential risks (Gunnarsdottir et al., 2012a; Mullenger et al., 2002).

Review and revision of the WSP annually, and after incidents, will help maintain its relevance, and keep operators aware of any changes or updates in the system. In the US, however, after water systems pass their initial assessment, the SDWA does not require them to update the system frequently nor to revise their practices. Rather, the SDWA mandates that they must keep up with contaminant regulation, which is reassessed every 5 years at the national level to determine which contaminants to regulate (SDWA Sec 1412). The SDWA’s broad application in regulation at the national level may not address system-specific contaminants-of-concern, which may leave certain systems more vulnerable to water contamination.

Team procedures and training

Three waterborne disease outbreaks were caused partially by source water contamination, which could be controlled by source water quality assessments and standards, as well as sanitary surveys, all of which are required by regulations. US water systems have an ORC that shall have knowledge of the entire water system, although knowledge on the safety of the source water may be unknown. WSPs require staff to have a thorough understanding of the entire water system, beginning with the source water. This understanding is reinforced through SOPs in order to increase the staff’s responsibilities and accountability. This aids in preventing incidents as
employees take greater responsibility for the system and understand the other responsible members’ roles (Byleveld et al., 2008). Understanding one individual’s role in the water system, and the roles of everyone else, aids in understanding the system as a whole and why procedures are carried out throughout the water system. Also, lessons from international examples of waterborne disease outbreaks for over 60 cases can be applied to the US, which indicate that a major cause of outbreaks stems from a lack of knowledge of the water system from operators and managers (Hrudey and Hrudey, 2004 and Hrudey and Hrudey, 2014). This improved awareness and understanding from WSPs helps to further reduce risks from source water contamination, even though both WSPs and regulations require source water assessments.

Individual roles and trainings are further emphasized by supporting programs in WSPs that ensure that the WSP approach is a part of training, research, development, and preventive maintenance in addition to daily operations. In contrast, US regulations require operators to be re-certified and update their training, but they do not require supporting programs to further embed this training into the system operations.

2.5 CONCLUSION

This comparative analysis identifies differences between WSPs and US regulations to ensure safe drinking water, highlighting the differences between the tailored approach of WSPs to address specific issues in each water system and the nationally-uniform regulated approach in the US, which attempts to broadly control for risks in all water systems. WSPs enhance a sense of ownership and an improved understanding of the greatest risks to each water system, helping to prioritize risks of each water system. In the US, a rules-based approach sets guidelines for all water systems to comply, regardless of their differences in size, location, or water source.
Potential added benefits of WSPs may help reduce future waterborne disease. However, the national regulation-based system of the US does not provide clear incentives for a voluntary approach that emphasizes preventive management. While voluntary optimization programs have been used in the US, the differences between WSPs and US regulations may be too great to expect voluntary initiatives to prompt these changes that may require a large investment of time and resources. Given the regulation-based environment of the US, it may be realistic to expect adoption of WSPs if the law requires them.

Current nation-wide regulations impose one set of standards for all drinking water systems, which in some cases does not promote the identification of system specific risks. The EPA regulates 114 contaminants to be monitored to specific maximum contaminant levels (MCL). While the EPA updates and adds to these contaminants every five years, there are many contaminants that are not monitored. Only contaminants that are deemed important nationally are regulated, while context specific risks are not accounted for or prioritized. As an example, from the drinking water quality test results from water systems since 2004, 49 contaminants that are not regulated by the EPA were found in drinking water at levels above government established health guidelines (Environmental Working Group, 2009). While the regulatory-based responsive approach to water quality risk management in the US has contributed to the substantially decreased waterborne disease risk, requiring water systems to identify and control for their own system-specific risks through a preventive approach could further reduce waterborne disease, rather than holding all water systems accountable to the same national regulatory standards, regardless of their differences in risks. One possible option to control for specific water system risks is an incentive-based system to encourage water systems to identify and control their distinct risks, which could promote a preventive approach to reduce waterborne disease.
The documented successful results of WSPs in improving water quality, increasing regulatory compliance, improving public health, and increasing system cost savings may help improve the management of water systems in the US. Implementation of WSPs may help reduce future waterborne disease in the US, but how to encourage water systems to adopt this approach remains a challenge. The US could assess its rule-based risk management system and national level enforcement of regulations to determine if there is room for additional regulations or alternative approaches. Given the similarities of sanitary surveys to WSPs, the US could also explore the option of requiring WSPs for each water system to replace or enhance parts of the sanitary surveys.

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Conflicts of Interest

The authors declare no conflict of interest.
CHAPTER 3: WATER SAFETY PLANS: BRIDGES AND BARRIERS TO IMPLEMENTATION IN NORTH CAROLINA

3.1 INTRODUCTION

Water Safety Plans (WSPs) are a comprehensive drinking water quality risk management process, emphasizing prevention, instead of reaction, to hazardous events (Bartram 2009; WHO 2004, 2005, 2012; Howard and Bartram 2014). WSPs require the proactive identification and management of risks in a drinking water system through six primary steps: (1.) Assembling a team; (2.) System analysis (3.) Operational monitoring (4.) Management and communication (5.) Review, approval and audit; and (6.) Assessing experience and future needs (Bartram et al 2009; see Figure 1). Benefits of using WSPs include increased regulatory compliance, decreased microbial growth in the water system, and lower incidence of clinical diarrhoea (Gunnarsdottir et al 2012). The goal of WSPs is to provide safe drinking water through: effective water supply practices, prevention of source water contamination, adequate water treatment to meet water quality targets, and prevention of re-contamination during storage and distribution of drinking water (WHO 2005, 11).

A dynamic methodology, a WSP is embedded in the daily operations and culture of a water system. Implementing a WSP requires a team that drives the plan, understands the water catchment area, treatment and distribution systems, has the capacity to maintain the water

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5 This chapter is under review at Journal of Water and Health. Amjad, U., Luh, J., Baum, R., Bartram, J. 2016. Water Safety Plans: Bridges and barriers to implementation in North Carolina. Journal of Water and Health. Individual contributions were as follows: Background research (Amjad, Baum, Luh), interviews (Amjad, Baum, Luh), qualitative analysis (Amjad, Baum, Luh), writing and revising (Amjad, Baum, Luh, Bartram).
system, continues internal training and consumer awareness, and pursues continuous review and refinement of the WSP. While a WSP is a large undertaking for a water system team, the World Health Organization (WHO) points out that, “The time it will take to establish a water safety plan [WSP] will depend upon a number of factors: staff experience; amount of data available on the water supply; size and complexity of the supply; and other systems that have already been adopted” (WHO 2005, 126).

**Figure 3.1. Water Safety Plan (adapted from WHO 2005, 20)**
For a detailed step-by-step guide to implementing WSPs please see Bartram et al (2009).

Organizational culture, or shared assumptions about work practices, influences the adoption and implementation of WSPs (Summerill et al 2010a). Examples of enabling characteristics of organizational culture are: proactive, involved leaders, attention to staff and stakeholder needs, accountability, and commitment to continual improvement. Disabling cultural characteristics include poor communication, inflexibility, and complacency. Challenges in the implementation of WSPs are partly due to the difficulty in evaluating the benefits of WSPs, although frameworks for evaluation have been suggested, as shown in Iceland, Bangladesh and Latin America (Gunnarsdottir et al 2012; Mudaliar 2012; Gelting et al 2014).

WSPs have been used in water systems in diverse countries such as Iceland, Bangladesh, New Zealand, and England (Gunnarsdottir et al 2012; Mahmud et 2007; Parker and Summerill 2013; Nijhawan et al 2014), thus demonstrating their use in both developed and developing countries. For countries that have consistently high compliance with water safety standards, WSP implementation arose from a desire to improve public health, especially following a contamination event. For example, in Australia, in 1998, the treated water supply for Sydney had high levels of *Cryptosporidium* that led to discussions about how to prevent such contamination from happening (Hamilton, 2006). This event led to the introduction of national regulations requiring water systems to carry out hazard analysis and critical control points (HACCP), which are similar to WSPs, in identifying potential hazards (Hamilton, 2006). Other countries, such as New Zealand and Germany, also had a desire to improve public health. In New Zealand, the Ministry of Health developed national regulations requiring WSPs, and in Germany, the Federal Ministry of Health and the Federal Environment Agency led the dialogue promoting adoption of
WSPs (Health Amendment Act, 2007; Schmoll et al., 2011). For the successful implementation of WSPs, clear public health messages and goals are critical (Summerill et al., 2010b).

The focus on improving public health and the involvement of the Ministry of Health in countries such as Australia, New Zealand, and Germany differs in attitude from the United States. While the US develops water quality standards based upon protecting public health, regulations reflect an environment of meeting regulatory standards for contaminant levels rather than preventing contamination at each water system. Additionally, the Environmental Protection Agency (EPA) of the US regulates 114 contaminants across the country and does not specify different contaminants for different contexts (USEPA). While these regulations have substantially reduced the risk of waterborne disease, system-specific risks exist and can cause contamination events that pose a risk to public health. Since these risks are different depending on the water system, it becomes important to identify specific public health hazards and risks for each water system in addition to meeting national guidelines and regulations.

In the US, many water utility operators, while unfamiliar with the term ‘water safety plan’, were already practicing many parts of a WSP that are required by US drinking water regulations, such as the National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations (Code of Federal Regulations Title 40 – Protection of the Environment, Parts 141-143). Some of these similarities between WSPs and US drinking water regulations include carrying out a source water quality assessment, meeting water treatment requirements, and identifying hazards through sanitary surveys. However, there are also gaps between WSPs and US drinking water regulations, stemming from the differences in the preventive nature of WSPs compared to the national standards and best treatment processes required by US national regulations. These differences can be seen in the areas of internal risk
assessments and prioritization, management procedures and plans, and team procedures and training (Baum et al. 2015). WSPs offer an improved sense of ownership and greater understanding of a specific water utility’s risks compared to the rules-based approach for national water regulations. WSPs could potentially benefit US regulations through enhanced management of procedures and plans, internal risk assessment and prioritization, and team procedures and training.

The purpose of this study was to examine attitudes toward deciding to use WSPs (adopting), and bridges and barriers of practicing risk management with WSPs (implementation) by water suppliers in the US state of North Carolina. To the knowledge of the authors, WSPs are not being used by US water utilities. Since WSPs are not legally required in the US, they would be a voluntary risk management approach. Water utilities in North Carolina are an insightful case study due to diverse characteristics, such as urban and rural settings, varied hydrological and geographical contexts, and rapid population growth. The overarching research question which guided the study was, ‘What are the institutional conditions for implementing WSPs in North Carolina water utilities?’ We examined this question in two parts: (1) What is the willingness of water utilities to implement WSPs? and (2) What is the ability of water utilities to implement WSPs? Willingness refers to the explicit verbal expression of interest, by water utility personnel, in deciding to use a WSP approach. Ability refers to the explicit description of the capability of a utility to integrate WSPs into their risk management practice by utility personnel.

3.2 METHODS

We employed qualitative methods because the study examined perceptions of water operators and managers, and in some cases town administrators, regarding how and why they
would use WSPs. The unit of analysis is a water utility that distributes water to households. Since interviewing all personnel within a utility and aggregating their perspectives was not realistic due to time and resource constraints, we instead interviewed individuals who work closely with water quality management, such as water operators and managers.

_Water utility selection_

We selected utilities in five of the seven administrative regions defined by the North Carolina Department of Natural Resources, based on our ability to connect with water utility managers and operators during the period of the study. These utilities varied in size, as defined by the United States Environmental Protection Agency (USEPA) based on population served (Table 3.1). The authors selected utilities based on their willingness to participate in this study, determined by an initial email or telephone call to the utility.

**Table 3.1 Characteristics of North Carolina Water Utilities Interviewed**

<table>
<thead>
<tr>
<th>Utility size defined by USEPA (population served) (SDWIS 2014)</th>
<th>Number of utilities interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small (25-500)</td>
<td>0</td>
</tr>
<tr>
<td>Small (501-3,300)</td>
<td>2</td>
</tr>
<tr>
<td>Medium (3,301-10,000)</td>
<td>5</td>
</tr>
<tr>
<td>Large (10,001-100,000)</td>
<td>3</td>
</tr>
<tr>
<td>Very large (&gt;100,001)</td>
<td>1</td>
</tr>
</tbody>
</table>

_Data collection_

Data was collected through semi-structured interviews (after Wengraf 2001) because of the open and flexible nature of the research questions. This method was advantageous because operators provided insightful information that the researchers may not have been aware to ask. Utility personnel, and some town managers if they were speaking on behalf of the utility, were asked about their willingness and ability to implement parts of or all of a WSP. All water utility
names, locations, and identities of personnel who were interviewed were kept confidential to protect the interview participants from repercussions for voicing their views, and to encourage candidness. The average duration of each interview was one hour, which provided ample time for the interview participant to narrate their views. Interviews were audio recorded and transcribed verbatim to maintain accuracy of responses by interview participants in the analysis. The study is exempt from further review from the Institutional Review Board of the University of North Carolina at Chapel Hill (record number 12-2522).

After explaining the basic principles of WSPs to the interview participant(s), three main questions were asked of participants: (1) What are your current practices of risk management of drinking water quality?; (2) Based on our description of WSPs, how do your existing practices match WSP processes?; (3) Would your utility be willing to implement the WSP approach? Why or why not?

Data analysis

Ethnography and grounded theory perspectives (Miles et al. 2014) were appropriate for analyzing interview transcripts because staff perceptions were gathered in their natural work environment of their water utility. Using Nvivo qualitative analysis software to assist with organizing the eleven interview transcripts and notes, we analyzed the interviews in two phases: Phase 1: Identification of themes to group words, phrases, or sentences (e.g. “background information on water utility” or “information sharing”); and Phase 2: Categorization of themes into sub-themes to explain and describe results of the interviews in relation to the research questions (e.g. “tariffs” and “non-revenue water” as sub-themes of “infrastructure maintenance”).
3.3 RESULTS

The results are divided into four sections according to the size of the water utilities – small, medium, large, and very large – following USEPA guidelines of water utility sizes for populations served. We find it useful to categorize the results as such because management characteristics tend to be similar among water providers that serve similarly sized populations, as they have somewhat similar numbers of employees, financial resources, and infrastructure size. Findings for each of the categories of utility size are summarized according to four themes: willingness to implement WSPs; ability to implement WSPs; current risk management practices for distributing safe water; and perceived benefits of WSPs to water quality risk management. Maintaining confidentiality of each utility and their personnel, we refer to the utilities as ‘Small 1 (S1), Small 2 (S2), Medium1 (M1), Medium 2 (M2), etc.

Small water utilities

Staff from two small water utilities (501-3,300 population served) that purchase their water from external sources and have approximately four staff members were interviewed (Table 3.2). S1 was not willing to implement WSPs, as its staff perceived that WSPs were not applicable to their system because they purchase water from another water system, and therefore stated that they have no control over the initial quality of the water or how a WSP would influence its risk management. In contrast, S2 staff reported that they would be willing to implement WSPs if financial benefits for the North Carolina case were clearer.

Willingness to implement WSPs may have roots in utilities’ perceived ability to do so. As mentioned above, S1 does not treat its own water, but instead purchases water from another
supplier and then distributes the purchased water to households. Even though S1 is transporting water from a supplier from which S1 claims they have no control over the quality, S1 still monitors water quality by analyzing samples once a week for chlorine levels. According to S1, a primary way for them to correct poor water quality is to flush the water in the distribution system. Therefore, S1 commented that WSPs may be more applicable to a larger system that treats its own water, and has more ‘control’ over the options for managing water quality.

Willingness to implement WSPs may also be linked to current risk management practices in a utility. Four employees work in S1, which contributes to more efficient information sharing and problem solving, “…there’s just four of us, so it’s easy to pass information back and forth, and everybody’s got input” (S1, Water Operator). S1’s review of risk management practices involves their four employees evaluating options and learning from infrastructure malfunctions shortly after an event, and determining how to make repairs. S1 is developing a database that records leaks and breaks through basic Geographic Information Systems mapping software and use of Google Nexus tablets for taking photos, and entering and checking data in the field. S1 also has an emergency management protocol that works through scenarios, steps, and stakeholders. In contrast, S2 does not have an emergency management protocol: “…we don’t have a playbook [that states], if this happens this is what you need to do” (S2, Town Manager). On preventive action, S2 is concerned about the tradeoff of immediate needs and long-term planning, “If you give me the choice of implementing it [WSPs] and not implementing it, I'm going to look at the fact that I've got two people and I'm going to say we need to worry more about the bypass we had at the sewer plant that hit the creek than going out and back flushing some lines or something like that” (S2, Town Manager).
S1 stated that a potential benefit of WSPs for them may be communication to various stakeholders, such as county officials and municipal customers to discuss how to maintain water quality. S2 did not see the clear benefits of implementing WSPs in North Carolina and stated the need for a balance of cost and prevention, and relevance to the North Carolina context, "Well, we need to do this, it happened in Milwaukee but we need to be doing this [too] in North Carolina when maybe the problem was entirely different and there is not that problem here" (S2, Town Manager).

### Table 3.2 Summary of Small Water Utilities’ Views on Implementing WSPs

<table>
<thead>
<tr>
<th>Small Utilities</th>
<th>Willingness to implement WSP</th>
<th>Ability to implement WSP</th>
<th>Current risk management practices (water quality)</th>
<th>Perceived Benefits of WSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop. Served: 501-3,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small 1 (S1) Purchases water from other source</td>
<td>No</td>
<td>No direct comment on ability. Utility did not perceive that WSPs are applicable to their system because they purchase water from another system.</td>
<td>Flushing the polluted water out of the system.</td>
<td>Communication with county level administration.</td>
</tr>
<tr>
<td>Small 2 (S2) Purchases water from other source</td>
<td>Yes If financial benefits and relevance to the North Carolina case were clear.</td>
<td>No, not enough staff time.</td>
<td>Operation and maintenance in emergency protocol.</td>
<td>Prevention scenarios.</td>
</tr>
</tbody>
</table>

### Medium water utilities

Five of the eleven utilities interviewed were of medium size, each serving a population between 3301-10,000 (Table 3.3). While three utilities were willing to implement WSPs (with two utilities not willing), all medium sized utilities responded that they were not able to
implement WSPs because of insufficient staff time, financial resources, or senior level support.

The responses of the utilities were similar, indicating that utilities would consider using WSPs if there were documented case studies of cost savings and if utilities did not have other priorities or understaffing:

...especially if it could save time, if there was a cost savings involved, monetary or something like that. I’d love to, but a lot of times I just don’t have the time to really think about it and say, ‘Well, which way’s going to work best here?’ I’ve got to get the water up on the hill (M4, Water Operator).

Each of the five medium sized utilities have risk management practices such as technological monitoring systems, for example VSAT (vulnerability self-assessment) (M1) or SCADA (supervisory control and data acquisition) (M2), and emergency plans (M3), or planning processes such as source protection (M4), well-head protection (M5).

**Table 3.3 Summary of Medium Water Utilities Views on Implementing WSPs**

<table>
<thead>
<tr>
<th>Medium Utility</th>
<th>Willingness to implement WSPs</th>
<th>Ability to implement WSPs</th>
<th>Current risk management practices (water quality)</th>
<th>Perceived Benefits of WSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium 1 (M1)</td>
<td>No</td>
<td>No</td>
<td>Using VSAT/local university resources</td>
<td>Improved communication and understanding between utility and town management.</td>
</tr>
<tr>
<td>Medium 2 (M2)</td>
<td>Yes</td>
<td>No</td>
<td>SCADA system</td>
<td>Enhanced protection of source water. Prevention-oriented utility</td>
</tr>
<tr>
<td>Medium 3 (M3)</td>
<td>Yes</td>
<td>No</td>
<td>Emergency management plan/risk management</td>
<td>Decrease risk of untreated water reaching the distribution system.</td>
</tr>
</tbody>
</table>
In terms of perceived benefits of WSPs, utility managers see WSPs as a way to deal with challenges they face. Climate conditions such as freezing is one example of recurring challenges, "We had a lot of lines frozen, tanks froze, meters froze that came really unexpected. We hadn’t seen that temperatures in years here" (M2, System Operator). Monitoring and recording pollution incidents is another challenge for utilities. M3 does not record incidents but uses a guide, somewhat of a template complaint log. With regard to water quality risks that could be addressed by using a WSP, a common theme that emerged was source water protection and the need for improved communication and understanding between the utility and town management. For example, M2 was concerned about prevention and unknown pollutants:

"...we test for contaminants but we don’t test for, ‘What if I get a big gasoline spill?,’ I don’t have a process that tests for that...We look for bacteria. We look for pesticides. We look for all the things that we know [are] out there...” (M2, Water System Operator).
Large water utilities

Personnel from three large utilities were interviewed (10,001-100,000 people served) (Table 3.4). L1 and L2 were not willing to implement WSPs, and L3 briefly explored how to embed WSPs into their practices before other urgent infrastructure maintenance and staffing changes halted the exploration.

The three large water utilities stated that they were not able to implement WSPs in their utilities because of perceived duplication and infrastructure maintenance. According to L2, their lack of willingness to implement WSPs was because, “...we’ve already got in a lot of different formats and in different contexts; we’ve got a lot if not all of this [WSPs]. It’s just not succinctly tied into the umbrella of a water safety plan or what not” (L2). In addition to WSPs’ perceived duplication, L2 is concerned about workload, aging infrastructure, and budgets, “We’re just more worried about managing the work load...managing aging infrastructure is probably the single biggest work load driver for us in our organization...that’s where our greatest priorities go.” L2 suggested that smaller utilities might benefit from WSPs if they have the staff and resources, “It may give them a vehicle and the motivation to develop a plan that they normally would not have.”

In the three large utilities, current risk management practices ranged from ‘established’ to ‘in need of assistance,’ meaning revision or development of plans. For example, L2 has a, “...very large and robust online database report catalogue system for any water supply in North Carolina with a public water supply ID number...That’s actually done by the state and managed by the state, but we certainly can access that information and use it” (L2). L2’s water system management plan focuses more on management, financial, and administrative challenges rather than just water quality, “...that’s probably at a higher altitude look at the management of the
water system. It would not probably get as detailed as this [WSP] type of program would...” L3 has a written disaster preparedness plan, but it is difficult to use preventively instead of reactively due to high costs and too few staff:

*Well, you can’t react to something until it happens...I wish we could check more often? Yeah, but can we afford it? No. I think I spent $37,000 last year on outside labs... [the] EPA says what method you will use to check for what parameter... I have one lab person. It takes four of us to run the company. It runs 24/7, 365, and working twelve-hour shifts it takes a minimum of four people to run it (L3).*

Table 3.4 Summary of Large Water Utilities Views on Implementing WSPs

<table>
<thead>
<tr>
<th>Large Utilities Pop. Served: 10,001-100,000</th>
<th>Willingness to implement WSP</th>
<th>Ability to implement WSP</th>
<th>Current Risk Management Practices (water quality)</th>
<th>Perceived Benefits of WSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large 1 (L1)</td>
<td>No</td>
<td>No</td>
<td>Boil orders due to turbidity</td>
<td>Preventive instead of reactive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SCADA system that needs upgrading</td>
<td>Comprehensive mapping of distribution lines</td>
</tr>
<tr>
<td></td>
<td>No Perceived duplication of existing practices</td>
<td>Not clear, but did comment that in general, a utility may be more able to implement WSPs if they could identify how it naturally fit with existing practices.</td>
<td>Uses online database of pollutants</td>
<td>Enhanced organization of information</td>
</tr>
<tr>
<td>Large 2 (L2)</td>
<td>No</td>
<td>No</td>
<td>Disasters Preparedness Plan</td>
<td>Improve water quality and costs savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has Water System Management Plan</td>
<td></td>
</tr>
<tr>
<td>Large 3 (L3)</td>
<td>Yes</td>
<td>No</td>
<td>Disaster Preparedness Plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Initially participated in implementation but did not complete due to other obligations.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
L1 noted that their management is reactive instead of preventive, “...our [preventive] maintenance is pretty much nonexistent. We are strictly with the one supervisor and the four-line crews, we are strictly reactive maintenance...” L1 gave examples of their reactive activities during the summer and winter months:

There’s no time to do valve exercising, hydrant flush, flushing the system. We do flush on a regular schedule during the summer...During the winter, it’s just by call basis when somebody has an issue, and most of the time, that’s after we have a breakage and there are sediment and stuff in the lines (L1).

Formal documentation of processes that could be shared among teams within a utility does not exist for L1. They instead rely on memory of personnel, “If we have a break over here, can we send water around it over here? We’re having to rely on the guy’s memory, so that’s not a very good place to be” (L1). The perceived benefit of WSPs was stated by L1 and L2 to be the potential for developing a library with the help of WSP structure. For example, L2 explained:

I think it [WSPs] could certainly be something that could be of value and benefit to an organization. It could possibly be used more as a library for organizing all of this data in a centralized way so that everyone has access to it and understands how to, maybe has a little bit better way of extracting information from all of these documents and procedures (L2).

Very large water utility

One ‘very large water utility’ (VL1) was interviewed, which has sixty staff members and serves over 250,000 people (Table 3.5). VL1 appreciated the process of WSPs but did not verbalize willingness to implement it in their work processes because they perceived their current risk management practices to be the same as or to surpass WSPs. However, VL1 did have suggestions on what makes for a successful water provider in the context of preventive risk management, “…you've got to be collaborative, you really do, and you've got some that that's
internal, but you've got collaboration... I think we need to go across boundaries.” As for what VL1 would change in their risk management, and possibly where WSPs could assist, they would like to have more exercises, “We've got a very, very good plan in writing, but we don't have enough exercises to actually practice that plan... We don't practice enough.” It is useful to note VL1’s approach to legally required rules and voluntary rules. For example, regarding the disinfection byproduct rule, “… driving most of what you see as far as optimization of the plant, [water source] management, building raw chemical storage towers, piloting new chemicals or different chemicals to help optimize the plants.” VL1 has chosen to voluntarily test for unregulated disinfection by-products because, “We're actually more proactive here, progressive. I think it's more of the people we hire, the way we hire them, the type of credentials that we want in the hiring process. We've got some very, very good operators now.” VL1 did not explicitly state that their staff are able to implement WSPs, however they have a larger number of staff that could potentially do so.

<table>
<thead>
<tr>
<th>Very Large Utility Pop. Served: 100,001+</th>
<th>Willingness to implement WSPs</th>
<th>Ability to implement WSPs</th>
<th>Current risk management practices (water quality)</th>
<th>Perceived Benefits of WSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Large 1 (VL1)</td>
<td>No</td>
<td>Not stated.</td>
<td>Focus on source water safety and security in relation to human security.</td>
<td>None stated.</td>
</tr>
<tr>
<td></td>
<td>Current utility activities are perceived to be similar to WSPs.</td>
<td>Potentially has sufficient staff, and has training programs for various operations.</td>
<td>Comprehensive in-house training for new operators.</td>
<td></td>
</tr>
</tbody>
</table>
Of the current risk management practices, VL1 focuses on water source safety in the sense of human security, referring to threats to human safety from deliberate contamination of a water supply, “I don't think there's many systems out there that have adequate ways of knowing what's coming into their plant. If they decide to poison the water or do whatever, how do we know until it's too late? So we’ve stepped up monitoring...” Several of VL1’s existing processes are somewhat similar to the WSP process such as an emergency response plan, chemical spill response plan, and operations response plan, all coordinated with the county. For example, if one water plant of VL1 could not pump or could not treat water, another plant would take over. With regard to control of operations, everything would move to another location and the entire water system would be run from another plant. VL1 also has in place various emergency response and operation response plans, “…We also have the operations response plan partnered with [a nearby county], more resources to us with all emergency services, so we're all tied in together.” VL1 has a training program, an emergency response plan, and an operations response plan. These activities are consistent with WSP processes and could be an entry point for further enhancement by WSPs. Duplication of existing practices was a concern of VL1. VL1 expressed that training of operators is a key activity in their utility, and training is encouraged across disciplines to create understanding of what is needed across teams:

We've got an extensive training program for operators .... The goal is for us to take someone that knows nothing about water and we can train [them] within eighteen months or less, we can have them fully functional. Cross-training takes place so that a lab staff member can go to a particular level of operator’s school that creates better understanding for what each team needs [VL1].

3.4 DISCUSSION

The results show that four of the eleven utilities were willing to adopt and implement WSPs, although they stated a lack of ability to do so. Seven of eleven utilities expressed they
were not willing to implement WSPs. Such findings are useful for determining if and how WSPs would be used in North Carolina, and how to integrate new risk management related programs in water utilities in general. Primary reasons that utilities were not willing to use WSPs were lack of staff time for integrating WSPs and lack of significant evidence that WSPs decrease operating costs. Perceived benefits of WSPs included improved organization of record keeping and communication between utility and city administration.

Many utility managers feared that WSPs would encroach on staff time and duplicate existing risk management practices. This finding is consistent with Mayr (2012) who found a similar view with small utilities (up to 2000 households for each supplier) in Austria in that lack of time and potential duplication of WSPs with existing practices were issues. To address this, a WSP implementation tool, a spreadsheet that translates utility information to WSP goals for small water utilities was developed (Mayr 2012). Furthermore, WHO published a step-by-step WSP implementation guide for small water suppliers (WHO 2012). A barrier to WSP uptake in New Zealand was cited as lack of staff time due to other more urgent priorities (Kot et al 2015). Kot et al (2015) note that a broader stakeholder view may help with WSP implementation, that is, community readiness in which knowledge of the issue, attitudes toward change, and resources could assist with preparing a community to use a WSP.

Unclear financial benefits of WSPs discouraged its use by North Carolina water utilities. The preference for financial benefits is contrary to recommendations that public health priorities be emphasized in order to motivate implementation, over financial, political, or other administrative gains (Summerill et al 2010b, 396). The primary purpose of a WSP is to protect public health (Bartram 2009). Potential impacts include financial benefits (Gelting et al 2012), but are not central. For the North Carolina case, this focus on cost savings implies that utilities’
current priority is financial. The water utilities view that efforts toward implementing WSPs in North Carolina would require additional funds and human resources.

Several of the utilities perceived communication and coordination between utility and town management, organizing utility records and documents, and promoting risk prevention as potential benefits of implementing WSPs. Similar to these findings, small water utilities in Alberta, Canada also expected improved organization and communication (Perrier et al. 2014). Consistent with another study, potential outcomes of implementing WSPs include increased communication and collaboration, improved knowledge and attitudes, increased training, improved operations and procedures, cost recovery and investment (Gelting et al. 2012).

Lack of staff time and of evidence for decreased operating costs are not surprising barriers to implementation of WSPs. In an industry where environmental and health regulations, and to some extent reputation among the community, and basic public health goals are important, it is difficult to expect utility personnel to add a voluntary measure that is untested in the US context. The utilities viewed WSPs as a way to organize their records and clarify communication with utilities and town management. This finding was unexpected because organization and communication are not primary goals of WSPs. WSP’s primary goals are preventive controls to protect water safety for public health, which may include enhancing organization and communication. Small and medium utilities commented on their more immediate need for improved organization of internal records and communication with the communities they serve, regarding water safety emergencies and preventive actions, so that they are able to better safeguard the quality of drinking water. These small and medium utilities voiced that they are not prepared to add yet another plan such as a WSP, to their existing activities that need enhanced organization. Available staff time is focused on priorities such as infrastructure maintenance, so
less urgent, but necessary, processes of organizing their records and existing risk management plans may be neglected.

Findings also show that the majority of the utility leaders believe that their organizational culture is reactive instead of preventive, with few opportunities for exploration and experimentation with new risk management methods. The utility leaders are aware of their reactive instead of preventive organizational culture, as explicitly stated in interviews, with the exception of VL1. Stricter regulations and fewer financial resources facilitate the conditions for reaction instead of prevention. While an incentive for prevention is public health, it is difficult to identify the factors that contribute to a lack of public health incidents, and therefore investment in risk prevention is overlooked. Furthermore, water infrastructure faces under-invest challenges (ASCE 2013) which facilitates a reactive culture in which money goes toward temporary maintenance fixes. The lesson from the NC case is that utilities would not voluntarily adopt a new or adjusted way of managing risks without evidence of benefits for NC utilities, such as decreases in operational costs. Examples of benefits resulting from studies in other countries were not convincing to the utilities.

Future research on bridges and barriers for WSP uptake and implementation in NC should focus on assessing the potential benefits of WSPs, such as evaluating possible cost saving outcomes, and organizing records and communication within utilities and between utilities and town management. Examining policy and institutional relationships of various stakeholders in water service delivery such as the state environmental regulator, customer protection organizations, and public health organizations would also reveal motivations and limitations of implementing WSPs. A community’s influence on the drinking water system is a future area of analysis for implementing WSPs in NC and the US.
3.5 CONCLUSION

Bridges to adopting and implementing WSPs in NC water utilities include the perceived benefit of increased organization of information and communication, improved risk management, and decreased operations and maintenance costs. A few utilities showed interest in developing a library of documents and protection of source water. Barriers to adopting and implementing WSPs in NC water utilities are clear: insufficient staff time and perceived duplication of existing practices. Findings show that lack of time and sufficient resources discouraged using WSP principles in whole or in part, alongside utilities’ existing risk management practices. Perceived duplication of existing practices, that WSPs are not legally required in the US, and that there are no examples from NC or the US were also reasons given for the lack of willingness and ability to implement WSPs.

Acknowledgements

We are grateful to all the North Carolina water utilities we interviewed and to the assistance provided by the North Carolina Rural Water Association in contacting utilities. This study was funded by the Centers for Disease Control and Prevention (CDC) and the National Environmental Health Association (NEHA). The contents of the paper do not necessarily represent the official views of CDC, NEHA, or the University of North Carolina at Chapel Hill.
DISCUSSION

The three components of this research all reveal the necessary enabling environment that would promote the scaling up and sustainability of preventive risk management approaches for drinking water systems in the US to ultimately better safeguard public health.

The systematic literature review (Chapter 1) reveals the importance of formal rules and specific conditions on an international, national, and local level to create an enabling environment to drive the widespread implementation of WSPs. In other developed countries, these different levels of support have all worked together to demonstrate the additional benefits of WSPs. A specific focus on public health benefits has been an important part of the enabling environment conditions that encourages local and national rules and conditions to change to improve public health.

The comparative analysis between WSP steps and US regulations (Chapter 2) reveals the potential benefits of improving the enabling environment in the US in order to improve drinking water safety through adopting WSPs. WSPs could add more benefits to current risk management practices that are mandated by regulations through requiring the implementation of internal risk assessment and prioritization, management procedures and plans, and team procedures and training. Water systems managers in the US are already doing many of the components of a WSP, similar to the situation in other high-income OECD countries prior to the creation of regulations requiring WSP implementation. With added formal rules requiring the implementation of WSPs, other countries have additionally benefited from more resources becoming available to improve guidance and support in implementing WSPs.

Water system managers in the US lack an adequate enabling environment to widely implement and sustain the practice of WSPs (Chapter 3). While they realize the benefits of
improving risk management, a perceived lack of time and resources pose barriers to implementation. While water system managers in the US desire to improve their risk management, increase organization of information and communication, and decrease operations and maintenance costs through WSPs, the barriers appear to outweigh these potential benefits for now. These barriers all point towards a lacking enabling environment, as the current conditions do not adequately support the implementation of WSPs.

Overall, the US would not be crafting an enabling environment with no foundation to create the conditions for widespread WSP adoption and implementation. Many formal rules (regulations) already exist that promote safe drinking water across all water systems. However, a regulation requiring WSPs embedded into the practices of each water system does not yet exist. In other countries, some water system managers had the resources to voluntarily implement WSPs, however the majority of water system managers needed additional resources and support to implement WSPs. The US situation mimics this state, with some water systems taking on voluntary initiatives to improve drinking water safety. However, a perceived lack of time and resources pose barriers to many other drinking water system managers. For most water system managers, formal rules of the enabling environment do not exist to promote WSP adoption yet.

Given the rule-based risk management system of the US, it may be best to follow the path of other developed countries in creating regulations requiring the implementation of WSPs. As was seen in other developed countries, such as Germany, with the addition of regulations requiring WSPs, the enabling environment can promote the creation of additional tools and resources to support scale-up of WSPs. With this additional support, the widespread uptake and sustainability of WSPs could be possible in the US. The EPA, who is charged with creating regulations to protect human health and the environment, would be following the lead of other developed countries by
creating an enabling environment to encourage the implementation and adoption of WSPs. Through creating the conditions and formal rules to require WSPs, the benefits of improved water system risk management and public health could be better supported.

CONCLUSION

The findings of this research indicate the potential benefits to US drinking water safety if a stronger enabling environment can be created to support the implementation of WSPs. Since many other developed countries formed a stronger enabling environment through the creation of regulations requiring WSPs, the US could similarly benefit through additional regulations. Since US drinking water regulations already cover many components of the WSP, only a few modifications would be needed to attain the benefits of complete WSPs. Once these additions to the enabling environment are made, many of the barriers to implementing WSPs will fall and the positive benefits of widespread WSP implementation can be realized.

Meaningful benefits through WSP implementation are attainable in the US, as can be seen through the experiences of other developed countries, such as Germany, Iceland, and Australia. In Germany, for example, water utilities were already carrying out 70%-90% of a WSP in their current practices, but all water utilities engaged in pilot WSPs saw significant added value of WSPs (Schmoll et al., 2011). In Iceland, WSPs have led to increased regulatory compliance, reduced contamination events, and decreases in incidence of clinical diarrhea (Gunnarsdottir et al., 2012a). In Australia, reductions in water plant failures and shut downs, enhanced backflow management, and improved reporting are some of the benefits from HACCP and WSP implementation (Jayaratne, 2008). These benefits from WSPs are similarly achievable in the US
through modification to the enabling environment, given the overlap between existing regulations and WSP steps.

While the US EPA has crafted and continues to craft regulations to improve drinking water safety, contamination events still contribute to waterborne disease affecting 19.5 million people per year. The US must continue to strive to enhance the enabling environment for improved drinking water safety to stimulate meaningful public health improvement.
APPENDIX: SUPPORTING INFORMATION

Articles included in systematic literature review:


Drinking Water HACCP Plan 1999 Yarra Valley Water, Australia.

Drinking Water Quality Risk Management Plan 2005 Yarra Valley Water, Australia


Hygiene Ordinance, 1995. SR 817.051, HyV Article 11. Ordinance on hygiene and microbiological requirements relating to foodstuffs, objects in contact with foodstuffs, workrooms and staff. Switzerland.


SVGW, SSIGE, 2003. HACCP in Drinking Water Supplies in Switzerland. Zurich, Switzerland.


REFERENCES


CDC, 2013. Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water and Other Nonrecreational Water. CDC, Atlanta, GA, USA.


Hygiene Ordinance, 1995. SR 817.051, HyV Article 11. Ordinance on hygiene and microbiological requirements relating to foodstuffs, objects in contact with foodstuffs, workrooms and staff. Switzerland.


Ojomo, E., Bartram, J., 2016 (under review). The enabling environment for drinking water programs: definition and descriptive and diagnostic frameworks.


Title XIV, 2002. Title XIV of the Public Health Service Act “Safe Drinking Water Act” Washington, D.C., USA.


